US 20220134131A1

(19) **United States**

(12) **Patent Application Publication**

(10) **Pub. No.: US 2022/0134131 A1**

(43) **Pub. Date: May 5, 2022**

BOURKE, Jr. et al.

(54) **ENERGY AUGMENTATION STRUCTURES FOR MEASURING AND THERAPEUTIC USES**

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(73) Assignee: **IMMUNOLIGHT, LLC**, Detroit, MI (US)

(21) Appl. No.: **17/433,911**

(22) PCT Filed: **Feb. 28, 2020**

(86) PCT No.: **PCT/US2020/020304**

§ 371 (c)(1),
(2) Date: **Aug. 25, 2021**

Related U.S. Application Data

(60) Provisional application No. 62/955,533, filed on Dec. 31, 2019, provisional application No. 62/946,648, filed on Dec. 11, 2019, provisional application No. 62/897,677, filed on Sep. 9, 2019, provisional application No. 62/855,508, filed on May 31, 2019, provisional application No. 62/813,390, filed on Mar. 4, 2019.

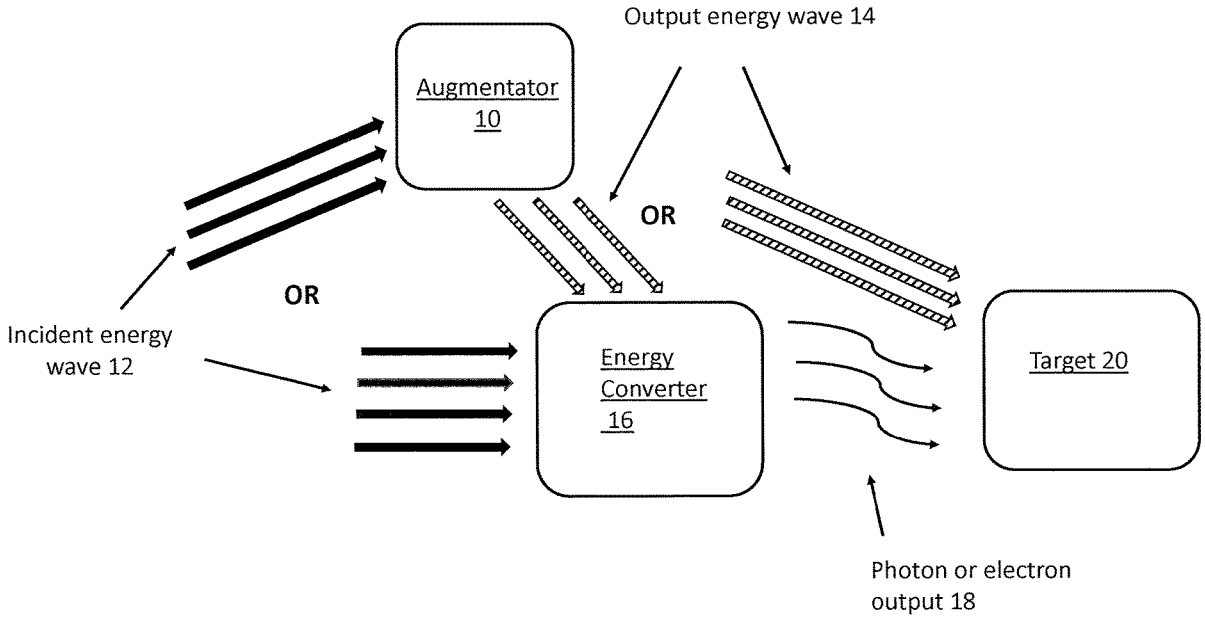
Publication Classification

(51) **Int. Cl.**
A61N 5/06 (2006.01)
A61K 41/00 (2006.01)

(52) **U.S. Cl.**
CPC ***A61N 5/0625*** (2013.01); ***A61N 5/0601*** (2013.01); *A61N 2005/0663* (2013.01); ***A61K 41/00*** (2013.01); *A61N 2005/0661* (2013.01); ***A61N 5/062*** (2013.01)

(57) **ABSTRACT**

An emission enhancement structure having at least one energy augmentation structure; and an energy converter capable of receiving energy from an energy source, converting the energy and emitting therefrom a light of a different energy than the received energy. The energy converter is disposed in a vicinity of the at least one energy augmentation structure such that the emitted light is emitted with an intensity larger than if the converter were remote from the at least one energy augmentation structure. Also described are various uses for the energy emitters, energy augmentation structures and energy collectors in a wide array of fields.



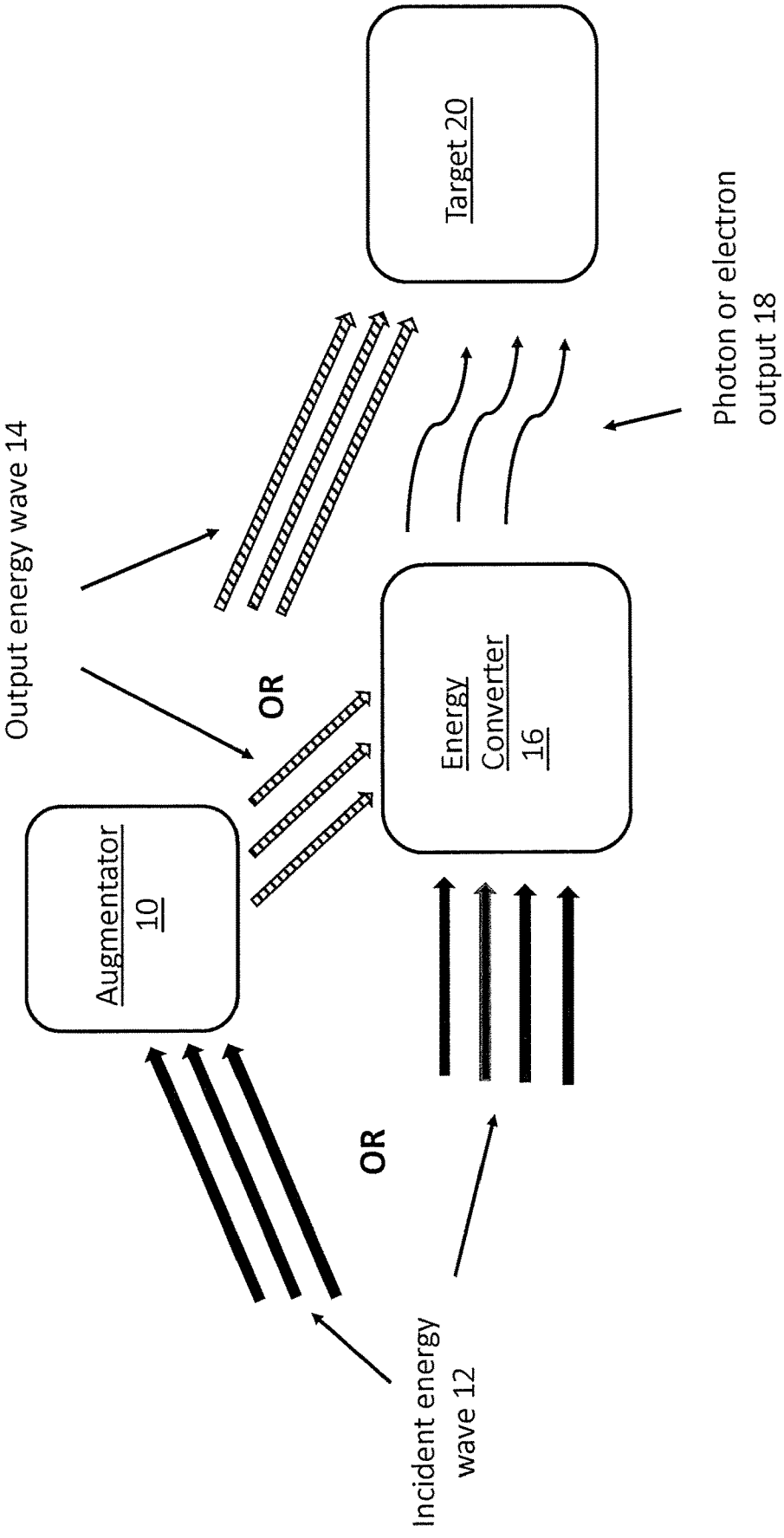

Target 20
Photon or electron output 18
Output energy wave 14
OR
Energy Converter 16
Augmentator 10
OR
Incident energy wave 12

Figure 1

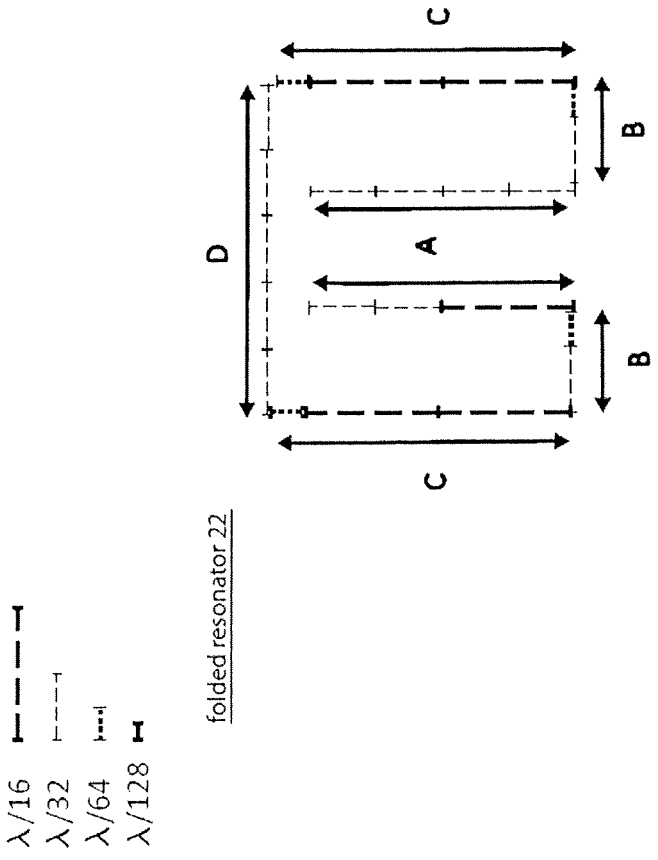


Figure 2

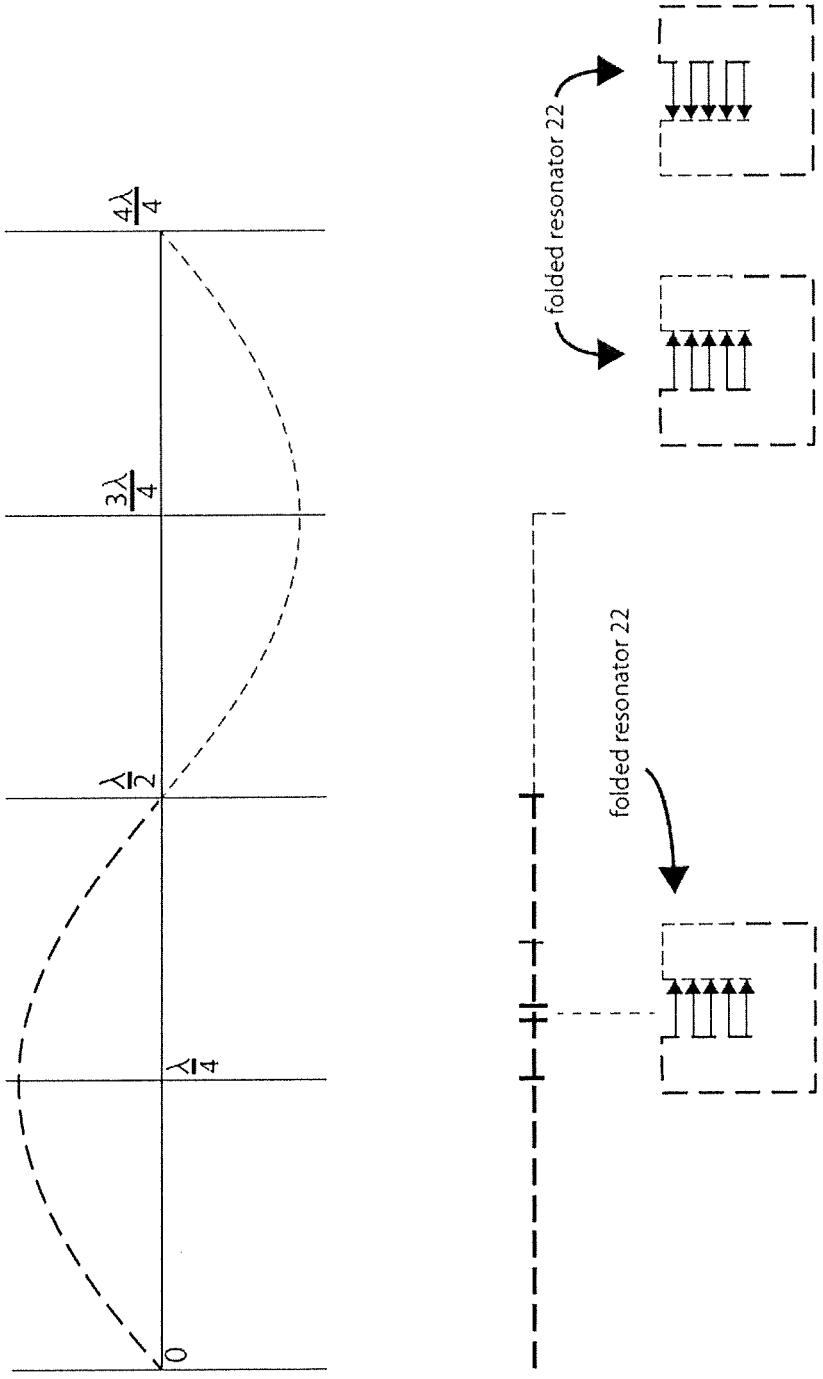


Figure 3

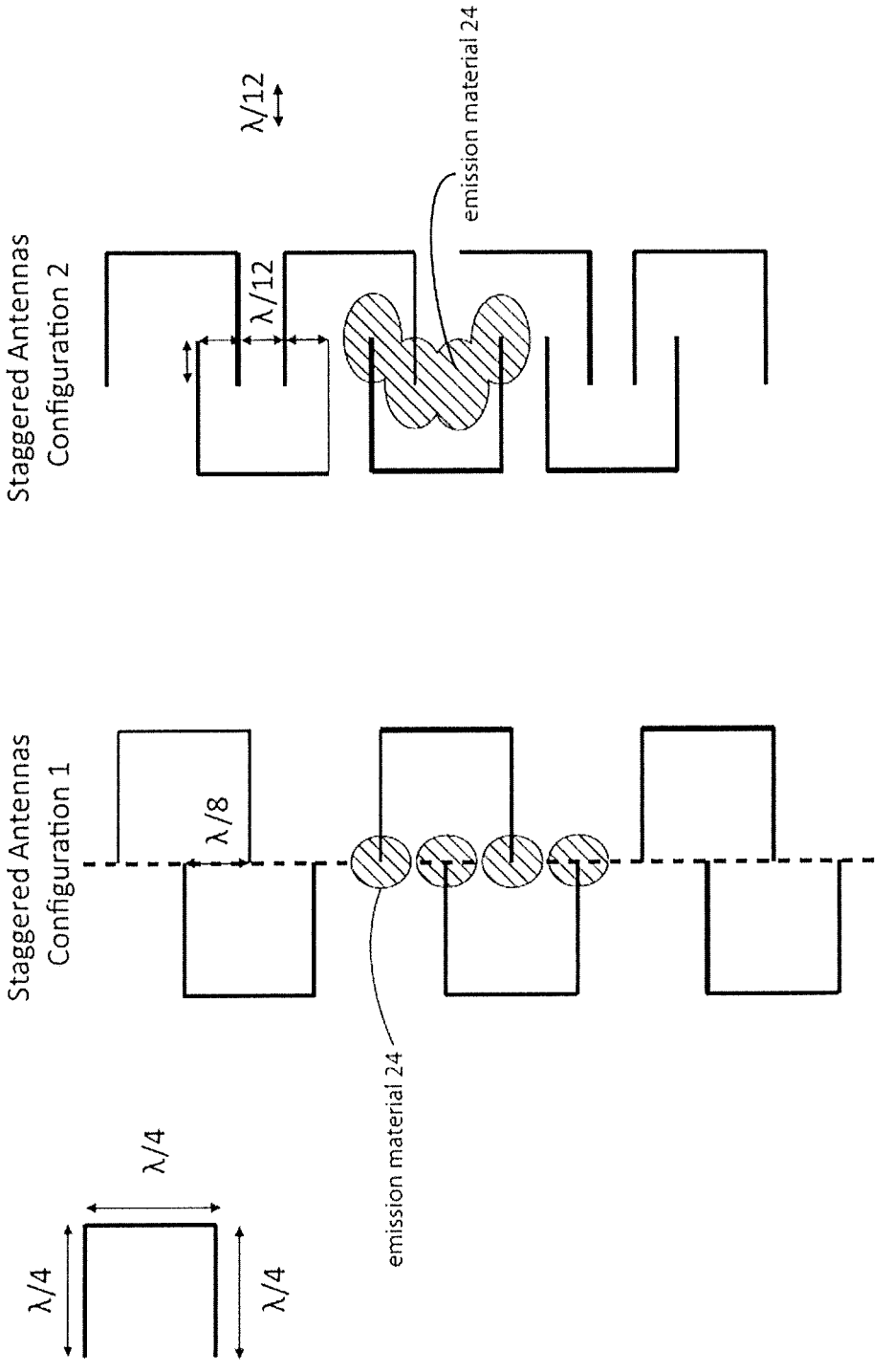

Staggered Antennas Configuration 2
λ/12
λ/12
emission material 24
Staggered Antennas Configuration 1
λ/8
emission material 24
λ/4
λ/4
λ/4

Figure 4

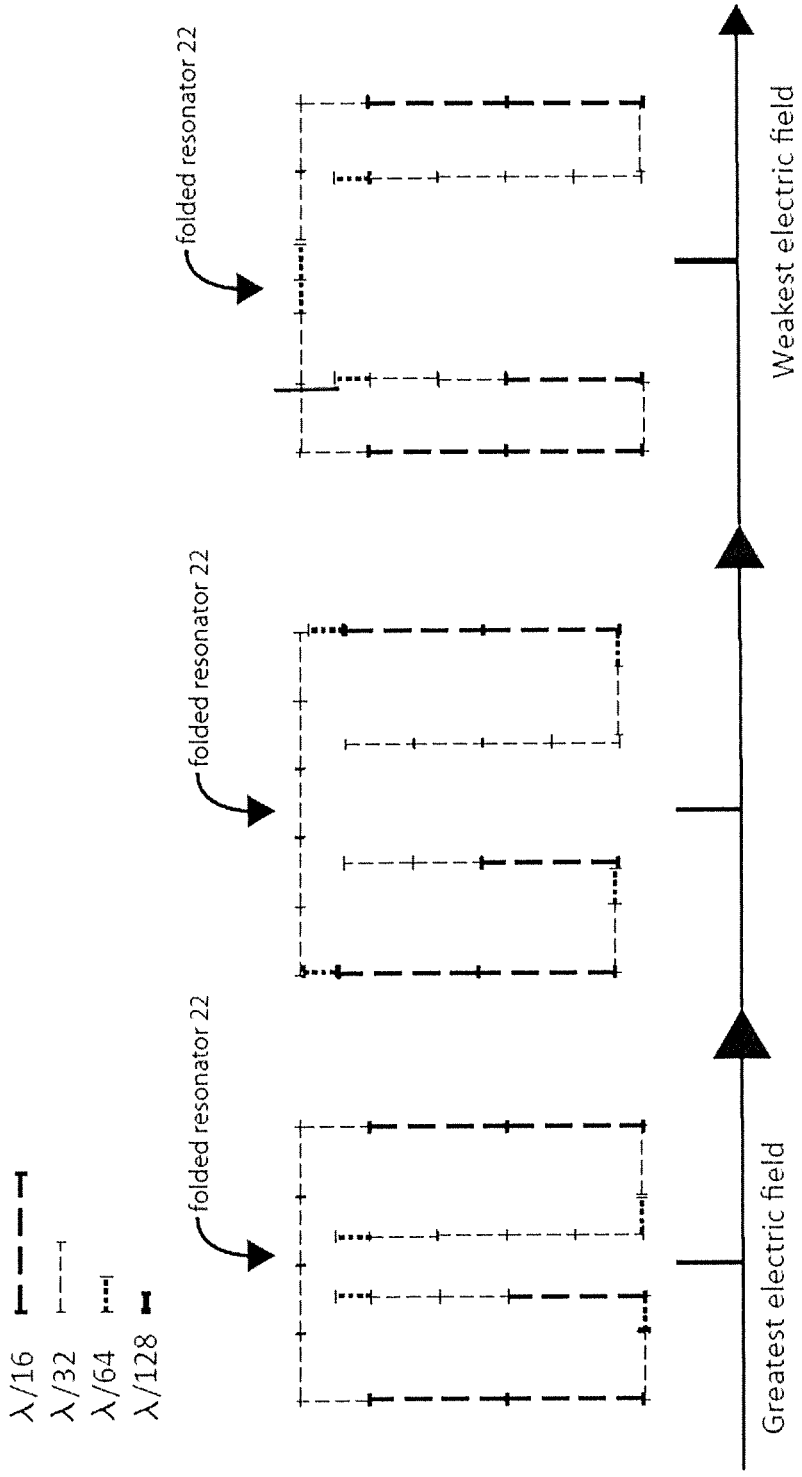

λ/16
λ/32
λ/64
λ/128
folded resonator 22
folded resonator 22
folded resonator 22
Greatest electric field
Weakest electric field

Figure 5

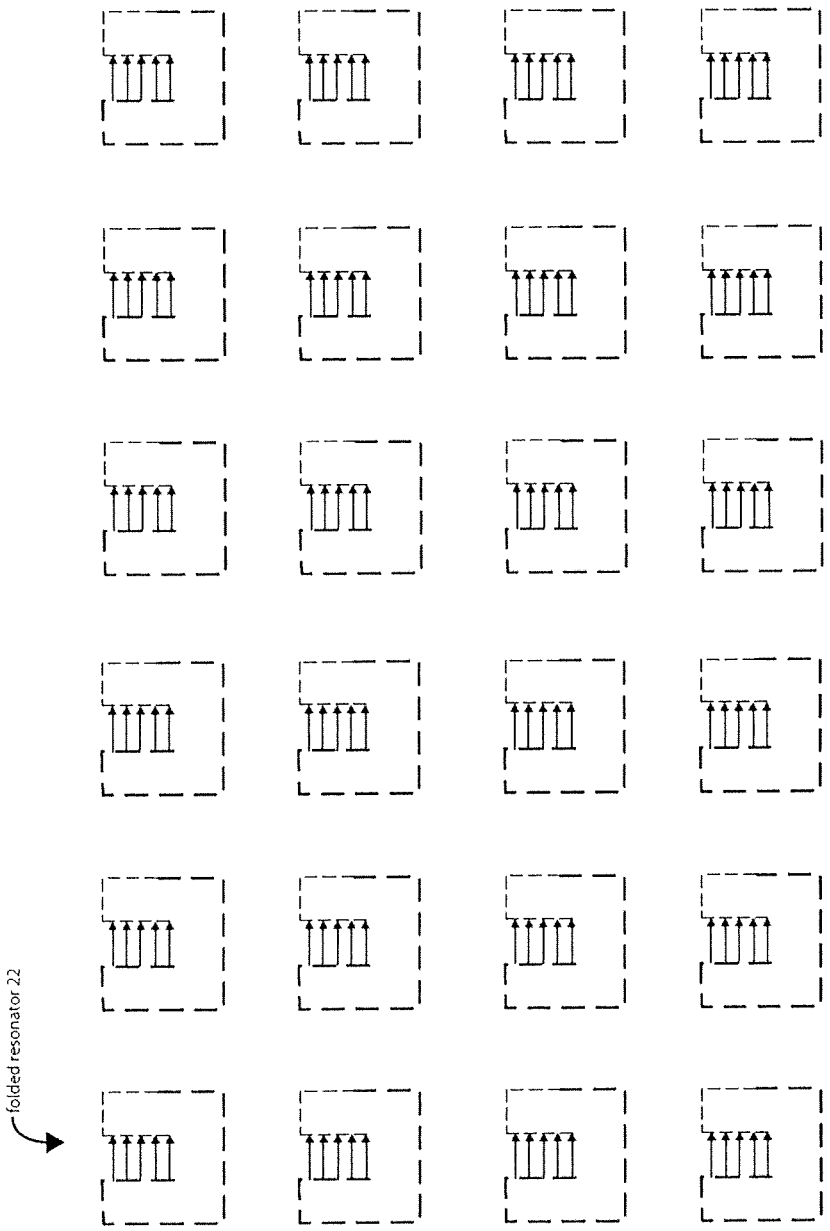


Figure 6

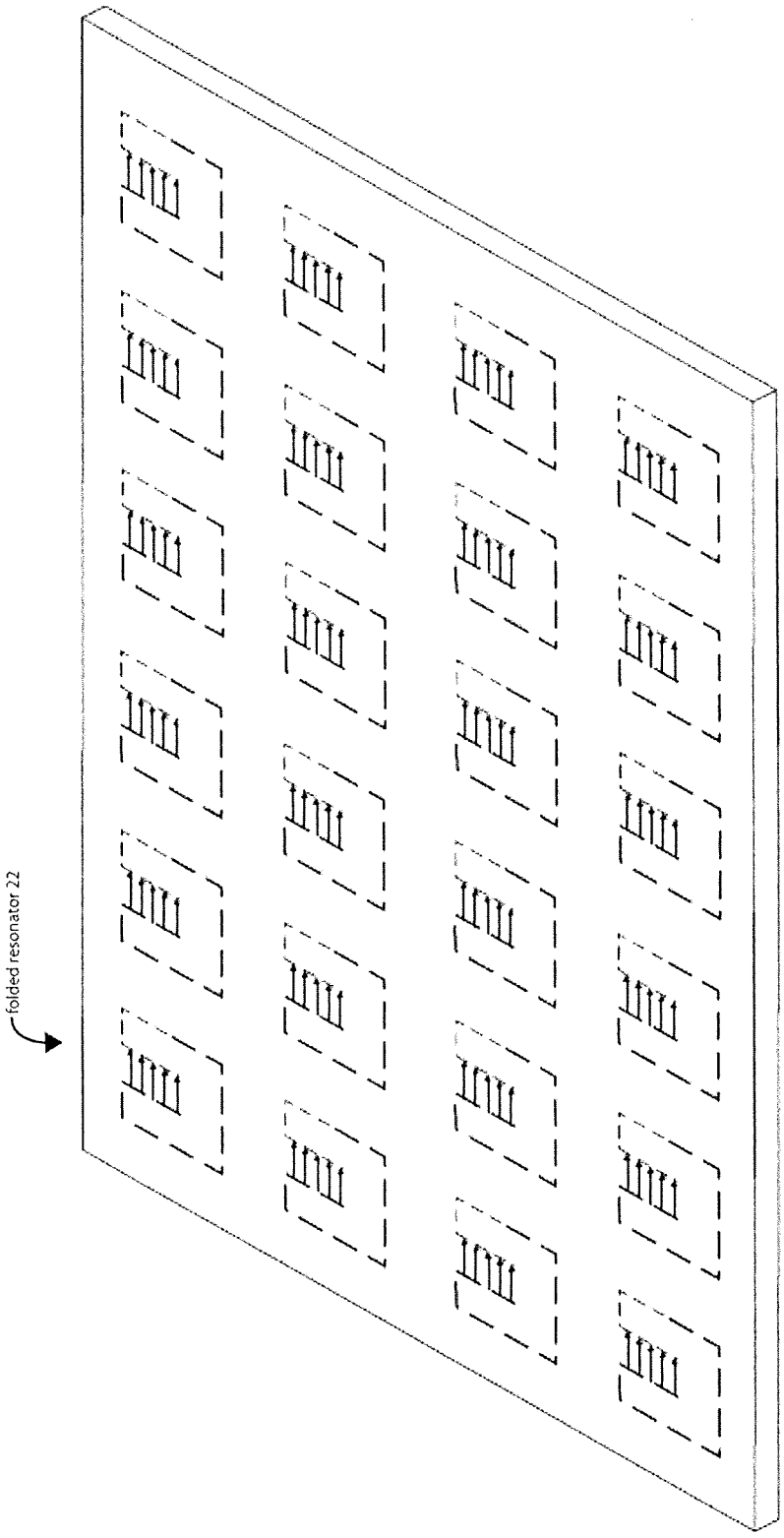


Figure 7A

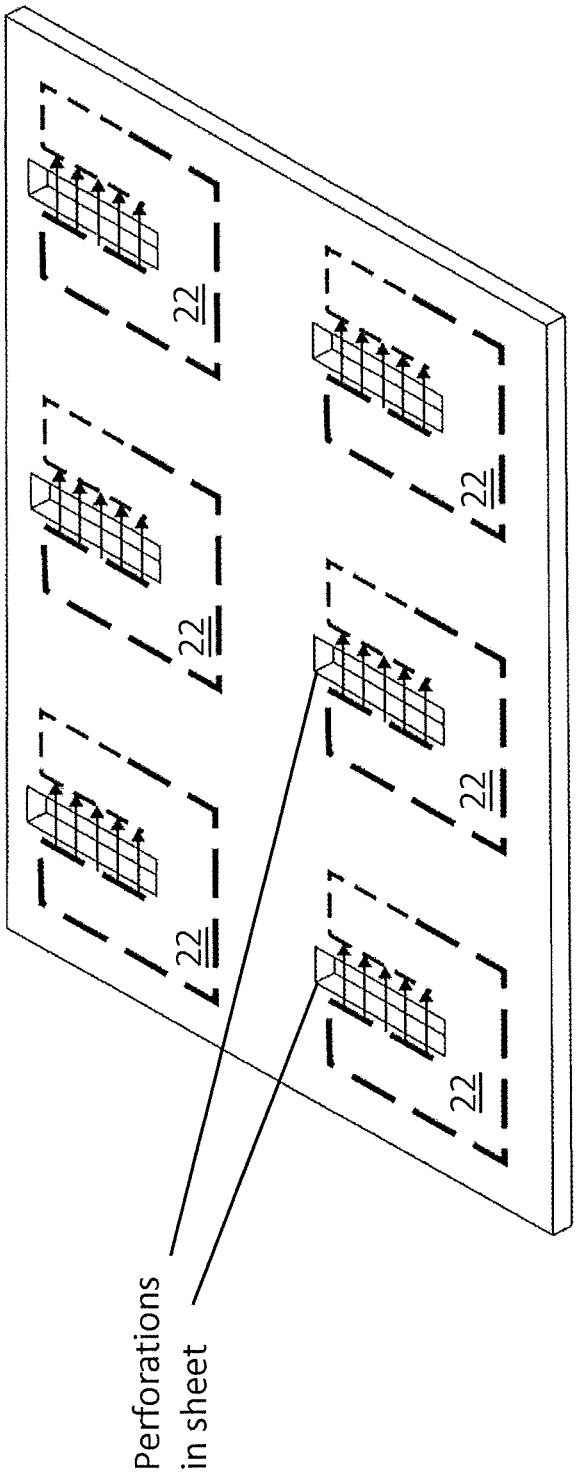


Figure 7B

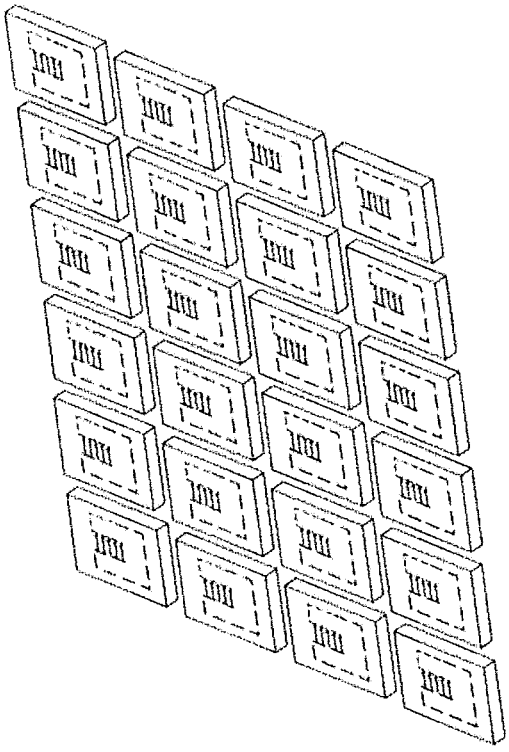


Figure 7C

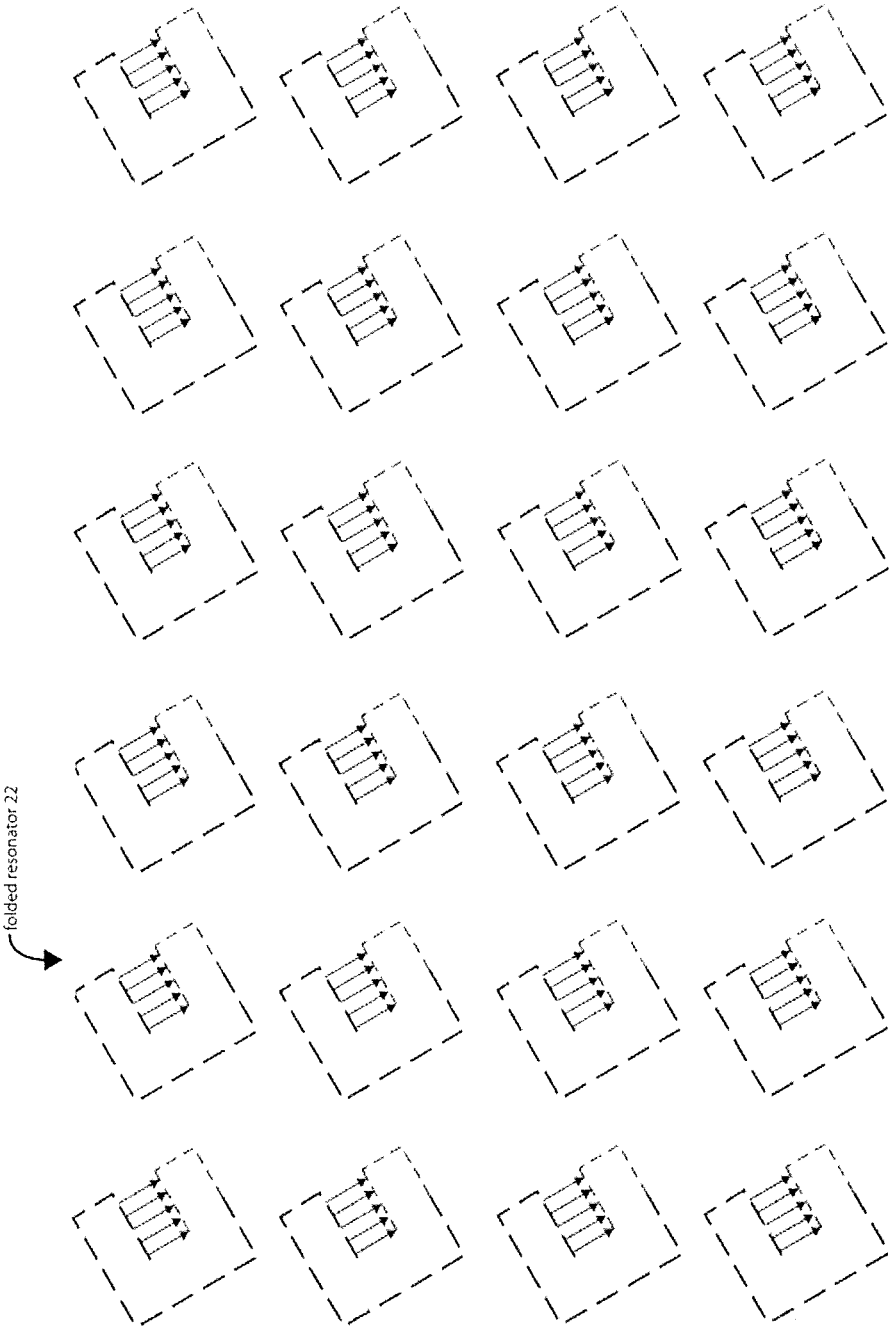


Figure 8

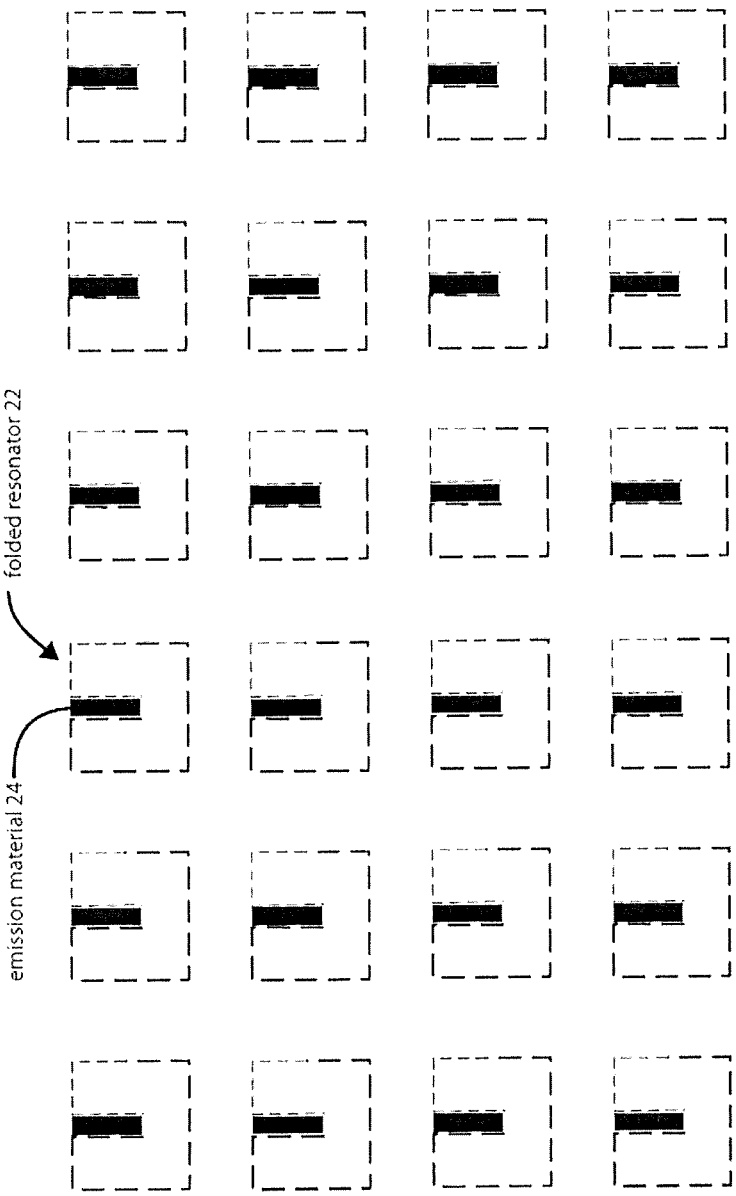


Figure 9

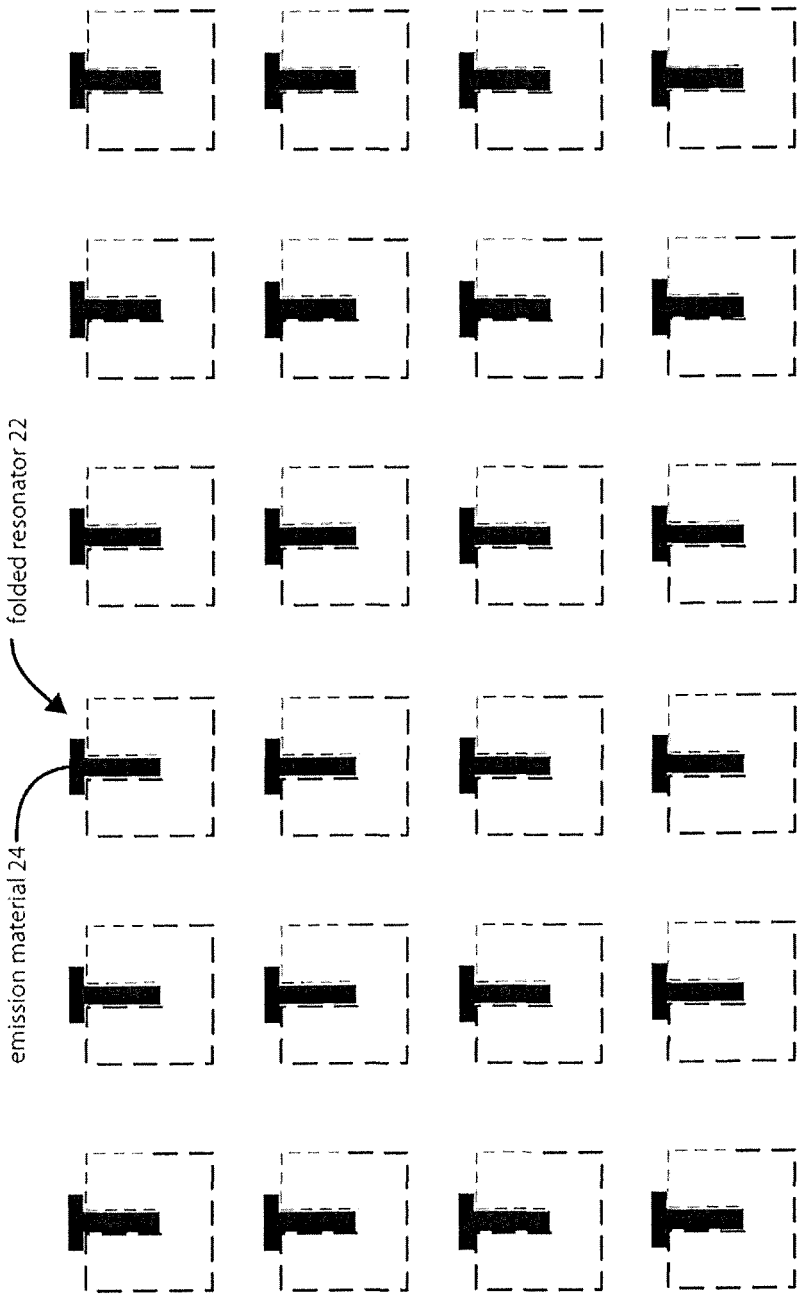


Figure 10

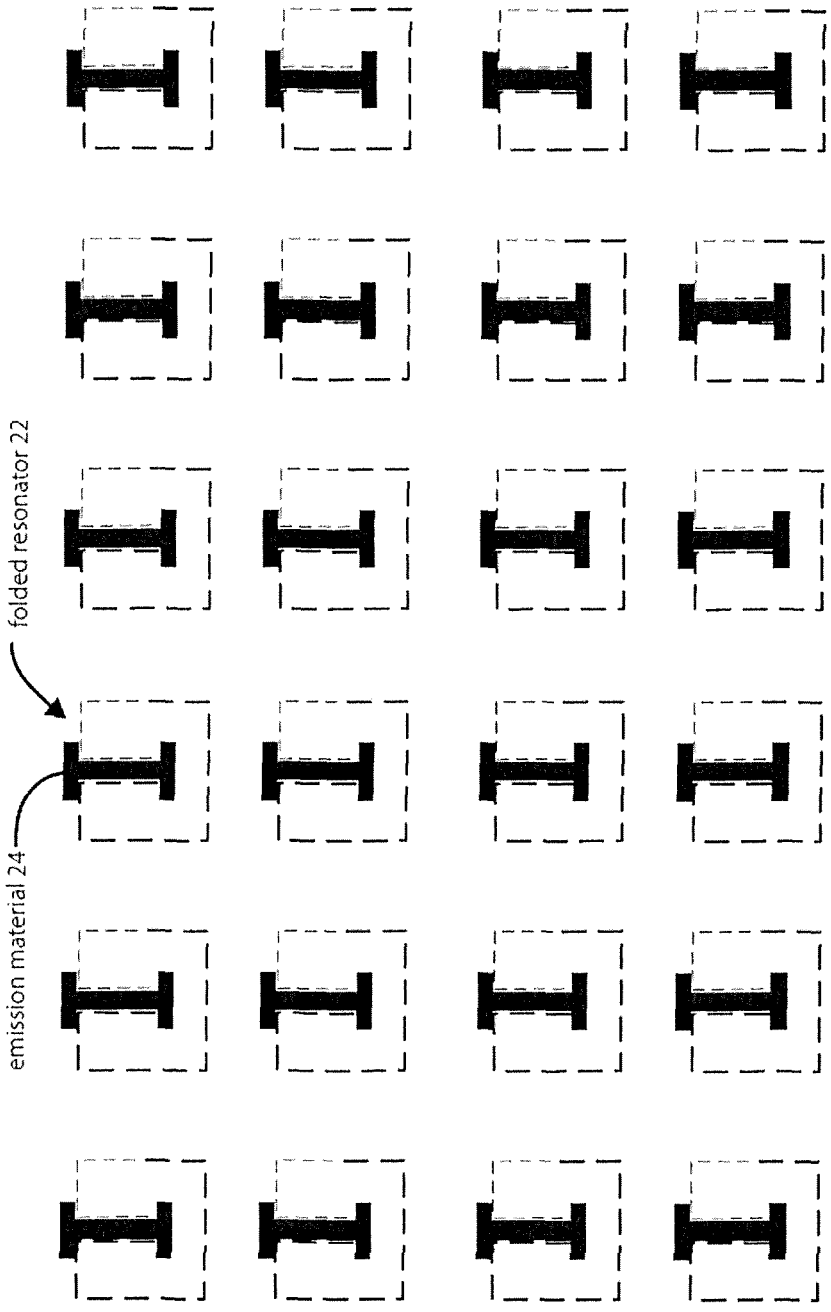


Figure 11

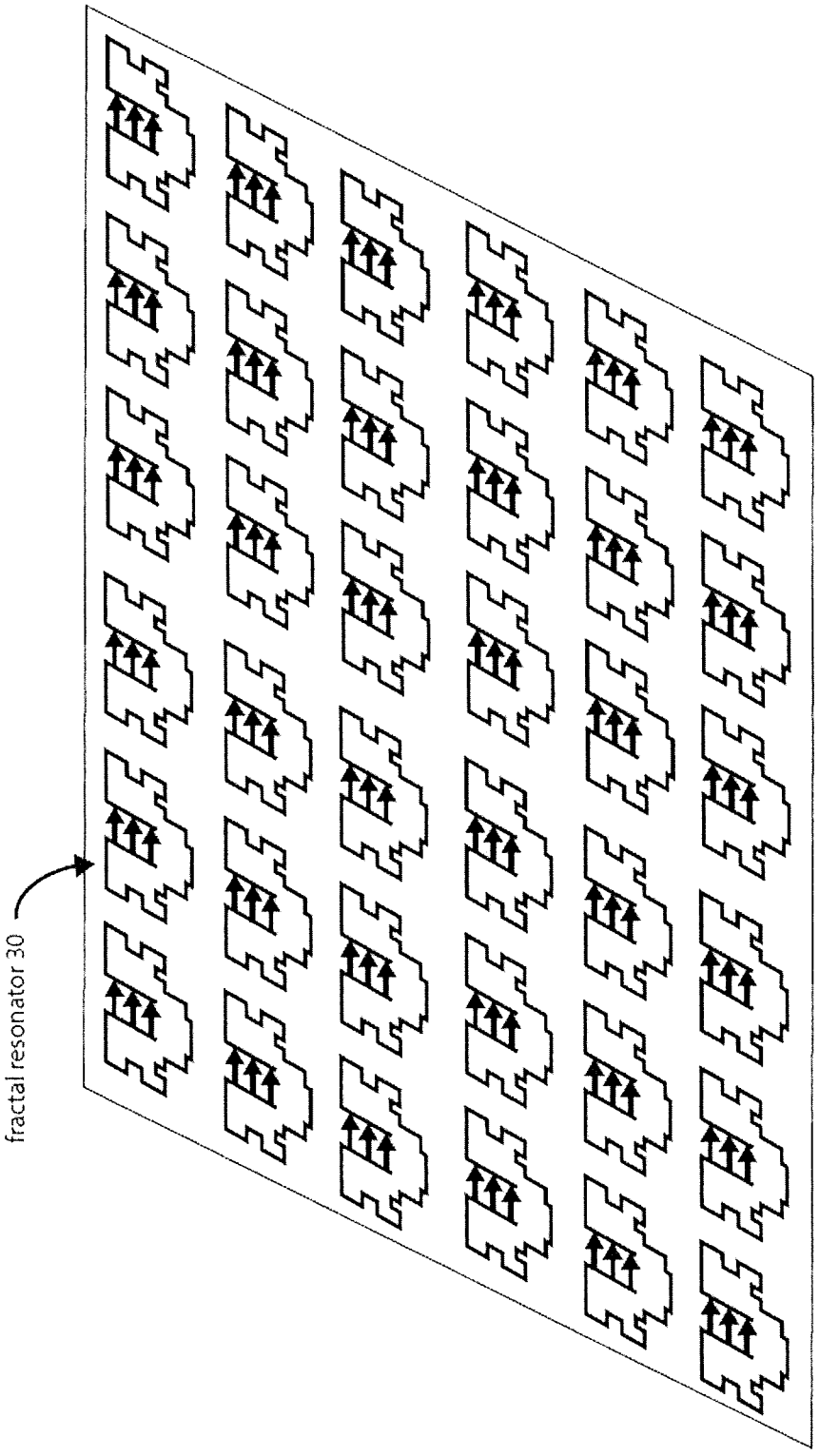


Figure 12

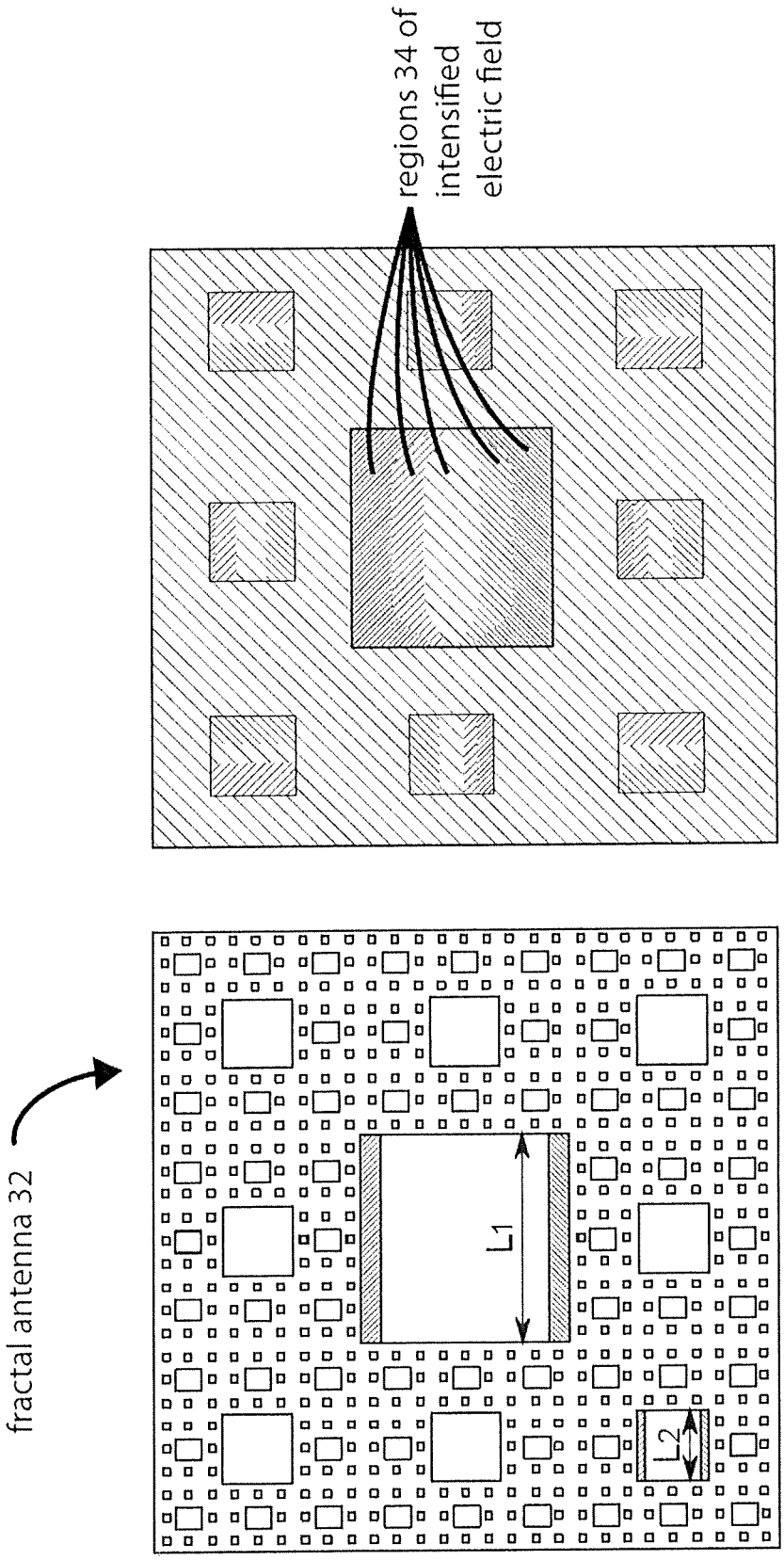

regions 34 of intensified electric field
fractal antenna 32
L1
L2

Figure 13

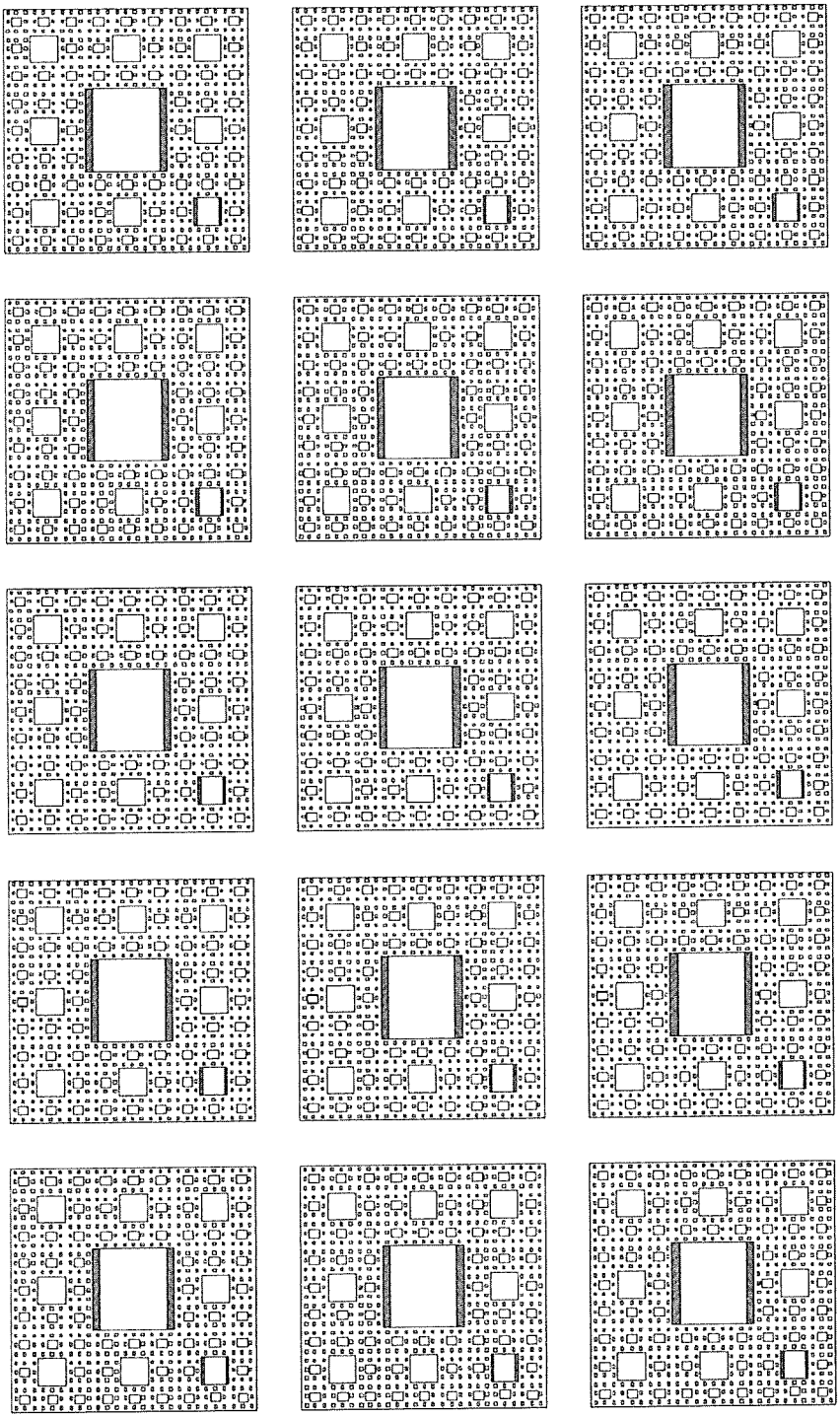


Figure 14

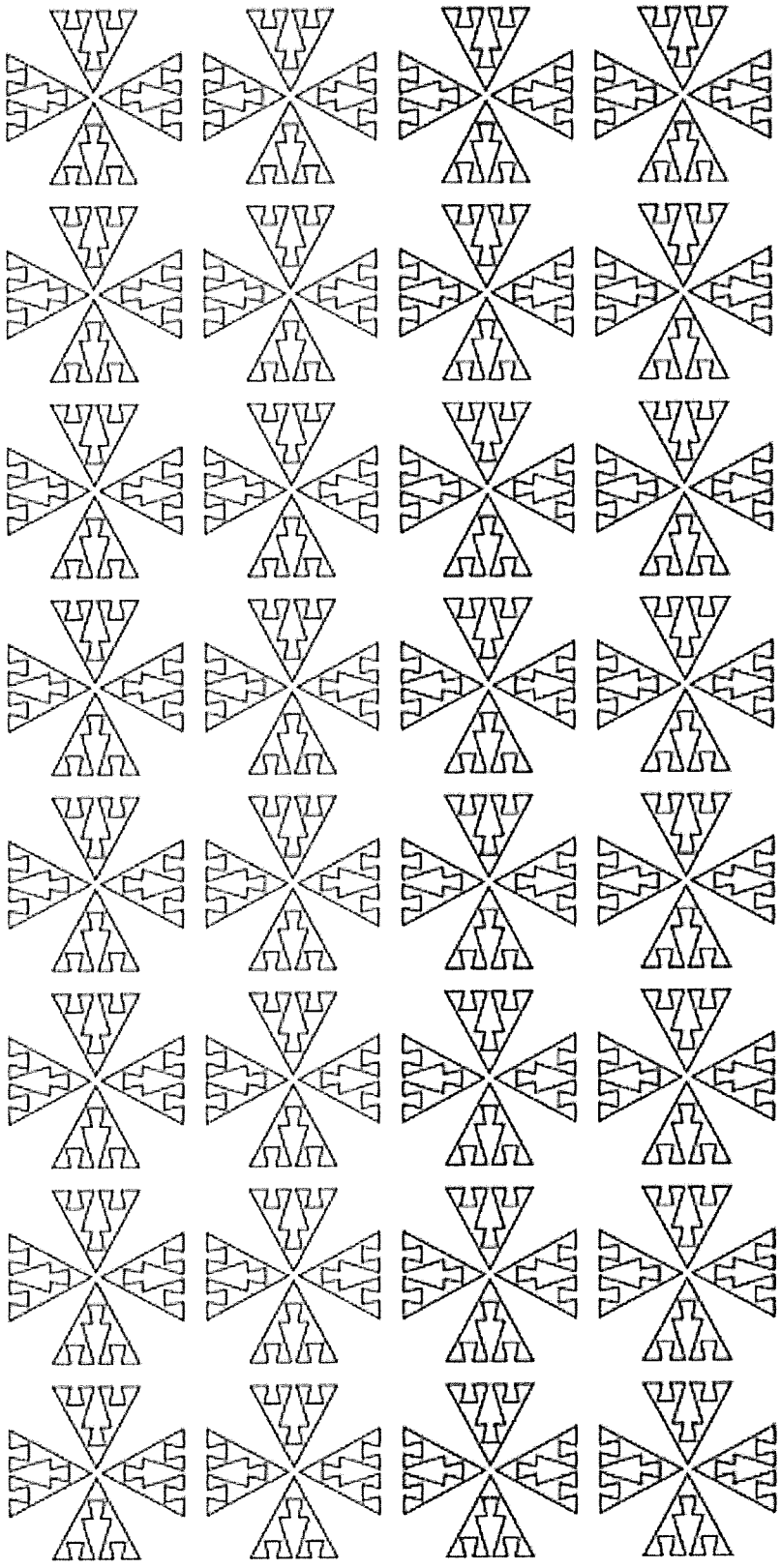


Figure 15

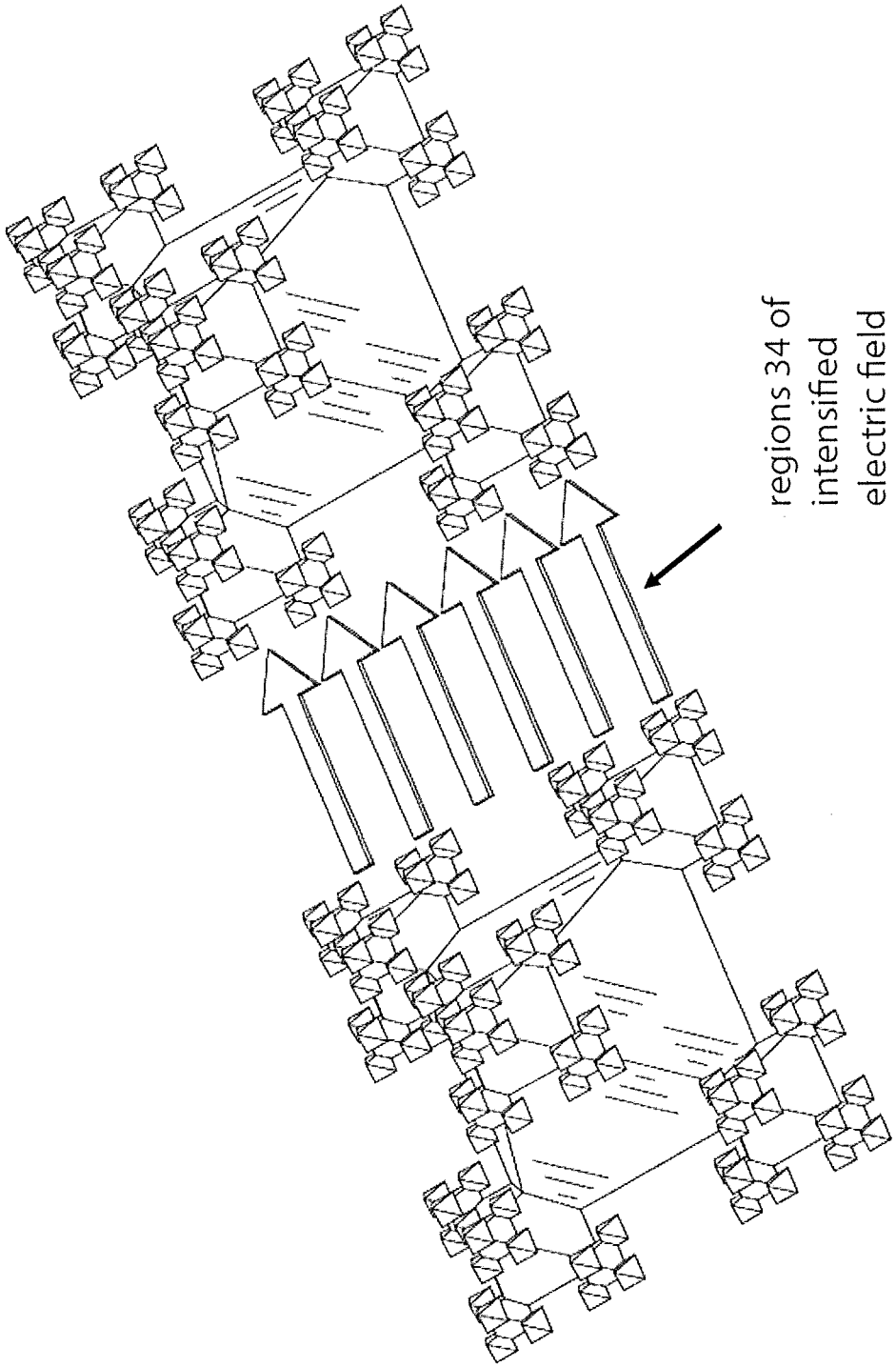


Figure 16

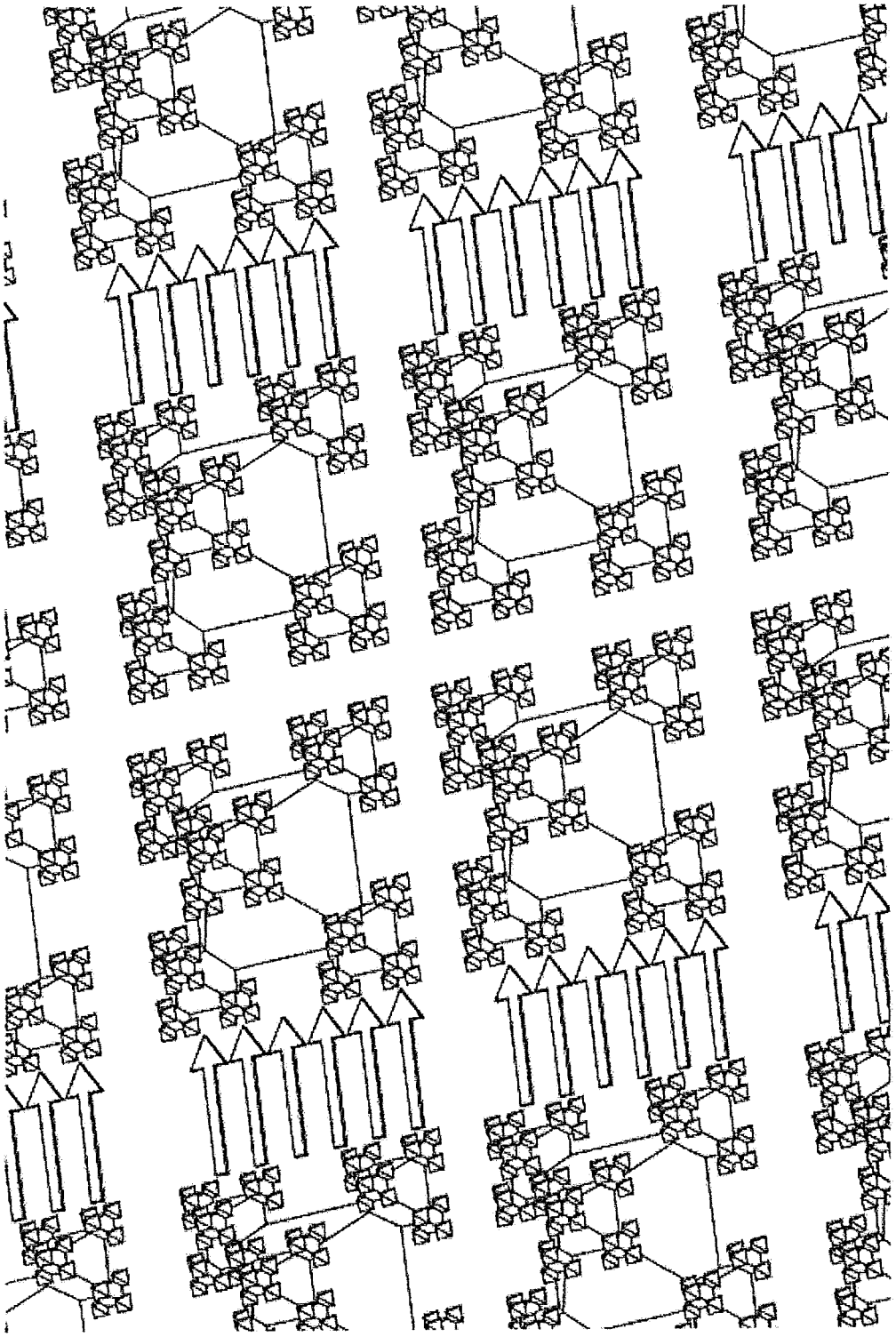


Figure 17

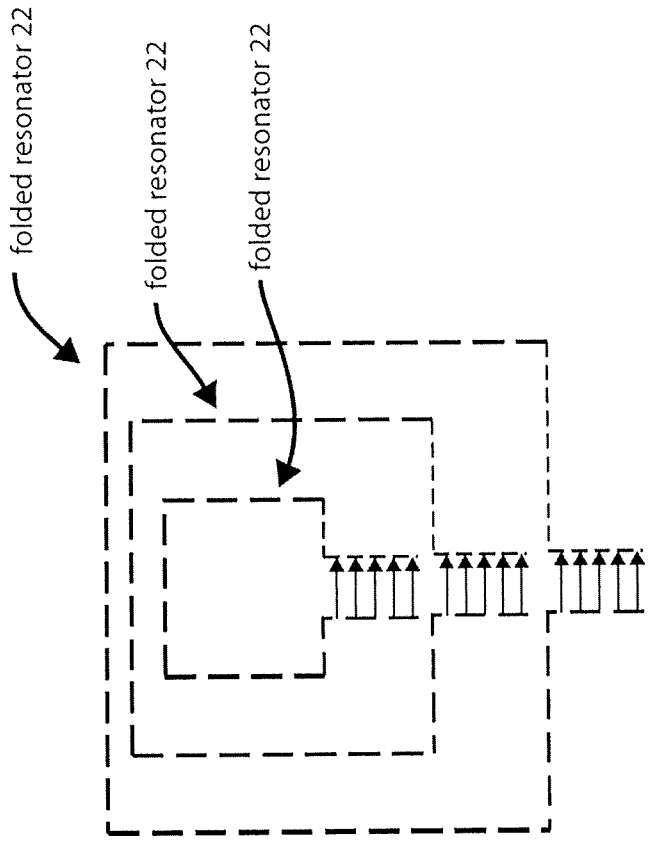


Figure 19

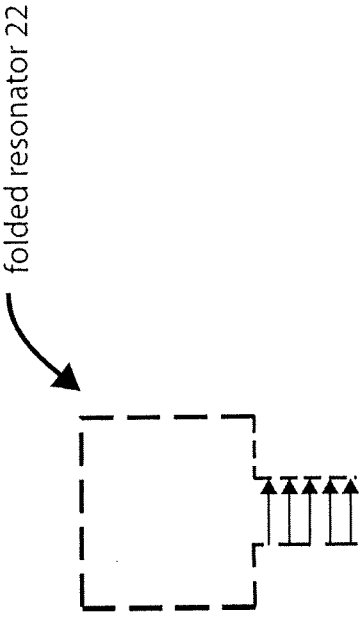


Figure 18

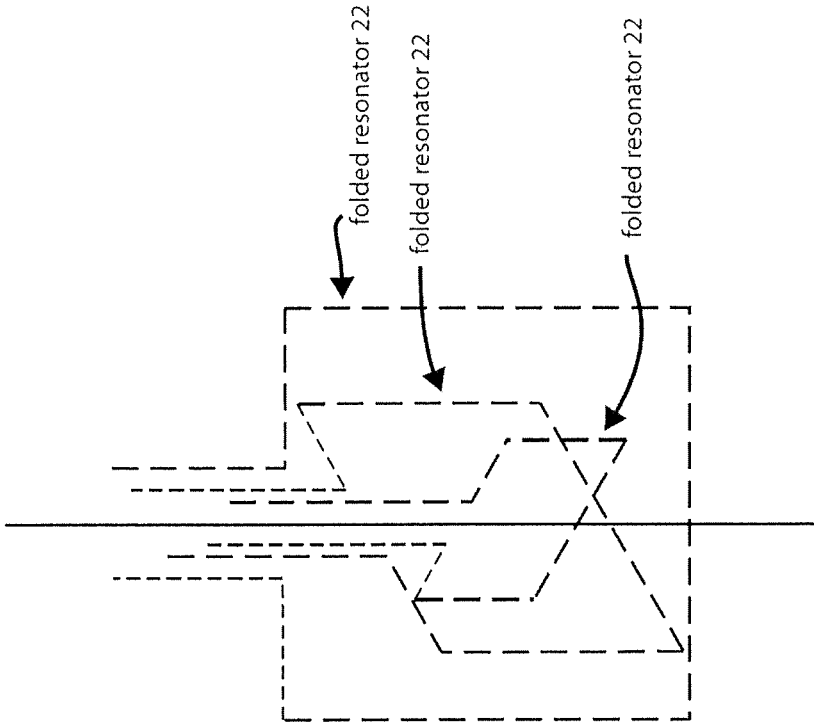


Figure 21

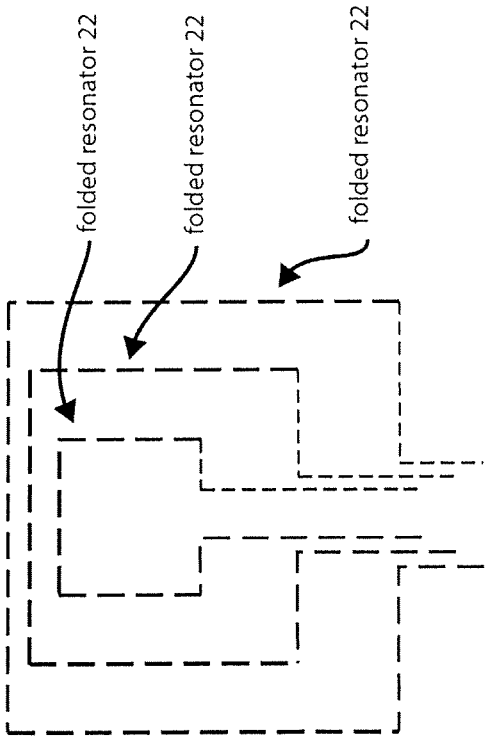


Figure 20

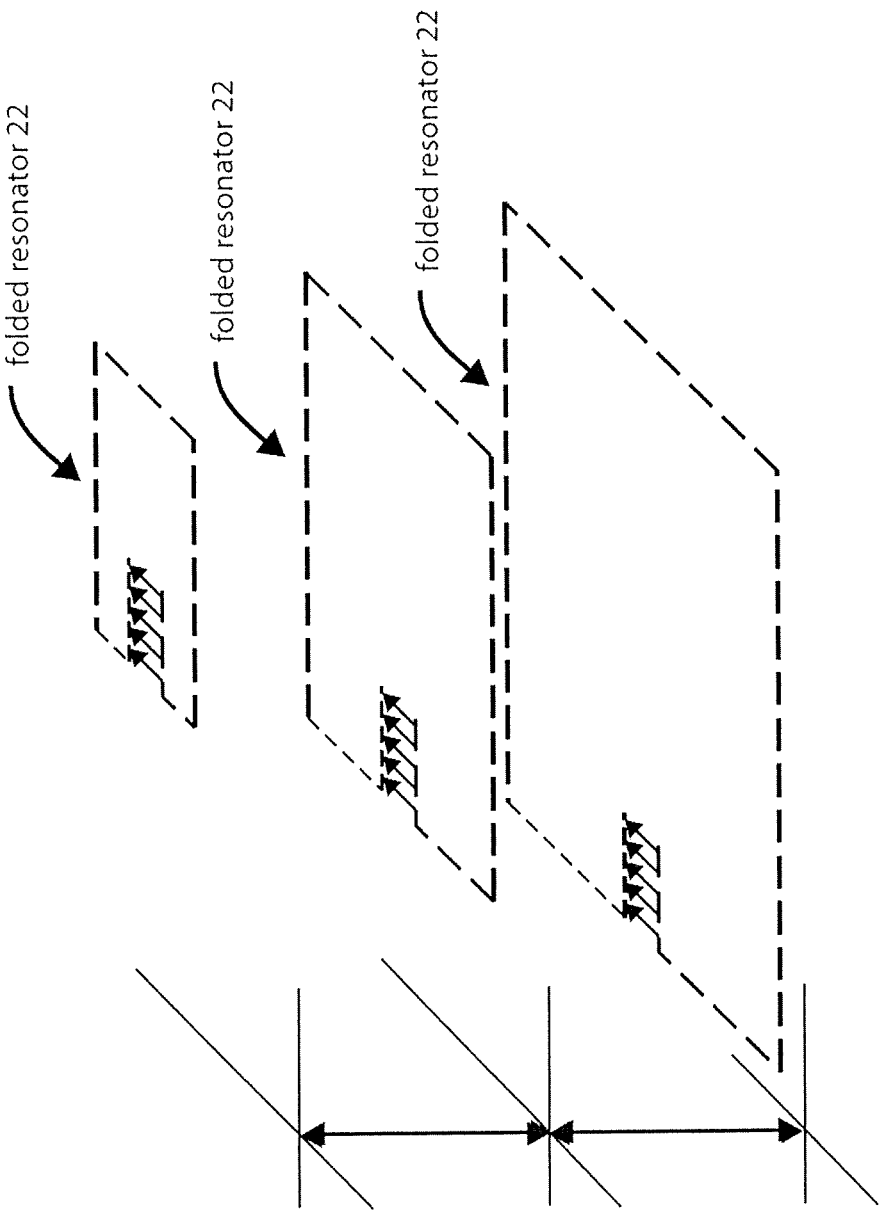

folded resonator 22
folded resonator 22
folded resonator 22

Figure 22

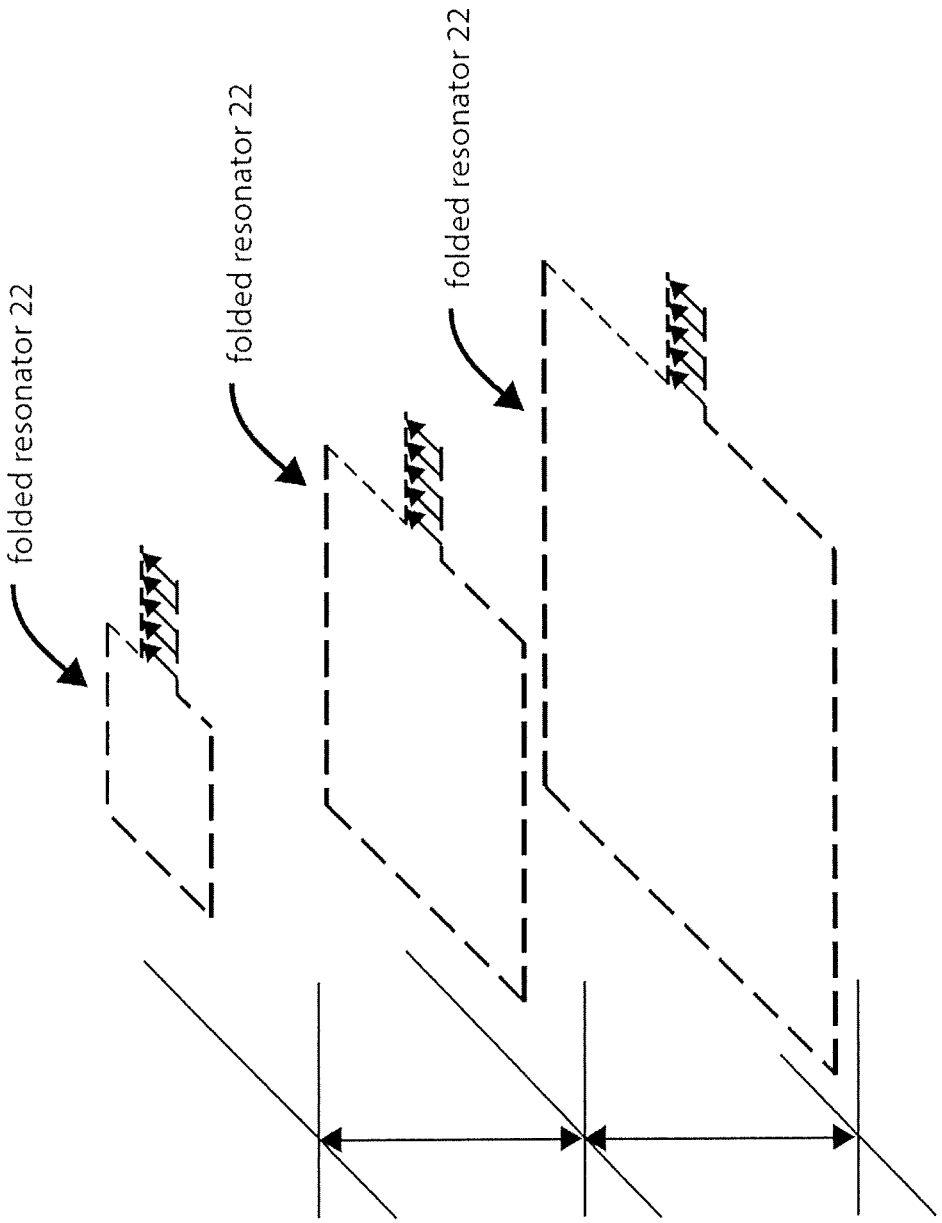

folded resonator 22
folded resonator 22
folded resonator 22

Figure 23

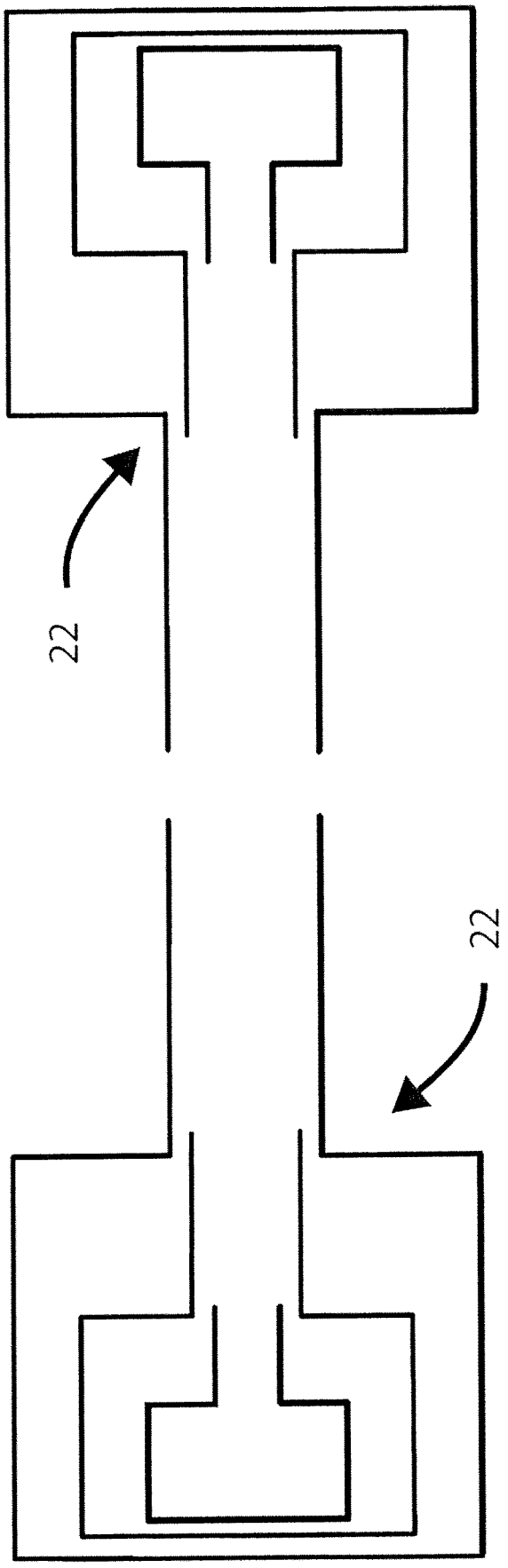


Figure 24A

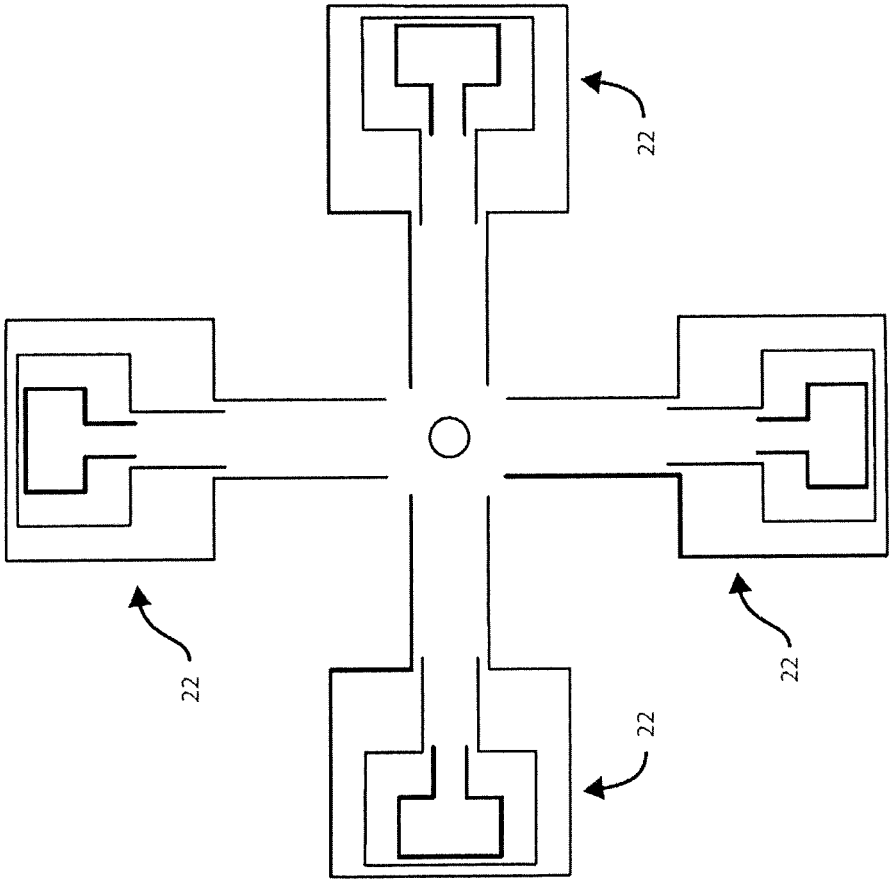


Figure 24B

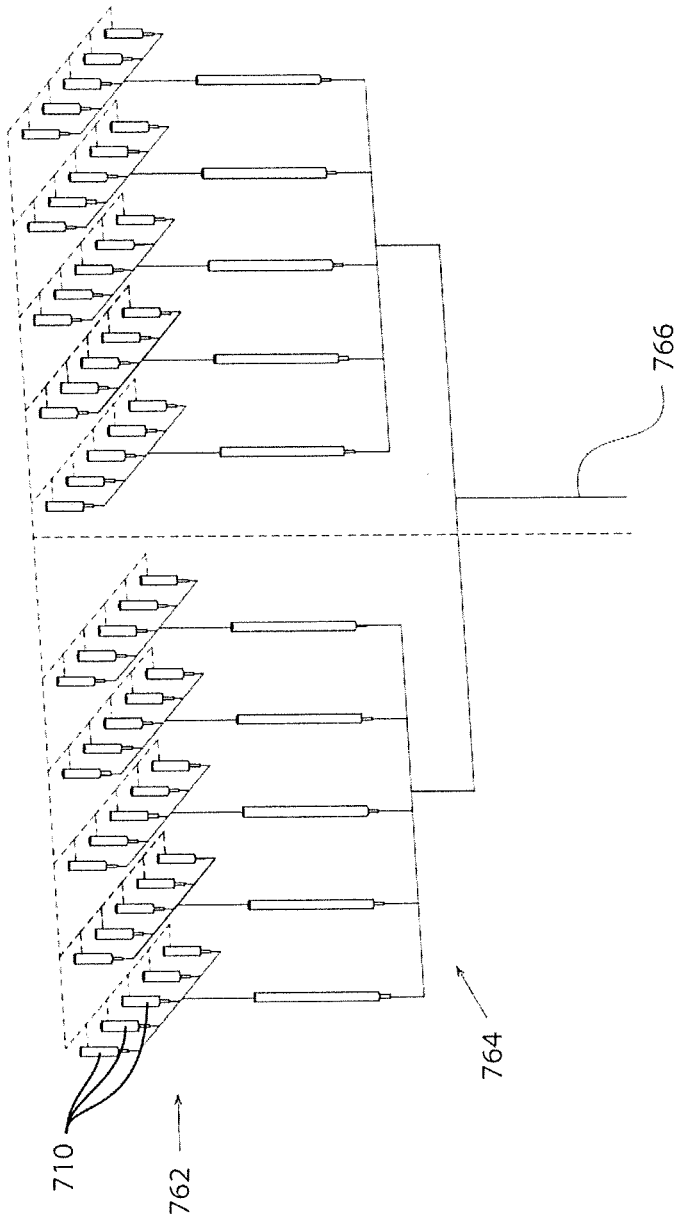


Figure 25A

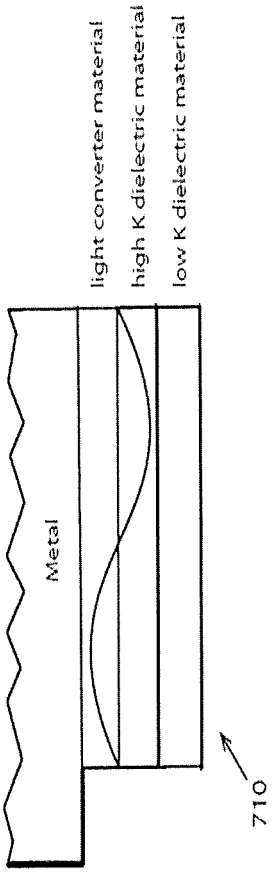

light converter material
high K dielectric material
low K dielectric material
Metal
710

Figure 25B

PLASMONICS PHOTO-ACTIVE PROBES
PHOTO-ACTIVE (PA) MOLECULE (PHOTOSENSITIZER)
METAL (e.g. Au, Ag)
MATERIAL CONTAINING PA
PROTECTIVE COATING
PA MOLECULES BOUND TO METAL NANOPARTICLE
PA-CONTAINING NANO-PARTICLE COVERED WITH METAL NANOPARTICLES
METAL NANOPARTICLE COVERED WITH PA NANOCAP
PA-CONTAINING NANO-PARTICLE COVERED WITH METAL NANOCAP
METAL NANOPARTICLE COVERED WITH PA NANOSHELL
PA-CONTAINING NANO-PARTICLE COVERED WITH METAL NANOSHELL
PA-CONTAINING NANO-PARTICLE COVERED WITH METAL NANOSHELL WITH PROTECTIVE COATING LAYER

Figure 26

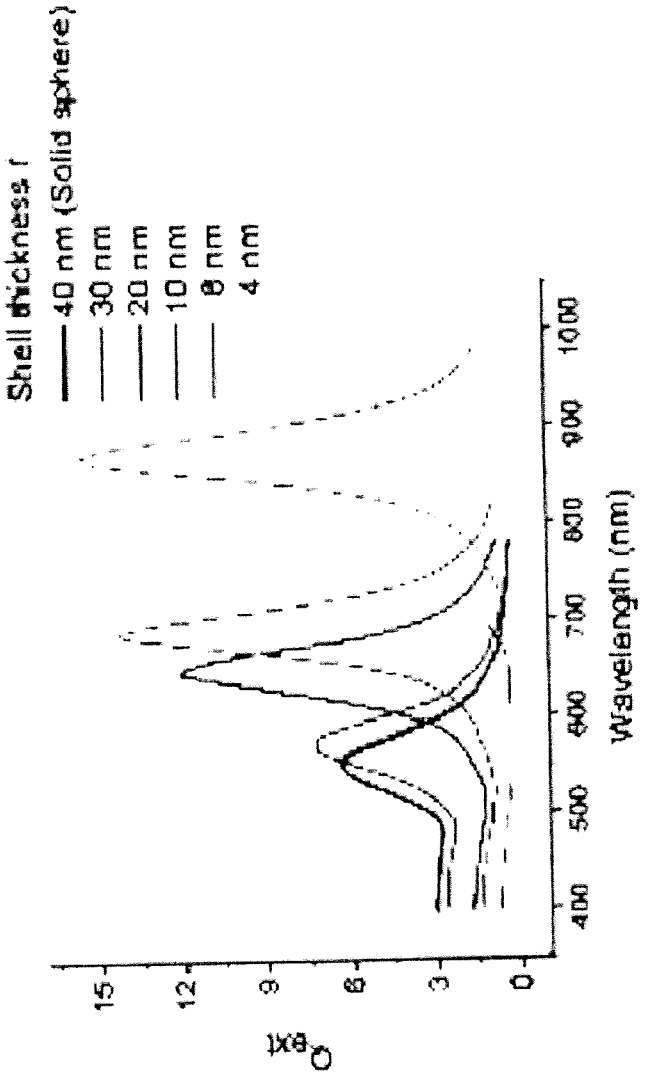

Shell thickness t
40 nm (Solid sphere)
30 nm
20 nm
10 nm
8 nm
4 nm
Q_{ext}
0
3
6
9
12
15
400
500
600
700
800
900
1000
Wavelength (nm)

Figure 27

Figure 28A

PLASMONICS PHOTO-ACTIVE PROBES WITH
ENERGY UPCONVERTING MATERIALS
PHOTO-ACTIVE (PA)
MOLECULE
(PHOTOSENSITIZER)
METAL (e.g. Au, Ag)
UPCONVERTING
MATERIAL (UCN)
PROTECTIVE
COATING
PA MOLECULES BOUND TO
UC NANOPARTICLE
UCN-CONTAINING NANO-
PARTICLE COVERED WITH
METAL NANOPARTICLES
METAL NANOPARTICLE
COVERED WITH UCN NANOCAP
UCN-CONTAINING NANO-
PARTICLE COVERED WITH
METAL NANOCAP
METAL NANOPARTICLE COVERED
WITH DIELECTRIC LAYER
AND UCN NANOSHELL
METAL NANOPARTICLE COVERED
WITH DIELECTRIC LAYER
AND METAL NANOSHELL
METAL NANOPARTICLE COVERED
WITH DIELECTRIC LAYER
AND METAL NANOSHELL WITH
PROTECTIVE COATING LAYER

Figure 28B

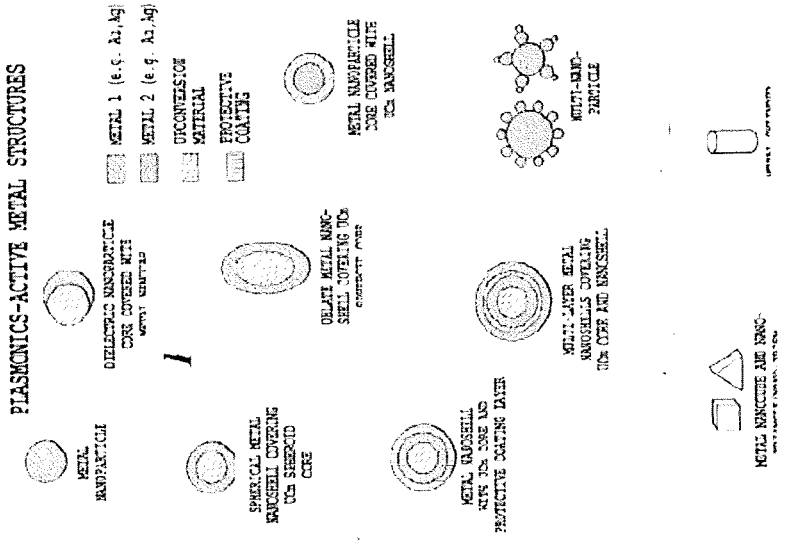

PLASMONICS-ACTIVE METAL STRUCTURES
METAL NANOPARTICLE
DIELECTRIC NANOPARTICLE CORE COVERED WITH
METAL 1 (e.g., Au, Ag)
METAL 2 (e.g., Au, Ag)
DISCONTINUOUS MATERIAL
PROTECTIVE COATING
SPHERICAL METAL NANOSHELL COVERING DIELECTRIC SPHEROID CORE
METAL NANOPARTICLE CORE COVERED WITH DIELECTRIC NANOSHELL
METAL NANOSHELL WITH DIELECTRIC CORE AND PROTECTIVE COATING LAYER
MULTI-LAYER METAL NANOSHELLS COVERING DIELECTRIC CORE AND NANOSHELL
MULTI-NANO-PARTICLE
METAL NANOCUBE AND NANO-

Figure 28C

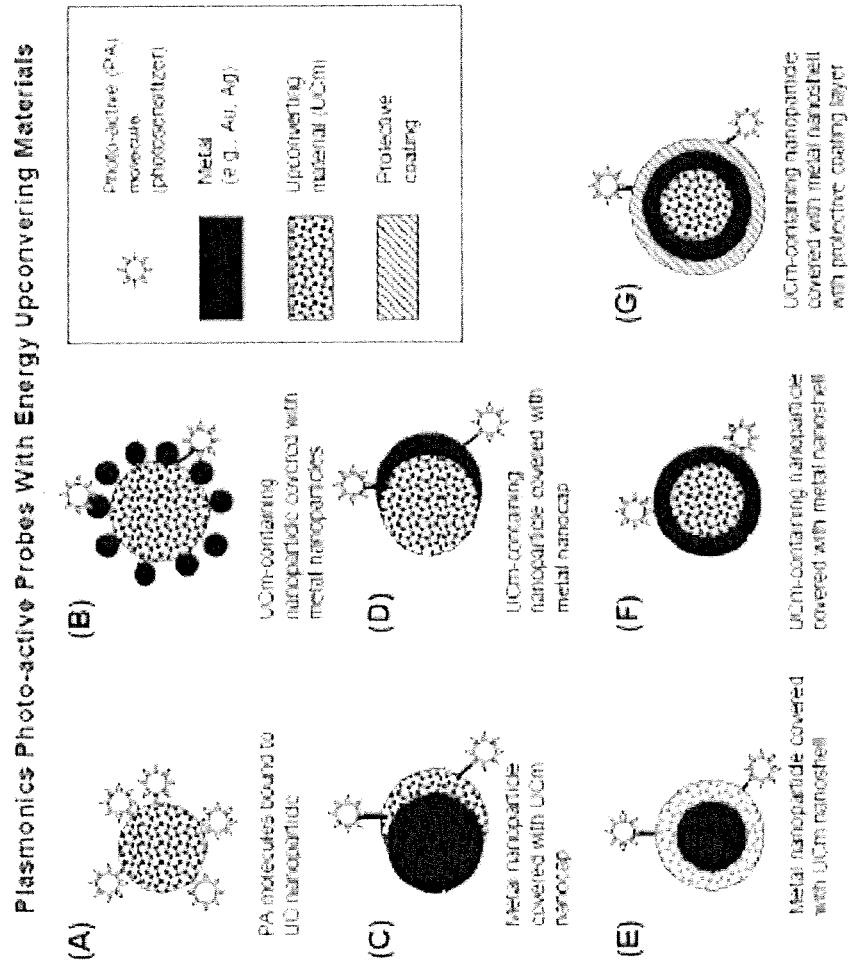

Plasmonics Photo-active Probes With Energy Upconvering Materials
(A)
PA molecules bound to UCm nanoparticle
(B)
Photo-active (PA) molecule (photosensitizer)
Metal (e.g., Au, Ag)
Upconverting material (UCm)
Protective coating
(C)
Metal nanoparticle covered with UCm nanocap
(D)
UCm-containing nanoparticle covered with metal nanocap
UCm-containing nanoparticle covered with metal nanoshell
(E)
Metal nanoparticle covered with UCm nanoshell
(F)
(G)
UCm-containing nanoparticle covered with metal nanoshell with protective coating layer

Figure 28D

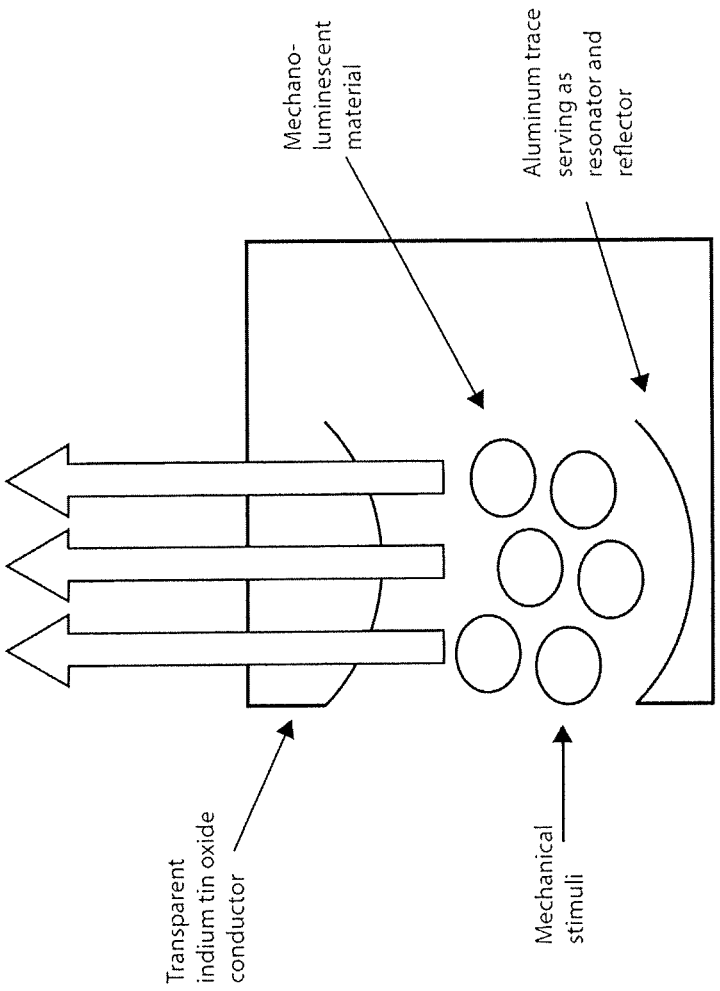

Mechano-luminescent material
Aluminum trace serving as resonator and reflector
Transparent indium tin oxide conductor
Mechanical stimuli

Figure 29

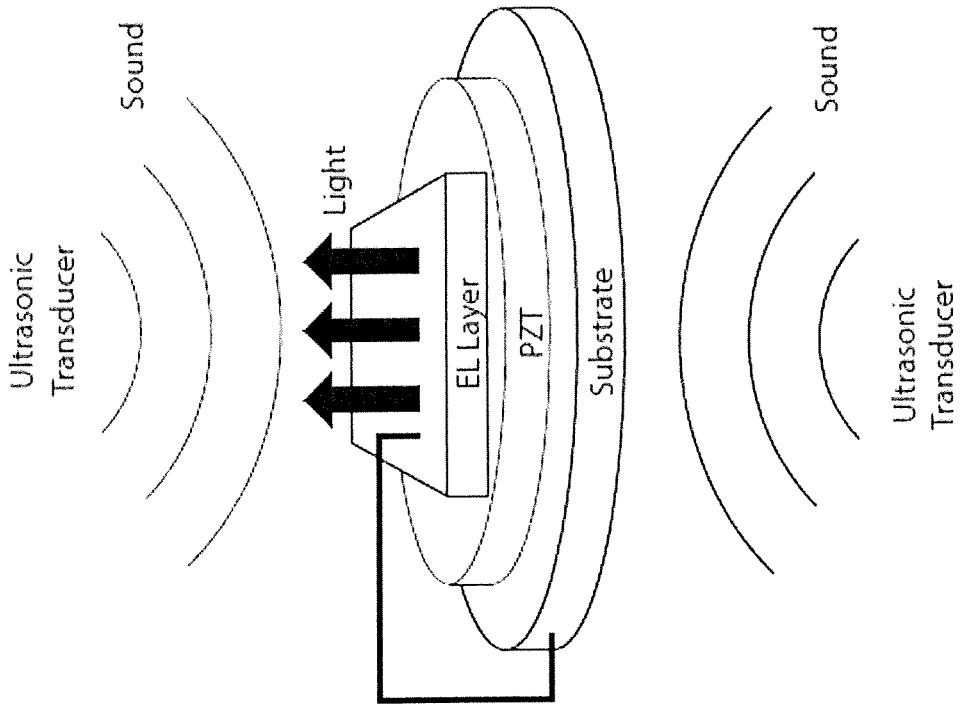

Ultrasonic Transducer
Sound
Light
EL Layer
PZT
Substrate
Sound
Ultrasonic Transducer

Figure 30

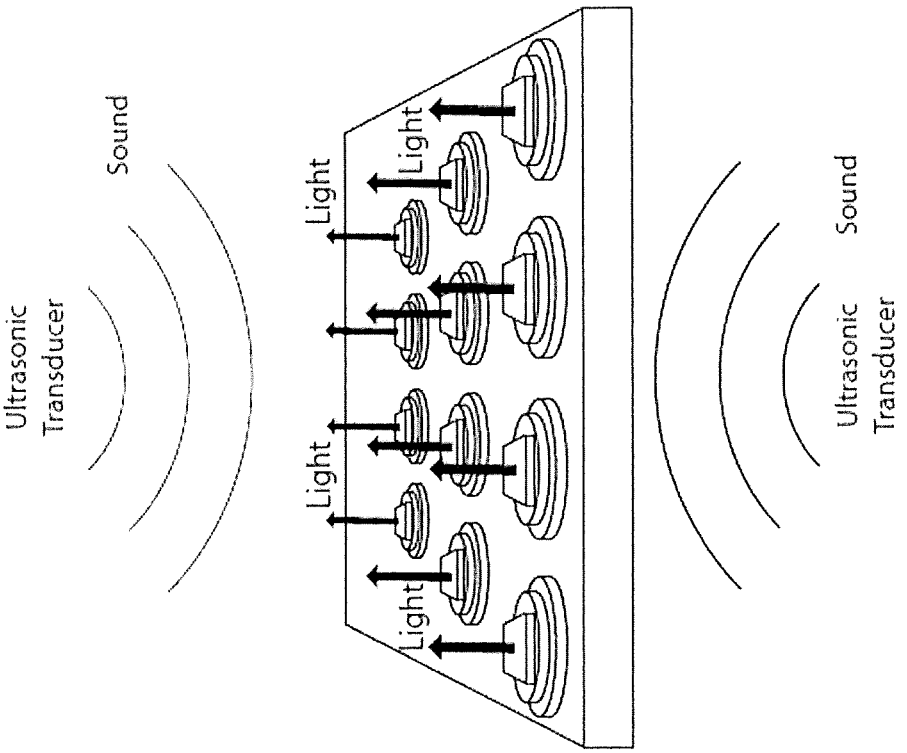

Ultrasonic Transducer
Sound
Light
Light
Light
Light
Sound
Ultrasonic Transducer

Figure 31

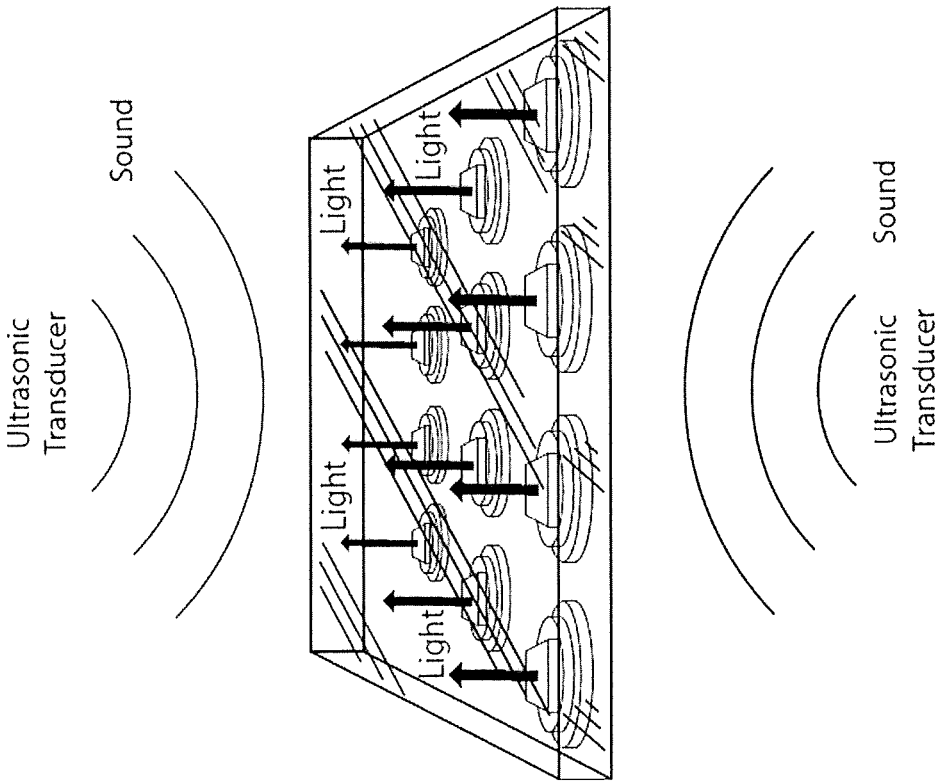

Ultrasonic Transducer
Sound
Light
Light
Light
Light
Sound
Ultrasonic Transducer

Figure 32

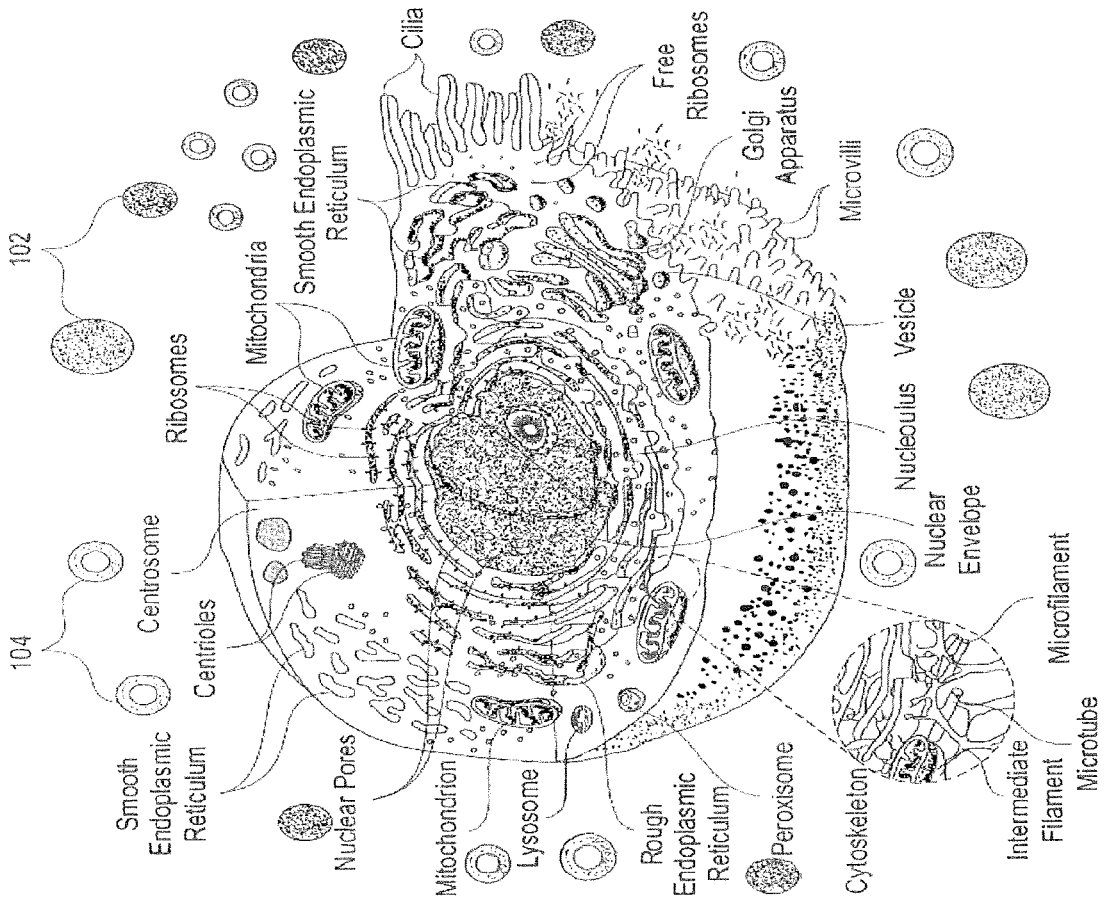

102
104
Centrosome
Centrioles
Smooth Endoplasmic Reticulum
Ribosomes
Mitochondria
Smooth Endoplasmic Reticulum
Cilia
Free Ribosomes
Golgi Apparatus
Microvilli
Vesicle
Nucleolus
Nuclear Envelope
Microfilament
Microtube
Intermediate Filament
Cytoskeleton
Peroxisome
Rough Endoplasmic Reticulum
Lysosome
Mitochondrion
Nuclear Pores

Figure 33A

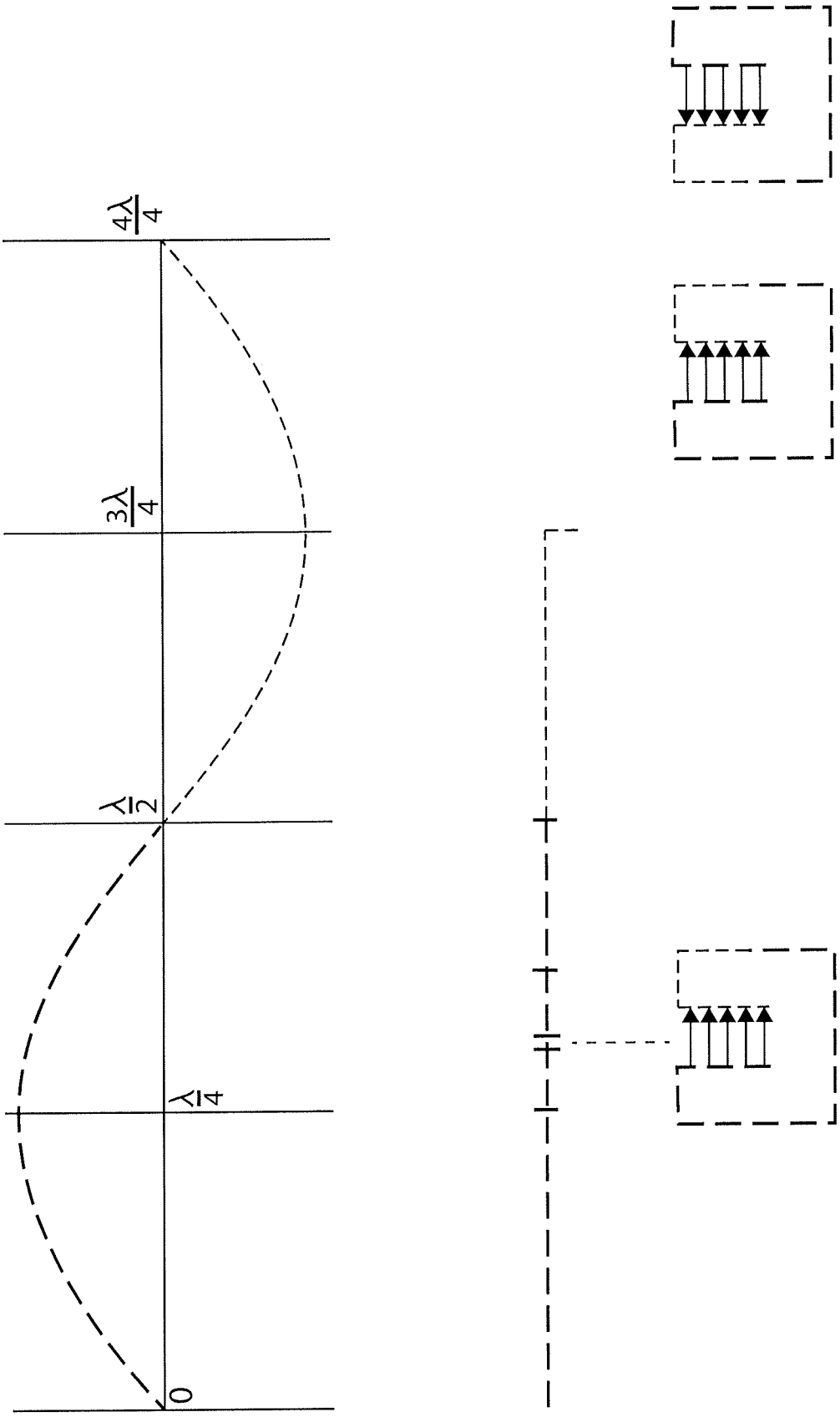


Figure 33B

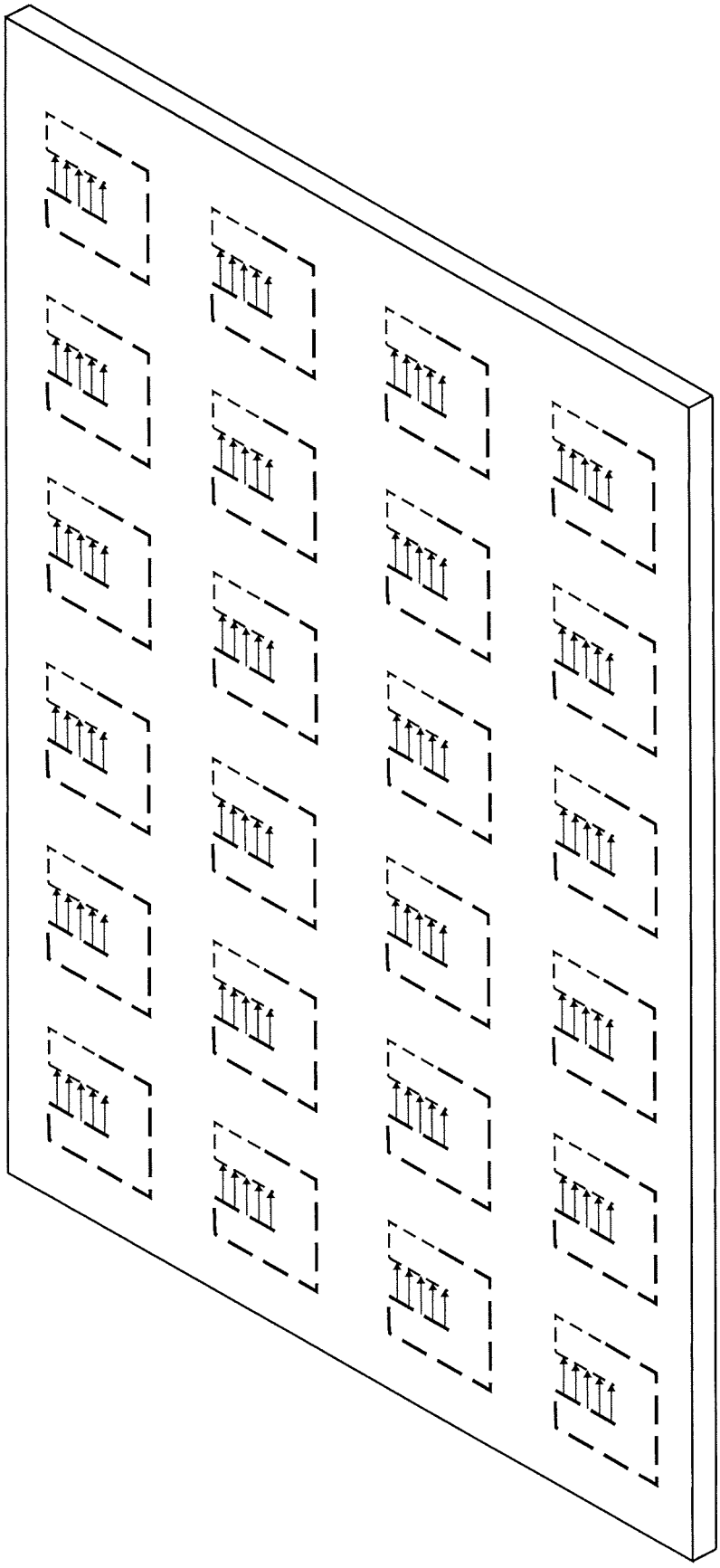


Figure 33C

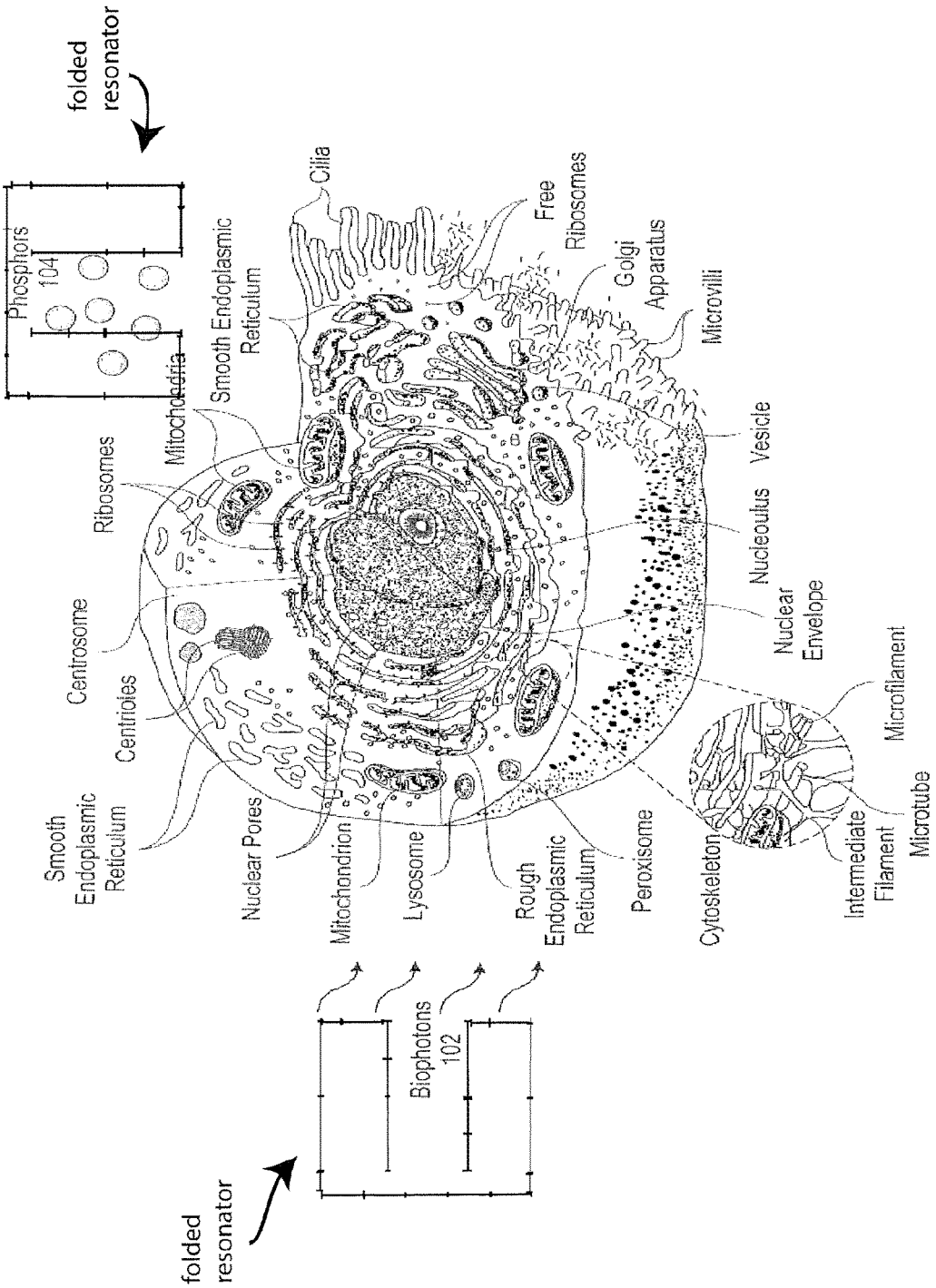

folded resonator
Phosphors 104
Cilia
Free Ribosomes
Golgi Apparatus
Microvilli
Smooth Endoplasmic Reticulum
Mitochondria
Ribosomes
Vesicle
Centrosome
Nucleolus
Centrioles
Nuclear Envelope
Microfilament
Smooth Endoplasmic Reticulum
Nuclear Pores
Mitochondrion
Lysosome
Rough Endoplasmic Reticulum
Peroxisome
Cytoskeleton
Intermediate Filament
Microtube
Biophotons 102
folded resonator

Figure 34

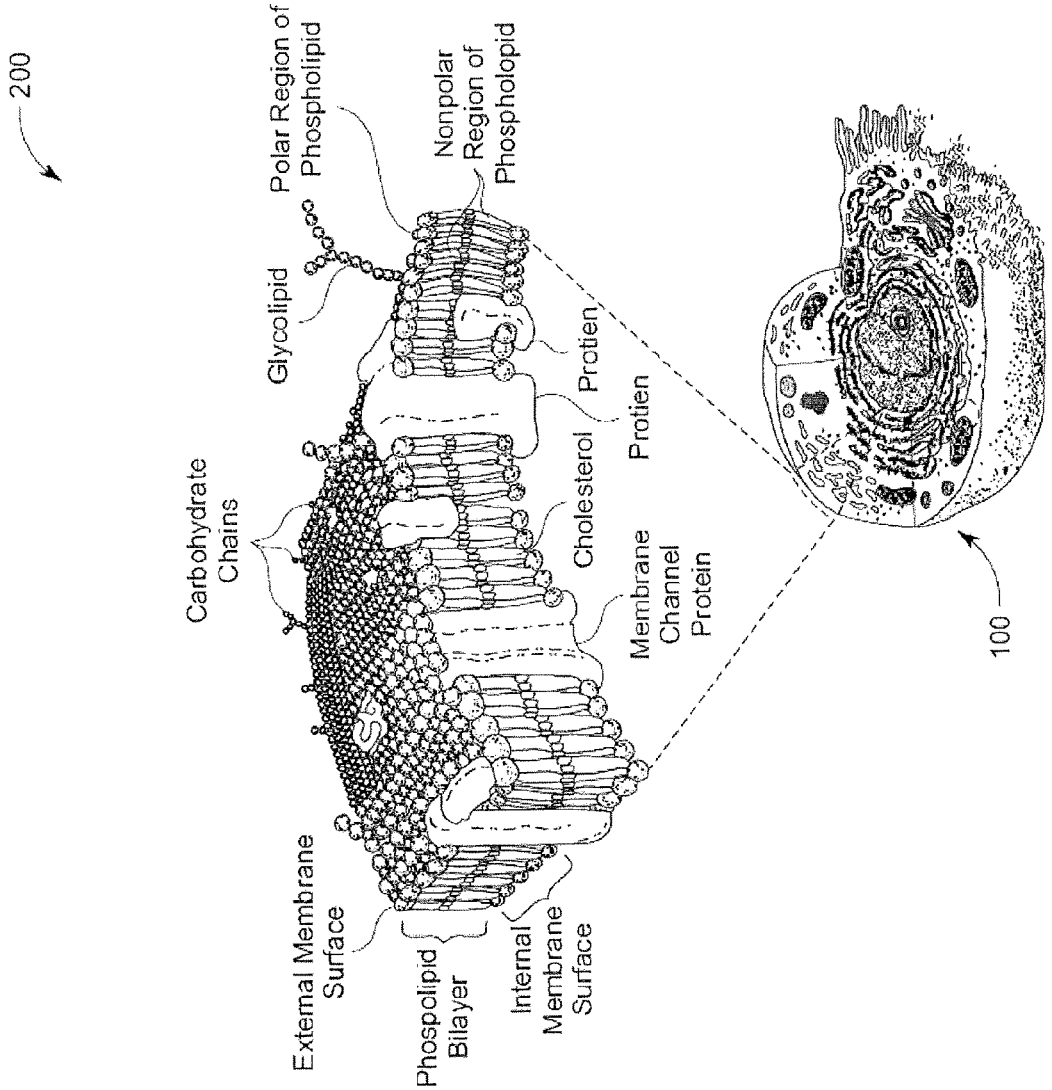

200
Polar Region of Phospholipid
Nonpolar Region of Phospholopid
Glycolipid
Protien
Protien
Cholesterol
Carbohydrate Chains
Membrane Channel Protein
External Membrane Surface
Phospolipid Bilayer
Internal Membrane Surface
100

Figure 35

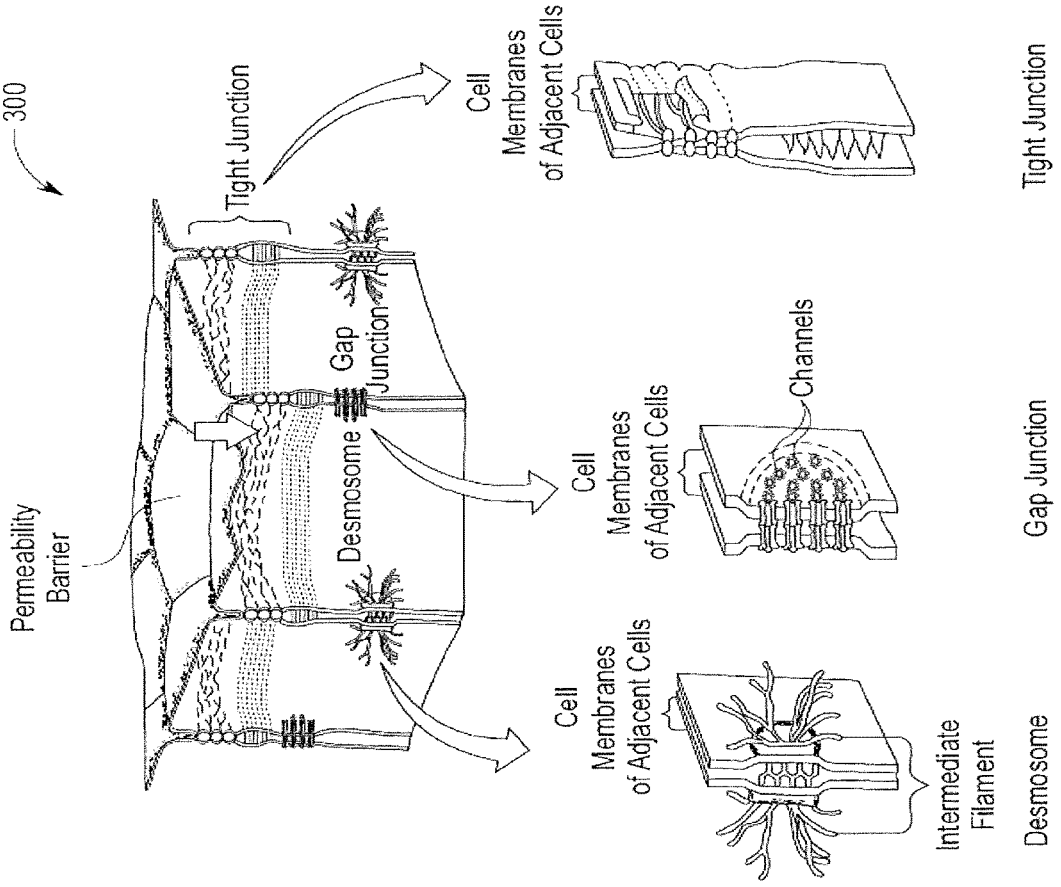

300
Permeability Barrier
Tight Junction
Gap Junction
Desmosome
Cell Membranes of Adjacent Cells
Cell Membranes of Adjacent Cells
Channels
Cell Membranes of Adjacent Cells
Intermediate Filament
Tight Junction
Gap Junction
Desmosome

Figure 36

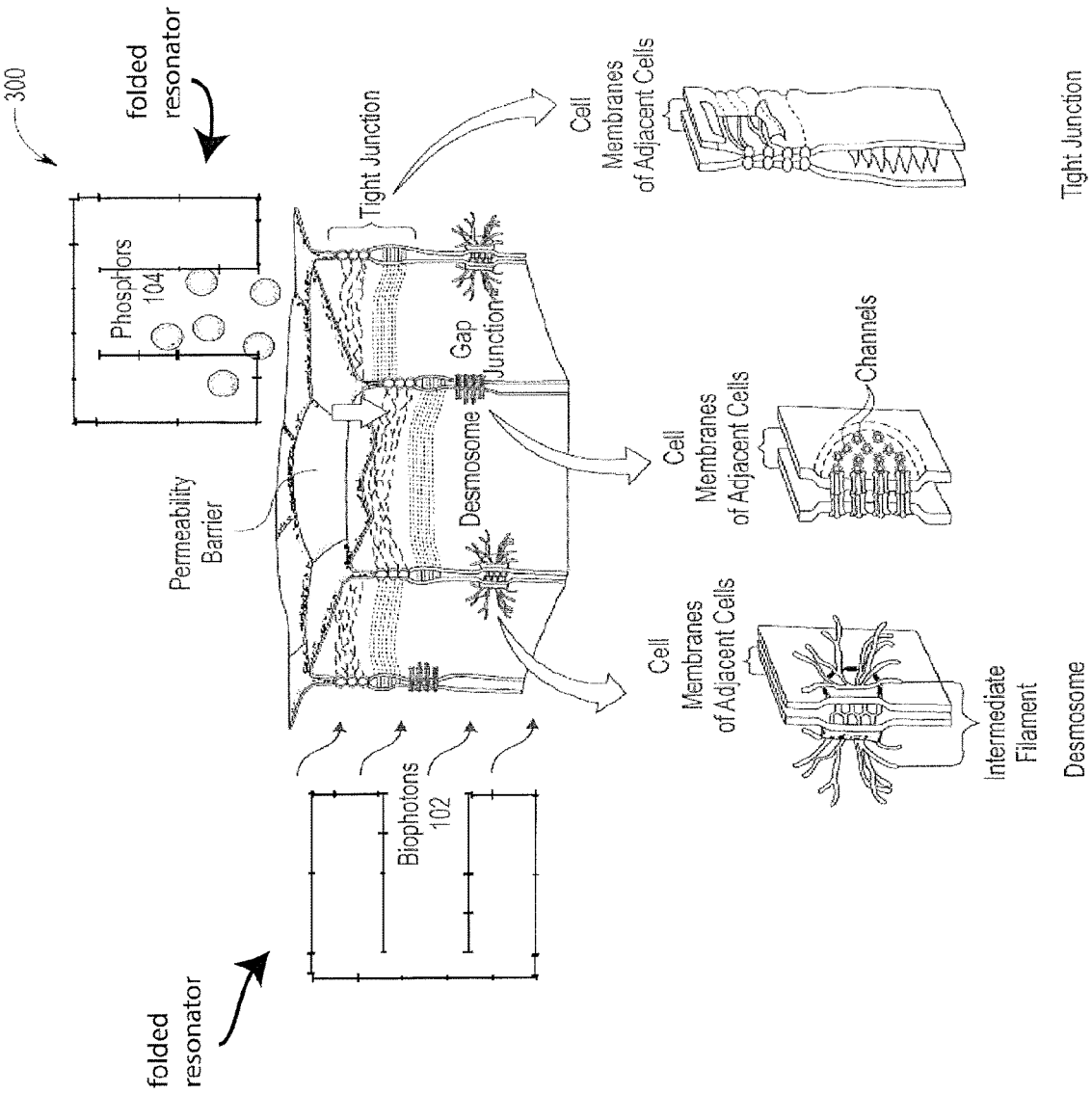

300
folded resonator
Phosphors 104
Tight Junction
Cell Membranes of Adjacent Cells
Gap Junction
Desmosome
Permeability Barrier
Channels
Biophotons 102
folded resonator
Intermediate Filament
Desmosome
Tight Junction

Figure 37

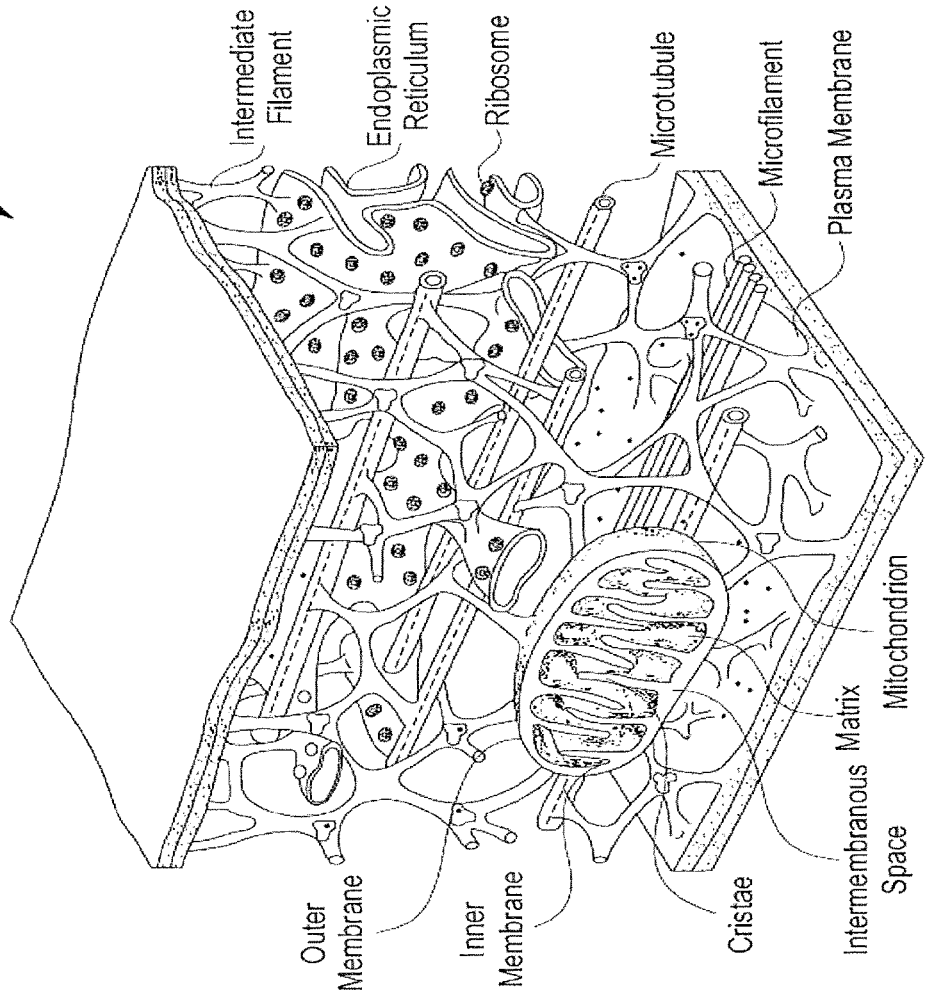

400
Intermediate Filament
Endoplasmic Reticulum
Ribosome
Microtubule
Microfilament
Plasma Membrane
Mitochondrion
Matrix
Intermembranous Space
Cristae
Inner Membrane
Outer Membrane

Figure 38

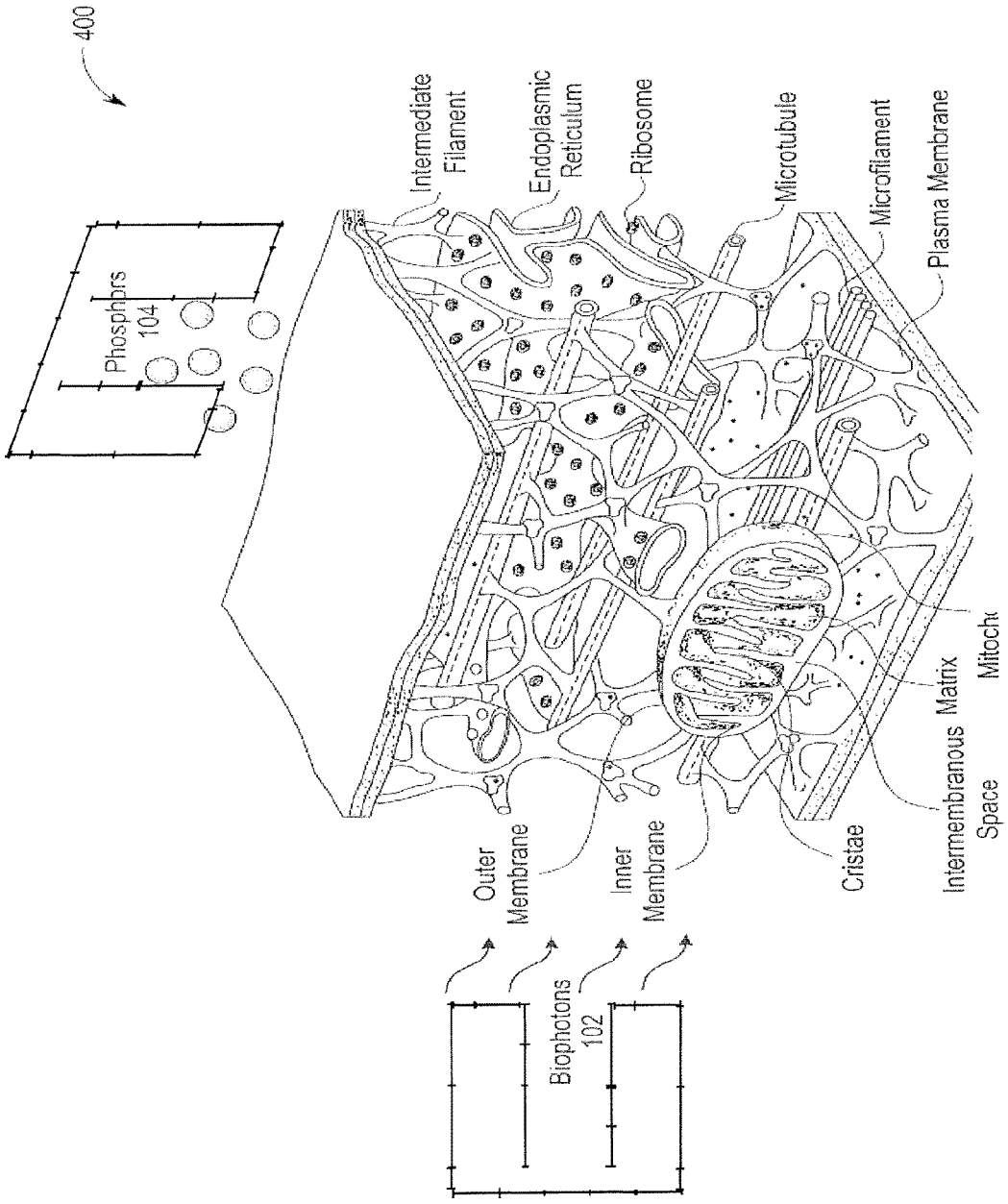

400
Phosphors
104
Intermediate Filament
Endoplasmic Reticulum
Ribosome
Microtubule
Microfilament
Plasma Membrane
Mitochr
Matrix
Intermembranous Space
Cristae
Outer Membrane
Inner Membrane
Biophotons
102

Figure 39

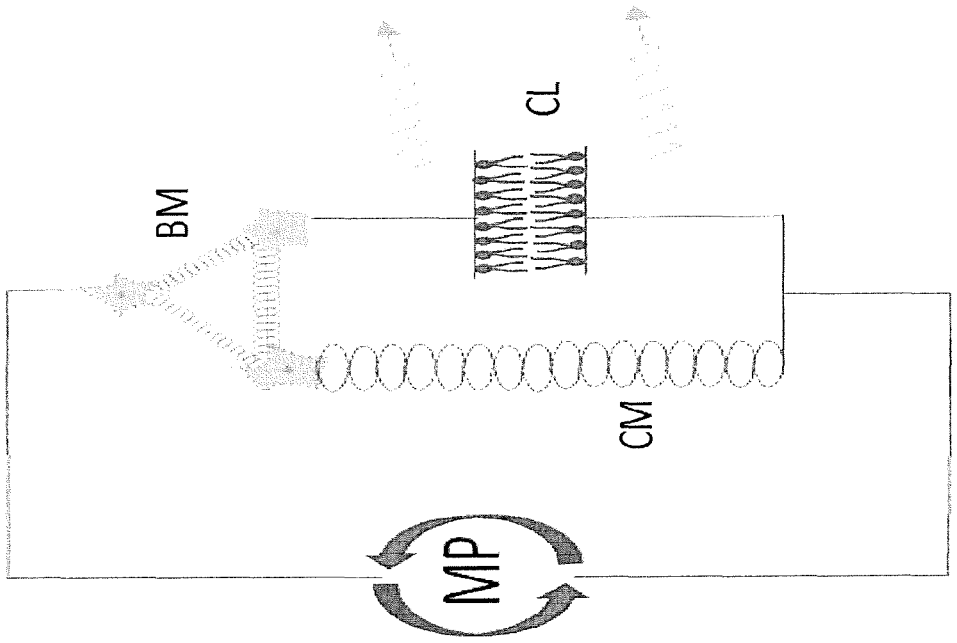


Figure 40B

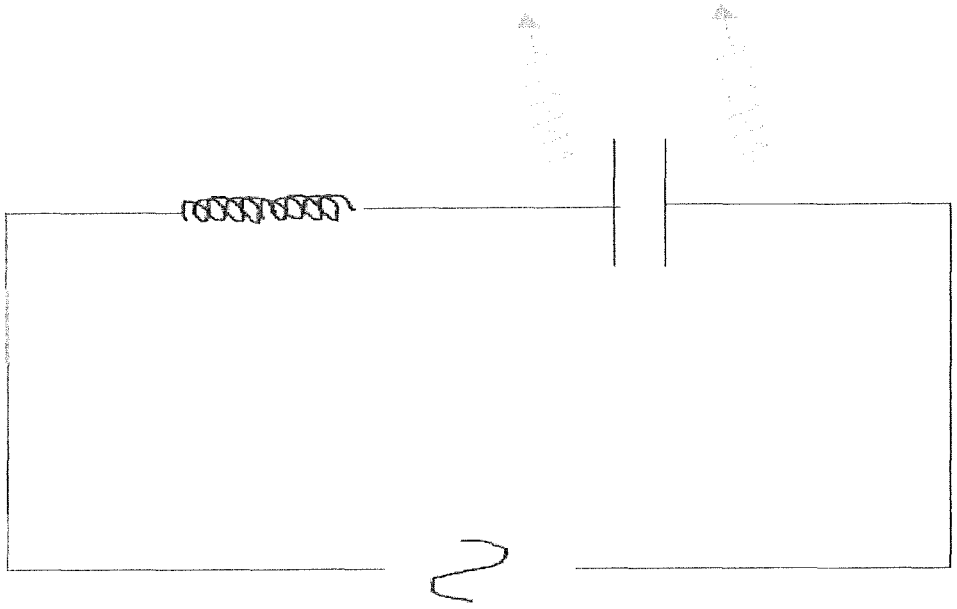


Figure 40A

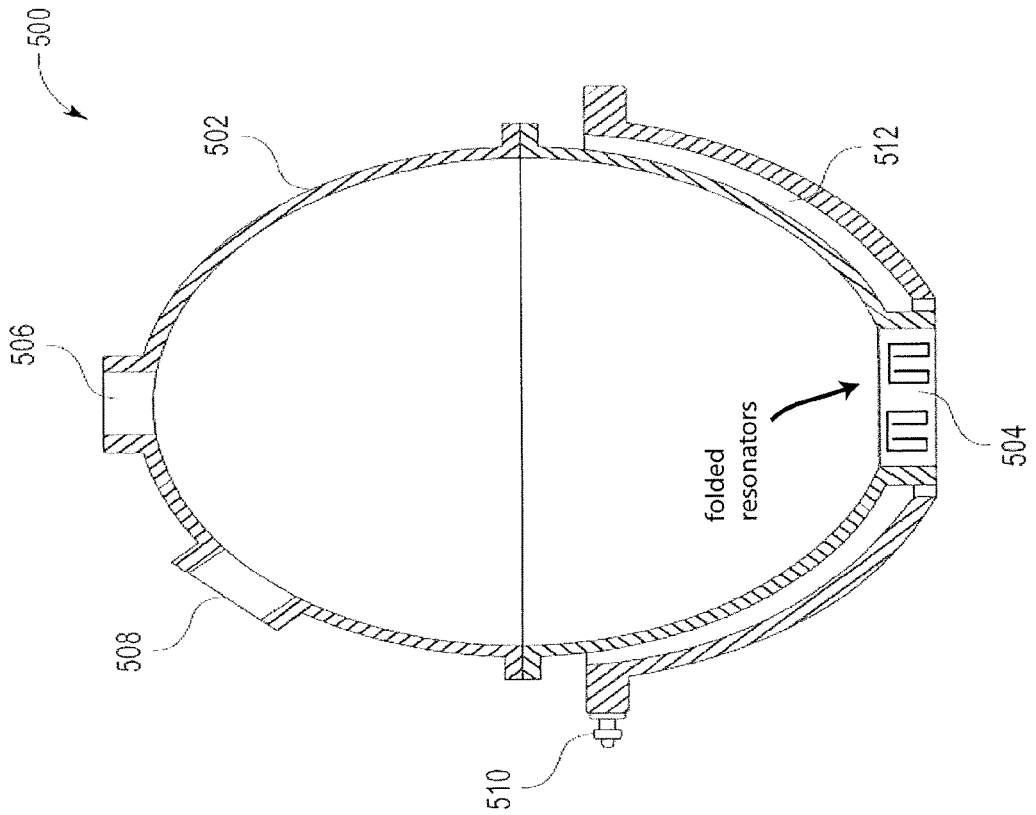


Figure 41

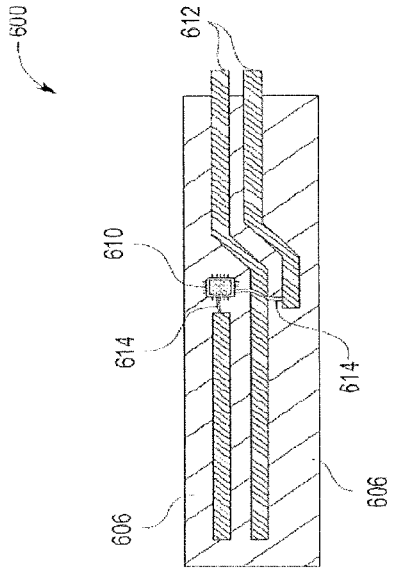


Figure 42A

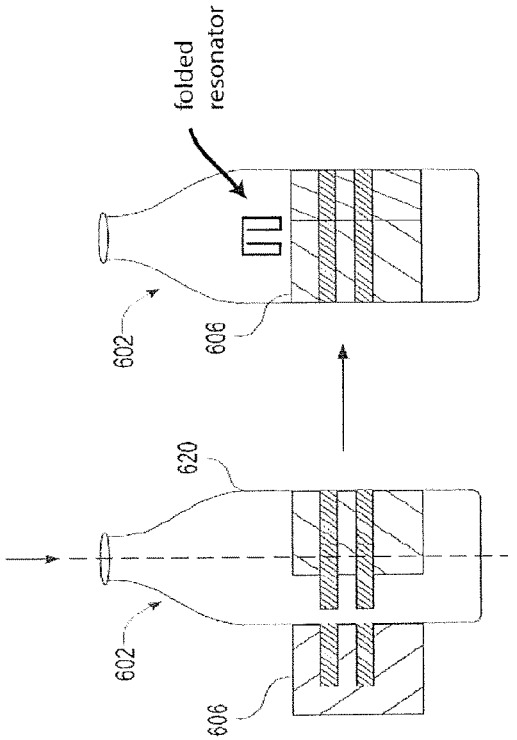


Figure 42B

Figure 42C

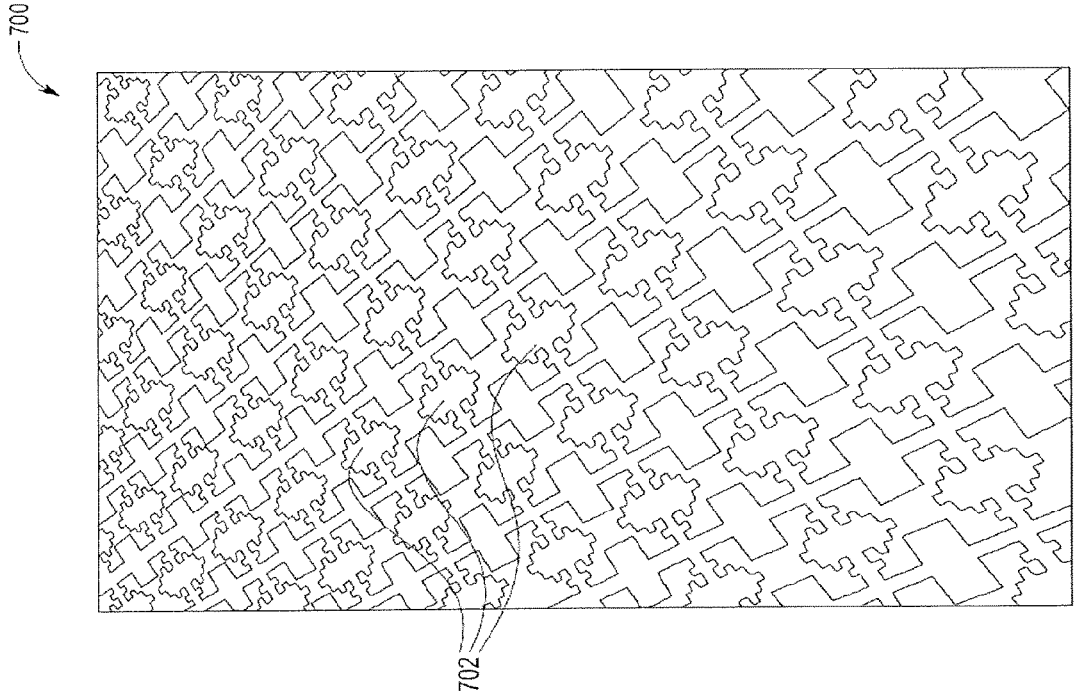


Figure 43

Figure 44

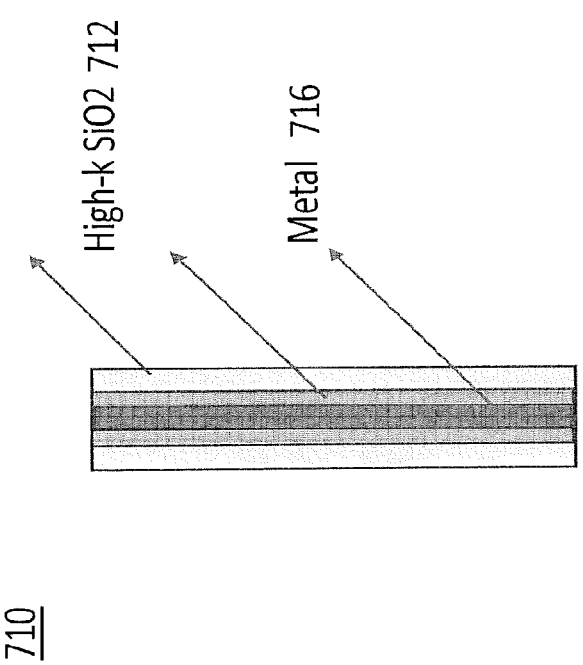
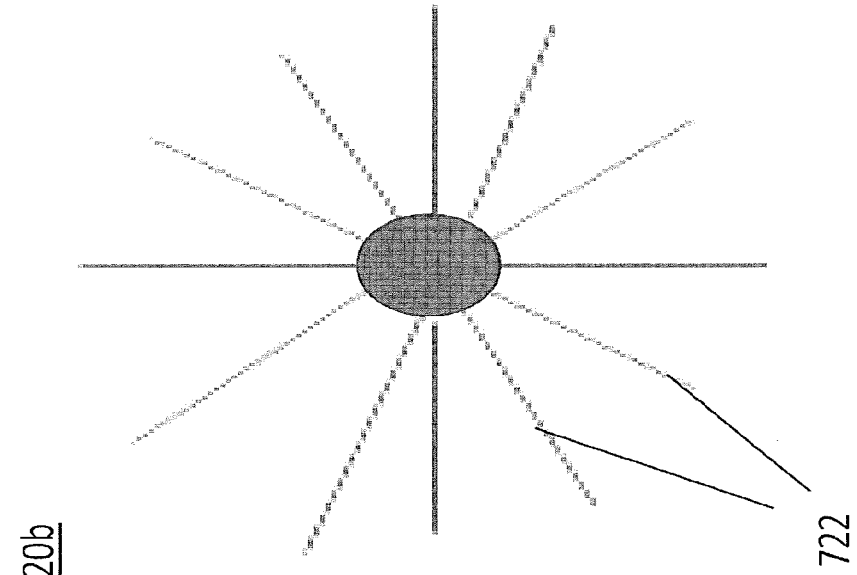


Figure 45



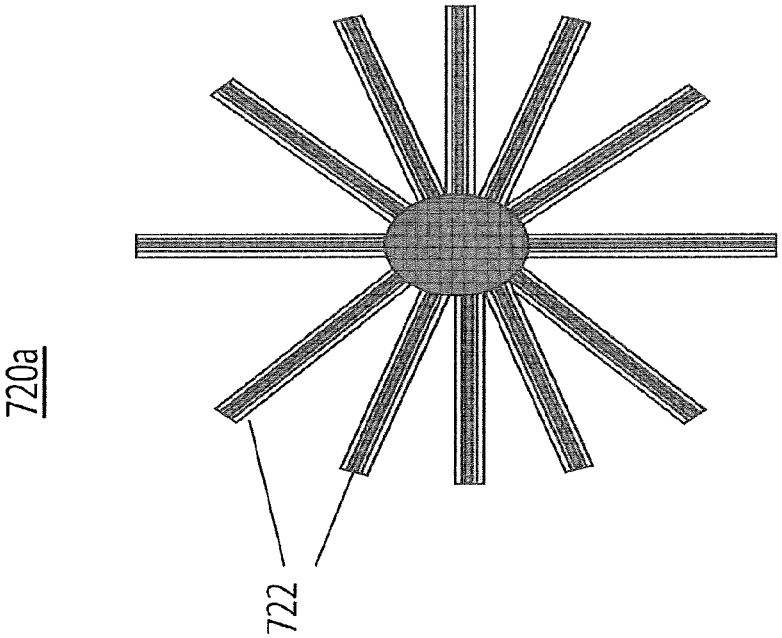


Figure 46

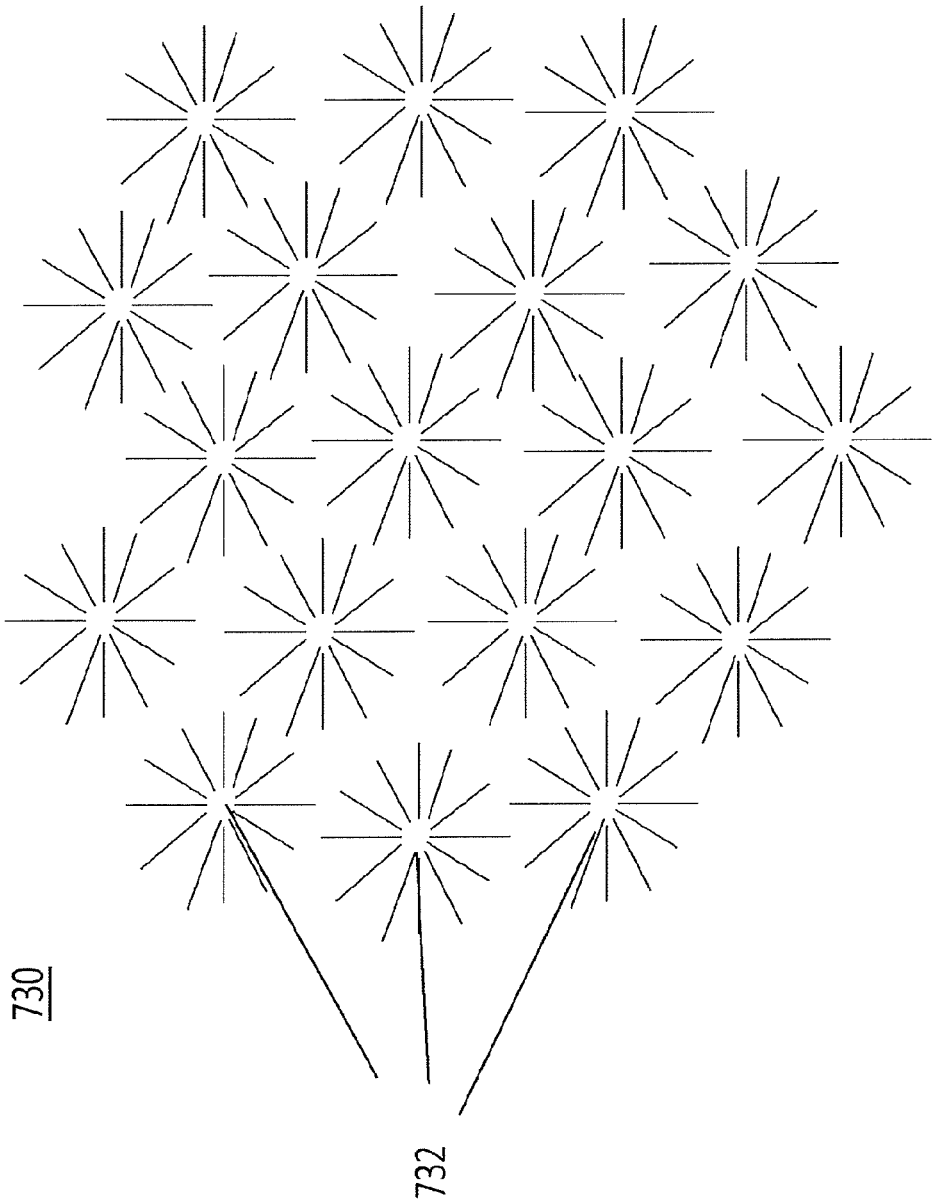


Figure 47

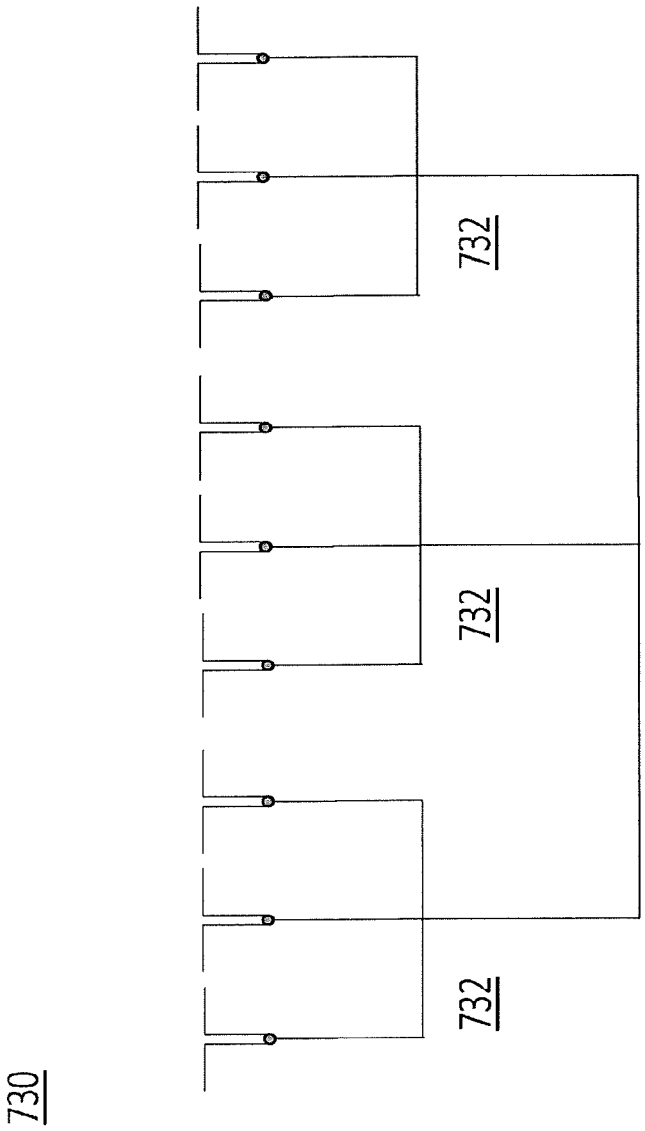


Figure 48

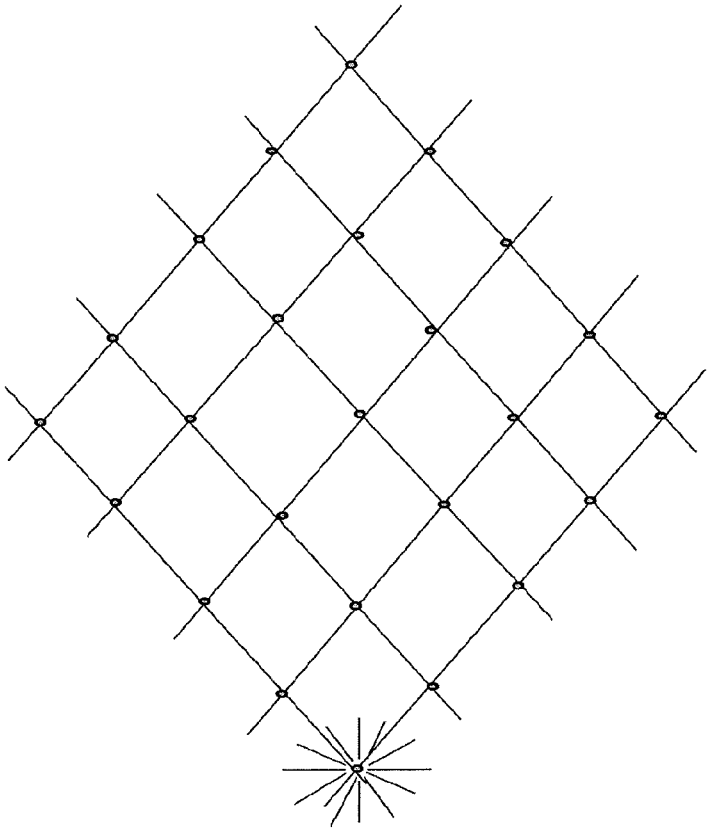


Figure 49

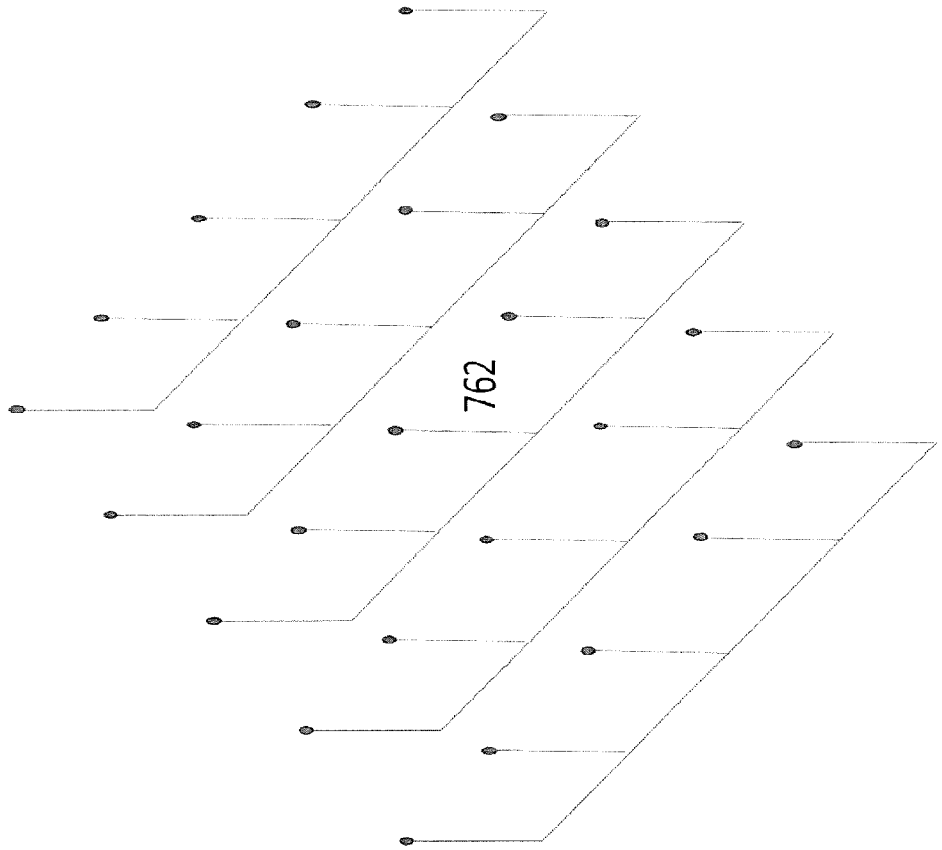


Figure 50

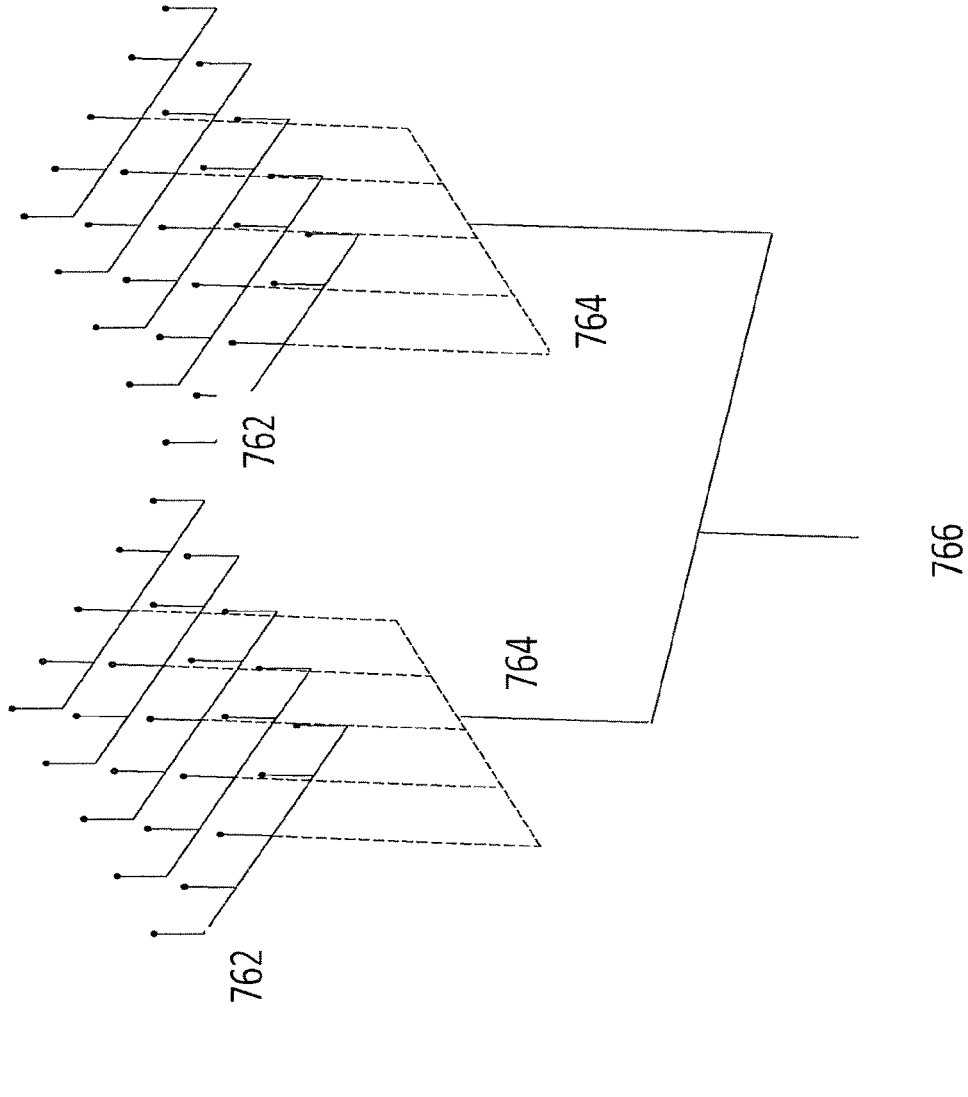


Figure 51

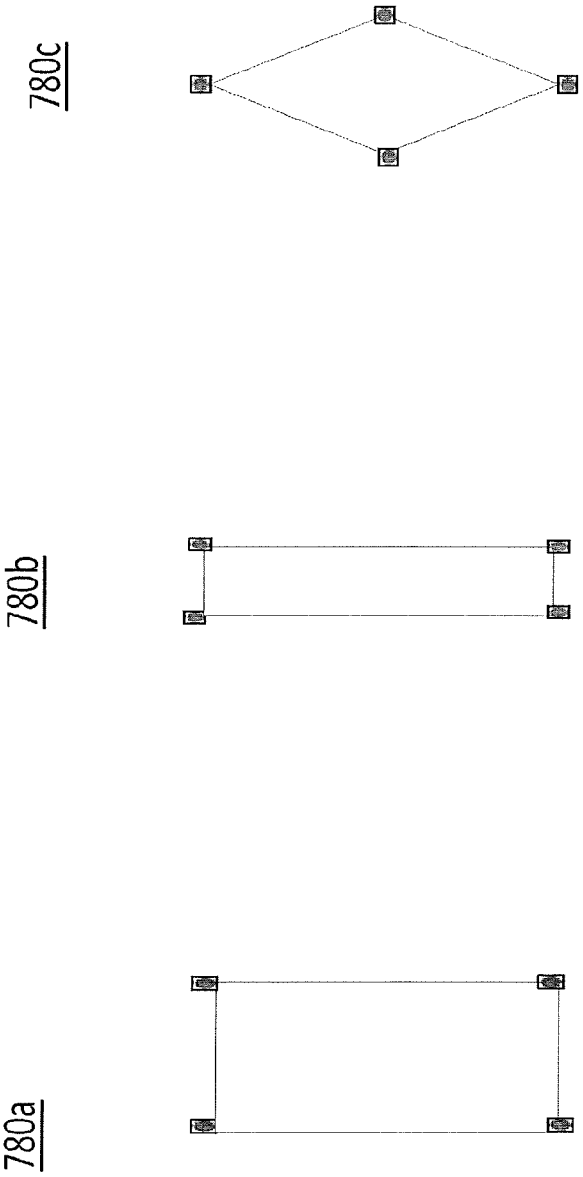


Figure 52

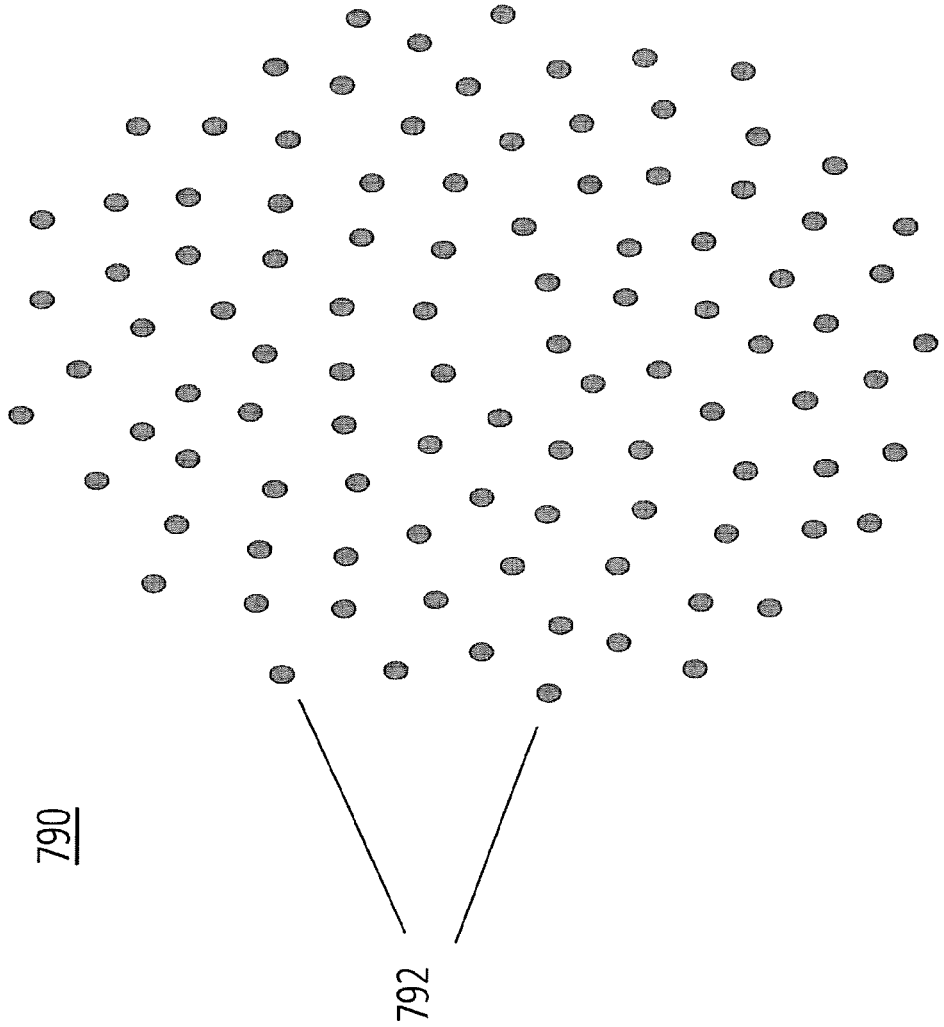


Figure 53

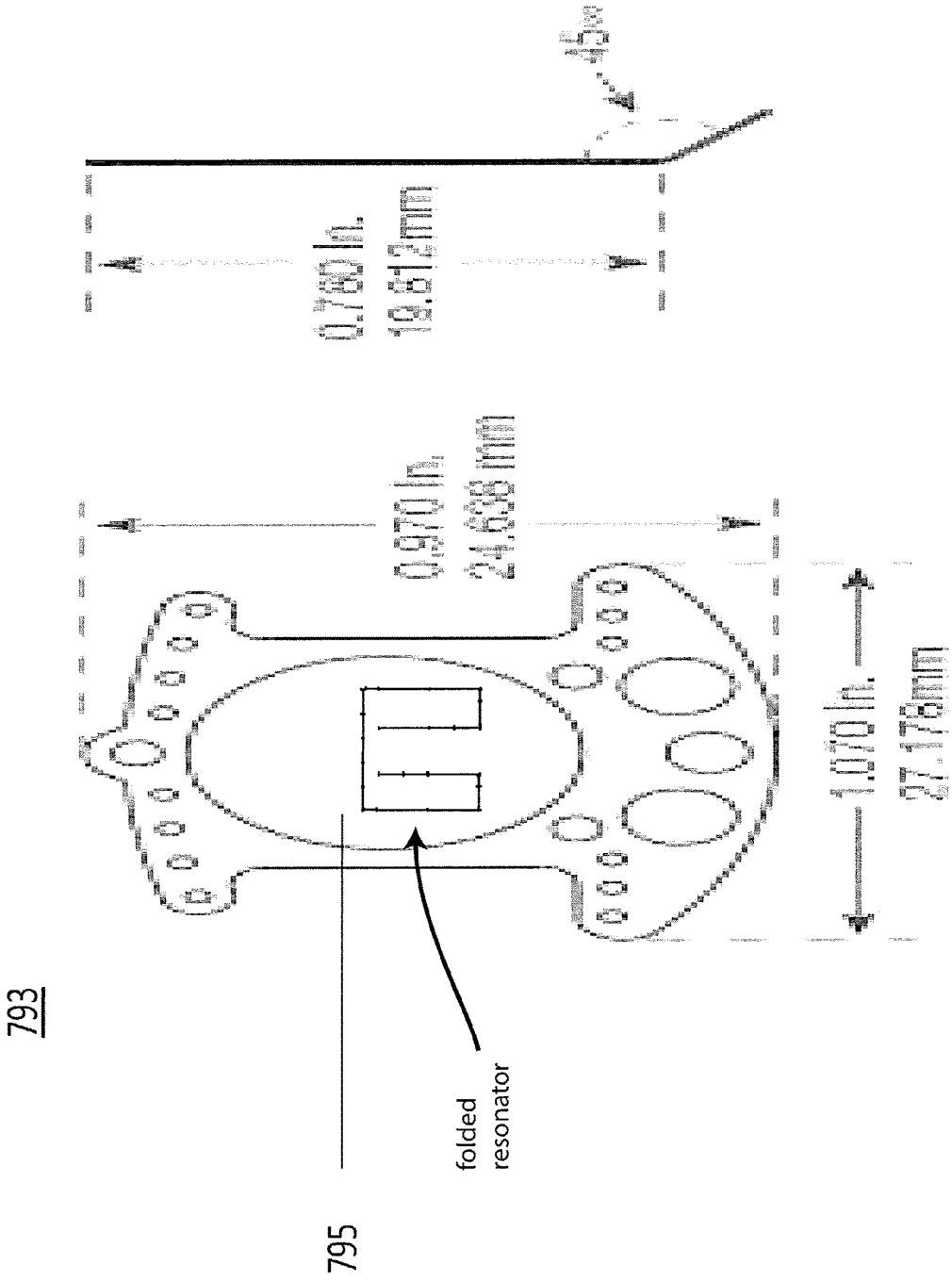
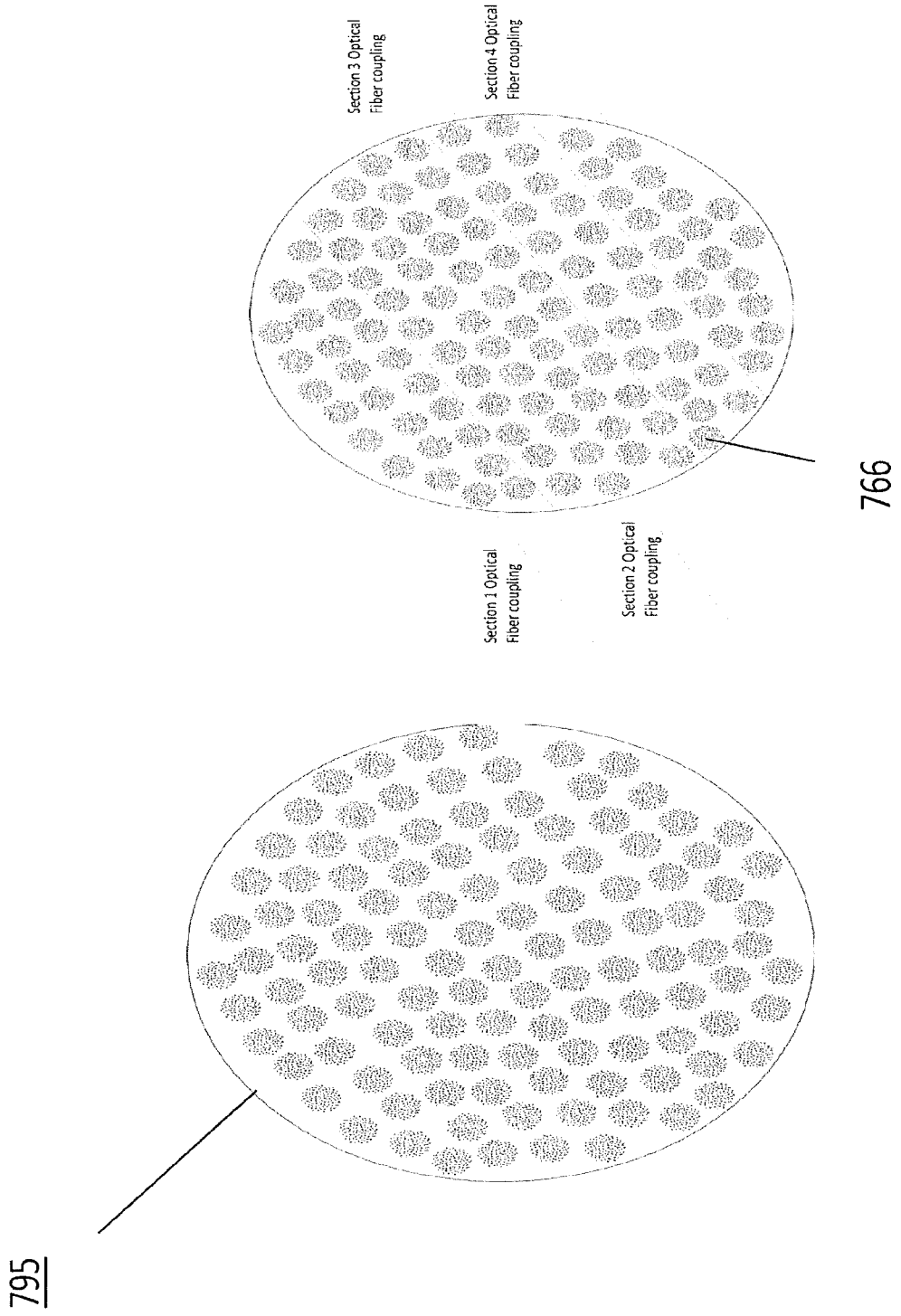

793
795
folded resonator
0.870 in.
24.638 mm
1.070 in.
27.178mm
0.780 in.
19.812mm
45°

Figure 54


Section 3 Optical Fiber coupling
Section 4 Optical Fiber coupling
766
Section 1 Optical Fiber coupling
Section 2 Optical Fiber coupling
795

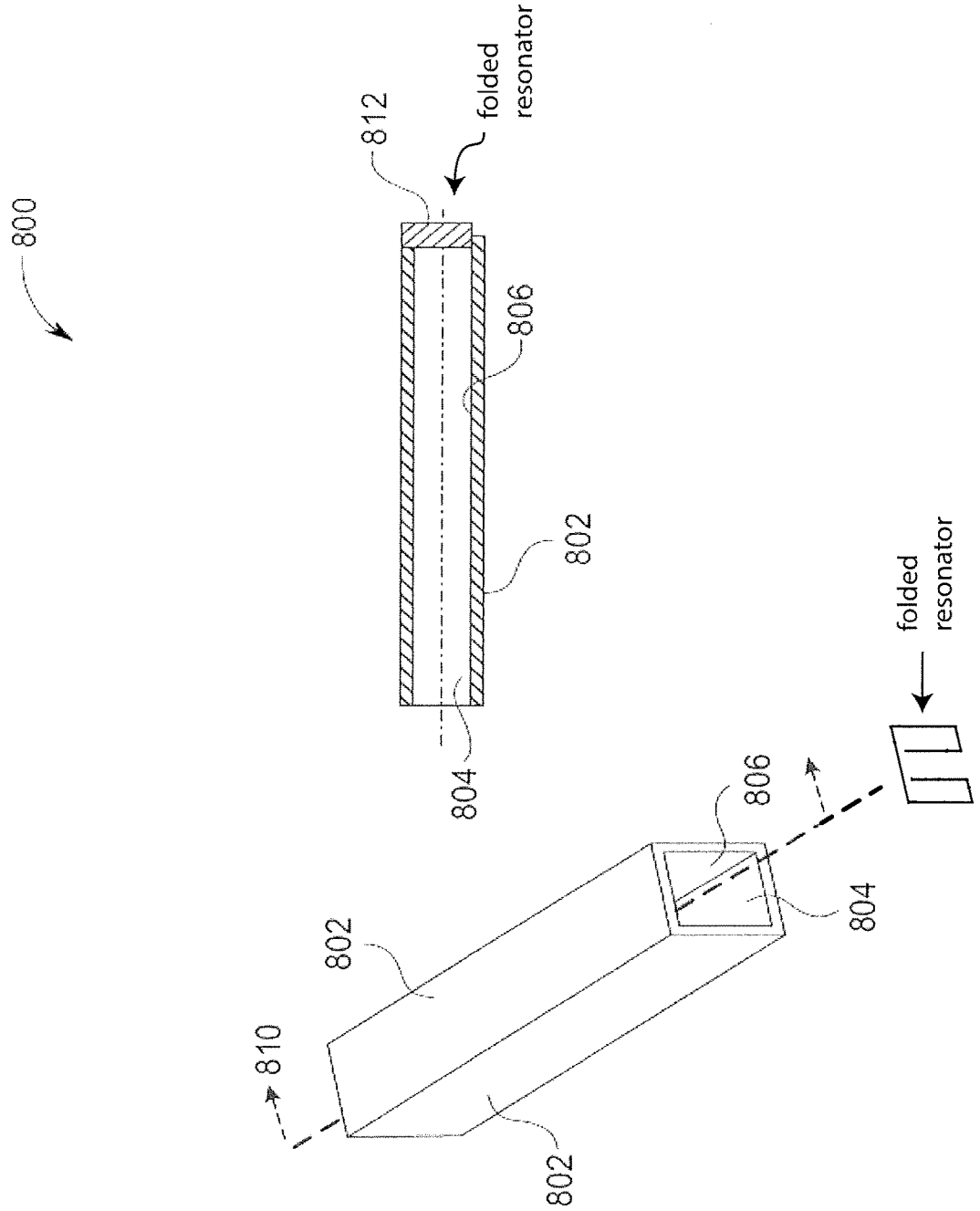

800
812
folded resonator
806
802
804
folded resonator
806
804
802
810
802

Figure 55

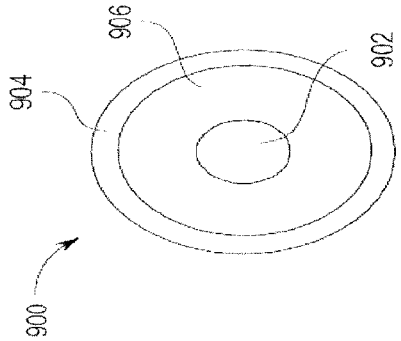


Figure 56A

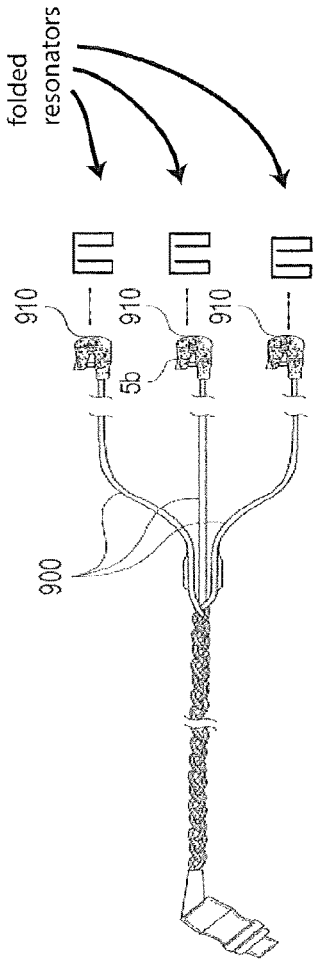


Figure 56B

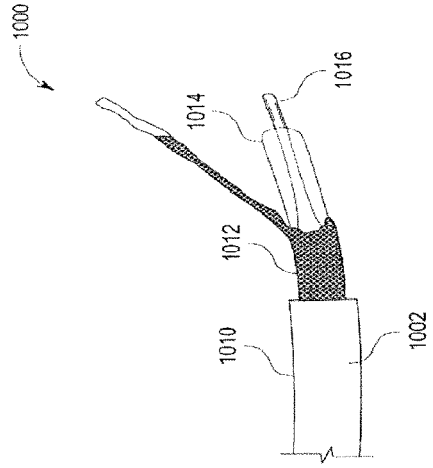


Figure 57A

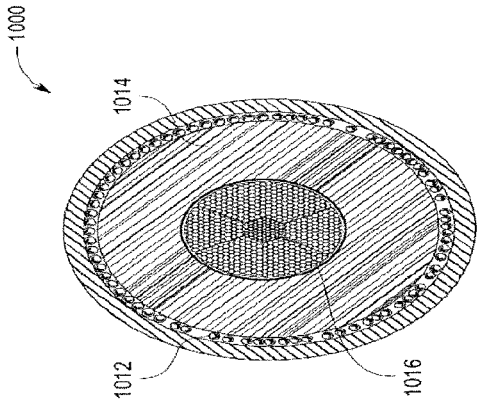


Figure 57B

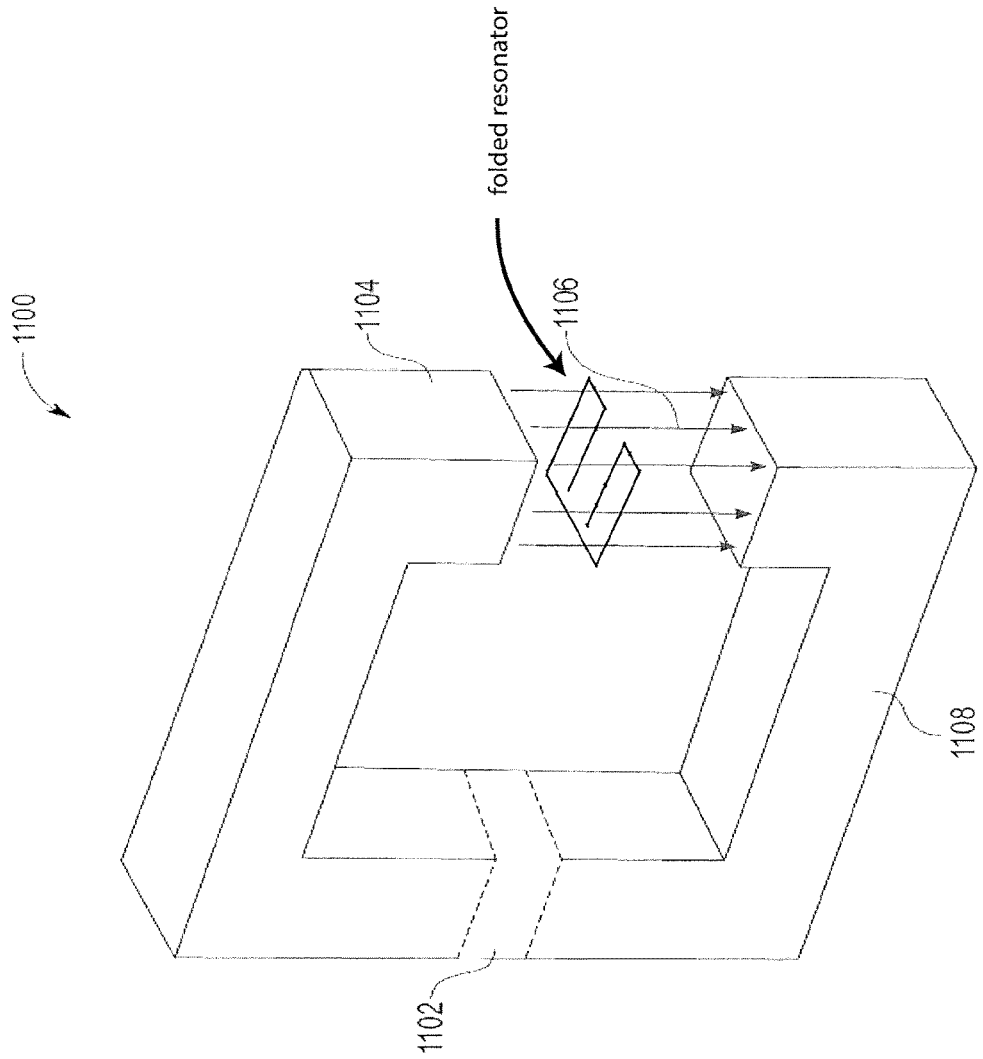


Figure 58

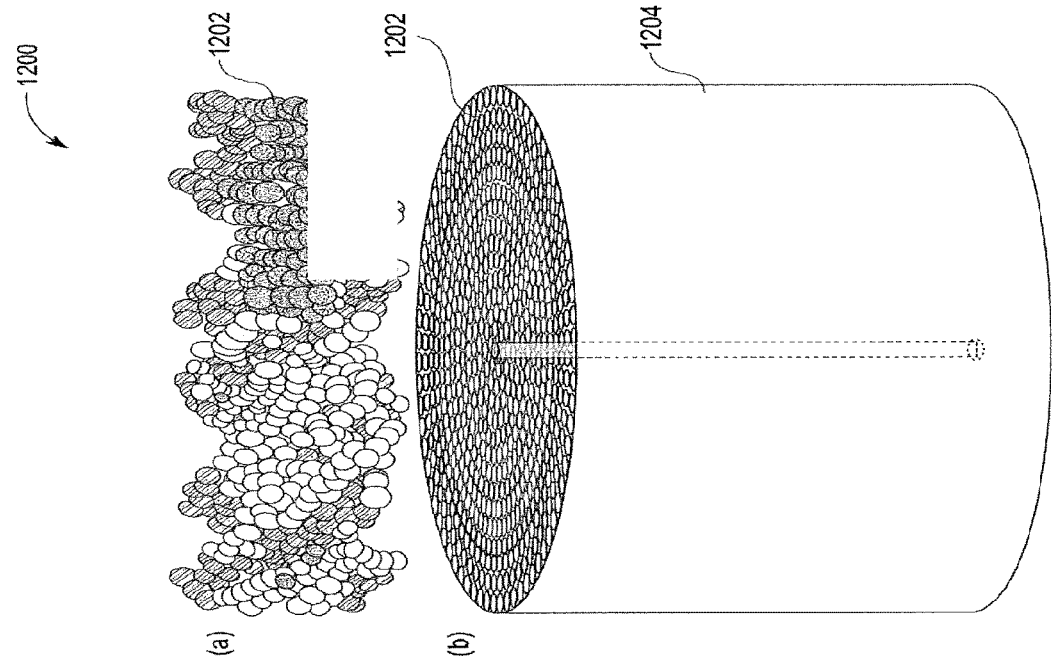


Figure 59

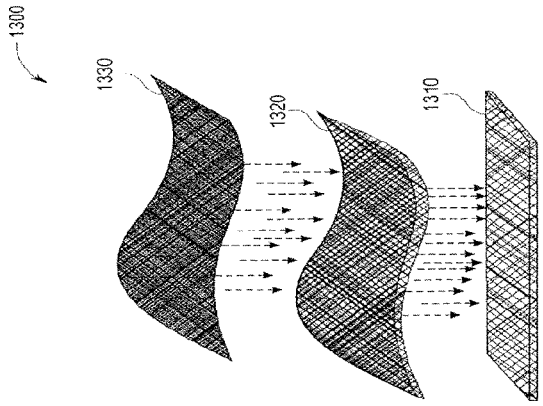


Figure 60A

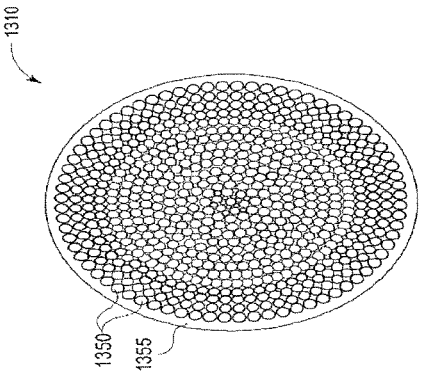


Figure 60B

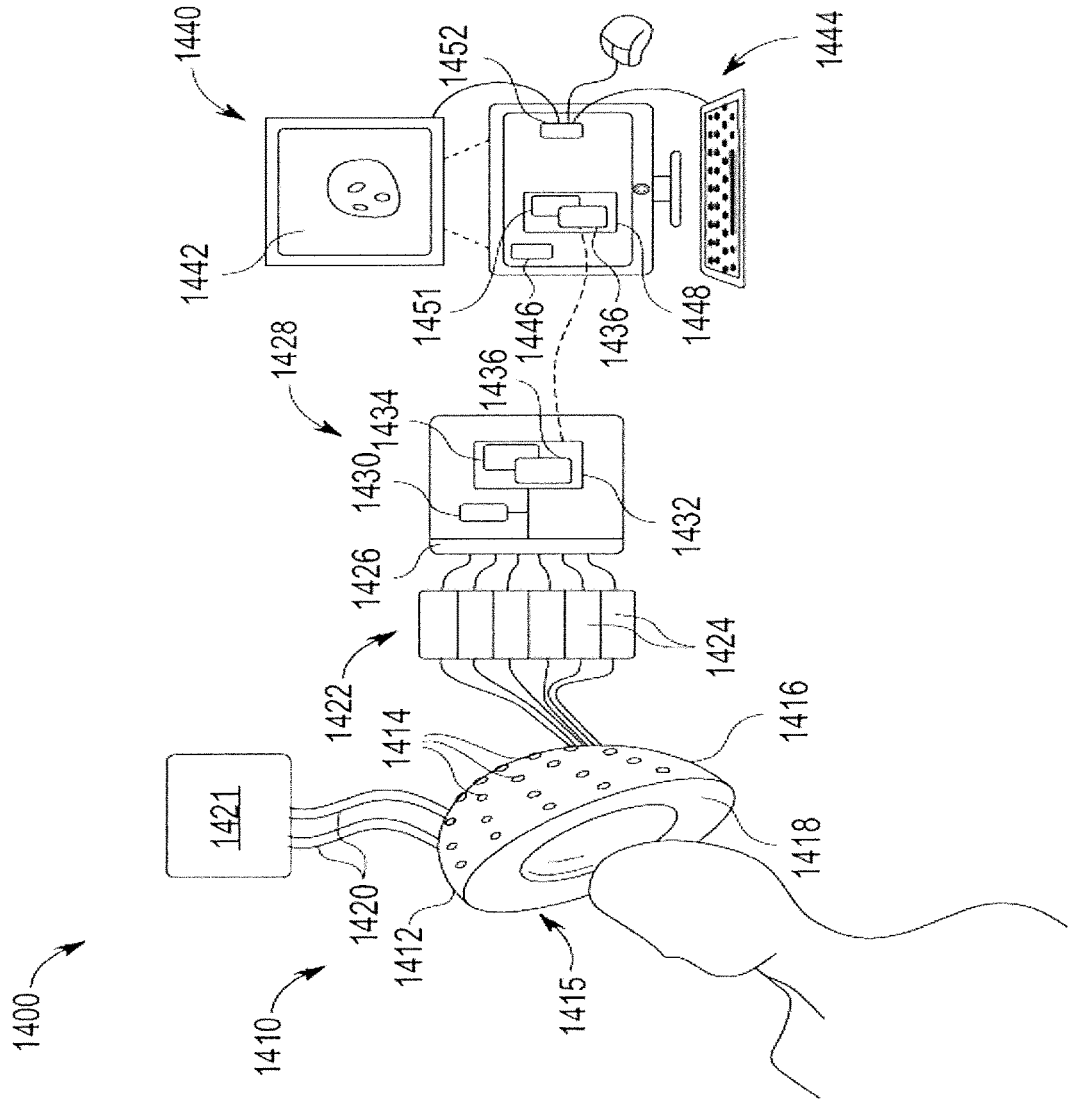

1400
1410
1412
1414
1415
1416
1418
1420
1421
1422
1424
1426
1428
1430
1432
1434
1436
1440
1442
1444
1446
1448
1451
1452

Figure 61

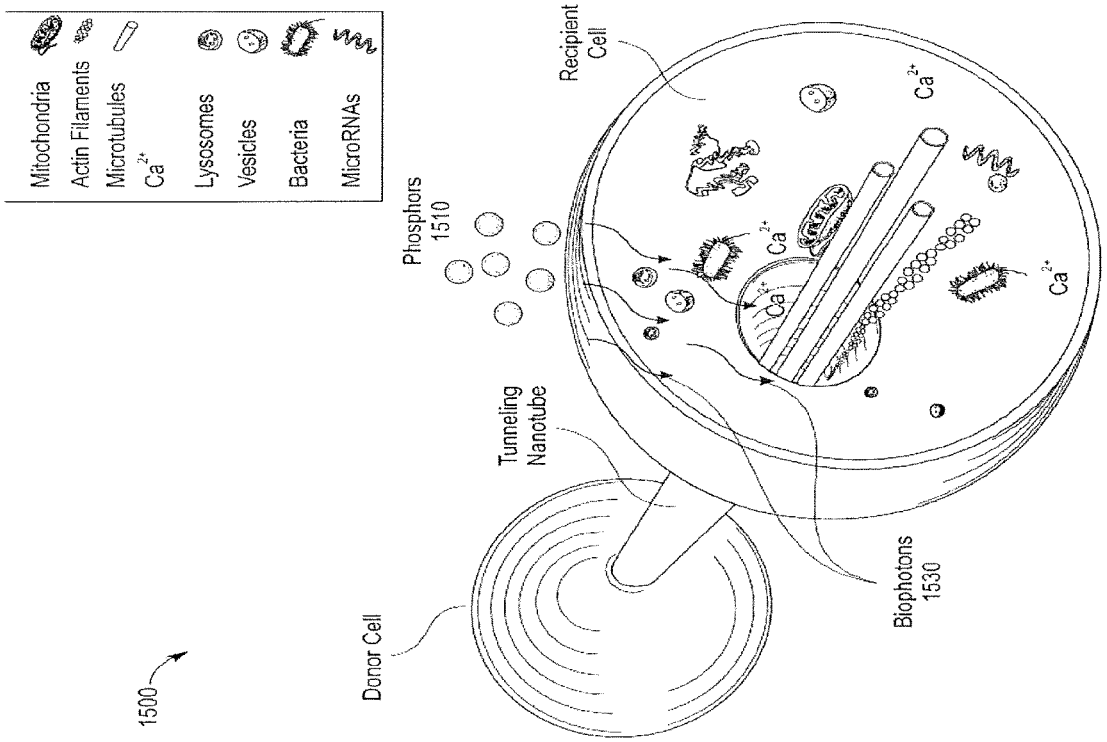

Mitochondria
Actin Filaments
Microtubules
Ca^{2+}
Lysosomes
Vesicles
Bacteria
MicroRNAs
1500
Donor Cell
Tunneling Nanotube
Phosphors 1510
Recipient Cell
Biophotons 1530
Ca^{2+}

Figure 62

Figure 63

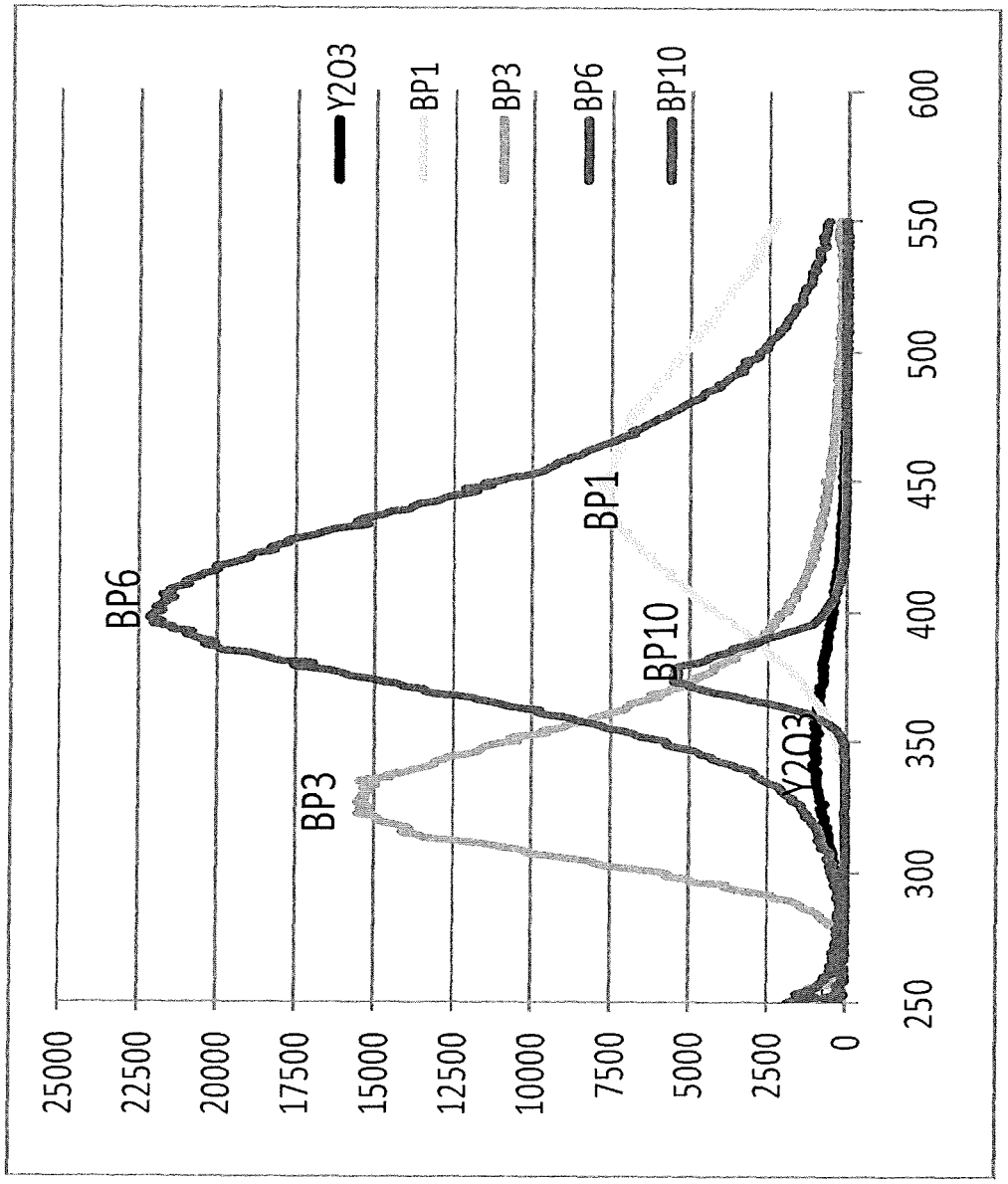

25000
22500
20000
17500
15000
12500
10000
7500
5000
2500
0
250
300
350
400
450
500
550
600
Y2O3
BP1
BP3
BP6
BP10
BP6
BP3
BP10
BP1
Y2O3

Figure 64

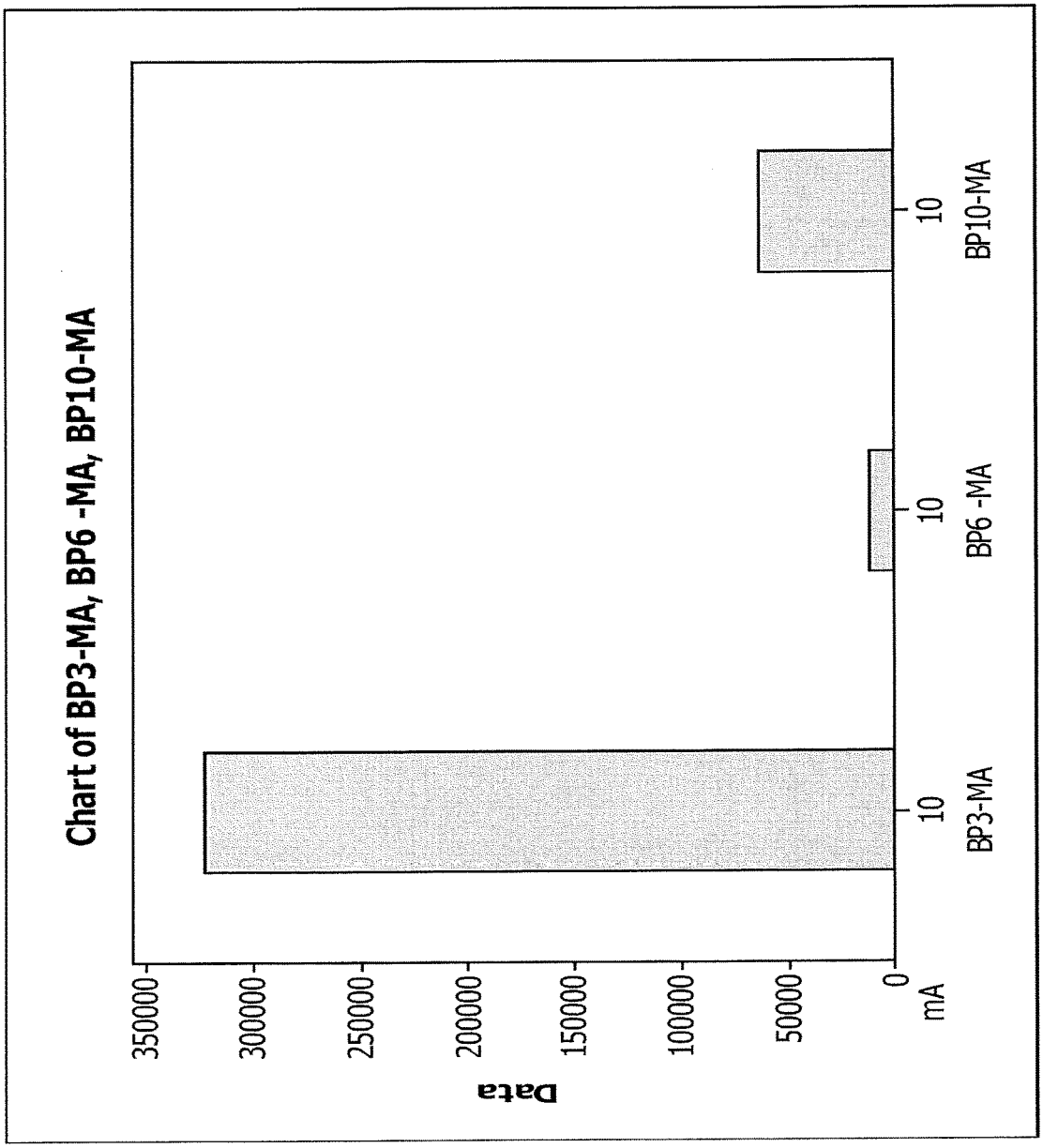


Chart of BP3-MA, BP6 -MA, BP10-MA
Data
350000
300000
250000
200000
150000
100000
50000
0
mA
10
BP3-MA
10
BP6 -MA
10
BP10-MA

Figure 65

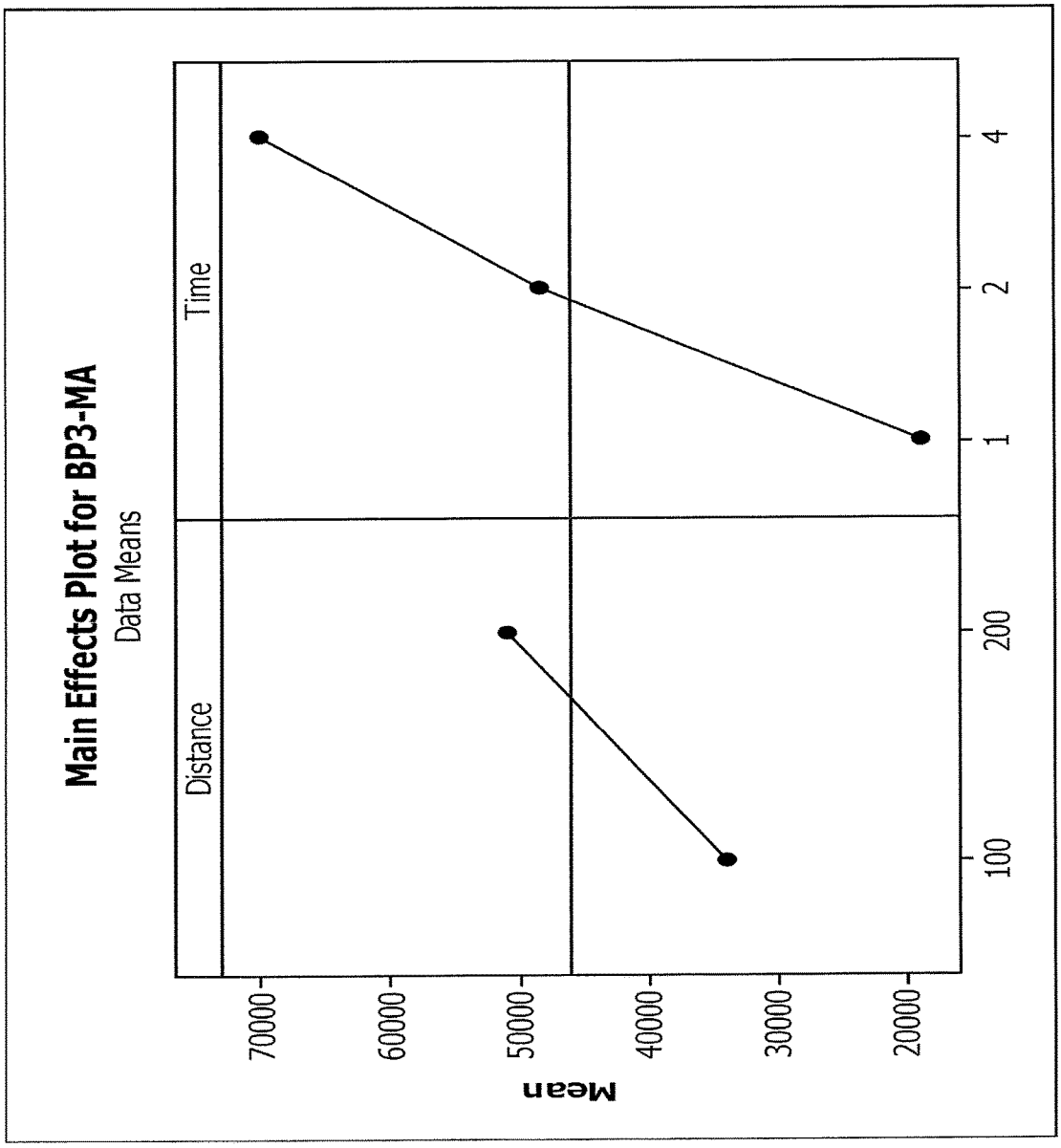

Main Effects Plot for BP3-MA
Data Means
Distance
Time
Mean
70000
60000
50000
40000
30000
20000
100
200
1
2
4

Figure 66

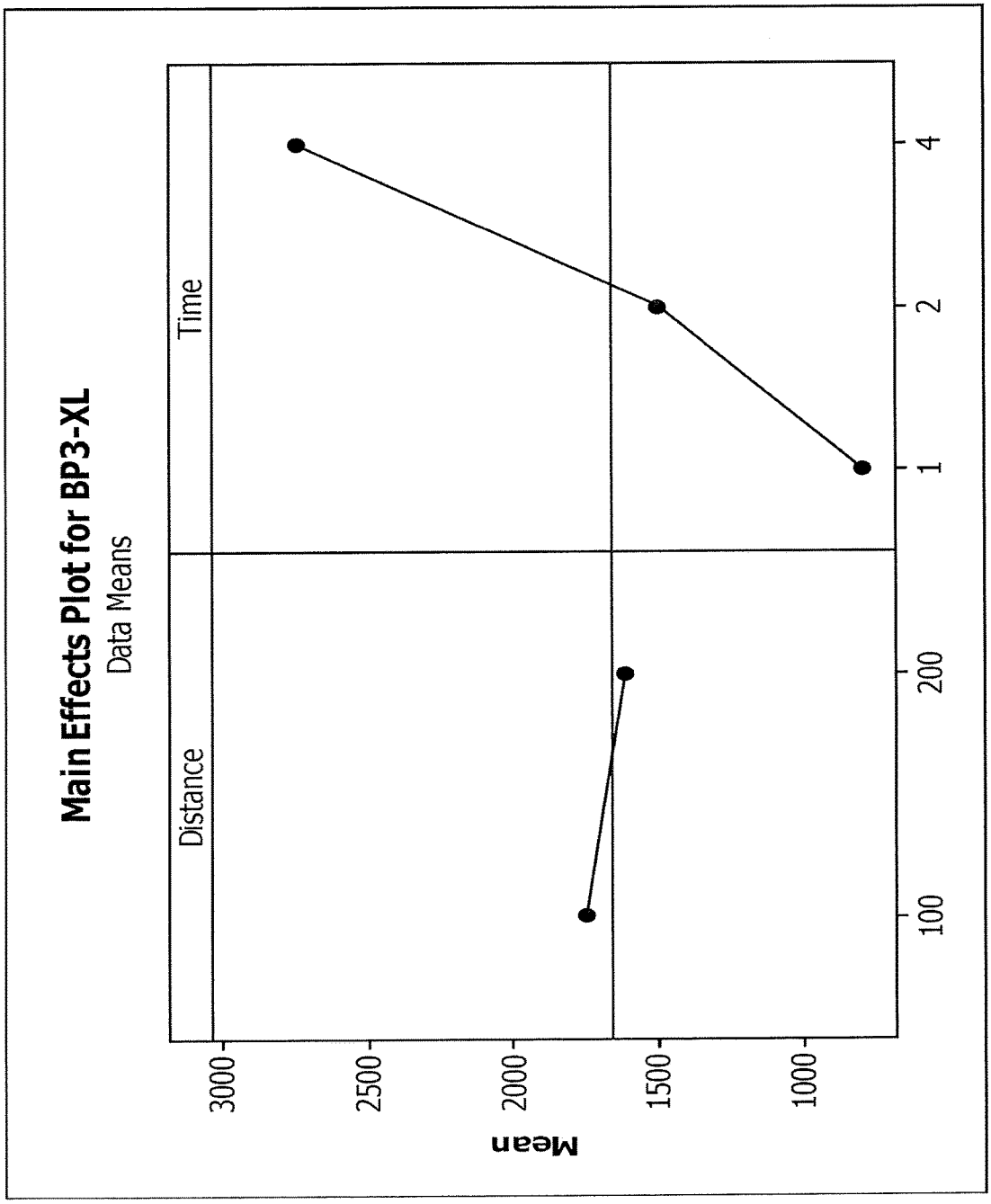

Main Effects Plot for BP3-XL
Data Means
Distance
Time
Mean
3000
2500
2000
1500
1000
100
200
1
2
4

Figure 67

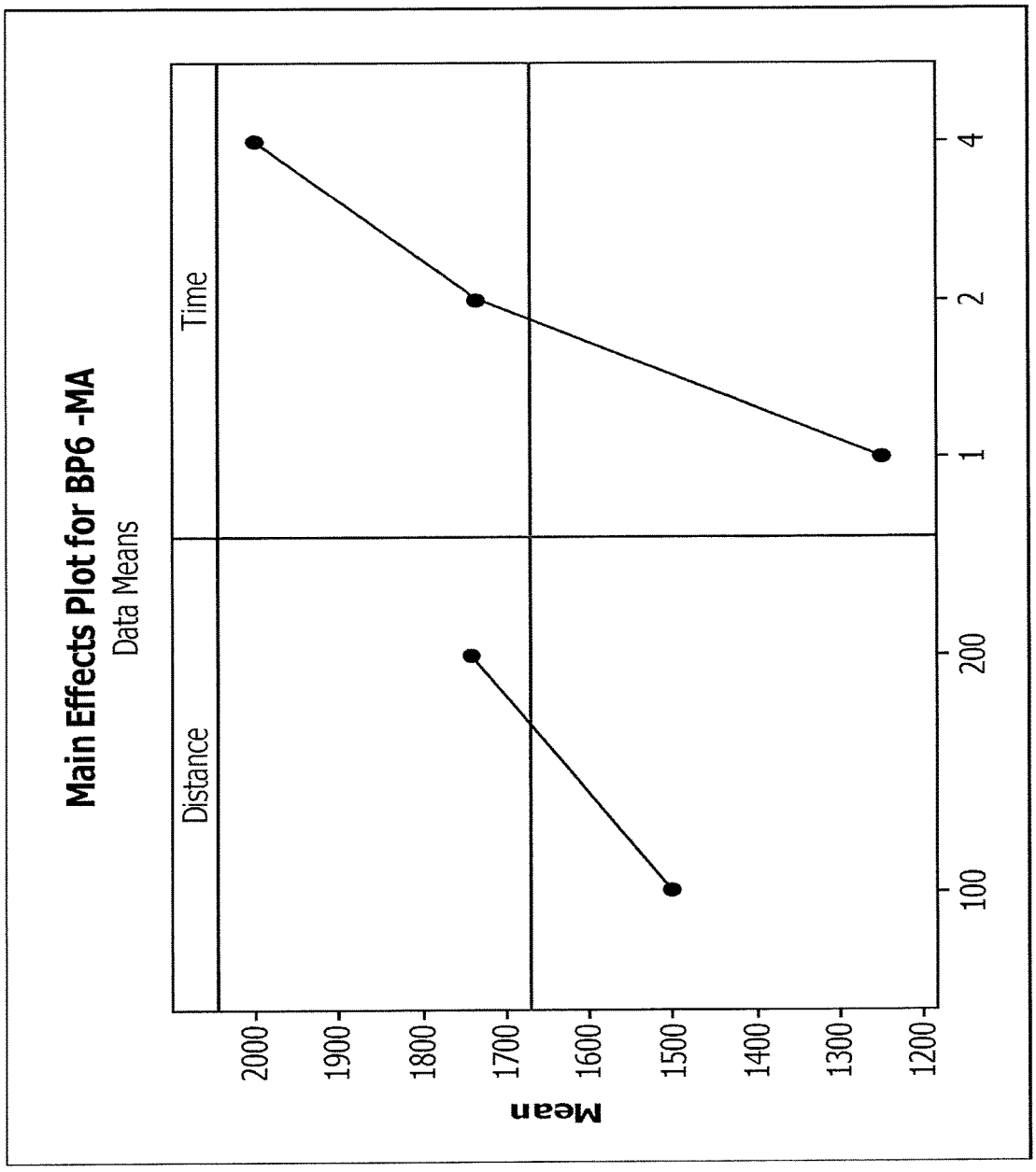

Main Effects Plot for BP6 -MA
Data Means
Distance
Time
Mean
2000
1900
1800
1700
1600
1500
1400
1300
1200
100
200
1
2
4

Figure 68

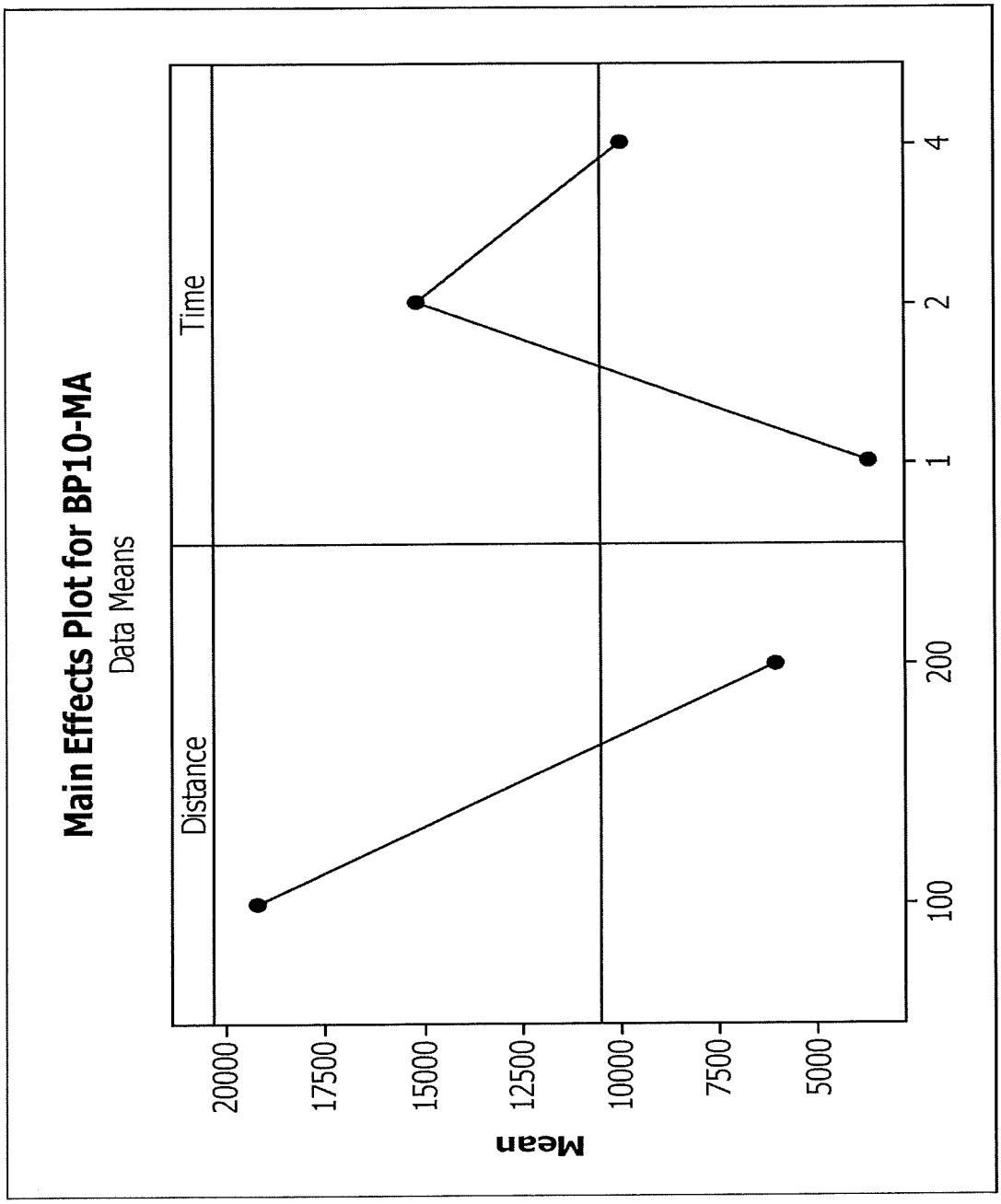

Main Effects Plot for BP10-MA
Data Means
Distance
Time
Mean
20000
17500
15000
12500
10000
7500
5000
100
200
1
2
4

Figure 69

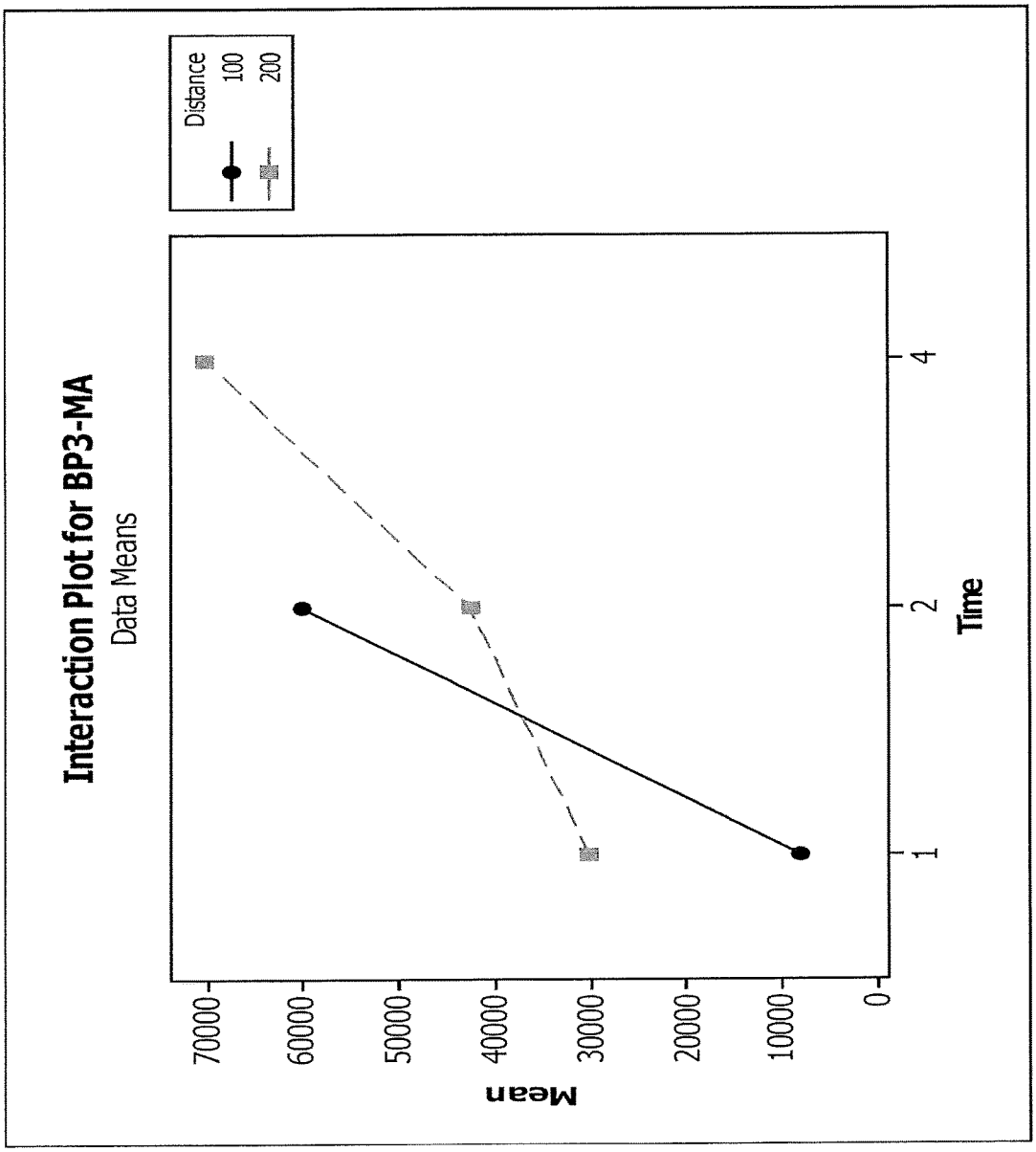

Interaction Plot for BP3-MA
Data Means
Distance
100
200
Mean
70000
60000
50000
40000
30000
20000
10000
0
1
2
4
Time

Figure 70

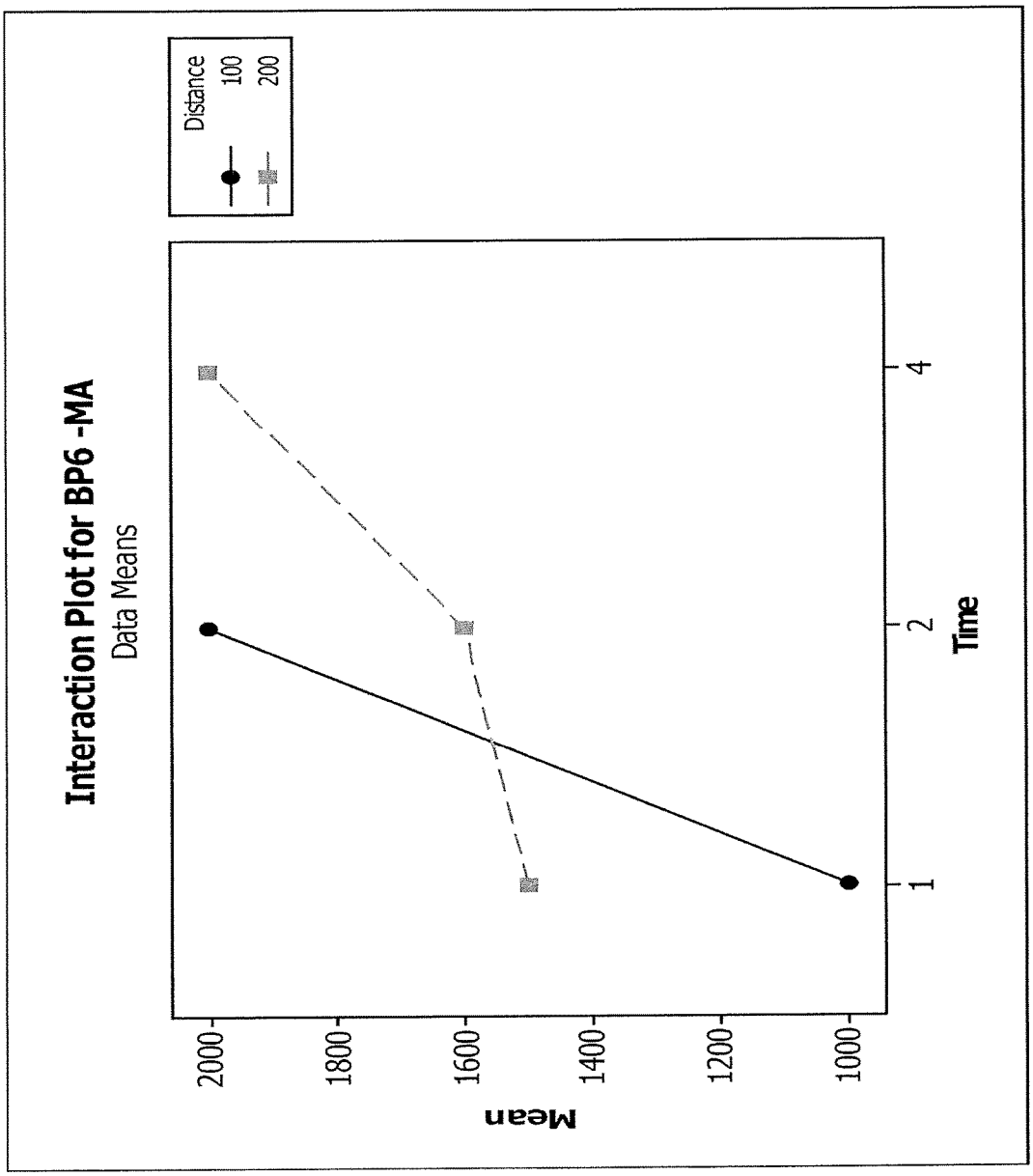

Interaction Plot for BP6 -MA
Data Means
Distance
100
200
Mean
2000
1800
1600
1400
1200
1000
Time
1
2
4

Figure 71

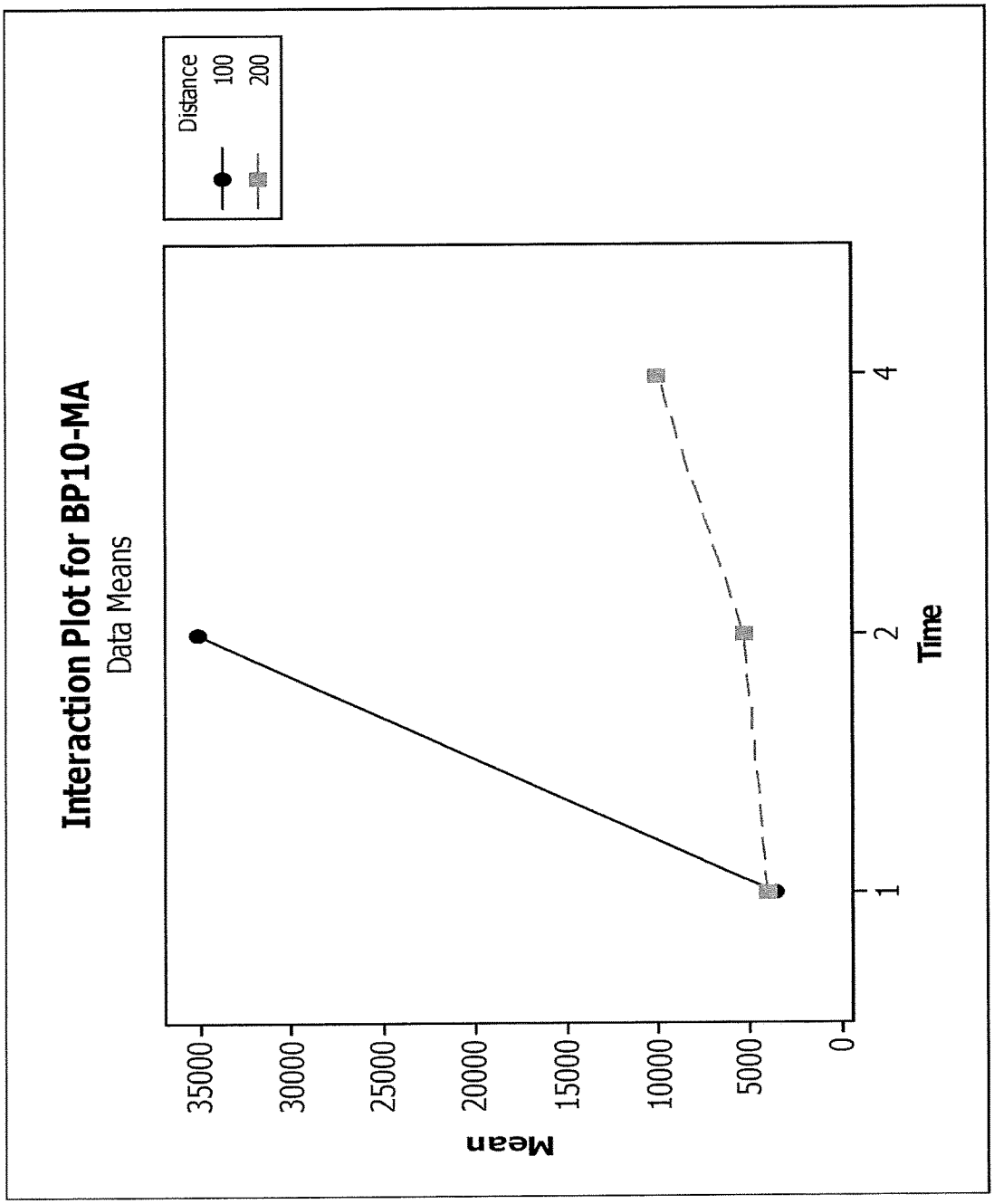

Interaction Plot for BP10-MA
Data Means
Distance
100
200
Mean
35000
30000
25000
20000
15000
10000
5000
0
1
2
4
Time

Figure 72

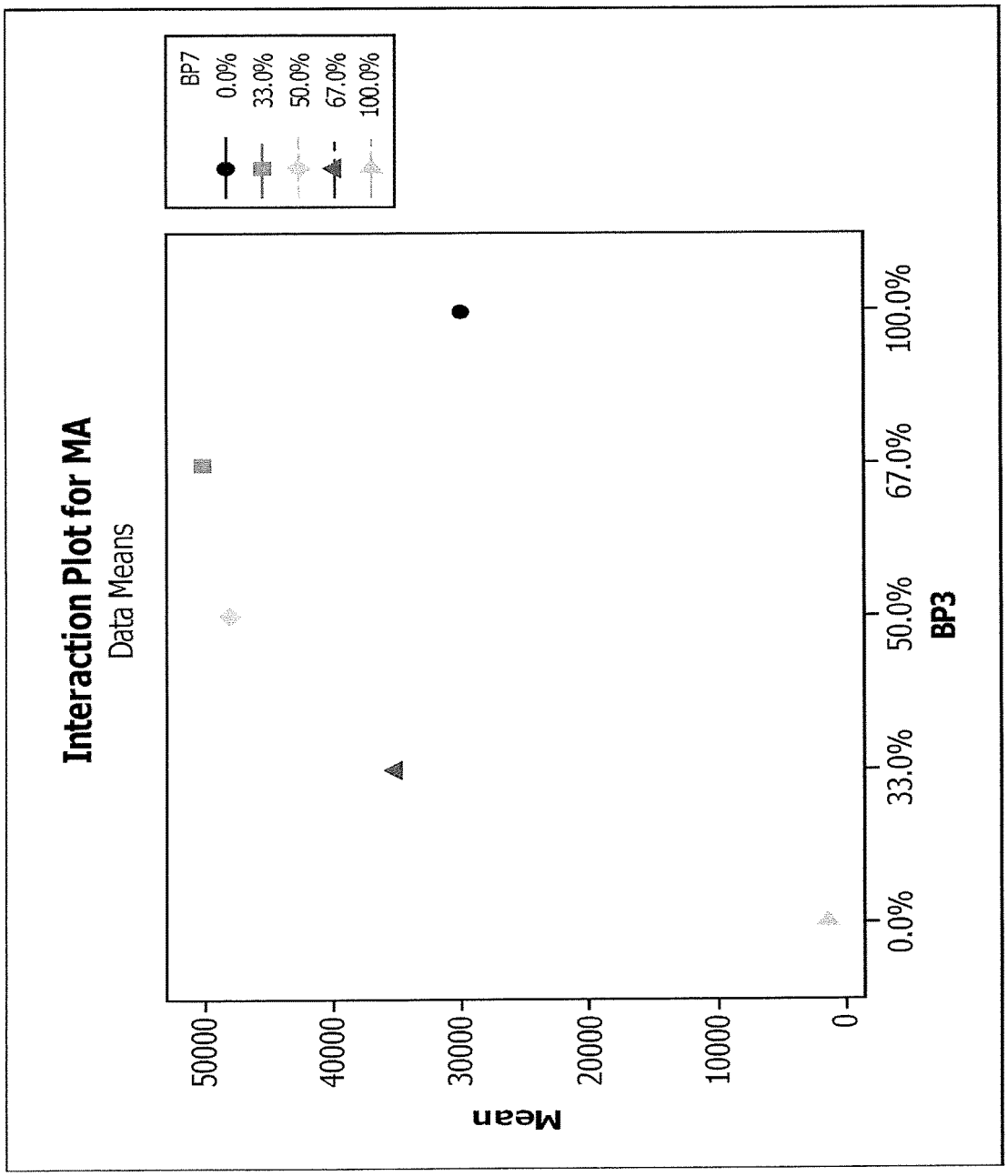

Interaction Plot for MA
Data Means
BP7
0.0%
33.0%
50.0%
67.0%
100.0%
Mean
50000
40000
30000
20000
10000
0
0.0%
33.0%
50.0%
67.0%
100.0%
BP3

Figure 73

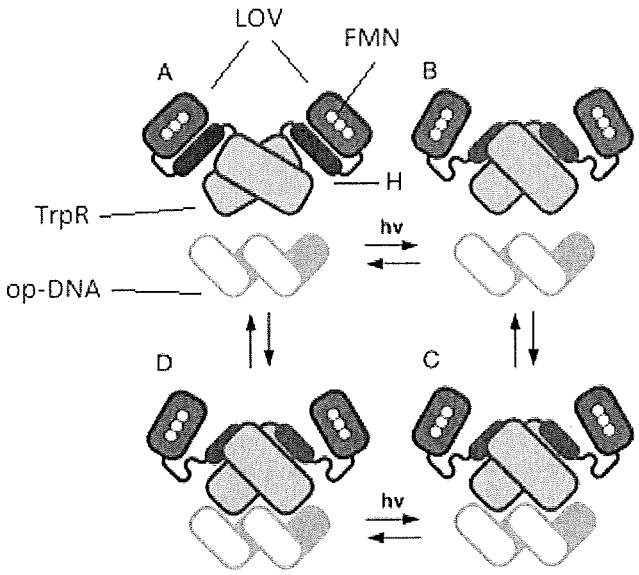


Figure 74

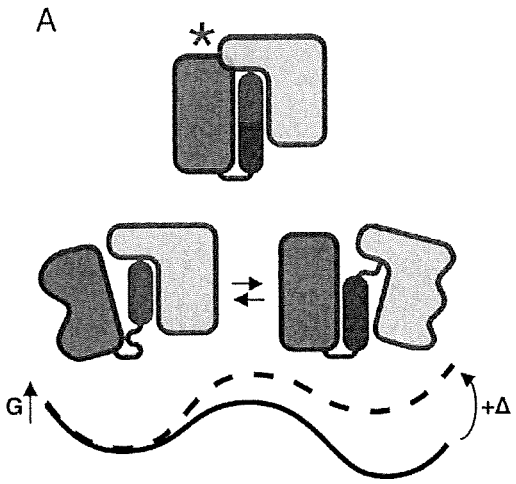


Figure 75

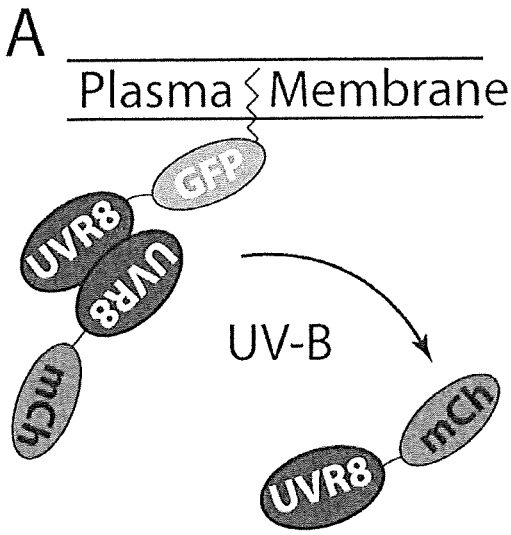


Figure 76

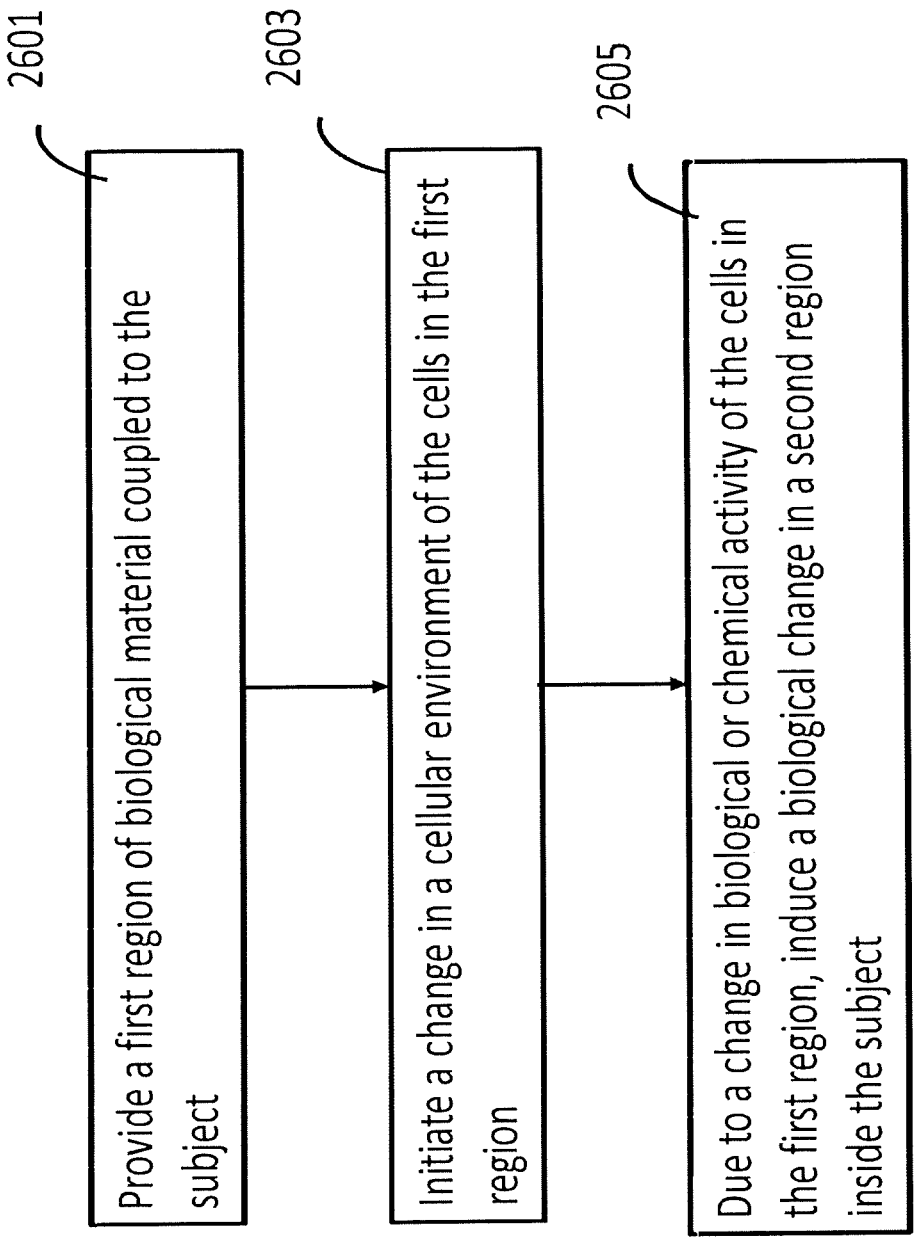
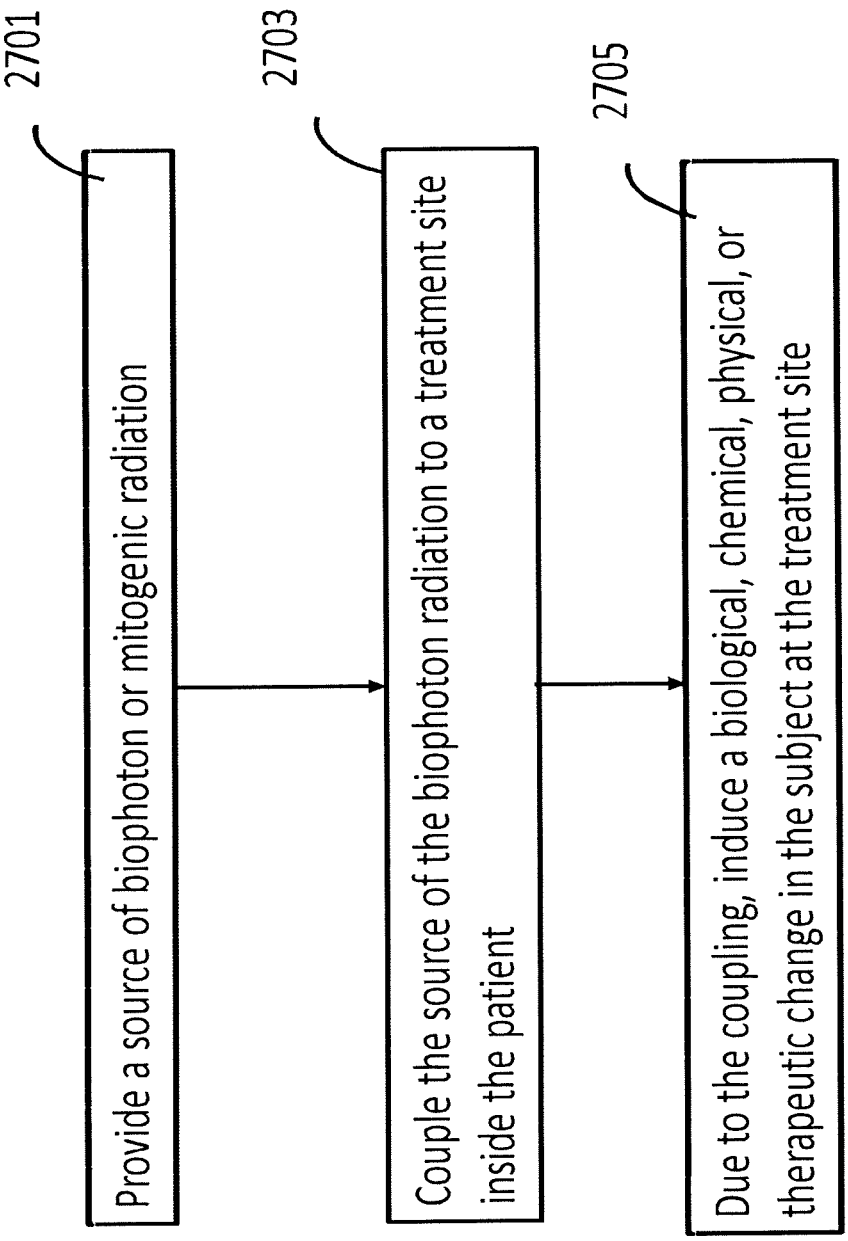
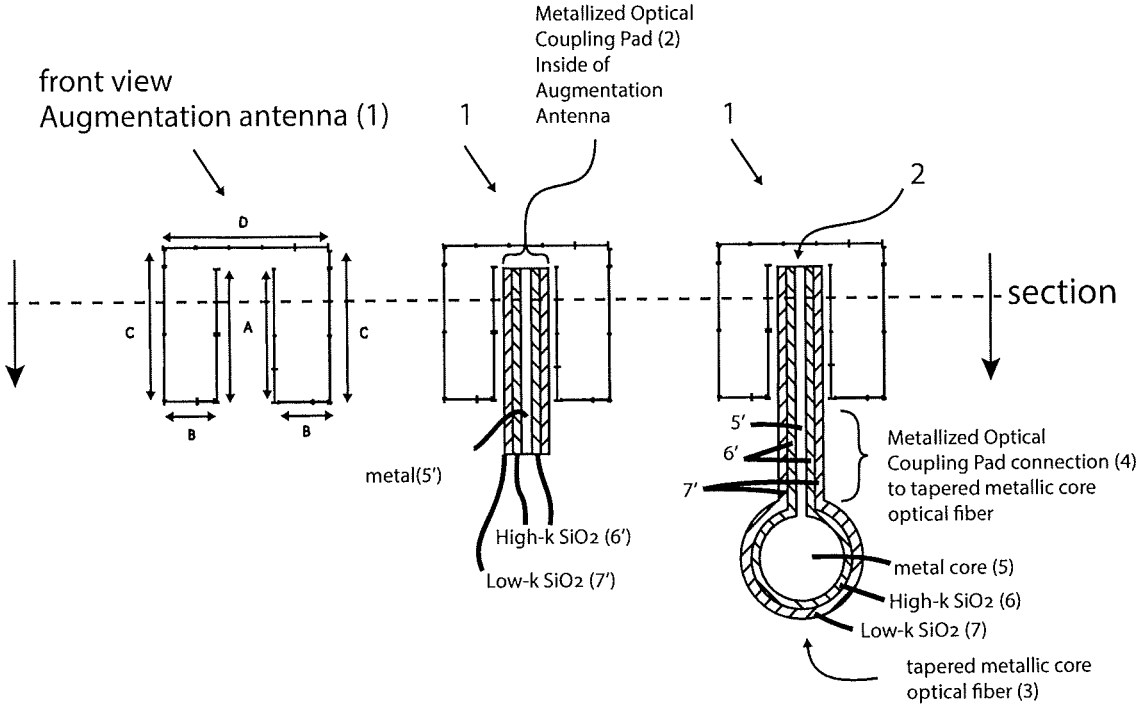
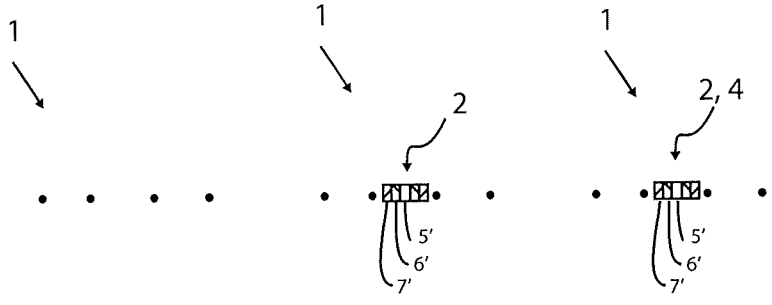

2601
Provide a first region of biological material coupled to the subject
2603
Initiate a change in a cellular environment of the cells in the first region
2605
Due to a change in biological or chemical activity of the cells in the first region, induce a biological change in a second region inside the subject

Figure 77


2701
Provide a source of biophoton or mitogenic radiation
2703
Couple the source of the biophoton radiation to a treatment site inside the patient
2705
Due to the coupling, induce a biological, chemical, physical, or therapeutic change in the subject at the treatment site


front view
Augmentation antenna (1)
D
C
A
C
B
B
Figure 78A
(front)
Metallized Optical
Coupling Pad (2)
Inside of
Augmentation
Antenna
1
metal(5')
High-k SiO2 (6')
Low-k SiO2 (7')
Figure 79A
(front)
1
2
section
5'
6'
7'
Metallized Optical
Coupling Pad connection (4)
to tapered metallic core
optical fiber
metal core (5)
High-k SiO2 (6)
Low-k SiO2 (7)
tapered metallic core
optical fiber (3)
Figure 80A
(front)


1
Figure 78B
(section)
1
2
5'
6'
7'
Figure 79B
(section)
1
2, 4
5'
6'
7'
Figure 80B
(section)

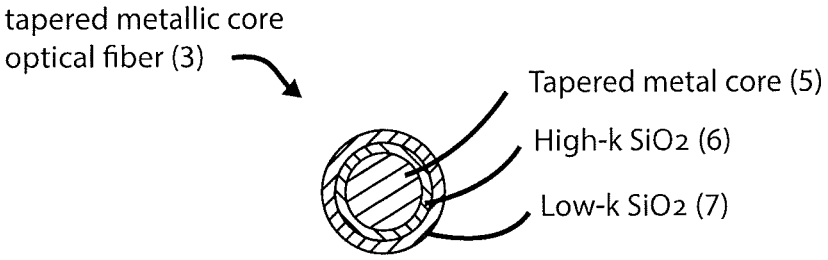


Figure 81B
(front)

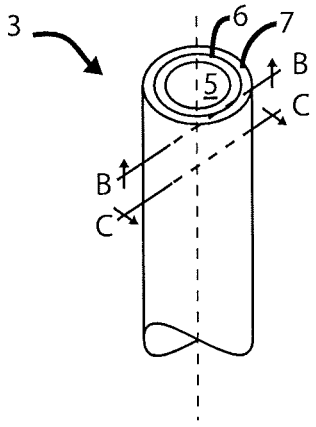


Figure 81A
(front)

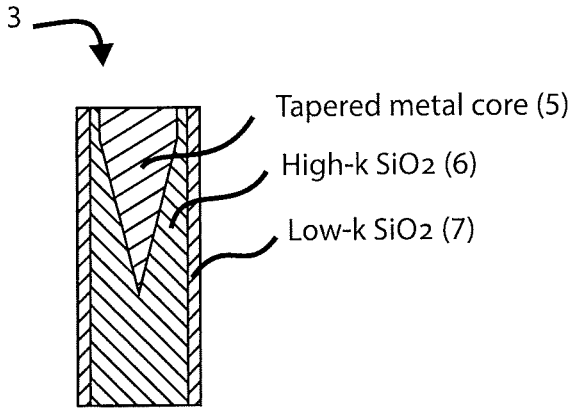


Figure 81C
(front)

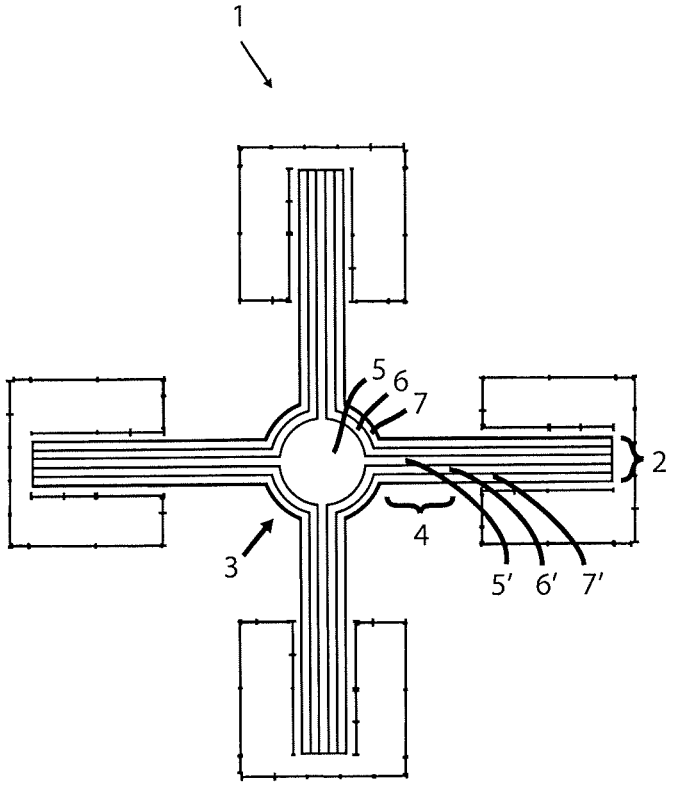


Figure 82

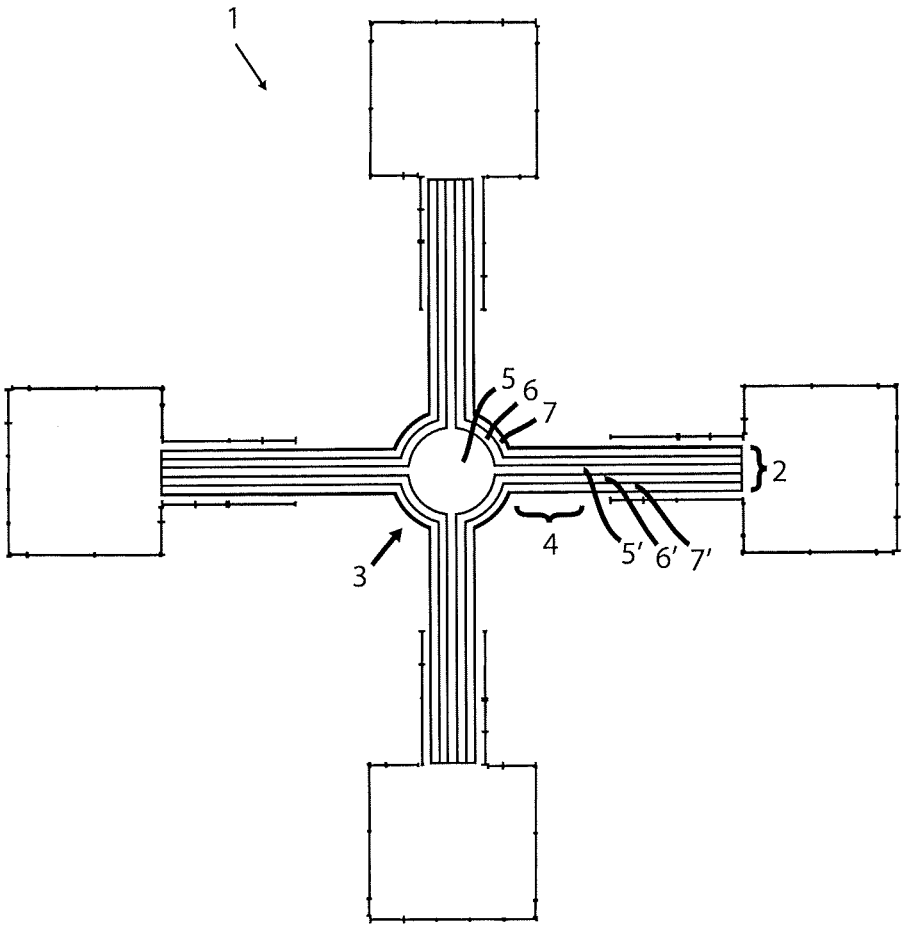


Figure 83

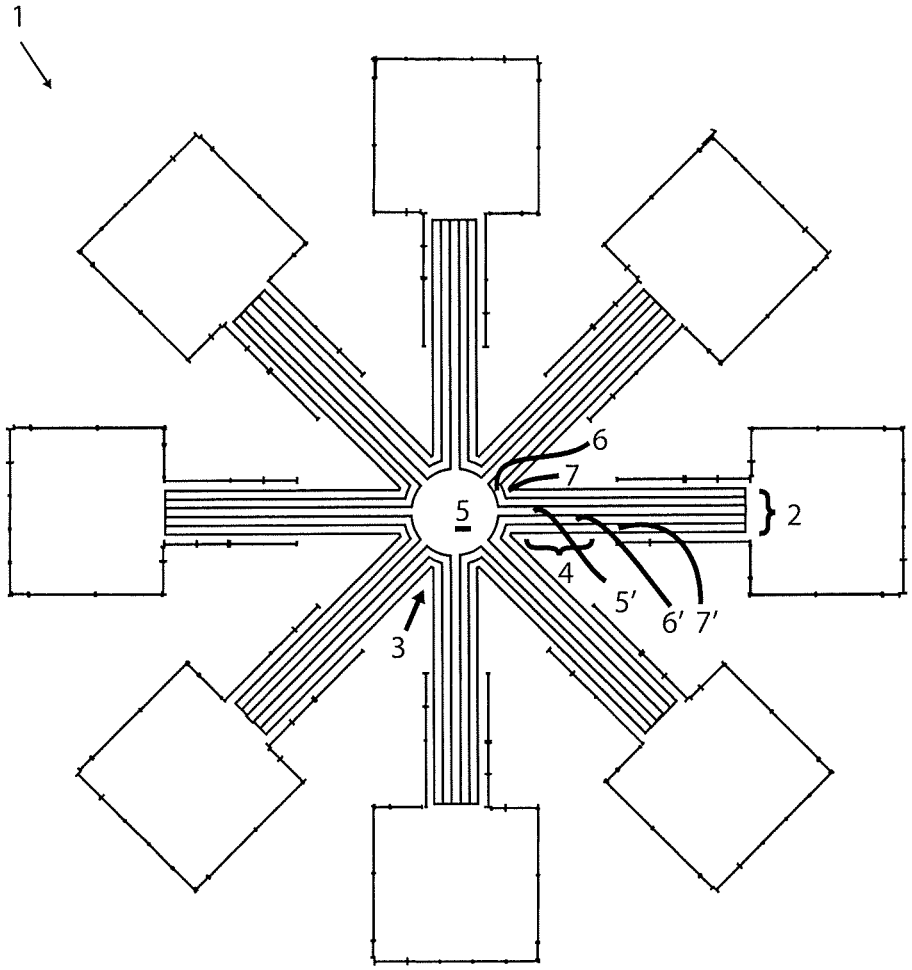


Figure 84
(front)

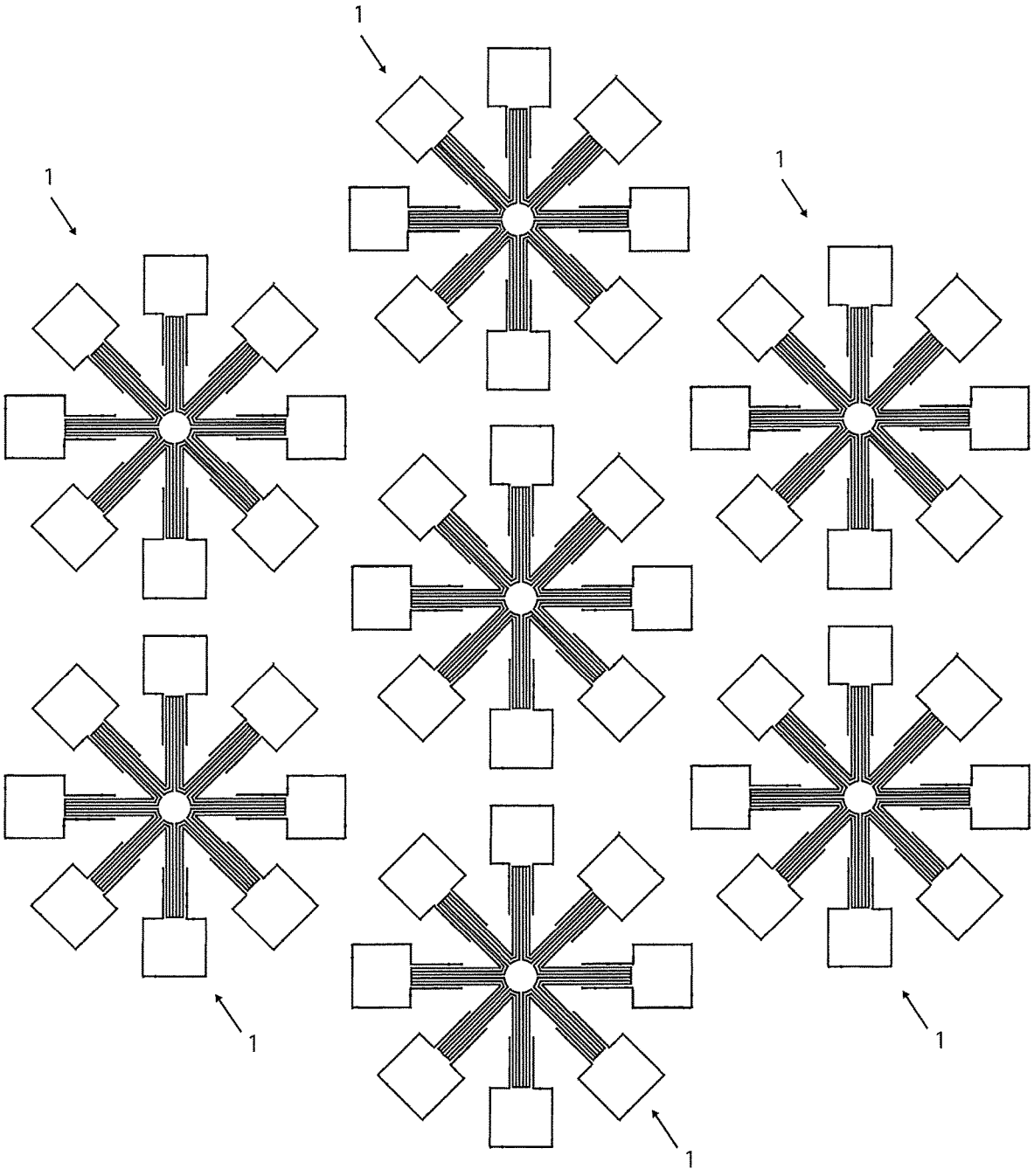


Figure 85
(front)

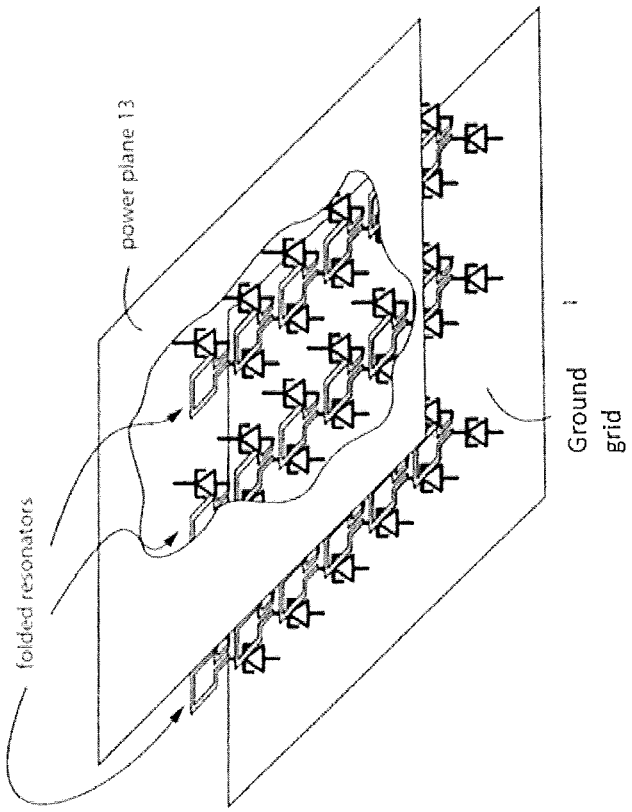


Figure 87

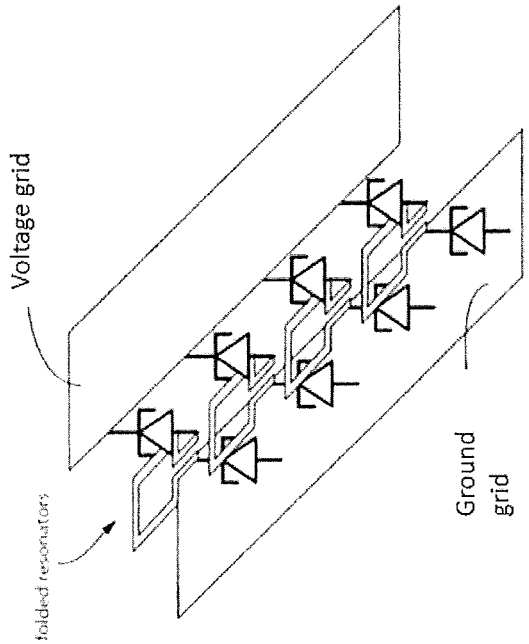


Figure 86

ENERGY AUGMENTATION STRUCTURES FOR MEASURING AND THERAPEUTIC USES

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is related to provisional application U.S. Ser. No. 62/955,533, filed Dec. 31, 2019, entitled ENERGY AUGMENTATION STRUCTURE; ENERGY COLLECTOR CONTAINING THE SAME; AND EMISSION ENHANCEMENTS UTILIZING AT LEAST ONE ENERGY AUGMENTATION STRUCTURE, the entire disclosure of which is incorporated herein by reference. This application is related to provisional application U.S. Ser. No. 62/946,648, filed Dec. 11, 2019, entitled ENERGY AUGMENTATION STRUCTURE; ENERGY COLLECTOR CONTAINING THE SAME; AND EMISSION ENHANCEMENTS UTILIZING AT LEAST ONE ENERGY AUGMENTATION STRUCTURE, the entire disclosure of which is incorporated herein by reference. This application is related to provisional application U.S. Ser. No. 62/897,677, filed Sep. 9, 2019, entitled ENERGY AUGMENTATION STRUCTURE; ENERGY COLLECTOR CONTAINING THE SAME; AND EMISSION ENHANCEMENTS UTILIZING AT LEAST ONE ENERGY AUGMENTATION STRUCTURE, the entire disclosure of which is incorporated herein by reference. This application is related to provisional application U.S. Ser. No. 62/855,508, filed May 31, 2019, entitled ENERGY AUGMENTATION STRUCTURE; ENERGY COLLECTOR CONTAINING THE SAME; AND COLOR ENHANCEMENT UTILIZING AT LEAST ONE ENERGY AUGMENTATION STRUCTURE, the entire disclosure of which is hereby incorporated by reference. This application is related to provisional application U.S. Ser. No. 62/813,390, filed Mar. 4, 2019, entitled COLOR ENHANCEMENT UTILIZING AT LEAST ONE ENERGY AUGMENTATION STRUCTURE, the entire disclosure of which is hereby incorporated by reference. This application is related to U.S. application Ser. No. 16/599,732, filed Oct. 11, 2019, pending, which claims priority to provisional application U.S. Ser. No. 62/745,057, filed Oct. 12, 2018, the entire contents of each of which are hereby incorporated by reference. This application is related to U.S. Ser. No. 13/204,355 filed Aug. 5, 2011, the entire disclosures of which are hereby incorporated by reference. This application is related to U.S. provisional patent application 61/371,549, filed Aug. 6, 2010. This application is related to U.S. provisional patent application 61/161,328, filed Mar. 18, 2009 and to U.S. provisional patent application 61/259,940, filed Nov. 10, 2009, the entire disclosures of which are hereby incorporated by reference. This application is related to U.S. Ser. No. 12/725,108, the entire disclosures of which are hereby incorporated by reference.

[0002] This application is related to Provisional Application Ser. No. 60/954,263, filed Aug. 6, 2007, and 61/030,437, filed Feb. 21, 2008, and U.S. application Ser. No. 12/059,484, filed Mar. 31, 2008, the contents of which are hereby incorporated herein by reference. This application is also related to U.S. application Ser. No. 11/935,655, filed Nov. 6, 2007; and Provisional Application Ser. No. 61/042,561, filed Apr. 4, 2008; 61/035,559, filed Mar. 11, 2008, and 61/080,140, filed Jul. 11, 2008, the entire contents of which are hereby incorporated herein by reference. This application is related to U.S. patent application Ser. No. 12/401,478 filed Mar. 10, 2009, the entire contents of which are hereby incorporated herein by reference. This application is related to U.S. patent application Ser. No. 11/935,655, filed Nov. 6, 2007, and Ser. No. 12/059,484, filed Mar. 31, 2008; U.S. patent application Ser. No. 12/389,946, filed Feb. 20, 2009; U.S. patent application Ser. No. 12/417,779, filed Apr. 3,2009, the entire disclosures of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0003] The invention relates to methods, systems, and devices for energy augmentation, with and without an energy modulation agent/energy conversion agent present, and uses particularly for generating or enhancing photon or electron emission and/or for enhancing light or photon collection, especially for measuring and inducing cell-to-cell communication, and therapeutic uses thereof.

Discussion of the Background

[0004] Presently, light (i.e., electromagnetic radiation from the radio frequency through the visible to the X-ray wavelength range) is used in a number of industrial, communication, electronic, and pharmaceutical processes. Light in the infrared and visible range is typically generated from an electrical energy source which for example either heats a material to extremely high temperatures where black body emission occurs (as in an incandescent lamp). Light in the visible and ultraviolet range is typically generated by heating a gas to an electrical discharge where transitions from one electronic state of the gas atom or molecule occur with the emission of light. There are also semiconductor based light sources (as in light emitting diodes and semiconducting lasers) where electrons/holes in a material recombine to produce light emission.

[0005] Visible light is defined as the electromagnetic radiation with wavelengths between 380 nm and 750 nm. In general, electromagnetic radiation including light is generated by the acceleration and deceleration or changes in movement (vibration) of electrically charged particles, such as parts of molecules (or adjacent atoms) with high thermal energy, or electrons in atoms (or molecules).

[0006] For reference purposes, infra-red (IR) radiation just beyond the red end of the visible region; and, ultra-violet (UV) radiation has a shorter wavelength than violet light. The UV portion of the spectrum is divided into three regions: UVA (315-400 nm), UVB (280-315 nm) and UVC (100-280 nm).

[0007] Industrial lamps used in lighting applications cover the visible range of wavelengths for proper white perception. Thermal sources like heated filaments can be made of different type conductors, including W-filaments, halogen-protected W-filaments, and electrically induced high temperature plasmas (arc lamps).

[0008] The power (energy emitted per second) of a radiant source is frequently expressed in watts (W), but light can also be expressed in lumens (lm) to account for the varying sensitivity of the eye to different wavelengths of light. The derived relevant units are the radiance (luminance) of a source in W/m^2 (lm/m^2) in a certain direction per steradian

(unit of solid angle) and the irradiance (illuminance) of a surface in W/m^2 (lm/m^2 or lux).

[0009] With the development of ultraviolet sources, ultraviolet radiation is being increasingly utilized for industrial, chemical, and pharmaceutical purposes. For example, UV light is known to sterilize media and is known to drive a number of photo-activated chemical processes such as the cross-linking of polymers in adhesives or coatings. Typically, ultraviolet sources use gas discharge lamps to generate emitted light in the ultraviolet range. The emitted light is then optically filtered to remove many of not all of the non-ultraviolet frequencies. Ultraviolet light can also be produced in semiconductor phosphors from the excitation of these phosphors from high energy sources such as, for example, X-ray irradiation.

[0010] With the development of infrared radiation sources, infrared radiation is being increasingly utilized for communications and signaling purposes. Typically, infrared sources use broad spectrum light sources referred to as glowbars to generate a broad spectrum of light centered in the infrared range or use lasers to emit very specific infrared wavelengths. For the broad band sources, the emitted light is optically filtered to remove many, if not all, of the non-infrared frequencies.

[0011] It is generally desirable to have devices, materials, and capabilities to convert light from one frequency range to another. Down conversion has been one way to convert higher energy light to lower energy, as used in the phosphors noted above. Up conversion has also been shown where lower energy light is converted to higher energy light. Typically, this process is a multi-photon absorption process where two or more photons are used to promote an excited electronic state in a host medium which in turn radiates at a wavelength of light that has a higher energy than the energy of the incident light which promoted the multi-photon absorption process. Both down conversion and up conversion have been studied and documented in the past.

[0012] Indeed, workers have studied the phenomenon of photoluminescence and fluorescence, which is the ability of certain solids to emit light when driven or charged by an external energy source. Many well-known phosphors and fluorescors are triggered by high-energy electrons or photons and emit photons of lower energy. It has been recognized that certain infrared phosphors can convert infrared light to light in the visible range (violet through red).

[0013] The properties of light such as its radiance is particularly important in reading or display applications where the human eye has to perceive and discern temporary images or permanent images (as for example shown by road and highway signs) formed with visible light. Televisions, computer monitors, displays, and signs use a cathode ray technology (CRT) technology where high energy electrons impinge on phosphors that emit visible light. Televisions, computer monitors, displays, and signs more recently have used liquid crystal display or plasma display technology to generate visible images discernable to the human eye.

[0014] In these and other reading or display applications, attempts have been made to develop displays with relatively high contrast images while minimizing the amount of broadband light emitted or reflected from a display, which may detract from the contrast of the image displayed.

[0015] In general, the up conversion and the down conversion discussed above have been used in a number of fields to in effect convert an incident wavelength of light to a different wavelength. In one example, high energy photons such as X-rays are converted by absorption in phosphors of the x-ray energy, and luminescence from the phosphors in the ultraviolet, visible, and/or near infrared spectrum has been used for driving photoactive reactions. In other examples, infrared or near infrared light has been up converted by absorption in phosphors of the infrared or near infrared light, and luminescence from the phosphors in the visible and/or ultraviolet spectrum. In other examples, light within the visible region can be down converted or up converted (depending on the phosphors chosen) to a different band within the visible wavelengths. This shifting (energy conversion) can be for color enhancement and can be used in solar cells to convert one part of the solar spectrum to another part more favorable for a photovoltaic device to generate power.

[0016] In many of these prior applications, metallic structures have been placed on the phosphors or in a vicinity of the phosphors to generate a plasmonics effect which essentially is an amplification of the local field very nearby the outside of the metallic structures. Plasmonic effects can enhance coupling of incident light into the phosphors and/or enhance the reactivity of the converted light tons nearby receptor. While the plasmons in the metal can propagate along the metal, the plasmons decay evanescently in the z direction normal to the metal/dielectric interface with 1/e decay length of the order of half the wavelength (~200 nm for wavelengths in the visible range).

[0017] In some prior applications, photonic band gap structures have been used. In a photonics band gap structure, the materials thereof consist or photonic crystals (PhCs) are materials with a periodic dielectric profile, which can prevent light of certain frequencies or wavelengths from propagating in one, two or any number of directions within the materials. In this way, light not suitable or detrimental to a process can be rejected while light more suitable for a process can be confined within the photonic band gap structure or better confined within the photovoltaic converter.

[0018] The problem with the plasmonics effect is that, as noted above, the plasmons and the electric field enhancement decays rapidly with distance away from the metal structure meaning that the effect is only useful for a small volume of interaction.

[0019] Light modulation from a deeply penetrating radiation like X-ray to a photo-catalytic radiation like UV or IR, opens the possibility for activating bio-therapeutic agents of various kinds within mammalian bodies. Other possibilities include the activation of photo-catalysts in mediums for cross-linking reactions in polymeric chains and polymer based adhesives. These examples are but two examples of a number of possibilities that can be more generally described as the use of a conversion material to convert an initiating radiation that is deeply penetrating to another useful radiation possessing the capability of promoting photo-based chemical reactions. The photo-chemistry is driven inside media of far ranging types including organic, inorganic or composited from organic and inorganic materials.

[0020] Photo-activation with no line of site required can be done in-vivo and ex-vivo such as those carried out in cell cultures. In turn, the photo activation of a select bio-therapeutic agent, and conceivably more than one agent at a time, can lead to the onset of a desirable chemical reaction, or a cascade of reactions, that in turn lead to a beneficial

therapeutic outcome. As an example, the binding of psoralen compounds to DNA through the formation of monoadducts and/or crosslinked adducts is well known to engender an immune response if done properly.

[0021] As background as to the physical and biological structures that the present invention can address, below is a summary of the various anatomical cell structures present in subjects to which the techniques of the present invention disclosed below can apply. Further details of anatomical structures can be found in U.S. Pat. No. 9,295,835 (the entire contents of which are incorporated herein by reference).

[0022] Cells generate their electrical energy and communication signals within the plasma membrane. The plasma membrane may also have electrical connections to adjacent cells of the same type. The nucleus is considered in communication with activities occurring in the plasma membrane, for that matter all other activities of the cell.

[0023] Cell signaling may be accomplished by a combination of electrical, photonic, and chemical interactions. Different types of cells should require a varied level of signaling qualities. The creation or generation of a given cell signal is believed to begin in the plasma membrane where raw material and chemical ions are taken in from the extracellular matrix to both generate electricity and establish the signal format. The plasma membrane is a sort-of cell wall that takes in the required raw material via its ion channels. Ion channels open and close to allow passage into and from the cell interior. Electrical signals are likely generated in the plasma membrane before they are sent via the cytoskeleton, all about the cell to go and participate and contribute to cell operations.

[0024] It is desirable to provide methods and/or devices by which such cell signaling can be induced to occur in the cells in order to assist the body in treating conditions, disorders, or diseases, and to provide the body with new pathways for maintaining health.

SUMMARY OF THE INVENTION

[0025] In one embodiment, there is provided an energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property.

[0026] In one embodiment, the energy augmentation structure may be one or more of an electromagnetic resonator structure, a folded resonator structure, and a fractal structure having a region of an intensified electromagnetic field within the structure.

[0027] In a further embodiment, there is provided an energy collector comprising at least one energy augmentation structure; and at least one energy converter capable of receiving an applied electromagnetic energy, converting the applied electromagnetic energy and emitting therefrom an emitted electromagnetic energy shifted in wavelength or energy from the applied electromagnetic energy and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted electromagnetic energy is emitted with at least one augmented property compared to if the energy converter were remote from the at least one energy augmentation structure.

[0028] In one embodiment, the energy converter noted above is disposed with an energy augmentation structure comprising one or more of an electromagnetic resonator structure, a folded resonator structure, and a fractal structure, any of which having a region of an intensified electromagnetic field within the resonating structures.

[0029] In one embodiment, the energy converter noted above includes one or more luminescing materials. As described herein, there are uses of the energy augmentation structure and/or energy collector embodiments which enhance bioluminescence, chemo-luminescence, photoluminescence, fluorescence, and mechano-luminescence.

[0030] In one embodiment, the energy converter noted above includes for the one or more luminescent materials phosphorescent materials, fluorescent materials, electroluminescent materials, chemo-luminescent materials, bioluminescent materials, and mechano-luminescent materials used in conjunction with or not in conjunction with the energy augmentation structure noted above. When used in conjunction with the energy augmentation structure noted above, the emitted electromagnetic energy from the luminescent material is emitted with at least one augmented property compared to if the energy converter (e.g., the luminescent material) were remote from the at least one energy augmentation structure.

[0031] In one embodiment, the energy converter noted above includes for the one or more luminescing materials phosphorescent materials, fluorescent materials, electroluminescent materials, chemo-luminescent materials, bioluminescent materials, and mechano-luminescent materials used in conjunction with or not in conjunction with the energy augmentation structure noted above and which emit one of ultra-violet, visible, near infrared, and infrared light. In this embodiment, UV-emitting electroluminescent materials or mechano-luminescent devices and materials can be used. In this embodiment, UV-emitting bioluminescent materials can be used.

[0032] In additional embodiments, there are provided uses of the energy augmentation structure and energy collector embodiments in medical treatments, measuring and/or inducing cell-to-cell communication, and other end uses.

[0033] In another embodiment, the energy converter noted above is disposed with an energy augmentation structure such that x-ray induced photoluminescence or fluorescence is higher compared to if the energy converter (e.g., x-ray induced photoluminescence or fluorescence materials) were remote from the at least one energy augmentation structure.

[0034] In another embodiment, the above noted distributed energy collector can deliver light to different positions within a medium inside a patient.

[0035] In another embodiment, the above noted distributed energy collector can collect or deliver light from or to different positions within a patient, including for example collecting or delivering light to different positions within an organ.

[0036] In another embodiment, a UV-emitting luciferase may be used alone or in conjunction with the above-noted energy augmentation structures to generate light inside a patient.

[0037] In another embodiment, there are provided uses of the energy augmentation structure and/or energy converters to enhance electron emission from surfaces in a vicinity of the energy augmentation structure.

[0038] In one embodiment, the energy converter noted above includes one or more electron emitting materials. The electron emitting materials may be photon-induced materials which photo-eject an electron under exposure to UV

light, The electron emitting materials may be thermally heated materials which emit electrons from heated surfaces of the emitting materials.

[0039] In one embodiment, the energy converter noted above includes for the one or more electron emitting materials nanoscale field emission tips. When used in conjunction with the energy augmentation structure noted above, the emitted electron flux from the electron emitting materials is higher compared to if the energy converter (e.g., the nanoscale field emission tips) were remote from the at least one energy augmentation structure.

[0040] It is to be understood that both the foregoing general description of the invention and the following detailed description are exemplary, but are not restrictive of the invention.

BRIEF DESCRIPTION OF THE FIGURES

[0041] A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

[0042] FIG. **1** is a schematic depicting an energy augmentator system of the invention with optional inclusion of an energy converter;

[0043] FIG. **2** is a schematic depicting a folded resonator as an illustrative energy augmentation structure of the invention;

[0044] FIG. **3** is a diagram depicting the basic concepts underlying one of the energy augmentation structures of this invention;

[0045] FIG. **4** is a schematic depicting a staggered antenna configuration as an illustrative energy augmentation structure of the invention;

[0046] FIG. **5** is a schematic depicting the effect of electrode spacing in the folded resonator of the invention;

[0047] FIG. **6** is a diagram showing a pattern of ¾ λ folded resonators distributed in space;

[0048] FIGS. **7**A-C is a diagram showing a pattern of ¾ λ folded resonators distributed in a plane or otherwise along a surface of an object;

[0049] FIG. **8** is a diagram showing a pattern of ¾ λ folded resonators distributed in a plane or otherwise along a surface of an object and having a different orientation than in FIG. **7**A;

[0050] FIG. **9** is a diagram showing a pattern of ¾ λ folded resonators having a light or photon or electron emitting material deposited in the region of between the opposing electrodes;

[0051] FIG. **10** is a diagram showing a pattern of ¾ λ folded resonators having a patterned deposit of a light or photon or electron emitting material in the region of between the opposing electrodes;

[0052] FIG. **11** is a diagram showing a pattern of ¾ λ folded resonators having a patterned deposit of a light or photon or electron emitting material in the region of between the opposing electrodes;

[0053] FIG. **12** is a diagram showing a pattern of ¾ λ folded resonators having for the metal traces a fractal pattern for the electrical path that loops around to connect the opposing electrodes;

[0054] FIG. **13** is a diagram showing a fractal antenna segment where the straight-line sides of the metal pads have locally intensified electric field;

[0055] FIG. **14** is a diagram showing a repeated pattern of the fractal antenna segment of FIG. **13**

[0056] FIG. **15** is a diagram showing a pattern of bowtie fractal antenna segments;

[0057] FIG. **16** is a diagram showing a paired three-dimensional fractal structure with an intensified electric field in between;

[0058] FIG. **17** is a diagram showing a pattern of the paired three-dimensional fractal structures;

[0059] FIG. **18** is a diagram showing a ¾ wavelength resonator with the distal ends of the resonator antenna protruding outwardly while maintaining parallelism;

[0060] FIG. **19** is a diagram showing a packing configuration for three different ¾ wavelength resonators, that are maintained in plane with no overlapping distal ends;

[0061] FIG. **20** is a diagram showing another packing configuration for three different ¾ wavelength resonators, that are maintained in plane with overlapping distal ends;

[0062] FIG. **21** is a diagram showing yet another packing configuration for the ¾ wavelength resonators, with an off (or out of) plane axial symmetry;

[0063] FIG. **22** is a diagram showing a multi-level packing configuration in parallel planes for the folded ¾ wavelength resonator shown;

[0064] FIG. **23** is a diagram showing a multi-level packing configuration in parallel planes with distal ends protruding out for the ¾ wavelength resonator in FIG. **22**;

[0065] FIG. **24**A is a diagram showing a different in-plane packing configuration;

[0066] FIG. **24**B is a diagram showing another different in-plane packing configuration;

[0067] FIG. **25**A is a schematic illustrating a distributed point light collector/transmitter of the invention;

[0068] FIG. **25**B is a schematic of a cross section of the collector/transmitter of FIG. **25**A.

[0069] FIG. **26** is a schematic illustrating various converter structures of the invention;

[0070] FIG. **27** is a schematic illustration of plasmon resonance as a function of shell thickness;

[0071] FIG. **28**A is a schematic illustrating other various converter structures of the invention;

[0072] FIG. **28**B is a further schematic illustrating other various converter structures of the invention;

[0073] FIG. **28**C is a schematic illustrating various plasmonics-active converter structures of the invention;

[0074] FIG. **28**D is a schematic illustration of photo-active molecules linked to plasmonics-active upconverter structures of the invention;

[0075] FIG. **29** is a diagram showing a mechanoluminescent emitter of the present invention;

[0076] FIG. **30** is a diagram showing a composite piezoelectric/electroluminescent emitter of the present invention;

[0077] FIG. **31** is a diagram showing a distribution of the composite emitters of FIG. **30** across a surface for light emission;

[0078] FIG. **32** is a diagram showing a distribution of the composite emitters of FIG. **30** within a target region for light emission;

[0079] FIG. **33**A is a schematic illustrating various cellular components of an example cell **100**.

[0080] FIG. **33**B is a schematic illustration of a folded resonator useful in various embodiments;

[0081] FIG. **33**C is a schematic illustration of an array of folded resonators useful in various embodiments;

[0082] FIG. **34** is a schematic showing the cellular components of FIG. **33**A along with the presence of biophotons and phosphors for emitting light to stimulate or mimic biophoton radiation.

[0083] FIG. **35** illustrates a schematic drawing of the structure of a plasma membrane **100** of the cell **100** shown in FIG. **33**A.

[0084] FIG. **36** illustrates a junction view **300** of the attachments between tumor cells.

[0085] FIG. **37** is a schematic showing the junction view of FIG. **36** along with the presence of biophotons and phosphors for emitting light to stimulate or mimic biophoton radiation.

[0086] FIG. **38** illustrates a pictorial drawing of the internal framework **400** of a cell, such as the cell **100** shown in FIG. **33**A.

[0087] FIG. **39** is a schematic showing the internal framework of FIG. **38** along with the presence of biophotons and phosphors for emitting light to stimulate or mimic biophoton radiation.

[0088] FIG. **40**A is a depiction of a conventional LRC circuit and an equivalent type biological circuit.

[0089] FIG. **40**B is a depiction of a conventional LRC circuit and an equivalent type biological circuit.

[0090] FIG. **41** (**5**) is a depiction of a biophoton collector **500** according to one embodiment of the present invention.

[0091] FIGS. **42**A-**42**C are depictions of an electromagnetic biophoton collector **600** according to one embodiment of the present invention.

[0092] FIG. **43** is a depiction of a fractal antenna according to one embodiment of the present invention.

[0093] FIG. **44** is a schematic showing a section of waveguide **710** according to one embodiment of the present invention, having a high-k dielectric material **712**, a low-k dielectric material **714** and a central metal **716**.

[0094] FIG. **45** is a schematic showing the antenna pickup area of one embodiment of the present invention having an open concentric polarization construction **720***a*.

[0095] FIG. **46** depicts an array **730** of antennae **732** according to one embodiment of the present invention.

[0096] FIG. **47** depicts a cross section of the stub configuration **730** shown in FIG. **46** with antennae **732** interconnected together according to one embodiment of the present invention.

[0097] FIG. **48** is a schematic of a multi-up arrayed antenna **750** according to one embodiment of the present invention.

[0098] FIG. **49** is another schematic of the multi-up arrayed antenna **750** shown in FIG. **48** showing a top-level interconnection network **762** under the top surface of multi-up arrayed antenna **750**, according to one embodiment of the present invention.

[0099] FIG. **50** is a further schematic of the multi-up arrayed antenna **750** shown in FIG. **48** showing the full interconnection network including top-level interconnection network **762** and bottom-level interconnection network **764**, according to a further embodiment of the present invention.

[0100] FIG. **51** is a depiction of antennae that can be arrayed in different manners including a square antenna **780***a*, a rectangular antenna **780***b*, and a diamond shaped antenna **780***c*, according to embodiments of the present invention.

[0101] FIG. **52** is a depiction of a spiral-type packing antenna arrangement **790** according to one embodiment of the present invention.

[0102] FIG. **53** is a depiction of a window chamber according to one embodiment of the present invention.

[0103] FIG. **54** is a depiction of a window **795** made of a quartz wafer that has different sections that are independent of each other, according to one embodiment of the present invention.

[0104] FIG. **55** is a depiction of a hollow optic biophoton bypass **800** according to one embodiment of the present invention.

[0105] FIG. **56**A is a depiction of an electrically conducting biophoton bypass **900** according to one embodiment of the present invention.

[0106] FIG. **56**B is a depiction of an electrically conducting biophoton bypass **900** according to one embodiment of the present invention.

[0107] FIG. **57**A is a depiction of another electrically conducting biophoton bypass **1000** according to one embodiment of the present invention.

[0108] FIG. **57**B is a depiction of another electrically conducting biophoton bypass **1000** according to one embodiment of the present invention.

[0109] FIG. **58** is a depiction of a magnetic biophoton bypass **1100** according to one embodiment of the present invention.

[0110] FIG. **59** is a depiction of a DNA-based biophoton bypass **1200** according to one embodiment of the present invention.

[0111] FIG. **60**A is a depiction of a living-cell biophoton radiator **1300** according to one embodiment of the present invention.

[0112] FIG. **60**B is a depiction of a living-cell biophoton radiator **1300** according to one embodiment of the present invention.

[0113] FIG. **61** is a depiction of a system **1400** of the present invention for application of microwave energy to a target region to locally heat the cells in the target region and thereby induce biophoton emission.

[0114] FIG. **62** is a depiction of an in vivo biophoton source **1500** according to one embodiment of the present invention.

[0115] FIG. **63** shows the spectral emission of the BP3, BP10, and BP6 phosphors.

[0116] FIG. **64** is a chart showing that photonic energy from BP3 tends to produce more MA than BP6 or BP10.

[0117] FIG. **65** is a chart showing MA formation under BP3 photonic energy as a function of distance from the X-ray source and time.

[0118] FIG. **66** is a chart showing XL under BP3 photonic energy as a function of distance from the X-ray source and time.

[0119] FIGS. **67-71** show results from other experiments corroborating MA formation and/or XL under photonic energy exposure.

[0120] FIG. **72** is a chart showing a non-linear effect on MA seen by mixing two phosphors.

[0121] FIG. **73** is a depiction of a helical "allosteric lever arm" as considered by Strickland et al. to be a mechanism for coupling the function of two proteins.

[0122] FIG. **74** is a depiction of a design of an allosteric, light activated repressor.

[0123] FIG. **75** is a depiction of the light-triggered dissociation of UVR8-tagged proteins.

[0124] FIG. **76** is a flowchart of one method for treating a subject according to an embodiment of the present invention.

[0125] FIG. **77** is a flowchart of another method for treating a subject according to a further embodiment of the present invention.

[0126] FIGS. **78**A, **78**B, **79**A, **79**B, **80**A, and **80**B depict cross sections and longitudinal views of a hybrid device including an augmentation antenna and a metallized optical coupling pad connected to a tapered metallic core optical fiber, according to one embodiment of the present invention.

[0127] FIGS. **81**A, **81**B, and **81**C depict different views of the tapered metallic optical fiber included with the hybrid optical collector/folded resonator device.

[0128] FIG. **82** is a depiction of an array of four inward folding antennas coupled to one common tapered metallic core optical fiber.

[0129] FIG. **83** is a depiction of an array of four outward folding antennas coupled to one common tapered metallic core optical fiber.

[0130] FIG. **84** is a depiction of an array of eight outward folding antennas coupled to one common tapered metallic core optical fiber.

[0131] FIG. **85** is a depiction of hexagonal close packing using sets of the eight outward folding antennas of FIG. **84**.

[0132] FIG. **86** is a depiction of a rectifying folded resonator array according to one embodiment of the invention.

[0133] FIG. **87** is a depiction of another rectifying folded resonator according to one embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0134] Reference will now be made in detail to a number of embodiments of the invention, examples of which are illustrated in the accompanying drawings, in which like reference characters refer to corresponding elements.

[0135] As noted above, energy converters such up conversion materials and down conversion materials have been used in a number of fields in effect to convert an incident wavelength of light to a different wavelength. Metallic structures have been placed on the phosphors or in a vicinity of the phosphors to generate a plasmonics effect which essentially is an amplification of the local field very nearby the outside of the metallic structures. In some applications, photonic band gap structures have been used in solar cell applications to prevent light of certain frequencies or wavelengths from propagating in one, two or any number of directions within the materials. Additionally, antireflection coatings and concentrators are well known in the literature.

[0136] The present inventors recognized that the shortcomings of these structures could be addressed by use of the energy augmentation structures described herein used separately or in conjunction with energy converters.

[0137] A. Energy Augmentation Structures

[0138] In the present invention, the term "energy augmentation" means effecting some change in one or more wavelengths of electromagnetic energy in at least one property, including, but not limited to, intensity, power, associated electrical field, associated magnetic field, wave amplitude, photonic flux, magnetic flux, phase, coherence, propagation direction, etc. The structure performing the energy augmentation can be termed an "energy augmentation structure" or an "energy augmentator". These terms are used interchangeably herein. Preferably the energy augmentation structure is a non-plasmonic structure (a structure that does not exhibit plasmonic properties).

[0139] The energy augmentator can take any desired form so long as it can perform the necessary function of augmenting the energy applied to it, causing a change in one or more wavelengths of electromagnetic energy in at least one property as noted above. Examples of such energy augmentators include, but are not limited to, at least one non-plasmonic member selected from the group consisting of resonators, fractal antennas, electrical grid patterns, antennas, cavities, etalons, nanoparticles, microparticles, nanostructures, and microstructures, just to name a few.

[0140] In one embodiment, as shown schematically in FIG. **1**, an energy augmentator **10** is provided that is capable of receiving or capturing one or more wavelengths of electromagnetic energy representing an incident energy wave **12**. Having received or captured the incident energy wave **12**, the energy augmentator **10** is capable of augmenting the one or more wavelengths of received or captured energy wave flux **12** in at least one property. As shown in FIG. **1**, in one embodiment, energy augmentator **10** then outputs an energy wave **14** with the at least one property augmented, with the augmented energy wave **14** incident on target **20**. Details of the augmentation are described below.

[0141] In another embodiment, the output (augmented) energy wave **14** (i.e., one or more output wavelengths of electromagnetic energy) can be incident on an energy converter **16** (such as the up conversion materials and down conversion materials noted above). The energy converter **16** can output photons or electrons **18** which can be directed to target **20**. In these embodiments, target **20** may receive the photons or electrons **18** or the output augmented energy wave **14** simultaneously or separately.

[0142] In one embodiment, the energy augmentator **10** may be one or more of an electromagnetic resonator structure, a folded resonator structure, and a fractal structure having a region of an intensified electromagnetic field within those structures.

[0143] FIG. **2** below is a diagram depicting a folded resonator structure **22** of this invention.

[0144] The resonator in one embodiment of the present invention is a ¾λ metal structure bent, as shown in FIG. **2** having a "folded" structure making for opposing electrodes between which an intense electric field is developed. Exemplary characteristics of the "folded structure" antenna are listed in the following table:

TABLE 1

	Wavelength (nm)										
Antenna Side	1400	1300	1200	1100	1000	900	800	700	600	500	400
A	175.0	162.5	150.0	137.5	125.0	112.5	100.0	87.5	75.0	62.5	50.0
B	65.6	60.9	56.3	51.6	46.9	42.2	37.5	32.8	2⑦.1	23.4	18.8

TABLE 1-continued

	Wavelength (nm)										
Antenna Side	1400	1300	1200	1100	1000	900	800	700	600	500	400
C	196.9	182.8	168.8	154.7	140.6	126.6	112.5	98.4	84.4	70.3	56.3
D	218.8	203.1	187.5	171.9	156.3	140.6	125.0	109.4	93.8	78.1	62.5
Total	1093.8	1015.6	937.5	859.4	781.3	703.1	625.0	546.9	468.8	3⍰0.6	312.5
3/4 lambda	1050	975	900	825	750	675	600	525	450	375	300

⍰ indicates text missing or illegible when filed

[0145] The calculations of a theoretical ¾ λ and the slightly oversized antenna to account for all the bending corners involved in making the antenna would result in this structure having a size between the theoretical 0.75*λ and the upper oversized limit 0.78*λ.

[0146] While the resonators shown in most of the drawings could be characterized as having a rectangular-shape loop connecting the opposing antenna sections or electrodes together, the invention is not so limited. Other "loop" shapes could be used, so long as the opposing electrodes are parallel and coplanar with one another, with the loop forming an electrical path having a length of ½ λ, with the opposing electrodes having a length of ⅛ λ each, thereby making the ¾ λ resonator.

[0147] FIG. **3** is a diagram depicting the basic concepts underlying one of the energy augmentation structures of this invention. In the depiction in FIG. **3** is a sinusoidal wave representing for example an instantaneous waveform of a light wave (an incident energy flux **12**). The depiction shows the length of ¾ of the wavelength ƛ, and how in one embodiment a ¾ ƛ resonator is constructed with the open ends of the resonator "folded" together to form in this embodiment a ¾ ƛ folded resonator **22**. As shown in FIG. **3**, the folded ends form a region of an intensified, amplified electric field denoted by the horizontally directed arrows between the opposing open ends. When light nominally of a wavelength ƛ (or harmonics thereof 2 ƛ, 3 ƛ, 4 ƛ, etc.) is incident on the folded antenna structure, a fraction-a of the light will be coupled into this structure establishing the amplified electric field. Since the light from sun comes continuously and at different rotational polarizations, subsequent light waves will continue to "pump" the electric fields in the resonant structure until some "loss" mechanism caps the strength of the electric fields. For resonators made of low loss materials, high Q-factors are obtained which, in this case, could mean that the electric field strength between the opposing electrodes may be for example 100 to 1000 times the peak amplitude of the electric field vector of the incident waveform.

[0148] In another embodiment, a resonating antenna could have the configuration below shown in FIG. **4**. Here, the ¾ ƛ structures oppose and are interdigitated together without a "folded" structure. In the depiction in FIG. **4**, the horizontal stubs are ¼ ƛ long, the vertical extending connectors are ¼ long, and the vertical spacing between the horizontal stubs and the extend of interdigitation varies as shown between configuration 1 and configuration 2. In one embodiment of the invention, an energy converter, a light or electron emitting material, or a color emitting or color converter material (i.e., emissive material **24**) is placed inside or around the region of an intensified electric field, as shown in FIG. **4**.

[0149] FIG. **5** shows that different ¾ ƛ folded resonators can be made having different distances between the opposing electrodes and thus different electric field strengths. In this way, the folded resonators of the invention can be adjusted such that the strength of the electric field between the opposing electrodes does not exceed the dielectric strength of any material in between. Exceeding the dielectric strength of any material in between could result in destruction of that material as intense current (e.g., a micro-arc) would flow during any time that the dielectric strength was exceeded, thus breaking the material down. As shown, here the opposing sides need not have an exact length of ⅛ λ.

[0150] In one embodiment of the invention, an energy converter, a light or electron emitting material, or a color emitting or color converter material (i.e., an emissive material) **24** is placed inside or around the regions of intensified electric field near/between the opposing electrodes. In one embodiment of the invention, the color emitting or color converter material may itself be absorbing a color light such as for example blue light and emitting lower energy, down-shifted red light. In this case, a red phosphor could be the color emitting or color converter material.

[0151] While the ¾ ƛ folded resonator in one embodiment could be designed to resonate at blue light (ƛ=420 to 440 nm), the resonator is preferably designed to resonate from light at a different frequency than the blue light that is being absorbed by the red phosphor. In one embodiment, for color enhancement for objects under solar light, the ¾ ƛ folded resonator could be designed to be driven by infrared light from the solar spectrum (e.g. ƛ=700 to 1000 nm) to generate the intensified electric field, and the red phosphor disposed in the region of intensified electric field would have a brighter red emission than if the intensified electric field were not present.

[0152] FIG. **6** is diagram showing a pattern of ¾ ƛ folded resonators **22** distributed in space. As to be discussed in more detail later, there are numerous ways to distribute the ¾ ƛ folded resonators. The present invention is not limited to the regular, uniformly spaced and sized resonators shown in FIG. **6**. There is no requirement that the distribution be regular, uniformly spaced, uniformly sized, or uniformly oriented. Differently sized, spaced, and oriented resonators may provide better utilization of the full spectrum of the sun or any other light source incident on the object.

[0153] FIG. **7** is diagram showing a pattern of ¾ ƛ folded resonators **22** distributed in a plane or otherwise along a surface of an object. In one embodiment, this pattern could be formed by lithographic or stamping processes onto a planar surface such as a glass plate or onto a curved sheet type product. In one embodiment, the glass plate could itself be a phosphorescent plate or could have sections of different phosphorescent material deposited in a pattern that would

align/match the respective positions of the opposing electrodes on each resonator. In one embodiment, the sheet product could be a laminate type of product applied to for example a nominally white object. Upon solar irradiation, the infrared part of the solar spectrum (normally only heating the surface) would generate the intensified electric field regions. In those regions, down converting phosphors converting deep blue and ultraviolet light to visible light would convert the deep blue and ultraviolet light of the solar spectrum to visible light, and the intensified electric field would enhance greater visible light emission.

[0154] In one embodiment, the energy augmentators could be disposed on a perforated sheet, as shown in FIG. **7**B. The perforations in one embodiment are in the regions of intensified electric field such that phosphors or other energy converting materials or devices could be disposed in the perforations.

[0155] In one embodiment (for color enhancement), the sheet product could be a laminate type of product applied to for example a nominally green object. Upon solar irradiation, the infrared part of the solar spectrum (normally only heating the surface) would generate the intensified electric field regions. In those regions, down converting phosphors converting blue, deep blue and ultraviolet light to green light would convert the blue, deep blue, and ultraviolet light of the solar spectrum to green light and the intensified electric field would enhance greater green light emission.

[0156] In one embodiment, the sheet product could be a laminate type of product applied to for example a nominally red object. Upon solar irradiation, the infrared part of the solar spectrum (normally only heating the surface) would generate the intensified electric field regions. In those regions, down converting phosphors converting green, blue, deep blue and ultraviolet light to red light would convert the green, blue, deep blue and ultraviolet light of the solar spectrum to red light and the intensified electric field would enhance greater red light emission.

[0157] In one embodiment, the energy augmentators could be disposed on a sheet and then separated into distinct pieces, as shown in FIG. **7**C, which could be readily added and mixed into a medium to be processed.

[0158] FIG. **8** is a diagram showing a pattern of ¾ λ folded resonators **22** distributed in a plane or otherwise along a surface of an object and having a different orientation than in FIG. **7**. By having different orientations, the rotating polarized sun light waves which may at one instance not have an electric field alignment conducive to driving the ¾ λ folded resonators, would have their electric field alignment conducive to driving resonators of a different orientation and therefore better aligned. Accordingly, if the sheet type products were used, layers of differently oriented ¾ λ folded resonators could be stacked together.

[0159] FIG. **9** is a diagram showing a pattern of ¾ λ folded resonators **22** having an energy converter, a light or electron emitting material, or a color emitting or color converter material (i.e., emissive material **24**) deposited in the region of between the opposing electrodes. Here, while shown in a plan view, the color converting or enhancing material deposited in the region of between the opposing electrodes may be deposited such that the color converting or enhancing material has an upper surface raised above the metal traces of the ¾ λ folded resonators. In this embodiment, the raised sections would intercept fringing fields of the intensified electric field between the opposing electrodes.

[0160] FIG. **10** is a diagram showing a pattern of ¾ λ folded resonators **22** having an energy converter, a light or electron emitting material, or a color emitting or color converter material (i.e., emissive material **24**) deposited in the region of between the opposing electrodes. Here, as before, the color converting or enhancing material deposited in the region of between the opposing electrodes may be deposited such that the color converting or enhancing material has an upper surface raised above the metal traces of the ¾ λ folded resonators. In this embodiment, the raised sections would intercept fringing fields of the intensified electric field between the opposing electrodes. In this embodiment, the raised sections would extend around the corners where geometrically the corners would further intensify the electric field.

[0161] FIG. **11** is a diagram showing a pattern of ¾ λ folded resonators **22** having an energy converter, a light or electron emitting material, or a color emitting or color converter material (i.e., emissive material **24**) deposited in the region of between the opposing electrodes. Here, as before, the color converting or enhancing material deposited in the region of between the opposing electrodes may be deposited such that the color converting or enhancing material has an upper surface raised above the metal traces of the ¾ λ folded resonators. In this embodiment, the raised sections would intercept fringing fields of the intensified electric field between the opposing electrodes. In this embodiment, the raised sections would extend around the corners where geometrically the corners would further intensify the electric field and would extend around the ends of the opposing electrodes.

[0162] In these embodiments shown in FIGS. **9**, **10**, and **11**, the energy converters, or light or electron emitting materials, or color emitting or color converter materials (i.e., emissive materials **24**) are disposed in a vicinity of one or more energy augmentation structures (i.e., the ¾λ folded resonators). As such, the energy augmentation structures preferably are in a region of intensified electric field. The intensified electric field may represent a region of intensified energy especially if there is electrical current flow conductively coupling the energy converter to the one energy augmentation structures. In later embodiments, conductively coupling the energy converter to the one energy augmentation structures has advantages. Accordingly, the energy converters or color converting or enhancing materials disposed in a vicinity of one or more energy augmentation structures may have a physical conductive connection between the energy converter and the at least one energy augmentation structure. Alternatively, the coupling may be more that of radiatively or capacitively coupling the electric fields from the resonant structure into energy converters or color converting or enhancing materials disposed inside the energy augmentation structure, outside the energy augmentation structure, in a layer with the energy augmentation structure, or in a layer above or below the energy augmentation structure.

[0163] As used herein, in a vicinity of refers to the disposition of one thing inside the structure of another thing, outside and nearby or adjacent the structure of the other thing, and can include the disposition of one thing above or below the other thing in any three dimensional direction.

Accordingly, in one embodiment of the present invention, the color converting or enhancing materials are disposed in a vicinity of the energy augmentation structures.

[0164] FIG. **12** is a diagram showing a pattern of ¾ λ folded resonators **30** having for its metal traces a fractal pattern for the electrical path that loops around to connect the opposing electrodes. A fractal pattern for the electrical path with this pattern means that the metal trace can support various wavelengths resonating with the ¾ λ characteristics because of the multiplicity of possible loop paths available because the widths of each segment of the conductive path vary in width permitting electrical paths of different physical lengths to exist around the loop.

[0165] FIG. **13** is a diagram showing another fractal antenna segment **32** where the straight-line sides of the metal pads have regions **24** of locally intensified electric field. Here, in one embodiment, the fractal antenna segment is designed for resonance in the infrared range, with the intensifies electric field regions **34** (for example as shown toward the straight-line sides of the metal pads being the place where blue phosphors and red phosphors (or other emissive materials **24**) would be deposited such that their emission, would be enhanced the intensified electric fields in those regions **34**.

[0166] FIG. **14** is a diagram showing a repeated pattern (array) of the fractal antenna segments **32** of FIG. **13**.

[0167] FIG. **15** is a diagram showing a pattern (array) of bowtie fractal antenna segments, providing an alternative embodiment to the fractal antenna segments of FIG. **14**.

[0168] In one embodiment of the invention, the resonant structures can comprise three-dimensional fractal patterns. Known in the art is the fabrication of three-dimensional fractal structures by nanoscale anisotropic etching of silicon such as described in Nanoscale etching of 3d fractal structures with many applications including 3d fractal antennas and structures for filters, by Brian Wang, Jun. 22, 2013, in the Journal of Micromechanics and Microengineering, (available at www.nextbigfuture.com/2013/06/nanoscale-etching-of-3d-fractal.html) the entire contents of which are incorporated herein by reference. In one embodiment of the invention, metal is deposited over a silicon three-dimensional fractal structure to form a multi-dimensional light collector.

[0169] FIG. **16** is a diagram showing a paired three-dimensional fractal structure with regions **34** of an intensified electric field in between the pairs. The paired three-dimensional fractal structure is a color enhancement structure according to one embodiment of the invention. In one embodiment of the invention, these pyramidal type structures would be metallized with opposing faces metalized, a first loop conductor formed around the other sides of the first pyramid, then connecting across a region between the pair, and then a second loop formed around the sides of the second pyramid to the metallized opposing face of the second pyramid, to mimic (as seem from above) the ¾ λ folded resonators shown in FIG. **3**.

[0170] In one embodiment, converter (emissive) materials **24** would be disposed nearby different sections of the pyramidal type structures and preferably between the opposing faces of the pair where the intensified electric field (depicted by the arrows) exists. With the three-dimensional aspect of this invention, red, yellow, green, and blue converters (or other designated emitters) could be disposed at different levels within this region of intensified electric field.

[0171] FIG. **17** is a diagram showing a pattern (array) of the paired three-dimensional fractal structures of FIG. **16**.

[0172] In these embodiments shown in FIGS. **12** to **17**, the energy converters, or light or electron emitting materials, or color emitting or color converter materials (i.e., emissive materials **24**) are disposed in a vicinity of one or more energy augmentation structures (i.e., the ¾ λ folded resonators). As such, the energy augmentation structures preferably are in a region of intensified electric field. The intensified electric field may represent a region of intensified energy especially if there is electrical current flow conductively coupling the energy converter to the one energy augmentation structures. In later embodiments, conductively coupling the energy converter to the one energy augmentation structures has advantages. Accordingly, the energy converters, or light or electron emitting materials, or color emitting or color converter materials disposed in a vicinity of one or more energy augmentation structures may have a physical conductive connection between the energy converter and the at least one energy augmentation structure. Alternatively, the coupling may be more that of radiatively coupling the electric fields from the resonant structure into energy converters or color converting or enhancing materials disposed inside the energy augmentation structure, outside the energy augmentation structure, in a layer with the energy augmentation structure, or in a layer above or below the energy augmentation structure.

[0173] The energy augmentation structures are not limited to those shown above. Other variants are possible. Moreover, in one embodiment of the invention, the ¾ λ folded resonators need not to have the "folded sections" which fold inwards as shown in FIG. **3**. Instead, as shown in FIG. **18**, the ¾ λ resonators of the invention can have folded sections which fold outward with the regions of intensified electric field being outside of the "loop" of the resonator. The distal ends of the antenna protrude outwardly while maintaining parallelism. Specifically, FIG. **8** is a schematic of a ¾ λ external-electrode folded resonator **22**. This external, opposed electrode pair design follows the general apportioning, scaling aspects, converter material placement, etc., shown in FIGS. **5** through **11** but with the internal folded sections being replaced by the external-electrode pair.

[0174] In one embodiment of the invention, the ¾ λ external-electrode folded resonator **22** provides the capability to be packed in a concentric-type arrangement with progressively increasing or decreasing size resonators. These resonators are maintained in plane with no overlapping distal ends. FIG. **19** is a schematic of a plurality of concentric-type ¾ λ external-electrode folded resonators **22**. Since each of the ¾ λ external-electrode folded resonators **22** has a different electrical length, the plurality of concentric-type ¾ λ external-electrode resonators will be "tuned" to the different wavelengths associated with the respective electrical lengths. Three different frequencies are therefore focused between the distal ends of the antennas.

[0175] In another embodiment, FIG. **20** is a schematic of a plurality of concentric-type ¾ λ external-electrode folded resonators **22** with overlapping electrodes. In one embodiment, the overlapping provides a more concentrated/enhanced field region than in the non-overlapping arrangement of FIG. **19**.

[0176] The present invention is not limited to planar concentric type packing arrangements as shown in FIG. **19** or **20**. The three different ¾ wavelength resonators in FIG.

20 are maintained in plane with overlapping distal ends. These antennas are inductively coupled. In one embodiment, the present invention utilizes an off plane configuration with axial symmetry where the antennas are in an axially rotated, multiple frequency, interleaved ¾ wave resonator structure. FIG. **21** is a schematic of an axially rotated, multiple frequency, interleaved ¾ wave resonators **22** showing (in this example) three differently sized resonators for multiple frequency resonance disposed about/along a common axis but axially rotated. In one embodiment, in this configuration, the resultant electric field is concentrated without one electrode section perturbing the electric fields from another.

[0177] In a further embodiment, there is provided an energy collector comprising at least one energy augmentation structure; and at least one energy converter capable of receiving an applied electromagnetic energy, converting the applied electromagnetic energy and emitting therefrom an emitted electromagnetic energy shifted in wavelength or energy from the applied electromagnetic energy and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted electromagnetic energy is emitted with at least one augmented property compared to if the energy converter were remote from the at least one energy augmentation structure.

[0178] In one embodiment, the present invention can use different levels for disposing ¾ λ resonators thereon regardless of the resonators being ¾ λ internally-folded resonators or ¾ λ external-electrode resonators. This packing is shown in FIGS. **22** and **23** for configuration in parallel planes with distal ends folded in or protruding out respectively.

[0179] In the embodiment of the invention depicted in FIG. **20** having a plurality of concentric-type ¾ λ external-electrode resonators **22**, the antennas are inductively decoupled. This configuration allows the electric field to be focused from three different frequencies in a longer path. This configuration can be used to create a mirror image configuration to extend the length of focused electric field as is illustrated in FIG. **24**A.

[0180] The resonator configuration in this case is mirror imaged with another set of antennas (folded resonators **22**) to create a longer path (doubled) of focused electric field. Furthermore, the resonator antenna configuration can be placed in more creative ways to enhance the electric field focusing around a target as is illustrated in the FIG. **24**B.

[0181] The configuration in FIG. **25** allows the surrounding of a target within the plane of the resonator structure/antenna for the purpose of heating and focusing energy around the target. This prevents heat dissipation in silicon where the thermal conductivity is high. The silicon substrate in such an instance can be single crystalline, polycrystalline or amorphous.

[0182] In one embodiment of the present invention, an "energy augmentation structure" represents a structure whereby a spatial region of the energy collector contains a converter material (or other light or electron emitting material) exposed to energy which stimulates emission of light at a different energy (wavelength) from that to which it is exposed while being in a spatial area/volume (e.g., between or around or in a vicinity of the folded structures or the external-electrode pairs) where there is an artificially induced higher electrical field and/or a higher energy density. These artificial regions can be produced for example by use of structures including, but not limited to, multiple level collection optics, resonators, fractal antennas, and electrical grid (or electrode) patterns.

[0183] By having the light or electron emitting materials disposed in a vicinity of the energy augmentation structures of this invention, regardless of the whether the energy augmentation structure is in a region of intensified electric field or otherwise outside the region of intensified electric field, the energy augmentation structures of the invention are able to produce light which can be used for a variety of applications, in particular for photostimulation of biological, chemical, and physical reactions such as for example photoactivation of photoreactive drugs, photoactivation of photosensitive materials such as adhesives or lithographic photoresists, or for direct interaction with biological and chemical agents in the environment of the augmentation structures, as in sterilization.

[0184] In one embodiment, the light or electron emitting materials noted above are disposed with an energy augmentation structure comprising one or more of an electromagnetic resonator structure, a folded resonator structure, and a fractal resonating structure, any of which having a region of an intensified electromagnetic field within the resonating structures.

[0185] In one embodiment, the energy converter or light or electron emitting materials noted above includes one or more luminescing materials. As described herein, there are uses of the energy augmentation structure and/or energy collector embodiments which enhance bioluminescence, chemo-luminescence, photoluminescence, fluorescence, mechano-luminescence, and/or electron emission.

[0186] In one embodiment, the energy converter or light emitting materials noted above includes for the one or more luminescent materials phosphorescent materials, fluorescent materials, electroluminescent materials, chemo-luminescent materials, bioluminescent materials, and mechano-luminescent materials used in conjunction with or not in conjunction with the energy augmentation structure noted above. When used in conjunction with the energy augmentation structure noted above, the emitted electromagnetic energy from the luminescent material is emitted with at least one augmented property compared to if the energy converter (e.g., the luminescent material) were remote from the at least one energy augmentation structure.

[0187] In one embodiment, the bioluminescent materials are UV-emitting bioluminescent materials such as catalyzed luciferase and luminescent proteins.

[0188] In one embodiment, the energy converter or light emitting materials noted above includes for the one or more luminescing materials phosphorescent materials, fluorescent materials, electroluminescent materials, chemo-luminescent materials, bioluminescent materials, and mechano-luminescent materials used in conjunction with or not in conjunction with the energy augmentation structure noted above and which emit one of ultra-violet, visible, near infrared, and infrared light. In this embodiment, UV-emitting electroluminescent materials or mechano-luminescent devices and materials can be used. In this embodiment, UV-emitting bioluminescent materials can be used.

[0189] In some embodiments, metallic patterns form a folded resonator having opposing electrodes with electric fields directed in between, and a converter is positioned between the opposing electrodes or within fringing electric field of the opposing electrodes or otherwise in a vicinity of

the opposing electrodes. In one example, the folded resonator is a ¾ ƛ folded resonator. In one example, metallic patterns comprise at least one of Au, Ag, Cu, Al, or transparent metal oxides. In another example, the metallic patterns can be formed with refractory metals such for example Ti, W, and Mo.

[0190] In some embodiments, the metallic patterns referenced above comprise an external external-electrode pair structure having opposing electrodes with electric fields directed in between, and a converter is positioned between the opposing electrodes or within fringing electric field of the opposing electrodes or otherwise in a vicinity of the opposing electrodes. In one example, the resonator is a ¾ ƛ external-electrode pair resonator. In one example, metallic patterns comprise at least one of Au, Ag, Cu, Al, or transparent metal oxides. In another example, the metallic patterns can be formed with refractory metals such for example Ti, W, and Mo.

[0191] In some embodiments, plural resonators and plural converters are disposed at multiple positions throughout a light collector. In one example, the plural converters are positioned to convert light being internally scattered within the light collector.

[0192] In some embodiments of the energy augmentation structures, a first level of metallic patterns (or a second level of metallic patterns) comprises a metal core cladded with a high-K dielectric and a subsequent cladding of a low-K dielectric. In some embodiments of the energy augmentation structures, the first level of metallic patterns noted above (or the second level of metallic patterns) comprises a radial pattern of conductors. In some embodiments of the energy augmentation structures, the first level of metallic patterns noted above (or the second level of metallic patterns) comprises a fractal pattern. In one example, the fractal pattern is embedded within a dielectric material.

[0193] In some embodiments of the energy augmentation structures, the first level of metallic patterns noted above (or the second level of metallic patterns) comprises a three-dimensional fractal structure.

[0194] In some embodiments of the energy augmentation structures, there is provided a panel with the first level of metallic patterns and the second level of metallic patterns and optionally multiple converters formed therein or thereon. In some embodiments of the augmentation structures, there is provided a sheet with the first level of metallic patterns and the second level of metallic patterns and optionally multiple converters formed therein or thereon.

[0195] In some embodiments of the energy augmentation structures, the first level of metallic patterns noted above (or the second level of metallic patterns) is of different sizes and/or orientations to each other of the first level of metallic patterns or with respect to the second level of metallic patterns.

[0196] In another embodiment, the energy augmentator can collect or distribute light.

[0197] FIG. **25**A is a schematic illustrating a distributed point light collector/transmitter of the invention showing a distribution of branches that can either collect light from distributed points **710** or conversely can distribute light from a central source **766** to the distributed points **710**. The section of the collector/transmitter is shown in FIG. **25**B showing a core metal, an optional light converter material, a high K dielectric, and a low K dielectric. In this arrangement, as shown, light is confined and not loss to scatter out of the collector/transmitter, except at the ends.

[0198] B. Energy Converters

[0199] In various embodiments of the invention, energy converters can be used with or without the energy augmentators described above. In some embodiments, the converters are for up conversion of light e.g., from the IR regime into visible electromagnetic radiation and for down conversion of light e.g., from the UV range into visible electromagnetic radiation. The invention in various embodiments up converts energy, preferably light in the visible spectrum. The invention encompasses a variety of applications where the up and down conversion materials with or without the energy augmentators are included to enhance electromagnetic energy emission, preferably light or photon emission. When an energy augmentator is present, it may be separate from or connected to the energy converter. In certain embodiments, the energy converter can have the energy augmentator formed on its surface through chemical vapor deposition ("CVD") or physical vapor deposition ("PVD") processes or other nanoscale "printing" methods. Such embodiments may be particularly useful in methods for treating human or animal patients, in which having such energy augmentators "imprinted" on a surface of the energy converter can guarantee proximity between the energy augmentator and the energy converter to maximize the interaction with the energy being applied. Alternatively, the energy augmentator can be formed on a surface of an inert non-energy converting particle, formed, for example, from silica or formed from a non-energy converting particle coated with an biologically and/or chemically inert coating (such as, for example, diamond, diamond-like carbon, or similar inert materials). Such an energy augmentator can then be co-administered with the energy converter to the human or animal patient.

[0200] Suitable energy modulation agents or energy converters (the two terms are used interchangeably herein) of the invention include, but are not limited to, a biocompatible fluorescing metal nanoparticle, fluorescing dye molecule, gold nanoparticle, a water soluble quantum dot encapsulated by polyamidoamine dendrimers, a luciferase (bioluminescence), a biocompatible phosphorescent molecule, a combined electromagnetic energy harvester molecule, and a lanthanide chelate capable of intense luminescence.

[0201] Alternatively, the energy modulation agent or energy converter can emit energy in a form suitable for absorption at a target site or receptor. For example, the initiation energy source may be acoustic energy and one energy converter may be capable of receiving acoustic energy and emitting photonic energy (e.g. sonoluminescent molecules) to be received by another energy converter that is capable of receiving photonic energy. Other examples include energy converters that receive energy at x-ray wavelength and emit energy at UV wavelength, preferably at UV-A wavelength. A plurality of such energy converters may be used to form a cascade to transfer energy from initiation energy source via a series of energy converters.

[0202] Resonance Energy Transfer (RET) is an energy transfer mechanism between two molecules having overlapping emission and absorption bands. Electromagnetic emitters are capable of converting an arriving wavelength to a longer wavelength. For example, UV-B energy absorbed by a first molecule may be transferred by a dipole-dipole interaction to a UV-A-emitting molecule in close proximity

to the UV-B-absorbing molecule. Alternatively, a material absorbing a shorter wavelength may be chosen to provide RET to a non-emitting molecule that has an overlapping absorption band with the transferring molecule's emission band. Alternatively, phosphorescence, chemiluminescence, or bioluminescence may be used to transfer energy to a target site or a receptor such as a photoactivatable agent.

[0203] In a further embodiment, a biocompatible emitting source, such as a fluorescing metal nanoparticle or fluorescing dye molecule, is selected as an energy converter that emits in the UV-A band. In another embodiment, an energy converter comprising a UV-A emitting source can be a gold nanoparticle comprising for example a cluster of 5 gold atoms.

[0204] In another embodiment, an energy converter comprising a UV- or light-emitting luciferase is selected as the emitting source. A luciferase may be combined with ATP or another molecule, which may then be oxygenated with additional molecules to stimulate light emission at a desired wavelength. Alternatively, a phosphorescent emitting source may be used as the energy converter. One advantage of a phosphorescent emitting source is that the phosphorescent emitting molecules or other source may be electroactivated or photoactivated prior to insertion into the tumor either by systemic administration or direct insertion into the region of the tumor. Phosphorescent materials may have longer relaxation times than fluorescent materials, because relaxation of a triplet state is subject to forbidden energy state transitions, storing the energy in the excited triplet state with only a limited number of quantum mechanical energy transfer processes available for returning to the lower energy state. Energy emission is delayed or prolonged from a fraction of a second to several hours. Otherwise, the energy emitted during phosphorescent relaxation is not otherwise different than fluorescence, and the range of wavelengths may be selected by choosing a particular phosphor.

[0205] In one embodiment, the energy converters of the invention can include persistent after-glow phosphor materials emitting light in the visible to near ultraviolet and ultraviolet range. In one embodiment, Eu-doped strontium aluminate is used as an energy converter in which deep UV light or x-ray or electron beans "charge" the photoluminescence such that these phosphors can be charged outside for example a patient and then injected into target or diseased site where UV photons would be emitted. In another embodiment, gadolinium strontium magnesium aluminate is used as an energy converter in which deep UV light or x-ray or electron beans "charge" the photoluminescence such that these phosphors can be charged outside for example a patient and then injected into target or diseased site where UV photons would be emitted. U.S. Pat. Appl. Publ. No. 20070221883 (the entire contents of which are incorporated herein by reference) describes specifically gadolinium-activated strontium magnesium aluminate having an excitation maximum at about 172 nm, and which emits in a narrow-band UV emission at about 310 nm. The '883 publication also describes other useful energy converters for this invention, making note of emission spectra between 300 nm and 320 nm for a $Sr(Al,Mg)_{12}O_{19}$:Gd phosphor and two 312 nm line emitting phosphors, $YMgB_5O_{10}$:Gd, Ce and $YMgB_5O_{10}$:Gd, Ce, Pr. WO2016200349 (the entire contents of which are incorporated herein by reference) describes long lasting yellowish-green emitting phosphorescent pigments in the strontium aluminate (SrAl2O4) system, which could serve as energy converters in the present invention. WO 2016200348 (the entire contents of which are incorporated herein by reference) describes long lasting bluish-green emitting phosphorescent pigments in the strontium aluminate (Sr4Al14O25) system, which could serve as energy converters in the present invention. Xiong et al in "Recent advances in ultraviolet persistent phosphors," Optical Materials X 2 (2019) (the entire contents of which are incorporated herein by reference) describes a number of ultraviolet persistent phosphors that could as energy converters in the present invention. The table below provides a listing of such persistent phosphors:

$SrO:Pb^{2+}$	390	>1 h
$CaAl_2O_4:Ce^{3+}$ Tb^{3+}	400	>10 h
$CaAl_2SiO_4:Ce^{3+}$ Tb^{3+}	413	>10 h
$Sr_2Al_2SiO_7:Ce^{3+}$	400	several minutes
$SrZrO_3$	395	<1000 s
$BaZrO_3:Mg^{2+}$	400	>2400 s
$SrZrO_3:Pr^{3+}$	356	
$CdSiO_3:Bi^{3+}$	360	
$CdSiO_3:Bi^{3+}$ Dy^{3+}	360	
$CdSiO_3:Bi^{3+}$ Gd^{3+}	344	>6 h
$Sr_2MgGe_2O_7:Pb^{2+}$	370	>12 h
$NaLuGeO_4Bi^{3+}$ Eu^{3+}	400	>63 h
$CaZnGe_2O_6:Bi^{3+}$	300-700	>12 h
$Cs_2NaYF_6:Pr^{3+}$	250	>2 h

[0206] In one embodiment, the phosphor described by Xiong et al as $CaAl_2O_4:Ce^{3+}$ having an emission peak of 400 nm and a persistent time of more than 10 h could be used, where it would be charged by x-ray irradiation outside a patient and then injected at a diseased site to provide internally generated UV light.

[0207] In one embodiment, the persistent phosphors noted could be activated ex vivo and introduced along with psoralen (or other photoactivatable drug) into the patient by exchange of a bodily fluid or for example by supplying the persistent phosphors and the photoactivatable drug into a patient's blood stream.

[0208] In one embodiment, the persistent phosphors noted could be activated in vivo by injection of the phosphors into a diseased site and then exposure to x-rays.

[0209] In another embodiment, a combined electromagnetic energy harvester molecule is designed, such as the combined light harvester disclosed in J. Am. Chem. Soc. 2005, 127, 9760-9768, the entire contents of which are hereby incorporated by reference. By combining a group of fluorescent molecules in a molecular structure, a resonance energy transfer cascade may be used to harvest a wide band of electromagnetic radiation resulting in emission of a narrow band of fluorescent energy. In another embodiment, a Stokes shift of an emitting source or a series of emitting sources arranged in a cascade is selected to convert a shorter wavelength energy, such as X-rays, to a longer wavelength fluorescence emission such an optical or UV-A.

[0210] In one embodiment, a lanthanide chelate capable of intense luminescence is used as an energy converter. In another embodiment, a biocompatible, endogenous fluorophore emitter is selected as an energy converter.

[0211] In one embodiment, the energy converters of the invention can include visible and UV-light emitting bioluminescent materials. In one embodiment, bioluminescent materials such as coelenterate-type luciferin analogues could be used including amide monoanion known to emit at 480 nm and oxyluciferin known to emit at 395 nm.

[0212] Among various materials, luminescent nanoparticles have attracted increasing technological and industrial interest. In the context of the invention, nanoparticle refers to a particle having a size less than one micron. While the description of the invention describes specific examples using nanoparticles, the invention in many embodiments is not limited to particles having a size less than one micron. However, in many of the embodiments, the size range of less than one micron, and especially less than 100 nm produces properties of special interest such as for example emission lifetime luminescence quenching, luminescent quantum efficiency, and concentration quenching and such as for example diffusion, penetration, and dispersion into mediums where larger size particles would not migrate.

[0213] This invention in various embodiments can use a wide variety of down conversion materials (or mixtures of down conversion materials) with or without the energy augmentators to enhance light or photon emission. These down conversion materials can include quantum dots, semiconductor materials, alloys of semiconductor materials, scintillation and phosphor materials, materials that exhibit X-ray excited luminescence (XEOL), organic solids, metal complexes, inorganic solids, crystals, rare earth materials (lanthanides), polymers, scintillators, phosphor materials, etc., and materials that exhibit excitonic properties. Accordingly, the down conversion materials to enhance light or photon emission can convert energy from one of ultraviolet light, x-rays, and high energy particles to visible light. The down conversion materials to enhance light or photon emission can convert energy from higher energy visible light to lower energy visible light.

[0214] In one embodiment of the invention, a quantum dot mixture with or without the energy augmentators can be used for the multiple nanoparticles. Quantum dots are in general nanometer size particles whose energy states in the material of the quantum dot are dependent on the size of the quantum dot. For example, quantum dots are known to be semiconductors whose conducting characteristics are closely related to the size and shape of the individual crystal. Generally, the smaller the size of the crystal, the larger the band gap, the greater the difference in energy between the highest valence band and the lowest conduction band becomes. Therefore, more energy is needed to excite the dot, and concurrently, more energy is released when the crystal returns to its resting state. In fluorescent dye applications, this equates to higher frequencies of light emitted after excitation of the dot as the crystal size grows smaller, resulting in a color shift from red to blue in the light emitted. Quantum dots represent one way to down convert ultraviolet light of the spectrum to a targeted wavelength or energy emission. Quantum dots represent one way to down convert blue light of the spectrum to a targeted wavelength or energy emission.

[0215] As described in U.S. Pat. No. 6,744,960 (the entire contents of which are incorporated by reference), different size quantum dots produce different color emissions. In that work and applicable to this invention, quantum dots can comprise various materials including semiconductors such as zinc selenide (ZnSe), cadmium selenide (CdSe), cadmium sulfide (CdS), indium arsenide (InAs), and indium phosphide (InP). Another material that may suitably be employed is titanium dioxide (TiO_2). The size of the particle, i.e., the quantum dot **18**, may range from about 2 to 10 nm. Since the size of these particles is so small, quantum physics governs many of the electrical and optical properties of the quantum dot. One such result of the application of quantum mechanics to the quantum dot **18** is that quantum dots absorb a broad spectrum of optical wavelengths and re-emit radiation having a wavelength that is longer than the wavelength of the absorbed light. The wavelength of the emitted light is governed by the size of the quantum dot. For example, CdSe quantum dots 5.0 nm in diameter emit radiation having a narrow spectral distribution centered about 625 nm while quantum dots **18** including CdSe 2.2 nm in size emit light having a center wavelength of about 500 nm. Semiconductor quantum dots comprising CdSe, InP, and InAs, can emit radiation having center wavelengths in the range between 400 nm to about 1.5 sm. Titanium dioxide TiO_2 also emits in this range. The linewidth of the emission, i.e., full-width half-maximum (FWHM), for these semiconductor materials may range from about 20 to 30 nm. To produce this narrowband emission, quantum dots simply need to absorb light having wavelengths shorter than the wavelength of the light emitted by the dots. For example, for 5.0 nm diameter CdSe quantum dots light having wavelengths shorter than about 625 nm is absorbed to produce emission at about 625 nm while for 2.2 nm quantum dots comprising CdSe light having wavelengths smaller than about 500 nm is absorbed and re-emitted at about 500 nm. In practice, however, the excitation or pump radiation is at least about 50 nanometers shorter than the emitted radiation.

[0216] Specifically, in one embodiment of the invention, a quantum dot mixture (QDM) coating can be deposited using CVD and or sol-gel techniques using standard precipitation techniques. The QDM coating can be made of a silicate structure that does not diminish UV output. Within the silicate family, silica (SiO_2) is suitable since it maximizes UV transmission through the coating. The coating can further include a second layer of a biocompatible glass. Such bio-compatible glass and glass ceramic compositions can contain calcium, a lanthanide or yttrium, silicon, phosphorus and oxygen. Other biocompatible materials and techniques are described in the following patents which are incorporated herein in their entirety: U.S. Pat. Nos. 5,034,353; 4,786,617; 3,981,736; 3,922,155; 4,120,730; and U.S. Pat. Appl. Nos. 2008/0057096; 2006/0275368; and 2010/0023101.

[0217] Further, the down conversion materials for the invention described here can be coated with insulator materials such as for example silica which will reduce the likelihood of any chemical interaction between the luminescent particles and the medium the particles are included therein. These and the other conversion materials described here can be used with or without energy augmentators. For biocompatible applications of inorganic nanoparticles, one of the major limiting factors is their toxicity. Generally speaking, all semiconductor nanoparticles are more or less toxic. For biocompatible applications, nanoparticles with toxicity as low as possible are desirable or else the nanoparticles have to remain separated from the medium. Pure TiO_2, ZnO, and Fe_2O_3 are biocompatible. CdTe and CdSe are toxic, while ZnS, CaS, BaS, SrS and Y_2O_3 are less toxic. In addition, the toxicity of nanoparticles can result from their inorganic stabilizers, such as TGA, or from dopants such as Eu^{2+}, Cr^{3+} or Nd^{3+}. Other suitable down conversion materials which would seem the most biocompatible are zinc sulfide, $ZnS:Mn^{2+}$, ferric oxide, titanium oxide, zinc oxide, zinc oxide containing small amounts of Al_2O_3, and AgI

nanoclusters encapsulated in zeolite. For non-medical applications, where toxicity may not be as critical a concern, the following materials (as well as those listed elsewhere) are considered suitable: lanthanum and gadolinium oxyhalides activated with thulium; Er^{3+} doped $BaTiO_3$ nanoparticles, Yb^{3+} doped $CsMnCl_3$ and $RbMnCl_3$, $BaFBr:Eu^{2+}$ nanoparticles, Cesium Iodine, Bismuth Germanate, Cadmium Tungstate, and CsBr doped with divalent Eu.

[0218] In various embodiments of the invention, the following luminescent polymers with or without energy augmentators are also suitable as conversion materials: poly (phenylene ethynylene), poly(phenylene vinylene), poly(p-phenylene), poly(thiophene), poly(pyridyl vinylene), poly (pyrrole), poly(acetylene), poly(vinyl carbazole), poly (fluorenes), and the like, as well as copolymers and/or derivatives thereof.

[0219] In various embodiments of the invention, the following materials with or without energy augmentators can be used similar to that detailed in U.S. Pat. No. 7,090,355, the entire contents of which are incorporated herein by reference. For down-conversion, the following materials can be used. Inorganic or ceramic phosphors or nano-particles, including but not limited to metal oxides, metal halides, metal chalcogenides (e.g. metal sulfides), or their hybrids, such as metal oxo-halides, metal oxo-chalcogenides. Laser dyes and small organic molecules, and fluorescent organic polymers. Semiconductor nano-particles, such as II-VI or III-V compound semiconductors, e.g. fluorescent quantum dots. Organometallic molecules including at least a metal center such as rare earth elements (e.g. Eu, Tb, Ce, Er, Tm, Pr, Ho) and transitional metal elements such as Cr, Mn, Zn, Ir, Ru, V, and main group elements such as B, Al, Ga, etc. The metal elements are chemically bonded to organic groups to prevent the quenching of the fluorescence from the hosts or solvents. Phosphors can be used including the Garnet series of phosphors: $(Y_mA_{1-m})_3(Al_nB_{1-n})_5O_{12}$, doped with Ce; where $0 \leq m$, $n \leq 1$, where A includes other rare earth elements, B includes B, Ga. In addition, phosphors containing metal silicates, metal borates, metal phosphates, and metal aluminates hosts can be used. In addition, nanoparticulates phosphors containing common rare earth elements (e.g. Eu, Tb, Ce, Dy, Er, Pr, and Tm) and transitional or main group elements (e.g. Mn, Cr, Ti, Ag, Cu, Zn, Bi, Pb, Sn, and Tl) as the fluorescent activators, can be used. Materials such as Ca, Zn, Cd in tungstates, metal vanadates, ZnO, etc. can be used.

[0220] The commercial laser dye materials obtained from several laser dye vendors, including Lambda Physik, and Exciton, etc. can also be used with or without energy augmentators. A partial list of the preferred laser dye classes includes: Pyrromethene, Coumarin, Rhodamine, Fluorescein, other aromatic hydrocarbons and their derivatives, etc. In addition, there are many polymers containing unsaturated carbon-carbon bonds, which also serve as fluorescent materials and find many optical and fluorescent applications. For example, MEH-PPV, PPV, etc. have been used in opto-electronic devices, such as polymer light emitting diodes (PLED). Such fluorescent polymers can be used directly as the fluorescent layer of the transparent 2-D display screen with and without energy augmentators.

[0221] As noted above, semiconductor nanoparticles (e.g., quantum dots) can be used with or without energy augmentators. The terms "semiconductor nanoparticles," in the art refers to an inorganic crystallite between 1 nm and 1000 nm in diameter, preferably between 2 nm to 50 nm. A semiconductor nano-particle is capable of emitting electromagnetic radiation upon excitation (i.e., the semiconductor nanoparticle is luminescent). The nanoparticle can be either a homogeneous nano-crystal, or comprises of multiple shells. For example, the nanoparticle can include a "core" of one or more first semiconductor materials, and may be surrounded by a "shell" of a second semiconductor material. The core and/or the shell can be a semiconductor material including, but not limited to, those of the group II-VI (ZnS, ZnSe, ZnTe, CdS, CdSe, CdTe, HgS, HgSe, HgTe, MgS, MgSe, MgTe, CaS, CaSe, CaTe, SrS, SrSe, SrTe, BaS, BaSe, BaTe, and the like) and III-V (GaN, GaP, GaAs, GaSb, InN, InP, InAs, InSb, and the like) and IV (Ge, Si, and the like) materials, and an alloy or a mixture thereof.

[0222] Fluorescent organometallic molecules containing rare earth or transitional element cations can be used for down conversion materials with or without energy augmentators. Such molecules include a metal center of rare earth elements including Eu, Tb, Er, Tm, Ce protected with organic chelating groups. The metal center may also include transitional elements such as Zn, Mn, Cr, Ir, etc. and main group elements such as B, Al, Ga. Such organometallic molecules can readily dissolve in liquid or transparent solid host media. Some examples of such fluorescent organometallic molecules include: 1. Tris(dibenzoylmethane)mono (phenanthroline)europium(III); 2. Tris(8-hydroxyquinoline) erbium; 3. Tris(1-phenyl-3-methyl-4-(2,2-dimethylpropan-1-oyl)pyrazolin-5-one)terbium(III); 4. Bis(2-methyl-8-hydroxyquinolato)zinc; 5. Diphenylborane-8-hydroxyquinolate.

[0223] Specific examples of down-conversion materials for red emission include those discussed above and europium complexes such as those described in JP Laid-open Patent Publication (Kokai) No. 2003-26969, constructed such that β-diketone ligand is coordinated to europium forming an europium complex capable of emitting red fluorescence. Other specific examples of the rare earth element complexes include complexes include lanthanum (Ln), europium (Eu), terbium (Tb), and gadolinium (Gd) and combinations thereof. An europium (Eu) complex is capable of emitting red fluorescence when irradiated with ultraviolet rays having a wavelength ranging from 365 nm to 410 nm. Terbium (Tb) is capable of emitting green fluorescence when irradiated with ultraviolet rays having a wavelength of 365 nm.

[0224] In other down-conversion embodiments, the down conversion materials which emit red light may include europium, light emitting particles which emit green light may include Terbium, and light emitting particles which emit blue or yellow light may include cerium (and/or thulium). In up-conversion embodiments, up conversion materials which emit red light may include praseodymium, light emitting particles which emit green light may include erbium, and light emitting particles which emit blue light may include thulium. In embodiments, the conversion materials can be light emitting particles made of fluorescent molecules that emit different colors (e.g. red, green, and blue), or different wavelengths or energies of light. In embodiments, the conversion materials can be light emitting particles made of pure organic or organo-metallic dyes with or without energy augmentators.

[0225] In addition to the combinations of rare earth complexes, such as a combination of a europium complex and a

terbium complex, it is also possible employ a combination of a europium complex and a green-emitting fluorescent substance which is not a complex, or a combination of a terbium complex and a red-emitting fluorescent substance which is not a complex.

[0226] Other down converter materials (which can be used with or without energy augmentators) include for example ZnS, PbS, SbS_3, MoS_2, PbTe, PbSe, BeO, MgO. Li_2CO_3, $Ca(OH)_2$, MoO_3, SiO_2, Al_2O_3, TeO_2, SnO_2, KBr, KCl, and NaCl. These materials can include dopants to tailor the emission properties, as noted above. Examples of doped (or alloyed) glass systems suitable for the include Y_2O_3:Gd, Y_2O_3:Dy, Y_2O_3:Tb, Y_2O_3:Ho, Y_2O_3:Er, Y_2O_3:Tm, Gd_2O_3:Eu, Y_2O_2S:Pr, Y_2O_2S:Sm, Y_2O_2S:Eu, Y_2O_2S:Tb, Y_2O_2S:Ho, Y_2O_2S:Er, Y_2O_2S:Dy, Y_2O_2S:Tm, ZnS:Ag:Cl (blue), ZnS:Cu:Al (green), Y_2O_2S:Eu (red), Y_2O_3:Eu (red), YVO_4:Eu (red), and Zn_2SiO_4:Mn (green).

[0227] With regard more specifically to down converter materials suitable for the invention, U.S. Pat. No. 4,705,952 (the contents of which are hereby incorporated herein by reference) describes an infrared-triggered phosphor that stores energy in the form of visible light of a first wavelength and released energy in the form of visible light of a second wavelength when triggered by infrared light. The phosphors in U.S. Pat. No. 4,705,952 were compositions of alkaline earth metal sulfides, rare earth dopants, and fusible salts. The phosphors in U.S. Pat. No. 4,705,952 were more specifically phosphors made from strontium sulfide, barium sulfide and mixtures thereof; including a dopant from the rare earth series and europium oxide, and mixtures thereof; and including a fusible salt of fluorides, chlorides, bromides, and iodides of lithium, sodium, potassium, cesium, magnesium, calcium, strontium, and barium, and mixtures thereof. The materials described in U.S. Pat. No. 4,705,952 are useful in various embodiments of the invention with or without energy augmentators. In one example, the infrared-triggered phosphors would be used in conjunction with the folded resonators, and the receipt of a microwave or IR signal would locally heat and trigger emission. (This application would be particularly well suited for color enhancement and/or security applications.)

[0228] In other embodiments of the invention, the down converter materials (or mixtures of down converters materials (which can be used with or without energy augmentators) can include Y_2O_3:Li. Sun et al "Luminescent properties of Li+ doped nanosized Y_2O_3:Eu," Solid State Comm. 119 (2001) 393-396 (the entire contents of which are incorporated herein by reference) describe such materials. Hou et al "Luminescent properties nano-sized Y_2O_3:Eu fabricated by co-precipitation method," Journal of Alloys and Compounds, vol. 494, issue 1-2, 2 Apr. 2010, pages 382-385 (the entire contents of which are incorporated herein by reference) describe that nano-sized yttria (Y_2O_3) powders have been successfully synthesized by a co-precipitation method. The powders were well crystallized, and the grains were almost spherical with good dispersibility. The quenching concentration of Eu^{3+} ions is 9 mol % which is much higher than micro-scaled powders. The incorporation of Li+ ions greatly improved the luminescence intensity. The highest emission intensity was observed with 4 mol % Li+ doped Y_2O_3:Eu powder ($(Y_{0.87}Eu_{0.09}Li_{0.04})_2O_3$) and the fluorescence intensity was increased by as much as 79%. Yi et al "Improved cathodoluminescent characteristics of Y_2O_3:Eu^{3+} thin films by Li-doping," Appl. Phys. A 87, 667-671 (2007) (the entire contents of which are incorporated herein by reference) describe cathodoluminescent spectra for both Y_2O_3:Eu^{3+} and Li-doped Y_2O_3:Eu^{3+} films and methods for making these materials.

[0229] Specific downconverting materials may also include at least one or more of Y_2O_3, Y_2O_3:Gd, Y_2O_2S, $NaYF_4$, $NaYbF_4$, YAG, YAP, Nd_2O_3, LaF_3, $LaCl_3$, La_2O_3, TiO_2, $LuPO_4$, YVO_4, YbF_3, YF_3, Na-doped YbF_3, ZnS, ZnSe, MgS, CaS, Zn_2SiO_4:Mn, LaOBr:Tm and alkali lead silicate including compositions of SiO_2, B_2O_3, Na_2O, K_2O, PbO, MgO, or Ag, and combinations or alloys or layers thereof. Furthermore, the down-converting materials can be sulfur containing phosphors, which can help for example in the rubber vulcanization or other photoactivated processes. An example of such a sulfur containing phosphor is: (Sr, Ca)Ga_2S_4. Other examples wherein said phosphor particles comprise a thiogallate host material selected from the group consisting of $SrGa_2S_4$, $CaGa_2S_4$ $BaGa_2S_4$, $MgGa_2S_4$ and solid solutions thereof. The particle size of such phosphor can be controlled from 25 nm to 300 microns in size as described in U.S. Pat. No. 6,153,123A. The downconverting materials can include a dopant including at least one of Er, Eu, Yb, Tm, Nd, Mn, Sb, Tb, Ce, Y, U, Pr, La, Gd and other rare-earth species or a combination thereof. The dopant can be included at a concentration of 0.01%-50% by mol concentration. At times it is preferable to have a combination of dopants rather than one dopant such is the case for a Mn and Sb in silicate matrices.

[0230] The invention in other embodiments can use a wide variety of up conversion materials (or mixtures of up converters) with or without the energy augmentators to enhance a particular wavelength or energy of light emitted from a material or surface. These up conversion materials can include similar materials as discussed above with regard to down conversion but typically included doped or impurity states in a host crystal that provide a mechanism for up conversion pumping. Accordingly, the up conversion materials to enhance wavelength or energy emission can convert energy from one of near infrared, infrared, and microwave irradiation. The upconversion materials to enhance color emission can convert energy from lower energy visible light to higher energy visible light.

[0231] In one example, a nanoparticle of a lanthanide doped oxide can be excited with near infrared light such as laser light at 980 nm and 808 nm to produce visible light in different parts of the red, green, blue spectrum (different wavelengths or energies) depending on the dopant trivalent rare earth ion(s) chosen, their concentration, and the host lattice.

[0232] The lanthanide doped oxides suitable for this invention differ from more traditional multi-photon up conversion processes where the absorption of, for example, two photons is needed in a simultaneous event to promote an electron from a valence state directly into an upper level conduction band state where relaxation across the band gap of the material produces fluorescence. Here, the co-doping produces states in the band gap of the $NaYF_4$ such that the Yb^{3+} ion has an energy state at $^2F_{5/2}$ pumpable by a single photon event and from which other single photon absorption events can populate even higher states. Once in this exited state, transitions to higher energy radiative states are possible, from which light emission will be at a higher energy than that of the incident light pumping the $^2F_{5/2}$ energy state. In other words, the energy state at $^2F_{5/2}$ of the Yb^{3+} ion is the

state that absorbs 980 nm light permitting a population build up serving as the basis for the transitions to the higher energy states such as the $^4F_{7/2}$ energy state. Here, transitions from the $^4F_{7/2}$ energy state produce visible emissions.

[0233] U.S. Pat. No. 7,008,559 (the entire contents of which are incorporated herein by reference) describes the upconversion performance of ZnS where excitation at 767 nm produces emission in the visible range. The materials described in U.S. Pat. No. 7,008,559 (including the ZnS as well as Er^{3+} doped $BaTiO_3$ nanoparticles and Yb^{3+} doped $CsMnCl_3$) are suitable in various embodiments of the invention with or without the energy augmentators.

[0234] Further, materials specified for up conversion materials in the invention (with or without energy augmentation) include CdTe, CdSe, ZnO, CdS, Y_2O_3, MgS, CaS, SrS and BaS. Such up conversion materials may be any semiconductor and more specifically, but not by way of limitation, sulfide, telluride, selenide, and oxide semiconductors and their nanoparticles, such as $Zn_{1-x}Mn_xS_y$, $Zn_{1-x}Mn_xSe_y$, $Zn_{1-x}Mn_xTe_y$, $Cd_{1-x}Mn_xS_y$, $Cd_{1-x}Mn_xSe_y$, $Cd_{1-x}Mn_xTe_y$, $Pb_{1-x}Mn_xS_y$, $Pb_{1-x}Mn_xSe_y$, $Pb_{1-x}Mn_xTe_y$, $Mg_{1-x}Mn_xS_y$, $Ca_{1-x}Mn_xS_y$, $Ba_{1-x}Mn_xS_y$ and Sr_{1-x}, etc. (wherein, $0<x\leq 1$, and $0<y\leq 1$). Complex compounds of the above-described semiconductors are also contemplated for use in the invention—e.g. $(M_{1-z}N_z)_{1-x}Mn_xA_{1-y}B_y$ (M=Zn, Cd, Pb, Ca, Ba, Sr, Mg; N=Zn, Cd, Pb, Ca, Ba, Sr, Mg; A=S, Se, Te, O; B=S, Se, Te, O; $0<x\leq 1$, $0<y\leq 1$, $0<z\leq 1$). Two examples of such complex compounds are $Zn_{0.4}Cd_{0.4}Mn_{0.2}S$ and $Zn_{0.9}Mn_{0.1}S_{0.8}Se_{0.2}$. Additional conversion materials include insulating and nonconducting materials such as BaF_2, BaFBr, and $BaTiO_3$, to name but a few exemplary compounds. Transition and rare earth ion co-doped semiconductors suitable for the invention include sulfide, telluride, selenide and oxide semiconductors and their nanoparticles, such as ZnS; Mn; Er; ZnSe; Mn, Er; MgS; Mn, Er; CaS; Mn, Er; ZnS; Mn, Yb; ZnSe; Mn, Yb; MgS; Mn, Yb; CaS; Mn, Yb etc., and their complex compounds: $(M_{1-z}N_z)_{1-x}(Mn_qR_{1-q})_xA_{1-y}B_y$ (M=Zn, Cd, Pb, Ca, Ba, Sr, Mg; N=Zn, Cd, Pb, Ca, Ba, Sr, Mg; A=S, Se, Te, O; B=S, . . . $0<z\leq 1$, $o<q\leq 1$).

[0235] Some nanoparticles such as ZnS:Tb^{3+}, Er^{3+}; ZnS:Tb^{3+}; Y_2O_3:Tb^{3+}, Y_2O_3:Tb^{3+}, Er3+; ZnS:Mn^{2+}; ZnS:Mn, Er^{3+} are known in the art to function for both down-conversion luminescence and upconversion luminescence and would be suitable for the invention with or without energy augmentators. In up-conversion embodiments, light emitting particles which emit red light may include praseodymium, light emitting particles which emit green light may include erbium, and light emitting particles which emit blue light may include thulium.

[0236] In general, the upconversion process generally requires one of more rare-earth dopants, such as Er, Eu, Yb, Tm, Nd, Tb, Ce, Y, U, Pr, La, Gd and other rare-earth species or a combination thereof, doped into a dielectric crystal (of any size >0.1 nm), including at least one of Y_2O_3, Y_2O_2S, $NaYF_4$, $NaYbF_4$, YAG, YAP, Nd_2O_3, LaF_3, $LaCl_3$, La_2O_3, TiO_2, $LuPO_4$, YVO_4, YbF_3, YF_3, Na-doped YbF_3, or SiO_2, where incident radiation is at longer wavelength than emissive radiation from the crystal. The wavelength emitted in based entirely on the dopant ion(s) chosen and their associated and relative concentration in the host crystal. For the example of upconversion in a Y_2O_3 host crystal, to achieve a blue emission (~450-480 nm) one could synthesize [Y_2O_3; Yb (3%), Tm (0.2%)], where the Yb and Tm are the percentages doped in the crystal relative to the Y atoms being 100%. Likewise, typical green upconversion materials are [Y_2O_3; Yb (5%), Ho (1%)] and [Y_2O_3; Yb (2%), Er (1%)], and typical red upconversion materials are [Y_2O_3; Yb (10%), Er (1%)] and [Y_2O_3; Yb (5%), Eu (1%)]. The concentrations of dopants relative to each other and the crystal matrix must be tuned for every combination, and there are multiple ways to achieve multiple wavelength or energy emissions from even the same dopants.

[0237] Up-conversion of red light with a wavelength of about 650 nm in Tm^{3+} doped flourozirconate glasses can be used in the invention to produce blue light. In this system, the blue light consists of two emission bands; one at 450 nm which is ascribed to the 1D2→3H4 transition, the others at 475 nm is ascribed to the 1G4→3H6 transition. The emission intensities of both bands have been observed by others to vary quadratically with the excitation power. For glasses with a Tm^{3+} concentration of 0.2 mol % and greater, cross-relaxation processes occur which decrease the up-conversion efficiency.

[0238] The emission of visible light upon excitation in the near-infrared (NIR) has been observed in optically clear colloidal solutions of $LuPO_4$:Yb^{3+}, Tm^{3+}, and $YbPO_4$:Er^{3+} nanocrystals in chloroform. Excitation at 975 nm has been shown by others to produce visible emission in the blue, green, or red spectral regions.

[0239] Tellurium and germanium oxides (tellurites and germanates) are also suitable upconverters. These glasses can be doped with Tm, Yb, Ho, Er, Pr, for example.

[0240] Yb^{3+} doped $BaZrO_3$ is also suitable for upconversion. Er^{3+} and/or Tm^{3+} doping are also suitable for tailoring the emission wavelengths.

[0241] In another embodiment, Nd^{3+}:$Cs_2NaGdCl_6$ and Nd^{3+}, Yb^{3+}:$Cs_2NaGdCl_6$ polycrystalline powder samples prepared by Morss method have been reported to be up converters and are suitable for the present invention. These materials, under 785 nm irradiation, have shown upconversion emissions near 538 nm (Green), 603 nm (Orange), and 675 nm (Red) were observed and assigned to 4G7/2→4I9/2, (4G7/2→4I11/2; 4G5/2→4I9/2), and (4G7/2→4I13/2; 4G5/2→4I11/2), respectively.

[0242] In another embodiment, Nd^{3+} and Ho^{3+} co-doped-based ZrF_4 fluoride glasses under 800 nm excitation have been reported to be up converters and are suitable for the present invention. Among the up-conversion luminescences for the ZrF_4 fluoride glasses, the green emission was seen to be extremely strong and the blue and red emission intensities were very weak.

[0243] In another embodiment, Tm^{3+}/Yb^{3+}-codoped TeO_2—Ga_2O_3—R_2O (R=Li, Na, K) glasses have been reported to be up converters and are suitable for the present invention. These materials, under excitation at 977 nm, showed intense blue upconversion emission centered at 476 nm along with a weak red emission at 650 nm.

[0244] In another embodiment, metal-to-ligand charge transfer (MLCT) transition in $[Ru(dmb)_3]^{2+}$ (dmb=4,4'-dimethyl-2,2'-bipyridine) in the presence of anthracene or 9,10-diphenylanthracene have been reported to be up converters and are suitable for the present invention. Upconverted singlet fluorescence resulting from triplet-triplet annihilation at low excitation power has been reported. In particular 9,10-diphenylanthracene (DPA) (substituted for anthracene) showed higher efficiencies for upconversion. In these experiments, workers with this material system assumed that DPA's increased singlet fluorescence quantum

yield (=0.95) relative to anthracene (=0.27)7. This work lead to an approximate 24.4±6.1 enhancement of green-to-blue light upconversion permitting direct visualization of the process at low excitation power, for example by a commercial green laser pointer (λ_{ex}532 nm, <5 mW peak power).

[0245] In certain embodiments, further energy converters include, but are not limited to, (not ranked by order of preference or utility):

[0246] CaF_2, ZnF_2, $KMgF_3$, $ZnGa_2O_4$, $ZnAl_2O_4$, Zn_2SiO_4, Zn_2GeO_4, $Ca_5(PO_4)_3F$, $Sr_5(PO_4)_3F$, $CaSiO_3$, $MgSiO_3$, ZnS, $MgGa_2O_4$, $LaAl_{11}O_{18}$, Zn_2SiO_4, $Ca_5(PO_4)_3F$, $Mg_4Ta_2O_9$, CaF_2, $LiAl_5O_8$, $LiAlO_2$, $CaPO_3$, AlF_3, and $LuPO_4$:Pr^{3+}. Examples further include the alkali earth chalcogenide phosphors which are in turn exemplified by the following non-inclusive list: MgS:Eu^{3+}, CaS:Mn^{2+}, CaS:Cu, CaS:Sb, CaS:Ce^{3+}, CaS:Eu^{2+}, CaS:$Eu^{2+}Ce^{3+}$, CaS:Sm^{3+}, CaS:Pb^{2+}, CaO:Mn^{2+}, CaO:Pb^{2+}.

[0247] Further examples include the ZnS type phosphors that encompass various derivatives: ZnS:Cu,Al(Cl), ZnS:Cl (Al), ZnS:Cu,I(Cl), ZnS:Cu, ZnS:Cu,In.

[0248] Also included are the compound IIIb-Vb phosphors which include the group IIIb and Vb elements of the periodic table. These semiconductors include BN, BP, BSb, AlN, AlP, AlAs, AlSb, GaN, GaP, GaAs, GaSb, InN, InP, InAs, InSb and these materials may include donors and acceptors that work together to induce light emission diodes. These donors include, but are not limited to, Li, Sn, Si, Li, Te, Se, S, O and acceptors include, but are not limited to, C, Be, Mg, Zn, Cd, Si, Ge. Further included are the major GaP light emitting diodes which include, but are not limited to, GaP:Zn,O, GaP:NN, Gap:N and GaP, which emit colors Red, Yellow, Green and Pure Green respectively.

[0249] The materials can further include such materials as GaAs with compositional variation of the following sort: $In_{1-y}(Ga_{1-x}Al_x)P$.

[0250] Also included is silicon carbide SiC, which has commercial relevancy as a luminescent platform in blue light emitting diodes. These include the polytypes 3C—SiC, 6H—SiC, 4H—SiC with donors such as N and Al and acceptors such as Ga and B.

[0251] Further examples include multiband luminescent materials include, but not limited to, the following compositions (Sr, Ca, Ba)$_5(PO_4)_3$Cl:Eu^{2+}, $BaMg_2Al_{16}O_{27}$:Eu^{2+}, $CeMgAl_{11}O_{19}$:Ce^{3+}:Tb^{3+}, $LaPO_4$:Ce^{3+}:Tb^{3+}, $GdMgB_5O_{10}$:Ce_3:Tb^{3+}, Y_2O_3:Eu^{3+}, (Ba,Ca,Mg)$_5(PO_4)_3$Cl:Eu^{2+}, $2SrO_{0.84}$P2O50.16B2O3:Eu^{2+}, $Sr_4Al_{14}O_{25}$:Eu^{2+}.

[0252] Materials typically used for fluorescent high pressure mercury discharge lamps are also included. These can be excited with X-Ray and are exemplified by way of family designation as follows: Phosphates (Sr, M)$(PO_4)_2$:Sn^{2+}, Mg or Zn activator, Germanate 4MgO.GeO_2:Mn^{4+}, 4(MgO, MgF_2)GeO_2:Mn^{4+}, Yttrate Y_2O_3:Eu^{3+}, Vanadate YVO_4:Eu^{3+}, Y(P,V)O_4:Eu^{3+}, Y(P,V)O_4:In^{+}, Halo-Silicate $Sr_2Si_3O_{82}SrCl_2$:Eu^{2+}, Aluminate $(Ba,Mg)_2Al_{16}O_{24}$:Eu^{2+}, (Ba, $Mg)_2Al_{16}O_{24}$:Eu^{2+}, Mn^{2+}, $Y_2O_3Al_2O_3$:Tb^{3+}.

[0253] Another grouping by host compound includes chemical compositions in the halophosphates phosphors, phosphate phosphors, silicate phosphors, aluminate phosphors, borate phosphors, tungstate phosphors, and other phosphors. The halophosphates include, but are not limited to: $3Ca_3(PO_4)_2$.Ca(F,Cl)$_2$:Sb^{3+}, $3Ca_3(PO_4)_2$.Ca(F,Cl)$_2$:Sb^{3+}/Mn^{2+}, $Sr_{10}(PO_4)_6Cl_2$:Eu^{2+}, (Sr,Ca)$_{10}(PO_4)_6Cl_2$:Eu^{2+}, (Sr, Ca)$_{10}(PO_4)_6$.nB_2O_3:Eu^{3+}, (Sr, Ca,Mg)$_{10}(PO_4)_6Cl_2$:Eu^{2+}. The phosphate phosphors include, but are not limited to: $Sr_2P_2O_7$:Sn^{2+}, (Sr,Mg)$_3(PO_4)_2$:Sn^{2+}, $Ca_3(PO_4)_2$.Sn^{2+}, $Ca_3(PO_4)_2$:Tl^{+}, (Ca,Zn)$_3(PO_4)_2$:Tl^{+}, $Sr_2P_2O_7$:Eu^{2+}, $SrMgP_2O_7$:Eu^{2+}, $Sr_3(PO_4)_2$:Eu^{2+}, $LaPO_4$:Ce^{3+}, Tb^{3+}, La_2O_3.0.2SiO_2.0.9P_2O_5:Ce^{3+}.Tb^{3+}, BaO.TiO_2.P_2O_5. The silicate phosphors Zn_2SiO_4:Mn^{2+}, $CaSiO_3$:Pb^{2+}/Mn^{2+}, (Ba, Sr, Mg)$_3Si_2O_7$:Pb^{2+}, $BaSi_2O_5$:Pb^{2+}, $Sr_2Si_3O_8$.2$SrCl_2$:Eu^2, $Ba_3MgSi_2O_8$:Eu^{2+}, (Sr,Ba)$Al_2Si_2O_8$:Eu^{2+}.

[0254] The aluminate phosphors include, but are not limited to: $LiAlO_2$:Fe^{3+}, $BaAl_8O_{13}$:Eu^{2+}, $BaMg_2Al_{16}O_{27}$:Eu^{2+}, $BaMg_2Al_{16}O_{27}$:Eu^{2+}/Mn^{2+}, $Sr_4Al_{14}O_{25}$:Eu^{2+}, $CeMgAl_{11}O_{19}$:Ce^{3+}/Tb^{3+}.

[0255] The borate phosphors include: $Cd_2B_2O_5$:Mn^{2+}, SrB_4O_7F:Eu^{2+}, $GdMgB_5O_{10}$:Ce^{3+}/Tb^{3+}, $GdMgB_5O_{10}$:Ce^{3+}/Mn^{3+}, $GdMgB_5O_{10}$:Ce^{3+}/Tb^{3+}/Mn^{2+}.

[0256] The tungstate phosphors include, but are not limited to: $CaWO_4$, (Ca,Pb)WO_4, $MgWO_4$. Other phosphors Y_2O_3:Eu^{3+}, Y(V,P)O_4:Eu^{2+}, YVO_4:Dy^{3+}, $MgGa_2O_4$:Mn^{2+}, 6MgO.As_2O_5:Mn^{2+}, 3.5MgO.0.5MgF_2.GeO_2:Mn^{4+}.

[0257] The activators to the various doped phosphors include, but are not limited to: Tl^{+}, Pb^{2+}, Ce^{3+}, Eu^{2+}, WO_4^{2-}, Sn^{2+}, Sb^{3+}, Mn^{2+}, Tb^{3+}, Eu^{3+}, Mn^{4+}, Fe^{3+}. The luminescence center Tl^{+} is used with a chemical composition such as: (Ca,Zn)$_3(PO_4)_2$:Tl^{+}, $Ca_3(PO_4)_2$:Tl^{+}. The luminescence center Mn^{2+} is used with chemical compositions such as $MgGa_2O_4$:Mn^{2+}, $BaMg_2Al_{16}O_{27}$:Eu^{2+}/Mn^{2+}, Zn_2SiO_4:Mn^{2+}, $3Ca_3(PO_4)_2$.Ca(F,Cl)$_2$:Sb^{2+}/Mn^{2+}, $CaSiO_3$:Pb^{2+}/Mn^{2+}, $Cd_2B_2O_5$:Mn^{2+}, CdB_2O_5:Mn^{2+}, $GdMgB_5O_{10}$:Ce^{3+}/Mn^{2+}, $GdMgB_5O_{10}$:Ce^{3+}/Tb^{3+}/Mn^{2+}. The luminescence center Sn2+ is used with chemical compositions such as: $Sr_2P_2O_7$:Sn^{2+}, (Sr,Mg)$_3(PO_4)_2$:Sn^{2+}. The luminescence center Eu^{2+} is used with chemical compositions such as: SrB_4O_7F:Eu^{2+}, (Sr,Ba)$Al_2Si_2O_8$:Eu^{2+}, $Sr_3(PO_4)_2$:Eu^{2+}, $Sr_2P_2O_7$:Eu^{2+}, $Ba_3MgSi_2O_8$:Eu^{2+}, $Sr_{10}(PO_4)_6Cl_2$:Eu^{2+}, $BaMg_2Al_{16}O_{27}$:Eu^{2+}/Mn^{2+}, (Sr,Ca)$_{10}(PO_4)_6Cl_2$:Eu^{2+}. The luminescence center Pb^{2+} is used with chemical compositions such as: (Ba,Mg,Zn)$_3Si_2O_7$:Pb^{2+}, $BaSi_2O_5$:Pb^{2+}, (Ba, Sr)$_3Si_2O_7$:Pb^{2+}.

[0258] The luminescence center Sb^{2+} is used with chemical compositions such as: $3Ca_3(PO_4)_2$.Ca(F,Cl)$_2$:Sb^{3+}, $3Ca_3(PO_4)_2$.Ca(F,Cl)$_2$:Sb^{3+}/Mn^{2+}.

[0259] The luminescence center Tb^{3+} is used with chemical compositions such as: $CeMgAl_{11}O_{19}$:Ce^{3+}/Tb^{3+}, $LaPO_4$:Ce^{3+}/Tb^{3+}, Y_2SiO_5:Ce^{3+}/Tb^{3+}, $GdMgB_5O_{10}$:Ce^{3+}/Tb^{3+}. The luminescence center Eu^{3+} is used with chemical compositions such as: Y_2O_3:Eu^{3+}, Y(V,P)O_4:Eu^{3+}. The luminescence center Dy^{3+} is used with chemical compositions such as: YVO_4:Dy^{3+}. The luminescence center Fe^{3+} is used with chemical compositions such as: $LiAlO_2$:Fe^{3+}. The luminescence center Mn^{4+} is used with chemical compositions such as: 6MgO.As_2O_5:Mn^{4+}, 3.5MgO0.5MgF_2.GeO_2:Mn^{4+}. The luminescence center Ce^{3+} is used with chemical compositions such as: $Ca_2MgSi_2O_7$:Ce^{3+} and Y_2SiO_5:Ce^{3+}. The luminescence center WO_4^{2-} is used with chemical compositions such as: $CaWO_4$, (Ca,Pb)WO_4, $MgWO_4$. The luminescence center TiO_4^{4-} is used with chemical compositions such as: BaO.TiO_2.P_2O_5.

[0260] Additional phosphor chemistries of interest using X-Ray excitations include, but are not limited to, the k-edge of these phosphors. Low energy excitation can lead to intense luminescence in materials with low k-edge. Some of these chemistries and the corresponding k-edge are listed below:

$BaFCl:Eu^{2+}$	37.38 keV
$BaSO_4:Eu^{2+}$	37.38 keV
$CaWO_4$	69.48 keV
$Gd_2O_2S:Tb^{3+}$	50.22 keV
$LaOBr:Tb^{3+}$	38.92 keV
$LaOBr:Tm^{3+}$	38.92 keV
$La_2O_2S:TB^{3+}$	38.92 keV
$Y_2O_2S:Tb^{3+}$	17.04 keV
$YTaO_4$	67.42 keV
$YTaO_4$:Nb	67.42 keV
ZnS:Ag	9.66 keV
(Zn, Cd)S:Ag	9.66/26.7 keV

[0261] These materials can be used alone or in combinations of two or more. A variety of compositions can be prepared to obtain the desired output wavelength or spectrum of wavelengths.

[0262] In the present invention, the phosphor selection could be chosen such that under x-ray or other high energy source irradiation, the light emitted from the phosphors could, for example, have exemplary characteristics including:

[0263] Emissions in 190-250 nm wavelength range;

[0264] Emissions in the 330-340 nm wavelength range.

[0265] Mechanoluminescent Materials (Organic and Inorganic):

[0266] In another embodiment of the invention, mechano-luminescent materials can be used as energy converters and optionally can be used with the energy augmentation structures described above.

[0267] Mechano-luminescent materials convert ultrasonic or mechanical energy (such as vibrations naturally existing on an article such as motor or vibrations from driven by transducers) into visible light. Here, for example, the mechano-luminescent materials would be placed in a vicinity (e.g., between or around or inside) the folded structures or the external-electrode pairs.

[0268] In one embodiment, an electromagnetic wave energy augmentator captures one or more wavelengths of electromagnetic energy, and augments the one or more wavelengths of electromagnetic energy in at least one property (such as electric field intensity in a vicinity of the mechano-luminescent materials), while at the same time the mechano-luminescent materials can be considered an energy converter converting the ultrasonic or mechanical energy into electromagnetic radiation (i.e., emitted light).

[0269] In one embodiment of the invention, the increased electric field in the folded structure or the external electrode pair increases the luminescence of the mechano-luminescent materials. The energy used to build the electric field in the folded structure or the external electrode pair being provided separately from the mechanical energy driving the mechano-luminescence.

[0270] Various mechano-luminescent materials suitable for the present invention with or without energy augmentators include $ZnS:Mn^{2+}$, $SrAl_2O_4:Eu^{2+}$, ZnS:Cu, $SrAMgSi_2O_7:Eu^{2+}$ (A=Ca, Sr, Ba), KCl, KI, KBr, NaF, NaCl, LiF, RbCl, RbBr, RbI, MgO, $SrAl_2O_4$, $CaAl_2O_4$, $Sr_{1-x}Ba_xAl_2O_4$ (x=0, 0.1, 0.2, 0.4), $Sr_{0.9}Ca_{0.1}Al_2O_4$, $Zn_2Ge_{0.9}Si_{0.1}O_4$, $MgGa_2O_4$, $ZnGa_2O_4$, $ZnAl_2O_4$, ZnS, ZnTe, $(ZnS)_{1-x}(MnTe)_x$ (x<¼), CaZnOS, BaZnOS, $Ca_2MgSi_2O_7$, $Sr_2MgSi_2O_7$, $Ba_2MgSi_2O_7$, $SrCaMgSi_2O_7$, $SrBaMgSi_2O_7$, $Sr_nMgSi_2O_{5+n}$ (1≤n≤2), $Ca_2Al_2SiO_7$, $Sr_2Al_2SiO_7$, $CaYAl_3O_7$, $CaAl_2Si_2O$, $Ca_{1-x}Sr_xAl_2Si_2O_8$ (x<0.8), $SrMg_2(PO_4)_2$, $Ba_{1-x}Ca_xTiO_3$(0.25<x<0.8), $Ba_{1-x}Ca_xTiO_3$, $LiNbO_3$, Sr_2SnO_4, $(Ca, Sr, Ba)_2SnO_4$, $Sr_3Sn_2O_7$, $Sr_3(Sn, Si)_2O_7$, $Sr_3(Sn, Ge)_2O_7$, $Ca_3Ti_2O_7$, $CaNb_2O_6$, $Ca_2Nb_2O_7$, $Ca_3Nb_2O_8$, $BaSi_2O_2N_2$, $SrSi_2O_2N_2$, $CaZr(PO_4)_2$, ZrO_2.

[0271] In one embodiment, a europium-holmium co-doped strontium aluminate can be used as a mechano-luminescent material (i.e., an energy converter) alone or in conjunction with the energy augmentators. The europium-holmium co-doped strontium aluminate and the other mechano-luminescent materials convert sonic or acoustic energy into photon emissions which may or may not be placed in a vicinity of the energy augmentators.

[0272] Yanim Jia, in "Novel Mechano-Luminescent Sensors Based on Piezoelectric/Electroluminescent Composites," Sensors (Basel). 2011; 11(4): 3962-396, the entire contents of which are incorporated by reference, describes a mechanoluminescent composite made of a piezoelectric material and an electroluminescent material. In this composite device, when a stress is applied to the piezoelectric layer, electrical charges will be induced at both the top and bottom faces of piezoelectric layer due to the piezoelectric effect. These induced electrical charges will result in a light output from the electroluminescent layer due to the electroluminescent effect.

[0273] Here, in one embodiment of the present invention with or without energy augmentators, such composites made of a piezoelectric material and an electroluminescent material, hereinafter "composite mechano-luminescent emitters," provides a structure that, upon stimulation with mechanical or vibrational energy such as from an acoustic or ultrasonic transducer, emit light.

[0274] Electroluminescent and phosphorescent materials (organic and inorganic): The present invention in various embodiments can utilize organic fluorescent molecules or inorganic particles capable or fluorescence and phosphorescence having crystalline, polycrystalline or amorphous micro-structures for the converters (optionally including the energy augmentation structures described above).

[0275] The list of inorganic molecules that can be used with or without energy augmentators for the electroluminescence and phosphorescent materials described below include but is not limited to the following inorganic electroluminescent phosphor materials:

[0276] $SrS:Ce^{3+}$

[0277] $CaGa_2S_4:Ce^{3+}$

[0278] $SrS:Cu^{+}$

[0279] $CaS:Pb^{2+}$

[0280] $BaAl_2S_4:Eu^{2+}$

[0281] $ZnS:Tb^{3+}$

[0282] $ZnMgS:Mn^{2+}$

[0283] $SrGa_2S_4:Eu^{2+}$

[0284] $CaAl_2S_4:Eu^{2+}$

[0285] $BaAl_2S_4:Eu^{2+}$

[0286] $ZnS:Mn^{2+}$

[0287] $MgGa_2O_4:Eu^{3+}$

[0288] $(Ca, Sr)Y_2S_4:Eu^{2+}$

[0289] $BaAl_2S_4:Eu^{2+}$

[0290] Organic molecules that can phosphoresce under the influence of an electric field are also of interest in the present application. The organic fluorescent compounds with high quantum yield include by way of illustration:

[0291] Naphthalene,

[0292] Pyrene,

[0293] Perylene,

[0294] Anthracene,

[0295] Phenanthrene,

[0296] p-Terphenyl,

[0297] p-Quartphenyl,

[0298] Trans-stilbene,

[0299] Tetraphenylbutadiene,

[0300] Distyrylbenzene,

[0301] 2,5-Diphenyloxazole,

[0302] 4-Methyl-7-diethylaminocoumarin,

[0303] 2-Phenyl-5-(4-biphenyl)-1,3,4-oxadiazole,

[0304] 3-Phenylcarbostyryl,

[0305] 1,3,5-Triphenyl-2-pyrazoline,

[0306] 1,8-Naphthoylene-1', 2'-bezimidazole,

[0307] 4-Amino-N-phenyl-naphthalimide.

[0308] The inorganic fluorescent and phosphorescent materials detailed here are numerous, and various examples are given by way of illustration rather than limitation and can be used with or without energy augmentators. Furthermore, these materials can be doped with specific ions (activators or a combination of activators) that occupy a site in the lattice structure in the case of crystalline or polycrystalline materials and could occupy a network forming site or a bridging and/or non-bridging site in amorphous materials. These compounds could include (not ranked by order of preference or utility) the following material examples:

[0309] CaF_2, ZnF_2, $KMgF_3$, $ZnGa_2O_4$, $ZnAl_2O_4$, Zn_2SiO_4, Zn_2GeO_4, $Ca_5(PO_4)_3F$, $Sr_5(PO_4)_3F$, $CaSiO_3$, $MgSiO_3$, ZnS, $MgGa_2O_4$, $LaAl_{11}O_8$, Zn_2SiO_4, $Ca_5(PO_4)_3F$, $Mg_4Ta_2O_9$, CaF_2, $LiAl_5O_8$, $LiAlO_2$, $CaPO_3$, AlF_3.

[0310] Further included are alkali earth chalcogenide phosphors which are in turn exemplified by the following non-inclusive list:

[0311] MgS:Eu^{3+}, CaS:Mn^{2+}, CaS:Cu, CaS:Sb, CaS:Ce^{3+}, CaS:Eu^{2+}, CaS:$Eu^{2+}Ce^{3+}$, CaS:Sm^{3+}, CaS:Pb^{2+}, CaO:Mn^{2+}, CaO:Pb^{2+}.

[0312] The examples include the ZnS type phosphors that encompass various derivatives:

[0313] ZnS:Cu,Al(Cl), ZnS:Cl(Al), ZnS:Cu,I(Cl), ZnS:Cu, ZnS:Cu,In.

[0314] Compound IIIb-Vb phosphors which include the group IIIb and Vb elements of the periodic table are suitable for converter materials. These semiconductors include BN, BP, BSb, AlN, AlP, AlAs, AlSb, GaN, GaP, GaAs, GaSb, InN, InP, InAs, InSb and these materials have donors and acceptors that work in together to induce light emission diodes. The donors include Li, Sn, Si, Li, Te, Se, S, O, and acceptors include C, Be, Mg, Zn, Cd, Si, Ge. As an example, GaP light emitting diodes include GaP:Zn, O, GaP:NN, Gap:N and GaP which emit colors Red, Yellow, Green and Pure Green respectively.

[0315] The compounded materials further include such materials as GaAs with compositional variation of the following sort: In1-y(Ga1-xAlx)yP (provides a simple example). Silicon Carbide SiC as a luminescent platform has commercial relevancy if the blue light emitting diodes. These include the polytypes 3C—SiC, 6H—SiC, 4H—SiC with donors such as N and Al and acceptors such as Ga and B.

[0316] Multiband luminescent materials suitable for converter materials include for example the following compositions:

[0317] (Sr, Ca, Ba)$_5(PO_4)_3Cl:Eu^{2+}$, $BaMg_2Al_{16}O_{27}:Eu^{2+}$, $CeMgAl_{11}O_{19}:Ce^{3+}:Tb^{3+}$, $LaPO_4:Ce^{3+}:Tb^{3+}$, $GdMgB_5O_{10}:Ce^{3+}:Tb^{3+}$, $Y_2O_3:Eu^{3+}$, $(Ba,Ca,Mg)_5(PO_4)_3Cl:Eu^{2+}$, $2SrO_{0.84}P_2O_5.0.16B_2O_3:Eu^{2+}$, $Sr_4Al_{14}O_{25}:Eu^{2+}$.

[0318] Other materials suitable for converter materials include those materials used for fluorescent high pressure mercury discharge lamps can be excited with X-Ray and are exemplified by way of family designation as follows:

[0319] Phosphates (Sr, M)$(PO_4)_2:Sn^{2+}$, Mg or Zn activator, Germanate $4MgO.GeO_2:Mn^{+}$, 4(MgO, MgF_2) $GeO_2:Mn^{4+}$, Yttrate $Y_2O_3:Eu^{3+}$, Vanadate $YVO_4:Eu^{3+}$, $Y(P,V)O_4:Eu^{3+}$, $Y(P,V)O_4:In^{+}$, Halo-Silicate $Sr2Si3O_8.2SrCl_2:Eu^{2+}$, Aluminate $(Ba,Mg)_2Al_{16}O_{24}:Eu^{2+}$, $(Ba,Mg)_2Al_{16}O_{24}:Eu^{2+},Mn^{2+}$, $Y_2O_3Al_2O_3:Tb^{3+}$.

[0320] Another grouping of materials suitable for converter materials by host compound include chemical compositions in the Halophosphates phosphors, Phosphate phosphors, Silicate phosphors, Aluminate phosphors, Borate phosphors, Tungstate phosphors, and other phosphors.

[0321] The halophosphates include by way of illustration:

[0322] $3Ca_3(PO_4)_2.Ca(F,Cl)_2:Sb^{3+}$, $3Ca_3(PO_4)_2.Ca(F,Cl)_2:Sb^{3+}/Mn^{2+}$, $Sr_{10}(PO_4)_6Cl_2:Eu^{2+}$, $(Sr,Ca)_{10}(PO_4)_6Cl_2:Eu^{2+}$, $(Sr,Ca)_{10}(PO_4)_6.nB_2O_3:Eu^{3+}$, $(Sr,Ca,Mg)_{10}(PO_4)_6Cl_2:Eu^{2+}$. The phosphate phosphors include by way of illustration $Sr_2P_2O_7:Sn^{2+}$, $(Sr,Mg)_3(PO_4)_2:Sn^{2+}$, $Ca_3(PO_4)_2.Sn^{2+}$, $Ca_3(PO_4)_2:Tl^{+}$, $(Ca,Zn)_3(PO_4)_2:Tl^{+}$, $Sr_2P_2O_7:Eu^{2+}$, $SrMgP_2O_7:Eu^{2+}$, $Sr_3(PO_4)_2:Eu^{2+}$, $LaPO_4:Ce^{3+}$, Tb^{3+}, $La_2O_3.0.2SiO_2.0.9P_2O_5:Ce^{3+}.Tb^{3+}$, $BaO.TiO_2.P_2O_5$. The silicate phosphors $Zn_2SiO_4:Mn^{2+}$, $CaSiO_3:Pb^{2+}/Mn^{2+}$, (Ba, Sr, Mg).$3Si_2O_7:Pb^{2+}$, $BaSi_2O_5:Pb^{2+}$, $Sr_2Si_3O_8.2SrCl_2:Eu^{2+}$, $Ba_3MgSi_2O_8:Eu^{2+}$, $(Sr,Ba)Al_2Si_2O_8:Eu^{2+}$.

[0323] The aluminate phosphors include:

[0324] $LiAlO_2:Fe^{3+}$, $BaAl_8O_{13}:Eu^{2+}$, $BaMg_2Al_{16}O_{27}:Eu^{2+}$, $BaMg_2Al_{16}O_{27}:Eu^{2+}/Mn^{2+}$, $Sr_4Al_{14}O_{25}:Eu^{2+}$, $CeMgAl_{11}O_{19}:Ce^{3+}/Tb^{3+}$.

[0325] The borate phosphors include:

[0326] $Cd_2B_2O_5:Mn^{2+}$, $SrB_4O_7F:Eu^{2+}$, $GdMgB_5O_{10}:Ce^{3+}/Tb^{3+}$, $GdMgB_5O_{10}:Ce^{3+}/Mn^{3+}$, $GdMgB_5O_{10}:Ce^{3+}/Tb^{3+}/Mn^{2+}$.

[0327] The tungstate phosphors include:

[0328] $CaWO_4$, $(Ca,Pb)WO_4$, $MgWO_4$. Other phosphors $Y_2O_3:Eu^{3+}$, $Y(V,P)O_4:Eu^{2+}$; $YVO_4:Dy^{3+}$, $MgGa_2O_4:Mn^{2+}$, $6MgO.As_2O_5:Mn^{2+}$, $3.5MgO.0.5MgF_2.GeO_2:Mn^{4+}$.

[0329] Activators of relevance to the various doped phosphors include the following list:

[0330] Tl^{+}, Pb^{2+}, Ce^{3+}, Eu^{2+}, WO_4^{2-}, Sn^{2+}, Sb^{3+}, Mn^{2+}, Tb^{3+}, Eu^{3+}, Mn^{4+}, Fe^{3+}.

[0331] In various embodiments, the luminescence center Tl+ can be used with a chemical composition such as:

[0332] $(Ca,Zn)_3(PO_4)_2:Tl^{+}$, $Ca_3(PO_4)_2:Tl^{+}$.

[0333] Similarly, the luminescence center Mn2+ can be used with chemical compositions such as

[0334] $MgGa_2O_4:Mn^{2+}$, $BaMg_2Al_{16}O_{27}:Eu^{2+}/Mn^{2+}$, $Zn_2SiO_4:Mn^{2+}$, $3Ca_3(PO_4)_2.Ca(F,Cl)_2:Sb^{2+}/Mn^{2+}$, $CaSiO_3:Pb^{2+}/Mn^{2+}$, $Cd_2B_2O_5:Mn^{2+}$, $CdB_2O_5:Mn^{2+}$, $GdMgB_5O_{10}:Ce^{3+}/Mn^{2+}$, $GdMgB_5O_{10}:Ce^{3+}/Tb^{3+}/Mn^{2+}$.

[0335] Further, the luminescence center Sn^{2+} can be used with chemical compositions such as:

[0336] $Sr_2P_2O_7:Sn^{2+}$, $(Sr,Mg)_3(PO_4)_2:Sn^{2+}$.

[0337] The luminescence center Eu^{2+} can also be used with chemical compositions such as:

[0338] $SrB_4O_7F:Eu^{2+}$, $(Sr,Ba)Al_2Si_2O_8:Eu^{2+}$, $Sr_3(PO_4)_2:Eu^{2+}$, $Sr_2P_2O_7:Eu^{2+}$, $Ba_3MgSi_2O_8:Eu^{2+}$, $Sr_{10}(PO_4)_6Cl_2:Eu^{2+}$, $BaMg_2Al_{16}O_{27}:Eu^{2+}/Mn^{2+}$, $(Sr,Ca)_{10}(PO_4)_6Cl_2:Eu^{2+}$.

[0339] The luminescence center Pb^{2+} can be used with chemical compositions such as:

[0340] $(Ba,Mg,Zn)_3Si_2O_7:Pb^{2+}$, $BaSi_2O_5:Pb^{2+}$, $(Ba,Sr)_3Si_2O_7:Pb^{2+}$.

[0341] The luminescence center Sb^{2+} can be used with chemical compositions such as:

[0342] $3Ca_3(PO_4)_2Ca(F,Cl)_2:Sb^{3+}$, $3Ca_3(PO_4)_2.Ca(F,Cl)_2:Sb^{3+}/Mn^{2+}$.

[0343] The luminescence center Tb3+ can be used with chemical compositions such as:

[0344] $CeMgAl_{11}O_{19}:Ce^{3+}/Tb^{3+}$, $LaPO_4:Ce^{3+}/Tb^{3+}$, $Y_2SiO_5:Ce^{3+}/Tb^{3+}$, $GdMgB_5O_{10}:Ce^{3+}/Tb^{3+}$.

[0345] The luminescence center Eu^{3+} can be used with chemical compositions such as:

[0346] $Y_2O_3:Eu^{3+}$, $Y(V,P)O_4:Eu^{3+}$.

[0347] The luminescence center Dy^{3+} can be used with chemical compositions such as:

[0348] $YVO_4:Dy^{3+}$.

[0349] The luminescence center Fe^{3+} can be used with chemical compositions such as:

[0350] $LiAlO_2:Fe^{3+}$.

[0351] The luminescence center Mn^{4+} can be used with chemical compositions such as:

[0352] $6MgO.As_2O_5:Mn^{4+}$, $3.5MgO.0.5MgF_2.GeO_2:Mn^{4+}$.

[0353] The luminescence center Ce^{3+} can be used with chemical compositions such as:

[0354] $Ca_2MgSi_2O_7:Ce^{3+}$ and $Y_2SiO_5:Ce^{3+}$.

[0355] The luminescence center WO_4^{2-} can be used with chemical compositions such as:

[0356] $CaWO_4$, $(Ca,Pb)WO_4$, $MgWO_4$.

[0357] The luminescence center TiO_4^{4-} can be used with chemical compositions such as:

[0358] $BaO.TiO_2.P_2O_5$.

[0359] In various embodiments of this invention, the phosphor chemistry utilized in x-ray excitations can be used with or without energy augmentators. Of particular interest is the k-edge of these phosphors. Low energy excitation can lead to intense luminescence in materials with low k-edge. Some of these chemistries and the corresponding k-edge are included as follows:

$BaFCl:Eu^{2+}$	37.38 keV
$BaSO_4:Eu^{2+}$	37.38 keV
$CaWO_4$	69.48 keV
$Gd_2O_2S:Tb^{3+}$	50.22 keV
$LaOBr:Tb^{3+}$	38.92 keV
$LaOBr:Tm^{3+}$	38.92 keV
$La_2O_2S:TB^{3+}$	38.92 keV
$Y_2O_2S:Tb^{3+}$	17.04 keV
$YTaO_4$	67.42 keV
$YTaO_4:Nb$	67.42 keV
ZnS:Ag	9.66 keV
(Zn, Cd)S:Ag	9.66/26.7 keV

[0360] In one embodiment of this invention, light from these materials (excited for example by high energy particles including x-rays, gamma rays, protons, and electrons) can have their emissions modulated by having those materials included in a vicinity of (including inside) the color enhancing structures described herein. For example, in medical treatments where x-ray excites phosphorescence to photostimulate reactions in a patient, simultaneous with irradiation by the high energy particles, there could be applied infrared irradiation to drive resonance in the energy augmentation structures described herein, where the x-ray phosphors would have enhanced light emissions when in the presence of the intensified electric fields. In another example, in medical or scientific instruments, for simultaneous with irradiation by the high energy particles, there could be applied electric fields to enhance emissions from these x-ray phosphors.

[0361] Electro Luminescent Materials: Various materials used for the electro-luminescence in the present invention with or without energy augmentators can include but are not limited to:

[0362] 4,4',4"-Tris[phenyl(m-tolyl)amino]triphenylamine (m-MTDATA)

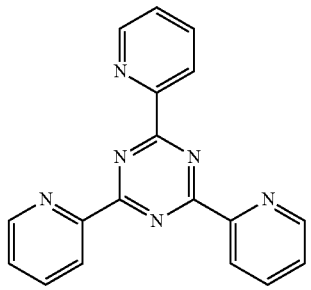
[0363] N,N'-Bis(3-methylphenyl)-N,N'-diphenylbenzidine (TPD)

[0364] 4,4',4"-Tris[phenyl(m-tolyl)amino]triphenylamine (m-MTDATA)

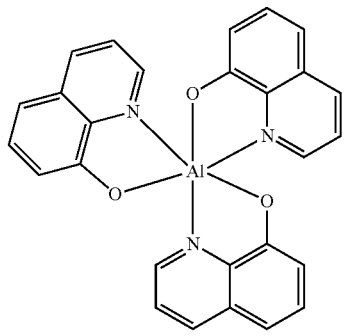
[0365] N,N'-Bis(3-methylphenyl)-N,N'-diphenylbenzidine (TPD)

[0366] Tris-(8-hydroxyquinoline)aluminum

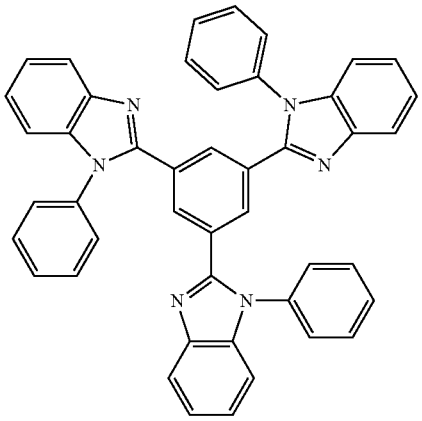
[0367] 2,4,6-Tris(2-pyridyl)-s-triazine (TPT)



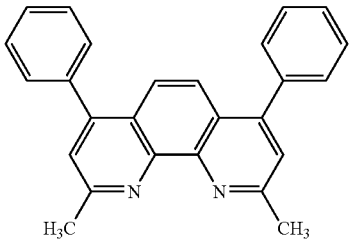
[0368] 2,2',2"-(1,3,5-Benzinetriyl)-tris(1-phenyl-1-H-benzimidazole) Alq



[0369] 2,2',2"-(1,3,5-Benzinetriyl)-tris(1-phenyl-1-H-benzimidazole) TPBI



[0370] 2,9-Dimethyl-4,7-diphenyl-1,10-phenanthroline, BCP2,9-Dimethyl-4,7-diphenyl-1,10-phenanthroline, BCP



[0371] Plasmonic enhancement structures: FIG. **26** is a schematic of a depiction of an upconverter or a down converter material (i.e., a photoactive material) according to one embodiment of the invention to be utilized in the color enhancement/augmentation structures noted herein with or without energy augmentators. FIG. **26** shows a number of structural configurations for placement of a dielectric core upconverter or a down converter material (which is of a nanometer sized scale) in proximity to a metal shell. Incident light at a wavelength λ_1 interacts with the upconverting dielectric core. The interaction of light λ_1 with the dielectric core produces a secondary emission at a frequency λ_2 which has a shorter wavelength than λ_1 and accordingly has a higher energy than λ_1. While the exact physical mechanisms for the upconversion may depend on the particular upconversion material and process being used in a particular application, for the purposes for discussion and illustration, the following explanation is offered.

[0372] In the context of FIG. **26**, when a wavelength λ_1 interacts with a dielectric material core, three separate processes are well understood for the upconversion process involving trivalent rare earth ions. These three processes are:

[0373] 1) excited state absorption whereby two photons are absorbed sequentially by the same ion to excite and populate one or more states;

[0374] 2) energy transfer upconversion which is a transfer of excitation from one ion to another already in an excited state; and

[0375] 3) a cooperative process of multiphotons where two nearby ions in excited states are emitting collectively from a virtual state.

[0376] Regardless of which one of these processes is occurring between the chosen ion(s) and the host lattice, the end result is a photon of energy greater than the excitation energy being emitted from the host lattice for the upconversion or down conversion process.

[0377] Therefore, the particular ion being activated (whether it be a dopant ion or a host ion of a lattice such as in the neodymium oxide) will be chosen based on the host material being processed, in order that the dopant ion or the host ion in the dielectric core provide ion states which are pumpable by a NIR source to generate the resultant emission λ_2.

[0378] Hence, the invention in one embodiment provides an upconversion or a down conversion material configured, upon exposure to a first wavelength λ_1 of radiation, to generate a second wavelength λ_2 of radiation having an energy higher or lower than the first wavelength λ_1. The system can include a metallic structure disposed in relation to the nanoparticle (e.g. a metallic shell covering a fraction of the nanoparticle). The system may include a receptor disposed in the medium in proximity to the nanoparticle. The receptor upon activation by the second wavelength k, may itself fluoresce producing visible light. In one embodiment of the invention, a physical characteristic of metallic structure (such as those described above and below in the drawings) is set to a value where a surface plasmon resonance in the metallic structure resonates at a frequency which provides spectral overlap with either the first wavelength λ_1 or the second wavelength λ_2. This system with a metallic structure disposed in relation to an up-conversion or a down-conversion nanoparticle becomes the converter utilized in the color enhancement/augmentation structures noted herein.

[0379] Within the context of the invention, the term "physical characteristic" of the metallic shell or core can relate to any characteristic of the metal itself or the shell or core dimensions or shape which affects the surface plasmon resonance frequency. Such physical characteristics can include, but are not limited to, a conductivity, a radial dimension, a chemical composition or a crystalline state of the metal shell or core.

[0380] In various embodiments, the metallic structures can be a metallic shell encapsulating at least a fraction of the nanoparticle in the metallic shell wherein a conductivity, a radial dimension, or a crystalline state of the metallic shell sets the surface plasmon resonance in the metallic structure to resonate at a frequency which provides spectral overlap with either the first wavelength λ_1 or the second wavelength λ_2. In various embodiments, the metallic structures can be a multi-layer metallic shell encapsulating at least a fraction of the nanoparticle in the metallic shell wherein a conductivity, a radial dimension, or a crystalline state of the metallic shell sets the surface plasmon resonance in the metallic structure to resonate at the first wavelength λ_1 and the second wavelength λ_2. This capability permits radiation at λ_1 and λ_2 to be amplified.

[0381] In various embodiments, the metallic structures can be a metallic particle existing in one or more multiple structures. These multiple structures can have a variety of shapes including for example sphere, spheroid, rod, cube, triangle, pyramid, pillar, crescent, tetrahedral shape, star or

combination thereof disposed adjacent the nanoparticle wherein a conductivity, a dimension (e.g. a lateral dimension or a thickness), or a crystalline state of the metallic structure sets the surface plasmon resonance in the metallic particle or rod to resonate at a frequency which provides spectral overlap with either the first wavelength λ_1 or the second wavelength λ_2. Such shapes are described in the present figures and in the figures in U.S. Ser. No. 12/401,478 which is incorporated by reference in its entirety. The shape choice can affect the frequency of the surface plasmon resonance. It is known that the plasmon band is changed by the shape of nanoparticles (e.g., prolate and obloid spheroids). The paper "Spectral bounds on plasmon resonances for Ag and Au prolate and oblate nanospheroids," in the Journal of Nanophotonics, Vol. 2, 029501 (26 Sep. 2008), the entire contents of which are incorporated by reference, shows plasmon resonance shifts for shaping of Ag and plasmon resonance shifts for shaping of Au of prolate and obloid spheroids. In one embodiment of the invention, with an increasing aspect ratio for a metallic structure of the invention, the prolate spheroid resonance is red shifted relative to a sphere with no lower limit (under the assumptions of a Drude dispersion model). On the other hand, the oblate resonances are "blue shifted" as the spheroid becomes increasingly flat, but up to a limit.

[0382] In various embodiments, the metallic structures disposed in relation to an up-conversion or a down-conversion nanoparticle can be a metallic structure disposed interior to the nanoparticle wherein a conductivity or a dimension (e.g. a lateral dimension or a thickness) of the metallic structure sets the surface plasmon resonance in the metallic structure to resonate at a frequency which provides spectral overlap with either the first wavelength λ_1 or the second wavelength λ_2. In various embodiments, the metallic structures can be a metallic multi-layer structure disposed interior to the nanoparticle wherein a conductivity or a dimension (e.g. a lateral dimension or a thickness) of the metallic structure sets the surface plasmon resonance in the metallic structure to resonate at the first wavelength λ_1 and the second wavelength λ_2. This capability once again permits radiation at λ_1 and λ_2 to be amplified.

[0383] In another embodiment, the invention provides a nanoparticle structure including a sub 1000 nm dielectric core and a metallic structure disposed in relation to the nanoparticle. The dielectric core includes at least one of Y_2O_3, Y_2O_2S, $NaYF_4$, $NaYbF_4$, YAG, YAP, Nd_2O_3, LaF_3, $LaCl_3$, La_2O_3, TiO_2, $LuPO_4$, YVO_4, YbF_3, YF_3, Na-doped YbF_3, or SiO_2. Such nanoparticle structures can exhibit in certain embodiments surface plasmon resonance in the metallic structures to enhance upconversion of light from a first wavelength λ_1 to a second wavelength λ_2.

[0384] As described above, a shell (or other structure) is in particular designed with a layer thickness (or for example a lateral dimension) to enhance the photon upconversion process through plasmonic enhancement. The thickness of the shell (or other physical characteristic) is "tuned" in its thickness to the absorption process by having a dimension in which plasmons (i.e., electrons oscillations) in shell have a resonance in frequency which provides spectral overlap with the absorption band targeted. Thus, if the upconversion is to be stimulated by 980 nm NIR light, then the thickness of the shell is "tuned" in a thickness to where a plasmon resonance resonates at a frequency also of 980 nm (or in the neighborhood thereof as plasmon resonances are typically broad at these wavelengths).

[0385] A plasmon resonating shell can be made of numerous transition metals, including though not limited to gold, silver, platinum, palladium, nickel, ruthenium, rhenium, copper, and cobalt or a combination or alloys or layers thereof. Such a plasmon resonating shell can be also made of a combination of metals and non-metals. When formed of a gold nanoshell, the recommended thickness to resonate with 980 nm light is approximately 3.5 nm surrounding an 80 nm upconverting core, as projected by extended Mie theory calculations. (See Jain et al., *Nanolett.* 2007, 7(9), 2854 the entire contents of which are incorporated herein by reference.) FIG. **27** is reproduced from Jain et al and illustrates the capability in the invention to "tune" the metal shell to have a spectral overlap with the excitation and/or emission radiation wavelengths.

[0386] In one embodiment of the invention, the metallic structures disposed in relation to an up-conversion or a down-conversion nanoparticle can be an alloy such as for example a Au:Ag alloy. The alloy content can be set to adjust the frequency of the surface plasmon resonance. In one embodiment of the invention, the metallic structures can be an alloy such as for example a Pt:Ag alloy. The alloy content can be set to adjust the frequency of the surface plasmon resonance. In one embodiment of the invention, the metallic structures can be an alloy such as for example a Pt:Au alloy. The alloy content can be set to adjust the frequency of the surface plasmon resonance.

[0387] In one embodiment of the invention, the converter nanoparticle can be an alloy of two or more materials. In this embodiment, the alloy can have a composition between the two or more materials which is set to a compositional value where excitation of the alloy at first wavelength λ_1 produces emission at the second wavelength λ_2. In one embodiment of the invention, the nanoparticle can be a zinc sulfide and zinc selenide alloy. In one embodiment of the invention, the nanoparticle can be a zinc sulfide and cadmium sulfide alloy.

[0388] In one embodiment of the invention, the zinc sulfide and zinc selenide nanoparticle alloy can have an alloy content set to provide a predetermined surface plasmon resonance. In one embodiment of the invention, the zinc sulfide and cadmium sulfide nanoparticle alloy can have an alloy content is set to provide a predetermined surface plasmon resonance.

[0389] Some techniques for producing nanoparticles and nanoparticle alloys which are suitable for the invention are described in the following documents, all of which are incorporated herein in their entirety: U.S. Pat. Nos. 7,645,318; 7,615,169; 7,468,146; 7,501,092; U.S. Pat. Appl. Publ. No. 2009/0315446; 2008/0277270; 2008/0277267; 2008/0277268: and WO 2009/133138.

[0390] In one embodiment of the invention, the thickness of the metal shell disposed in relation to an up-conversion or a down-conversion nanoparticle is set depending on the absorption frequency (or in some cases the emission frequency) of the particular dopant ions in the dielectric core to enhance the total efficiency of the emission process of the upconverted light. Accordingly, the thickness of the shell can be considered as a tool that in one instance enhances the absorption of λ_1, and in another instance can be considered as a tool that enhances the emission of λ_2, or in other

situations can be considered an enhancement feature that in combination enhances the overall net process.

[0391] Additionally, plasmon-phonon coupling may be used to reduce a resonance frequency through the tuning of the bands to a degree off resonance. This may be useful in optimizing resonance energy transfer processes for the purpose of shifting the outputted color to a color desirable for a painted, colored, or displayed surface. In one example, FIG. **27** shows an example of the plasmon resonance shift as a function of shell thickness.

[0392] Here, in one embodiment of the invention, the capability to produce stimulated emission at a targeted wavelength or color or energy is complemented by the ability to design nanoparticles that have designed absorption bands. Such absorption materials could for example further serve to improve the monochromaticity of light observed from a paint, ink, dye, or otherwise reflecting surface treated with the color enhancing compositions of the invention.

[0393] Details of the preparation of this nanoparticle system are included in U.S. Ser. No. 12/725,108, the entire contents of which are incorporated herein by reference. The absorption spectrum of Y_2O_3 alone (lower trace) is fairly featureless, showing absorption due to the tri-arginine near 200 nm and a gentle slope associated with scattering and absorption by the Y_2O_3 nanoparticles extending into the visible portion of the spectrum. The gold-coated Y_2O_3(upper trace), on the other hand, exhibit a strong absorption band at 546 nm, which is characteristic of the plasmonics resonance band due to the gold shell around the Y_2O_3 cores. The red-shifting of the plasmon absorption to 546 nm is consistent with the presence of a gold shell around a dielectric core.

[0394] In one embodiment of the invention, the converter materials for the upconverter dielectric core can include a wide variety of dielectric materials, as described above. In various embodiments of the invention, the upconverter dielectric core includes more specifically lanthanide doped oxide materials. Lanthanides include lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu). Other suitable dielectric core materials include non-lanthanide elements such as yttrium (Y) and scandium (Sc). Hence. suitable dielectric core materials include Y_2O_3, Y_2O_2S, $NaYF_4$, $NaYbF_4$, Na-doped YbF_3, YAG, YAP, Nd_2O_3, LaF_3, $LaCl_3$, La_2O_3, TiO_2, $LuPO_4$, YVO_4, YbF_3, YF_3, or SiO_2. These dielectric cores can be doped with Er, Eu, Yb, Tm, Nd, Tb, Ce, Y, U, Pr, La, Gd and other rare-earth species or a combination thereof.

[0395] Lanthanides usually exist as trivalent cations, in which case their electronic configuration is (Xe) $4f^n$, with n varying from 1 (Ce^{3+}) to 14 (Lu^{3+}). The transitions within the f-manifold are responsible for many of the photophysical properties of the lanthanide ions, such as long-lived luminescence and sharp absorption and emission lines. The f-electrons are shielded from external perturbations by filled 5s and 5p orbitals, thus giving rise to line-like spectra. The f-f electronic transitions are LaPorte forbidden, leading to long excited state lifetimes, in the micro- to millisecond range.

[0396] Accordingly, examples of doped materials in the invention include oxides such as yttrium oxide and neodymium oxide and aluminum oxide as well as sodium yttrium fluoride and nanocrystalline perovskites and garnets such as yttrium aluminum garnet (YAG) and yttrium aluminum perovskite (YAP). Of these materials, doping is required for some, but not all of these materials, for promoting upconversion efficiencies. In various embodiments of the invention, the host nanocrystals are doped with trivalent rare earth lanthanide ions from those lanthanide series elements given above.

[0397] More specifically, in various embodiments of the invention, pairs of these dopants are introduced in order to make accessible more energy states in the host crystal. The activation and pumping of these energy states follows closely the principles discussed above. Doping concentrations in the invention can range from 0.2% to 20% roughly per ion into the host lattice or in a weight or mol % variation. The efficiency of the upconversion processes of specific bands in these materials can be modulated by the percentages doped to induce and enhance targeted emissions. Lanthanide doped upconverters while not limited to, can use the following mol percent dopant compositions: 5% Er, 10% Yb, 0.2% Tm+3% Yb, and 1% Er+10%/0 Yb.

[0398] The size of the nanocrystal will also have an effect on the efficiency of the upconversion process, as a larger nanocrystal will have more sites for dopant ions to be accommodated into the host lattice, therefore enabling more emissions from the same doped host than if the nanocrystal were smaller. While the dopant percentages listed above are not rigidly fixed, these numbers provide a rudimentary teaching of the typical percentages one would use in obtaining a particular dielectric core material of the invention.

[0399] Moreover, some of these host crystals (e.g., neodymium oxide) in one embodiment of the invention may require no specific doping to facilitate upconversion, which has been seen in one instance in Nd_2O_3 with an excitation wavelength of 587 nm producing emissions at 372 nm, 402 nm, and 468 nm. See Que, W et al. Journal of Applied Physics 2001, vol 90, pg. 4865, the entire contents of which are incorporated herein by reference. Doping neodymium oxide with Yb^{3+}, in one embodiment of the invention, would enhance upconversion through sensitizing the Nd^{3+} ions with a lower energy Yb^{3+} activator.

[0400] In one embodiment of the invention, the dielectric core is coated, such as for example with a metallic shell, to enhance electron-phonon coupling and thereby increase up conversion or down conversion efficiency, as discussed above. In another embodiment of the invention, the shell can include a SiO_2- and/or TiO_2-coating, and this coating is in one embodiment coated on doped Y_2O_3 upconverting nanoparticles to thereby, in some instances, increase the upconversion efficiency relative to an uncoated nanocrystal. In another embodiment of the invention, the shell can include a SiO_2- and/or TiO_2-coating, and this coating is in one embodiment coated on doped Y_2O_3 down converting nanoparticles to thereby, in some instances, increase the down conversion efficiency relative to an uncoated nanocrystal. Further, in one embodiment of the invention, the coating can be a polymer. In one embodiment, this coating is provided on $NaYF_4$:Ln/$NaYF_4$ dielectric core. Such coatings can increase the upconversion efficiency relative to an uncoated upconverter.

[0401] In another embodiment of the invention, phonon modes of undoped host-lattice (e.g., Y_2O_3) nanocrystals are modulated, for example, by Au, Ag, Pt, and Pd shells of varying thicknesses. In various embodiments of the inven-

tion, the upconverter dielectric core and the shell system includes as upconverting nanocrystals Y_2O_3:Ln with $NaYF_4$ shells, Y_2O_3:Ln with Au(Ag,Pt) shells, $NaYF_4$:Ln with Y_2O_3 shells, $NaYF_4$:Ln with Au(Ag,Pt) shells. In this system, the core diameter and shell outer/inner diameter of the metallic coatings can be set to dimensions that are expected to be tunable to a plasmon mode overlap.

[0402] In other embodiments as discussed below, the metal coating or the metallic structure disposed in relation to an up-conversion or a down-conversion nanoparticle can exist inside the dielectric and the relative position of the metal structure to the dielectric structure can enhance plasmon resonance. These structures with the metallic structure inside can be referred to as a metallic core up converter or a metallic core down converter. The metallic core technique for energy conversion is useful since it takes advantage of metal nano-particles that have improved surface morphology compared to shell coatings on core dielectrics. The metal or metallic alloy in the inner core metallic energy converter can be selected to tune its plasmonic activity. These structures with the metallic structure outside can be referred to as a core up converter or a core down converter.

[0403] In various embodiments of the invention, the upconverter or down converter dielectric core can be coated with thiol-terminated silanes to provide a coating of SiO_2 about the core of similar reactivity to Y_2O_3. In one embodiment of the invention, the above-described methodology is used to synthesize core-shell nanoparticles of Y_2O_3:Ln with $NaYF_4$ shells, Y_2O_3:Ln with Au(Ag,Pt) shells, $NaYF_4$:Ln with Y_2O_3 shells, $NaYF_4$:Ln with Au(Ag,Pt) shells where core and shell diameters varying from 2 to 20 nm. In these material systems, the tuned ratio of core-to-shell diameter may permit a plasmon-phonon resonance which should amplify absorption of NIR light and/or upconverted emission. In these material systems, control of the core and shell diameters is one factor determining the size dependent effect and subsequent tuning of plasmon-phonon resonance.

[0404] In one embodiment of the invention, the upconverter dielectric core can be mixed core-shell materials including for example semiconducting Y_2O_3 and $NaYF_4$ cores doped with various Ln series metals, which have been shown to possess large upconverting efficiencies. These doped Y_2O_3 and $NaYF_4$ cores will have shells of Au(Ag,Pt, Pd) or undoped Y_2O_3 and $NaYF_4$ matrices which have the potential to enhance or tune the phonon modes needed for energy transfer in the upconversion process. Solubility can be enhanced, for example, by addition of thiolated organics (Au shell), organic chain triethanolsilane (Y_2O_3 shell), and trioctylphosphine-oleic amine ($NaYF_4$ shell). All core-shell nanoparticles may further be solubilized into a colloidal suspension with the addition of triarginine peptide, polyethylene glycol, and polyethyleneimine surfactants.

[0405] FIG. **28**A shows some of the various embodiments of the converter structures of the invention that can be designed: (a) a structure including upconverter (UC) molecules bound to a metal (gold) nanoparticle; (b) a structure including an UC-containing nanoparticle covered with metal nanoparticles, (c) a metal nanoparticle covered with an UC-containing nanocap; (d) an UC-containing nanoparticle covered with metal nanocap, (e) a metal nanoparticle covered with UC nanoshell, (f) an UC-containing nanoparticle covered with metal nanoshell, (g) an UC-containing nanoparticle covered with metal nanoshell with protective coating layer.

[0406] The configurations (while shown in the FIG. **28**A with UC-containing materials) would be applicable for enhancement for down converting materials such as the quantum dots or phosphors described herein. Moreover, in one embodiment of the invention, dielectric spacers (for examples silicates as discussed below) can be used with the structure of FIG. **6**A-b to space apart the particle type metallic structures. In another embodiment of the invention, dielectric spacers can be used with the structure of FIG. **28**A to space apart the metal layers, whether or not these layers are partial metal layers or continuous metal layers. See the schematics in FIG. **28**B

[0407] In various embodiments of the invention, multi-layer metallic nanoshells discussed in this application have the potential capability to enhance electromagnetically two spectral regions. Accordingly, the metallic structures of the invention can be used in the upconverting mode to enhance both the excitation at wavelength λ_1 and the emission at wavelength λ_2. This feature also can be used in the down converting to enhance primarily the emission at wavelength λ_2 and potentially the excitation at wavelength λ_1.

[0408] Such metallic structures in various embodiments of the invention include conducting materials made for example of metals, or doped glasses or doped semiconductors. These conducting materials can be in the form of pure or nearly pure elemental metals, alloys of such elemental metals, or layers of the conducting materials regardless of the constituency. The conducting materials can (as noted above) include non-metallic materials as minor components which do not at the levels of incorporation make the composite material insulating.

[0409] Similarly, in various embodiments of the invention, the up or down converting materials can include at least one of a dielectric, a glass, or a semiconductor. The up or down converting materials can include an alloy of two or more dielectric materials, an alloy of two or more glasses, or an alloy of two or more semiconductors.

[0410] Accordingly, FIG. **28**A represents embodiments of the invention where the dielectric core is supplemented with a shell. The shell can include a metal layer of a prescribed thickness. The metal layer can include materials such as nickel, gold, iron, silver, palladium, platinum and copper and combinations thereof. The metal layer can be also made of a combination of metals and non-metals. The shell functions as a plasmonic shell where surface plasmons can form in the metal between the dielectric core and the outer environment acting as an exterior dielectric. The shell (as shown) may not be a complete shell. Partial metallic shells or metallic shells of varying thicknesses are also acceptable in the invention.

[0411] As discussed below, the metallic shells in another embodiment of the invention serve as scattering centers for UV light where UV light which, even if absorbed in a paint or coating layer contributes at a minimum to localized heating of the paint or coating layer material, will be scattered from the paint or coated layer.

[0412] FIG. **28**C shows still further embodiments of plasmonics-active nanostructures having upconverting (UC) materials that can be designed: (a) a metal nanoparticle, (b) an UC nanoparticle core covered with metal nanocap, (c) a spherical metal nanoshell covering an UC spheroid core, (d) an oblate metal nanoshell covering UC spheroid core, (e) a metal nanoparticle core covered with UC nanoshell, (f) a metal nanoshell with protective coating layer, (g) multi-layer

metal nanoshells covering an UC spheroid core, (h) multi-nanoparticle structures, (i) a metal nanocube and nanotriangle/nanoprism, and (j) a metal cylinder.

[0413] FIG. **28**D shows yet other embodiments of plasmonics-active nanostructures having upconverting materials with linked photo-active (PA) molecules that can be designed. For example, for the case of psoralen (as the PA molecule), the length of the linker between the PA molecule and the UC material or the metal surface is tailored such that it is sufficiently long to allow the PA molecules to be active (attach to DNA) and short enough to allow efficient excitation of light from the UC to efficiently excite the PA molecules. FIG. **28**D shows (a) PA molecules bound to an UC nanoparticle, (b) an UC material-containing a nanoparticle covered with metal nanoparticles, (c) a metal nanoparticle covered with UC material nanocap, (D) an UC material-containing nanoparticle covered with metal nanocap, (e) a metal nanoparticle covered with an UC material nanoshell, (f) an UC material-containing nanoparticle covered with metal nanoshell, (g) an UC material-containing nanoparticle covered with metal nanoshell with protective coating layer.

[0414] With the upconverter and down converter structures of the invention, a plasmonics effect is advantageous. A plasmonics effect can increase the local intensity of the received light or the local intensity of the emitted light from the up and/or down converter structures of the invention. A plasmonics effect can occur throughout the electromagnetic region provided the suitable nanostructures, nanoscale dimensions, metal types are used. Plasmonic effects are possible over a wide range of the electromagnetic spectrum, ranging from gamma rays and X rays throughout ultraviolet, visible, infrared, microwave and radio frequency energy. However, for practical reasons, visible and NIR light are used for metal structures such as for example silver and gold nanoparticles, since the plasmon resonances for silver and gold occur in the visible and NIR region, respectively.

[0415] In various embodiments, nanoparticles of neodymium and ytterbium doped yttrium oxide, europium and ytterbium doped yttrium oxide, and any combination of rare earth trivalent ions doped into a neodymium oxide nanocrystal can be used. The dual doped yttrium oxide of composition neodymium and ytterbium and also the dual doped europium and ytterbium are new for the yttrium oxide host lattice, although such dual doped systems have been shown to work in other host lattices such as YAG.

[0416] These dual doped lanthanide glasses have been shown to upconvert efficiently on bulk materials, and thereby can provide new upconverter structures at the nanoscale. There are advantages offered by these yttrium oxide nanostructures of the invention. The small scale synthetic methodology for creating nanoscale yttrium oxide is easier to control and produce in yttrium oxide than in YAG. The host structure of yttrium oxide scintillates by down conversion. These combinations of dopants in yttrium oxide for example can provide predetermined emission colors for the yttrium oxide nanocrystal for the color shifting of the invention.

[0417] In one embodiment of the invention, a dual dopant permits excitation of either ion in the host glass. For instance, excitation by 980 nm light excites an ytterbium ion, where through transfer of energy from one excited state of the ytterbium ion to another dopant provides a mechanism for upconversion emission of light in the visible and NIR spectral regions.

[0418] Up-conversion phosphors similar in chemical compositions to the down-conversion fluorescent materials discussed above can be used. The up-conversion phosphors can include laser dyes, e.g., the organic small molecules that can be excited by the absorption of at least two infrared photons with emission of visible light. The up-conversion phosphors can include fluorescent polymers, e.g., the class of polymers that can be excited by the absorption of at least two infrared photons with emission of visible light. The up-conversion phosphors can include inorganic or ceramic particles or nano-particles, including the conventional up-conversion phosphors (e.g. metal fluorides, metal oxides) that can be excited by the absorption of at least two infrared photons with emission of visible light. The up-conversion phosphors can include semiconductor particles, including nano-particles such as II-VI or III-V compound semiconductors, e.g. quantum dots, described in details in the "down-conversion" semiconductors above.

[0419] Fluorescent up-conversion inorganic phosphors can include but are not limited to metal oxides, metal halides, metal chalcogenides (e.g. sulfides), or their hybrids, such as metal oxo-halides, metal oxo-chalcogenides. Fluorescent up-conversion inorganic phosphors are usually doped with rare earth elements (e.g. Yb^{3+}, Er^{3+}, Tm^{3+}). Some host examples include, but are not limited to: $NaYF_4$, YF_3, $BaYF_5$, LaF_3, La_2 MoO_8, $LaNbO_4$, LnO_2S; where Ln is the rare earth elements, such as Y, La, Gd).

[0420] These converters (and the other energy converters described herein which receive energy and generate light or electron emission) can optionally include any of the energy augmentation structures described above.

[0421] In various embodiments of the invention, energy converters can be used with the energy augmentators described above for color enhancement. In some embodiments, the converters are up conversion of light e.g., from the IR regime into visible electromagnetic radiation and for down conversion of light e.g., from the UV range into visible electromagnetic radiation. The invention in various embodiments up converts energy, preferably light in the visible spectrum. The invention encompasses a variety of applications where the up and down conversion materials with or without energy augmentators are included to enhance the color of the object being displayed. These application areas can include paints on signs, walls, cars, buildings, boats, airplanes. These application areas can include display monitors, computer monitors, telephone displays, watch dials, instrument dials to name but a few.

[0422] Among various materials, luminescent nanoparticles have attracted increasing technological and industrial interest. In the context of the invention, nanoparticle refers to a particle having a size less than one micron. While the description of the invention describes specific examples using nanoparticles, the invention in many embodiments is not limited to particles having a size less than one micron. However, in many of the embodiments, the size range of less than one micron, and especially less than 100 nm produces properties of special interest such as for example emission lifetime luminescence quenching, luminescent quantum efficiency, and concentration quenching and such as for example diffusion, penetration, and dispersion into mediums where larger size particles would not migrate.

[0423] This invention in various embodiments can use a wide variety of down conversion materials (or mixtures of down conversion materials) with or without the energy

augmentators to enhance a particular color of light observable to an observer. These down conversion materials can include quantum dots, semiconductor materials, alloys of semiconductor materials, scintillation and phosphor materials, materials that exhibit X-ray excited luminescence (XEOL), organic solids, metal complexes, inorganic solids, crystals, rare earth materials (lanthanides), polymers, scintillators, phosphor materials, etc., and materials that exhibit excitonic properties. Accordingly, the down conversion materials to enhance color emission can convert energy from one of ultraviolet light, x-rays, and high energy particles to visible light. The down conversion materials to enhance color emission can convert energy from higher energy visible light to lower energy visible light with or without the energy augmentators.

[0424] In one embodiment of the invention, a quantum dot mixture with or without the energy augmentators can be used for color enhancement. Quantum dots are in general nanometer size particles whose energy states in the material of the quantum dot are dependent on the size of the quantum dot. For example, quantum dots are known to be semiconductors whose conducting characteristics are closely related to the size and shape of the individual crystal. Generally, the smaller the size of the crystal, the larger the band gap, the greater the difference in energy between the highest valence band and the lowest conduction band becomes. Therefore, more energy is needed to excite the dot, and concurrently, more energy is released when the crystal returns to its resting state. In fluorescent dye applications, this equates to higher frequencies of light emitted after excitation of the dot as the crystal size grows smaller, resulting in a color shift from red to blue in the light emitted. Quantum dots represent one way to down convert ultraviolet light of the spectrum to a targeted color emission, such as for example a green light emission. Quantum dots represent one way to down convert blue light of the spectrum to a targeted color emission, such as for example a green light emission.

[0425] As described in U.S. Pat. No. 6,744,960 (the entire contents of which are incorporated by reference), different size quantum dots produce different color emissions. In that work and applicable to this invention, quantum dots can comprise various materials including semiconductors such as zinc selenide (ZnSe), cadmium selenide (CdSe), cadmium sulfide (CdS), indium arsenide (InAs), and indium phosphide (InP). Another material that may suitably be employed is titanium dioxide (TiO_2). The size of the particle, i.e., the quantum dot **18**, may range from about 2 to 10 nm. Since the size of these particles is so small, quantum physics governs many of the electrical and optical properties of the quantum dot. One such result of the application of quantum mechanics to the quantum dot **18** is that quantum dots absorb a broad spectrum of optical wavelengths and re-emit radiation having a wavelength that is longer than the wavelength of the absorbed light. The wavelength of the emitted light is governed by the size of the quantum dot. For example, CdSe quantum dots 5.0 nm in diameter emit radiation having a narrow spectral distribution centered about 625 nm while quantum dots **18** including CdSe 2.2 nm in size emit light having a center wavelength of about 500 nm. Semiconductor quantum dots comprising CdSe, InP, and InAs, can emit radiation having center wavelengths in the range between 400 nm to about 1.5 μm. Titanium dioxide TiO_2 also emits in this range. The linewidth of the emission, i.e., full-width half-maximum (FWHM), for these semiconductor materials may range from about 20 to 30 nm. To produce this narrowband emission, quantum dots simply need to absorb light having wavelengths shorter than the wavelength of the light emitted by the dots. For example, for 5.0 nm diameter CdSe quantum dots light having wavelengths shorter than about 625 nm is absorbed to produce emission at about 625 nm while for 2.2 nm quantum dots comprising CdSe light having wavelengths smaller than about 500 nm is absorbed and re-emitted at about 500 nm. In practice, however, the excitation or pump radiation is at least about 50 nanometers shorter than the emitted radiation.

[0426] Specifically, in one embodiment of the invention, a quantum dot mixture (QDM) coating can be deposited using CVD and or sol-gel techniques using standard precipitation techniques to be used with or without the energy augmentators. The QDM coating can be made of a silicate structure that does not diminish UV output. Within the silicate family, silica (SiO_2) is suitable since it maximizes UV transmission through the coating. The coating can further include a second layer of a biocompatible glass. Such bio-compatible glass and glass ceramic compositions can contain calcium, a lanthanide or yttrium, silicon, phosphorus and oxygen. Other biocompatible materials and techniques are described in the following patents which are incorporated herein in their entirety: U.S. Pat. Nos. 5,034,353; 4,786,617; 3,981,736; 3,922,155; 4,120,730; and U.S. Pat. Appl. Nos. 2008/0057096; 2006/0275368; and 2010/0023101.

[0427] Further, the down conversion materials for the invention described here can be coated with insulator materials such as for example silica which will reduce the likelihood of any chemical interaction between the luminescent particles and the medium the particles are included therein. These and the other conversion materials here can be used with or without the energy augmentators. For biocompatible applications of inorganic nanoparticles, one of the major limiting factors is their toxicity. Generally speaking, all semiconductor nanoparticles are more or less toxic. For biocompatible applications, nanoparticles with toxicity as low as possible are desirable or else the nanoparticles have to remain separated from the medium. Pure TiO_2, ZnO, and Fe_2O_3 are biocompatible. CdTe and CdSe are toxic, while ZnS, CaS, BaS, SrS and Y_2O_3 are less toxic. In addition, the toxicity of nanoparticles can result from their inorganic stabilizers, such as TGA, or from dopants such as Eu^{2+}, Cr^{3+} or Nd^{3+}. Other suitable down conversion materials which would seem the most biocompatible are zinc sulfide, ZnS:Mn^{2+}, ferric oxide, titanium oxide, zinc oxide, zinc oxide containing small amounts of Al_2O_3, and AgI nanoclusters encapsulated in zeolite. For non-medical applications, where toxicity may not be as critical a concern, the following materials (as well as those listed elsewhere) are considered suitable: lanthanum and gadolinium oxyhalides activated with thulium; Er^{3+} doped $BaTiO_3$ nanoparticles, Yb^{3+} doped $CsMnCl_3$ and $RbMnCl_3$, BaFBr:Eu^{2+} nanoparticles, Cesium Iodine, Bismuth Germanate, Cadmium Tungstate, and CsBr doped with divalent Eu.

[0428] In various embodiments of the invention, the following luminescent polymers are also suitable as conversion materials with or without the energy augmentators: poly (phenylene ethynylene), poly(phenylene vinylene), poly(p-phenylene), poly(thiophene), poly(pyridyl vinylene), poly (pyrrole), poly(acetylene), poly(vinyl carbazole), poly (fluorenes), and the like, as well as copolymers and/or derivatives thereof.

[0429] In various embodiments of the invention, the following materials can be used similar to that detailed in U.S. Pat. No. 7,090,355, the entire contents of which are incorporated herein by reference. For down-conversion, the following materials can be used with or without the energy augmentators. Inorganic or ceramic phosphors or nanoparticles, including but not limited to metal oxides, metal halides, metal chalcogenides (e.g. metal sulfides), or their hybrids, such as metal oxo-halides, metal oxo-chalcogenides. Laser dyes and small organic molecules, and fluorescent organic polymers. Semiconductor nano-particles, such as II-VI or III-V compound semiconductors, e.g. fluorescent quantum dots. Organometallic molecules including at least a metal center such as rare earth elements (e.g. Eu, Tb, Ce, Er, Tm, Pr, Ho) and transitional metal elements such as Cr, Mn, Zn, Ir, Ru, V, and main group elements such as B, Al, Ga, etc. The metal elements are chemically bonded to organic groups to prevent the quenching of the fluorescence from the hosts or solvents. Phosphors can be used including the Garnet series of phosphors: $(Y_mA_{1-m})_3(Al_nB_{1-n})_5O_{12}$, doped with Ce; where 0≤m, n≤1, where A includes other rare earth elements, B includes B, Ga. In addition, phosphors containing metal silicates, metal borates, metal phosphates, and metal aluminates hosts can be used. In addition, nanoparticulates phosphors containing common rare earth elements (e.g. Eu, Tb, Ce, Dy, Er, Pr, Tm) and transitional or main group elements (e.g. Mn, Cr, Ti, Ag, Cu, Zn, Bi, Pb, Sn, TI) as the fluorescent activators, can be used. Materials such as Ca, Zn, Cd in tungstates, metal vanadates, ZnO, etc. can be used with or without the energy augmentators.

[0430] The commercial laser dye materials obtained from several laser dye vendors, including Lambda Physik, and Exciton, etc. can also be used with or without the energy augmentators. A partial list of the preferred laser dye classes includes: Pyrromethene, Coumarin, Rhodamine, Fluorescein, other aromatic hydrocarbons and their derivatives, etc. In addition, there are many polymers containing unsaturated carbon-carbon bonds, which also serve as fluorescent materials and find many optical and fluorescent applications. For example, MEH-PPV, PPV, etc. have been used in optoelectronic devices, such as polymer light emitting diodes (PLED). Such fluorescent polymers can be used directly as the fluorescent layer of the transparent 2-D display screen.

[0431] As noted above, semiconductor nanoparticles (e.g., quantum dots) can be used with or without the energy augmentators. The terms "semiconductor nanoparticles," in the art refers to an inorganic crystallite between 1 nm and 1000 nm in diameter, preferably between 2 nm to 50 nm. A semiconductor nano-particle is capable of emitting electromagnetic radiation upon excitation (i.e., the semiconductor nano-particle is luminescent). The nanoparticle can be either a homogeneous nano-crystal, or comprises of multiple shells. For example, the nanoparticle can include a "core" of one or more first semiconductor materials, and may be surrounded by a "shell" of a second semiconductor material. The core and/or the shell can be a semiconductor material including, but not limited to, those of the group II-VI (ZnS, ZnSe, ZnTe, CdS, CdSe, CdTe, HgS, HgSe, HgTe, MgS, MgSe, MgTe, CaS, CaSe, CaTe, SrS, SrSe, SrTe, BaS, BaSe, BaTe, and the like) and III-V (GaN, GaP, GaAs, GaSb, InN, InP, InAs, InSb, and the like) and IV (Ge, Si, and the like) materials, and an alloy or a mixture thereof.

[0432] Fluorescent organometallic molecules containing rare earth or transitional element cations can be used for down conversion materials with or without the energy augmentators. Such molecules include a metal center of rare earth elements including Eu, Tb, Er, Tm, Ce protected with organic chelating groups. The metal center may also include transitional elements such as Zn, Mn, Cr, Ir, etc. and main group elements such as B, Al, Ga. Such organometallic molecules can readily dissolve in liquid or transparent solid host media. Some examples of such fluorescent organometallic molecules include: 1. Tris(dibenzoylmethane)mono (phenanthroline)europium(III); 2. Tris(8-hydroxyquinoline) erbium; 3. Tris(1-phenyl-3-methyl-4-(2,2-dimethylpropan-1-oyl)pyrazolin-5-one)terbium(III); 4. Bis(2-methyl-8-hydroxyquinolato)zinc; 5. Diphenylborane-8-hydroxyquinolate.

[0433] Specific examples of down-conversion materials for red emission include those discussed above and europium complexes such as those described in JP Laid-open Patent Publication (Kokai) No. 2003-26969, constructed such that p-diketone ligand is coordinated to europium forming an europium complex capable of emitting red fluorescence. Other specific examples of the rare earth element complexes include complexes include lanthanum (Ln), europium (Eu), terbium (Tb), and gadolinium (Gd) and combinations thereof. A europium (Eu) complex is capable of emitting red fluorescence when irradiated with ultraviolet rays having a wavelength ranging from 365 nm to 410 nm. Terbium (Tb) is capable of emitting green fluorescence when irradiated with ultraviolet rays having a wavelength of 365 nm.

[0434] In other down-conversion embodiments with or without the energy augmentators, the down conversion materials which emit red light may include europium, light emitting particles which emit green light may include Terbium, and light emitting particles which emit blue or yellow light may include cerium (and/or thulium). In up-conversion embodiments, up conversion materials which emit red light may include praseodymium, light emitting particles which emit green light may include erbium, and light emitting particles which emit blue light may include thulium. In embodiments, the conversion materials can be light emitting particles made of fluorescent molecules that emit different colors (e.g. red, green, and blue). In embodiments, the conversion materials can be light emitting particles made of pure organic or organo-metallic dyes with or without the energy augmentators.

[0435] In addition to the combinations of rare earth complexes, such as a combination of a europium complex and a terbium complex, it is also possible employ a combination of a europium complex and a green-emitting fluorescent substance which is not a complex, or a combination of a terbium complex and a red-emitting fluorescent substance which is not a complex.

[0436] Other down converter materials with or without the energy augmentators include for example ZnS, PbS, SbS_3, MoS_2, PbTe, PbSe, BeO, MgO. Li_2CO_3, $Ca(OH)_2$, MoO_3, SiO_2, Al_2O_3, TeO_2, SnO_2, KBr, KCl, and NaCl. These materials can include dopants to tailor the emission properties, as noted above. Examples of doped (or alloyed) glass systems suitable for the include Y_2O_3:Gd, Y_2O_3:Dy, Y_2O_3:Tb, Y_2O_3:Ho, Y_2O_3:Er, Y_2O_3:Tm, Gd_2O_3:Eu, Y_2O_2S:Pr, Y_2O_2S:Sm, Y_2O_2S:Eu, Y_2O_2S:Tb, Y_2O_2S:Ho, Y_2O_2S:Er, Y_2O_2S:Dy, Y_2O_2S:Tm, ZnS:Ag:Cl (blue), ZnS:Cu:Al (green), Y_2O_2S:Eu (red), Y_2O_3:Eu (red), YVO_4:Eu (red), and Zn_2SiO_4:Mn (green).

[0437] With regard more specifically to down converter materials suitable for the invention with or without the energy augmentators, U.S. Pat. No. 4,705,952 (the contents of which are hereby incorporated herein by reference) describes an infrared-triggered phosphor that stores energy in the form of visible light of a first wavelength and released energy in the form of visible light of a second wavelength when triggered by infrared light. The phosphors in U.S. Pat. No. 4,705,952 were compositions of alkaline earth metal sulfides, rare earth dopants, and fusible salts. The phosphors in U.S. Pat. No. 4,705,952 were more specifically phosphors made from strontium sulfide, barium sulfide and mixtures thereof; including a dopant from the rare earth series and europium oxide, and mixtures thereof; and including a fusible salt of fluorides, chlorides, bromides, and iodides of lithium, sodium, potassium, cesium, magnesium, calcium, strontium, and barium, and mixtures thereof. The materials described in U.S. Pat. No. 4,705,952 are useful in various embodiments of the invention with or without the energy augmentators.

[0438] In other embodiments of the invention, the down converter materials (or mixtures of down converters materials can include Y_2O_3:Li. Sun et al "Luminescent properties of Li+ doped nanosized Y_2O_3:Eu," Solid State Comm. 119 (2001) 393-396 (the entire contents of which are incorporated herein by reference) describe such materials. Hou et al "Luminescent properties nano-sized Y_2O_3:Eu fabricated by co-precipitation method," Journal of Alloys and Compounds, vol. 494, issue 1-2, 2 Apr. 2010, pages 382-385 (the entire contents of which are incorporated herein by reference) describe that nano-sized yttria (Y_2O_3) powders have been successfully synthesized by a co-precipitation method. The powders were well crystallized, and the grains were almost spherical with good dispersibility. The quenching concentration of Eu^{3+} ions is 9 mol % which is much higher than micro-scaled powders. The incorporation of Li+ ions greatly improved the luminescence intensity. The highest emission intensity was observed with 4 mol % Li+ doped Y_2O_3:Eu powder ($(Y_{0.87}Eu_{0.09}Li_{0.04})_2O_3$) and the fluorescence intensity was increased by as much as 79%. Yi et al "Improved cathodoluminescent characteristics of Y_2O_3:Eu^{3+} thin films by Li-doping," Appl. Phys. A 87, 667-671 (2007) (the entire contents of which are incorporated herein by reference) describe cathodoluminescent spectra for both Y_2O_3:Eu^{3+} and Li-doped Y_2O_3:Eu^{3+} films and methods for making these materials.

[0439] The invention in other embodiments can use a wide variety of up conversion materials (or mixtures of up converters) with or without the energy augmentators to enhance a particular color of light observable from reflective material or surface. These up conversion materials can include similar materials as discussed above with regard to down conversion but typically included doped or impurity states in a host crystal that provide a mechanism for up conversion pumping. Accordingly, the up conversion materials to enhance color emission can convert energy from one of near infrared, infrared, and microwave irradiation. The upconversion materials to enhance color emission can convert energy from lower energy visible light to higher energy visible light.

[0440] Upconversion materials with or without the energy augmentators can be used in various ways to enhance visible light emission by way of conversion of infrared light from a solar spectrum (as in daylight exposure) or a black body spectrum (as in an incandescent lamp). In one example, a nanoparticle of a lanthanide doped oxide can be excited with near infrared light such as laser light at 980 nm and 808 nm to produce visible light in different parts of the red, green, blue spectrum depending on the dopant trivalent rare earth ion(s) chosen, their concentration, and the host lattice.

[0441] The lanthanide doped oxides suitable for this invention differ from more traditional multi-photon up conversion processes where the absorption of, for example, two photons is needed in a simultaneous event to promote an electron from a valence state directly into an upper level conduction band state where relaxation across the band gap of the material produces fluorescence. Here, the co-doping produces states in the band gap of the $NaYF_4$ such that the Yb^{3+} ion has an energy state at $^2F_{5/2}$ pumpable by a single photon event and from which other single photon absorption events can populate even higher states. Once in this exited state, transitions to higher energy radiative states are possible, from which light emission will be at a higher energy than that of the incident light pumping the $^2F_{5/2}$ energy state. In other words, the energy state at $^2F_{5/2}$ of the Yb^{3+} ion is the state that absorbs 980 nm light permitting a population build up serving as the basis for the transitions to the higher energy states such as the $^4F_{7/2}$ energy state. Here, transitions from the $^4F_{7/2}$ energy state produce visible emissions.

[0442] U.S. Pat. No. 7,008,559 (the entire contents of which are incorporated herein by reference) describes the upconversion performance of ZnS where excitation at 767 nm produces emission in the visible range. The materials described in U.S. Pat. No. 7,008,559 (including the ZnS as well as Er^{3+} doped $BaTiO_3$ nanoparticles and Yb^{3+} doped $CsMnCl_3$) are suitable in various embodiments of the invention with or without the energy augmentators.

[0443] Further, materials specified for up conversion materials in the invention with or without the energy augmentators include CdTe, CdSe, ZnO, CdS, Y_2O_3, MgS, CaS, SrS and BaS. Such up conversion materials may be any semiconductor and more specifically, but not by way of limitation, sulfide, telluride, selenide, and oxide semiconductors and their nanoparticles, such as $Zn_{1-x}Mn_xS_y$, $Zn_{1-x}Mn_xSe_y$, $Zn_{1-x}Mn_xTe_y$, $Cd_{1-x}Mn_xS_y$, $Cd_{1-x}Mn_xSe_y$, $Cd_{1-x}Mn_xTe_y$, $Pb_{1-x}Mn_xS_y$, $Pb_{1-x}Mn_xSe_y$, $Pb_{1-x}Mn_xTe_y$, $Mg_{1-x}Mn_xS_y$, $Ca_{1-x}Mn_xS_y$, $Ba_{1-x}Mn_xS_y$ and Sr_{1-x}, etc. (wherein, $0<x\leq 1$, and $0<y\leq 1$). Complex compounds of the above-described semiconductors are also contemplated for use in the invention—e.g. $(M_{1-z}N_z)_{1-x}Mn_xA_{1-y}B_y$ (M=Zn, Cd, Pb, Ca, Ba, Sr, Mg; N=Zn, Cd, Pb, Ca, Ba, Sr, Mg; A=S, Se, Te, O; B=S, Se, Te, O; $0<x\leq 1$, $0<y\leq 1$, $0<z\leq 1$). Two examples of such complex compounds are $Zn_{0.4}Cd_{0.4}Mn_{0.2}S$ and $Zn_{0.9}Mn_{0.1}S_{0.8}Se_{0.2}$. Additional conversion materials include insulating and nonconducting materials such as BaF_2, BaFBr, and $BaTiO_3$, to name but a few exemplary compounds. Transition and rare earth ion co-doped semiconductors suitable for the invention include sulfide, telluride, selenide and oxide semiconductors and their nanoparticles, such as ZnS; Mn; Er; ZnSe; Mn, Er; MgS; Mn, Er; CaS; Mn, Er; ZnS; Mn, Yb; ZnSe; Mn, Yb; MgS; Mn, Yb; CaS; Mn, Yb etc., and their complex compounds: $(M_{1-z}N_z)_{1-x}(Mn_qR_{1-q})_xA_{1-y}B_y$ (M=Zn, Cd, Pb, Ca, Ba, Sr, Mg; N=Zn, Cd, Pb, Ca, Ba, Sr, Mg; A=S, Se, Te, O; B=S, . . . $0<z\leq 1$, $o<q\leq 1$).

[0444] Some nanoparticles such as ZnS:Tb^{3+}, Er^{3+}; ZnS:Tb^{3+}; Y_2O_3:Tb^{3+}; Y_2O_3:Tb^{3+}, Er^{3+}; ZnS:Mn^{2+}; ZnS:Mn, Er^{3+} are known in the art to function for both down-conversion luminescence and upconversion luminescence

and would be suitable for the invention with or without the energy augmentators. In up-conversion embodiments, light emitting particles which emit red light may include praseodymium, light emitting particles which emit green light may include erbium, and light emitting particles which emit blue light may include thulium.

[0445] In general, the upconversion process generally requires one of more rare-earth dopants, such as Er, Eu, Yb, Tm, Nd, Tb, Ce, Y, U, Pr, La, Gd and other rare-earth species or a combination thereof, doped into a dielectric crystal (of any size >0.1 nm), including at least one of Y_2O_3, Y_2O_2S, $NaYF_4$, $NaYbF_4$, YAG, YAP, Nd_2O_3, LaF_3, $LaCl_3$, La_2O_3, TiO_2, $LuPO_4$, YVO_4, YbF_3, YF_3, Na-doped YbF_3, or SiO_2, where incident radiation is at longer wavelength than emissive radiation from the crystal. The wavelength emitted in based entirely on the dopant ion(s) chosen and their associated and relative concentration in the host crystal. For the example of upconversion in a Y_2O_3 host crystal, to achieve a blue emission (~450-480 nm) one could synthesize [Y_2O_3; Yb (3%), Tm (0.2%)], where the Yb and Tm are the percentages doped in the crystal relative to the Y atoms being 100%. Likewise, typical green upconversion materials are [Y_2O_3; Yb (5%), Ho (1%)] and [Y_2O_3; Yb (2%), Er (1%)], and typical red upconversion materials are [Y_2O_3; Yb (10%), Er (1%)] and [Y_2O_3; Yb (5%), Eu (1%)]. The concentrations of dopants relative to each other and the crystal matrix must be tuned for every combination, and there are multiple ways to achieve multiple colors from even the same dopants with or without the energy augmentators.

[0446] Up-conversion of red light with a wavelength of about 650 nm in Tm^{3+} doped flourozirconate glasses can be used in the invention to produce blue light. In this system, the blue light consists of two emission bands; one at 450 nm which is ascribed to the 1D2→3H4 transition, the others at 475 nm is ascribed to the 1G4→3H6 transition. The emission intensities of both bands have been observed by others to vary quadratically with the excitation power. For glasses with a Tm^{3+} concentration of 0.2 mol % and greater, cross-relaxation processes occur which decrease the upconversion efficiency.

[0447] The emission of visible light upon excitation in the near-infrared (NIR) has been observed in optically clear colloidal solutions of $LuPO_4$:Yb^{3+}, Tm^{3+}, and $YbPO_4$:Er^{3+} nanocrystals in chloroform. Excitation at 975 nm has been shown by others to produce visible luminescence in the blue, green, or red spectral regions.

[0448] Tellurium and germanium oxides (tellurites and germinates) are also suitable upconverters. These glasses can be doped with Tm, Yb, Ho, Er, Pr, for example.

[0449] Yb^{3+} doped $BaZrO_3$ is also suitable for upconversion. Er^{3+} and/or Tm^{3+} doping are also suitable for tailoring the emission wavelengths.

[0450] In another embodiment, Nd^{3+}:$Cs_2NaGdCl_6$ and Nd^{3+}, Yb^{3+}:$Cs_2NaGdCl_6$ polycrystalline powder samples prepared by Morss method have been reported to be up converters and are suitable for the present invention. These materials, under 785 nm irradiation, have shown upconversion emissions near 538 nm (Green), 603 nm (Orange), and 675 nm (Red) were observed and assigned to 4G7/2→4I9/2, (4G7/2→4I11/2; 4G5/2→4I9/2), and (4G7/2→4I13/2; 4G5/2→4I11/2), respectively.

[0451] In another embodiment, Nd^{3+} and Ho^{3+} co-doped-based ZrF_4 fluoride glasses under 800 nm excitation have been reported to be up converters and are suitable for the present invention. Among the up-conversion luminescences for the ZrF_4 fluoride glasses, the green emission was seen to be extremely strong and the blue and red emission intensities were very weak.

[0452] In another embodiment, Tm^{3+}/Yb^{3+}-codoped TeO_2—Ga_2O_3—R_2O (R=Li, Na, K) glasses have been reported to be up converters and are suitable for the present invention. These materials, under excitation at 977 nm, showed intense blue upconversion emission centered at 476 nm along with a weak red emission at 650 nm.

[0453] In another embodiment, metal-to-ligand charge transfer (MLCT) transition in $[Ru(dmb)_3]^{2+}$ (dmb=4,4'-dimethyl-2,2'-bipyridine) in the presence of anthracene or 9,10-diphenylanthracene have been reported converters and are suitable for the present invention. Upconverted to be up converters and are suitable for the present invention. Upconverted singlet fluorescence resulting from triplet-triplet annihilation at low excitation power has been reported. In particular 9,10-diphenylanthracene (DPA) (substituted for anthracene) showed higher efficiencies for upconversion. In these experiments, workers with this material system assumed that DPA's increased singlet fluorescence quantum yield (=0.95) relative to anthracene (=0.27)7. This work lead to an approximate 24.4±6.1 enhancement of green-to-blue light upconversion permitting direct visualization of the process at low excitation power, for example by a commercial green laser pointer (λ_{ex}=532 nm, <5 mW peak power).

[0454] The structures described herein for color enhancement with the energy augmentation structures are denoted as color enhancing/energy augmentation structures or as energy enhancing/augmentation structures.

[0455] By having the energy converters or color converting or enhancing materials disposed in a vicinity of the energy augmentation structures of this invention, regardless of the whether the energy augmentation structure is in a region of intensified electric field or otherwise outside the region of intensified electric field, the color enhancing/energy augmentation structures or the energy enhancing/augmentation structures of the invention are able to produce light which can be used for a variety of applications, in particular for photostimulation of biological, chemical, and physical reactions such as for example photoactivation of photoreactive drugs, photoactivation of photosensitive materials such as adhesives or lithographic photoresists, or for direct interaction with biological and chemical agents in the environment of the augmentation structures, as in sterilization.

[0456] Accordingly, in one embodiment of the invention, the color enhancement structures described herein can receive polychromatic light from a variety of sources such as sunlight, incandescent bulbs, fluorescent tube, and LED light sources with each having different wavelengths or wavelength bands. For these wavelength different bands, the resonators are "matched" or "tuned" to those wavelengths such that an intense electric field is established especially between the external-electrode pairs, or the folded resonator electrode pairs if used. In those regions of intense electric field can be disposed color converters (up and/or down phosphors) which can take light from one of the different wavelengths or wavelength bands, and have light of another wavelength or of different wavelength bands be emitted therefrom. In one embodiment, the intense electric field increases the intensity of the emitted light from the phosphors. Moreover, unlike the above-noted plasmonics where

the electric field enhancement is restricted to regions within 100 to 200 nm of the metal, the resonators establish an increased electric field within the volume of the external-electrode pair, or the folded resonator electrode pairs if used, such that the phosphor material in a vicinity and within the external-electrode pair (or the folded resonator electrode pairs) exhibits an intensity larger than if the converter were remote from the resonator.

[0457] In view of the above, this invention is directed in general to methods and systems for color enhancement utilizing a color enhancement structure having a) an energy collector comprising at least one energy augmentation structure, and b) an energy converter capable of converting a second wavelength/quantum of electromagnetic energy into and emitting therefrom a third wavelength of light shifted in wavelength/energy from the second wavelength/quantum of electromagnetic energy. In one embodiment, the energy converter is disposed in a vicinity of the at least one energy augmentation structure such that the light shifted in wavelength is emitted with an intensity larger than if the converter were remote from the at least one energy augmentation structure. For ease of understanding, the term "wavelength" will be used to describe the electromagnetic energy entering into the energy converter, even though that electromagnetic energy may be better described in certain embodiments based upon its energy level or strength.

[0458] By having the energy converters or color converting or enhancing materials disposed in a vicinity of the energy augmentation structures of this invention, regardless of the whether the energy augmentation structure is in a region of intensified electric field or otherwise outside the region of intensified electric field, the color enhancing/augmentation structures or the energy enhancing/augmentation structures of the invention are able to enhance the conversion of one form of energy to another, as a conversion from one or more wavelengths of light to other wavelengths of light, or as a conversion from the one or more wavelengths of light to electrical energy, or as a conversion from the one or more wavelengths of light to heat.

[0459] Conversion from the one or more wavelengths of light to other wavelengths of light is useful for color shifting and color enhancement applications. Conversion from the one or more wavelengths of light to electrical energy is useful for harvesting solar energy using for example photovoltaic cells. Conversion from the one or more wavelengths of light to heat is useful also for harvesting solar energy using for example thermoelectric cells or other heat-to-electrical energy devices such as thermoelectric generators.

[0460] In some embodiments of the color enhancing/energy augmentation structures, the color enhancing structure includes a multi-dimensional light collector comprising a first level of metallic patterns and a second level of metallic patterns offset in at least one of a lateral or axial direction from the first level of metallic patterns. At least one of the metallic patterns optionally comprises a first resonator dimensioned to be resonant with a first wavelength of light. The first resonator can be one of a folded structure or an external-electrode pair structure as noted above. The color enhancement structure has a converter capable of converting a second wavelength of light into and emitting therefrom a third wavelength of light shifted in wavelength from the second wavelength of light. The converter is disposed with the first resonator such that the light shifted in wavelength is emitted with an intensity larger than if the converter were remote from the first resonator.

[0461] In some embodiments, the energy converter being disposed in a vicinity of the at least one energy augmentation structure is conductively coupled the energy converter to the at least one energy augmentation structure.

[0462] For example, in some embodiments, the energy converter being disposed in a vicinity of the at least one energy augmentation structure comprises a physical conductive connection between the energy converter and the at least one energy augmentation structure.

[0463] In some embodiments of the color enhancing/energy augmentation structures, the color enhancing structure, the energy converter comprises a down converter converting ultraviolet or blue light into red, yellow, or green light. In some embodiments of the color enhancing/augmentation structures, the energy converter comprises an up converter converting infrared or red light into yellow, green light, or blue light.

[0464] In some embodiments of the color enhancing/energy augmentation structures, the metallic patterns referenced above comprises a folded resonator having opposing electrodes with electric fields directed in between, and the converter is positioned between the opposing electrodes or within fringing electric field of the opposing electrodes or otherwise in a vicinity of the opposing electrodes. In one example, the folded resonator is a ¾ ƛ folded resonator. In one example, metallic patterns comprise at least one of Au, Ag, Cu, Al, or transparent metal oxides. In another example, the metallic patterns can be formed with refractory metals such for example Ti, W, and Mo.

[0465] In some embodiments of the color enhancing/energy augmentation structures, the metallic patterns referenced above comprises an external external-electrode pair structure having opposing electrodes with electric fields directed in between, and the converter is positioned between the opposing electrodes or within fringing electric field of the opposing electrodes or otherwise in a vicinity of the opposing electrodes. In one example, the resonator is a ¾ ƛ external-electrode pair resonator. In one example, metallic patterns comprise at least one of Au, Ag, Cu, Al, or transparent metal oxides. In another example, the metallic patterns can be formed with refractory metals such for example Ti, W, and Mo.

[0466] In some embodiments of the color enhancing/energy augmentation structures, the color enhancing structure, there is an antireflection film disposed on at least one of the metallic patterns or on the converter.

[0467] In some embodiments of the color enhancing/energy augmentation structures, the color enhancing structure, the first resonator noted above comprises plural resonators, the converter noted above comprises plural converters, and the plural converters are disposed at multiple positions throughout the light collector. In one example, the plural converters are positioned to convert light being internally scattered within the light collector.

[0468] In some embodiments of the color enhancing/energy augmentation structures, the first level of metallic patterns noted above (or the second level of metallic patterns) comprises a metal core cladded with a high-K dielectric and a subsequent cladding of a low-K dielectric. In some embodiments of the color enhancing/energy augmentation structures, the first level of metallic patterns noted above (or the second level of metallic patterns) comprises a radial

pattern of conductors. In some embodiments of the color enhancing/energy augmentation structures, the first level of metallic patterns noted above (or the second level of metallic patterns) comprises a fractal pattern. In one example, the fractal pattern is embedded within a dielectric material.

[0469] In some embodiments of the color enhancing/energy augmentation structures, the first level of metallic patterns noted above (or the second level of metallic patterns) comprises a three-dimensional fractal structure.

[0470] In some embodiments of the color enhancing/energy augmentation structures, the light collector comprises a transparent panel with the first level of metallic patterns and the second level of metallic patterns and optionally multiple converters formed therein. In some embodiments of the color enhancing/augmentation structures, the light collector comprises a transparent sheet with the first level of metallic patterns and the second level of metallic patterns and optionally multiple converters formed therein.

[0471] In some embodiments of the color enhancing/energy augmentation structures, the first level of metallic patterns noted above (or the second level of metallic patterns) are of different sizes and/or orientations to each other of the first level of metallic patterns or with respect to the second level of metallic patterns.

[0472] Indeed, FIG. **29** is a schematic of a reflective resonator of this invention including mechano-luminescent materials, in this example the mechano-luminescent materials being placed between a folded resonator structure, although mechano-luminescent materials could be placed between an external electrode pair resonator structure. Thus, in one embodiment, an electromagnetic wave energy augmentator captures one or more wavelengths of electromagnetic energy, and augments the one or more wavelengths of electromagnetic energy in at least one property (such as electric field intensity in a vicinity of the mechano-luminescent materials), while at the same time the mechano-luminescent materials can be considered an energy converter converting the ultrasonic or mechanical energy into electromagnetic radiation (i.e., emitted light).

[0473] In one embodiment of the invention, the increased electric field in the folded structure or the external electrode pair increases the luminescence of the mechano-luminescent materials. The energy used to build the electric field in the folded structure or the external electrode pair being provided separately from the mechanical energy driving the mechano-luminescence.

[0474] For example, the reflective resonator of FIG. **29** could be placed adjacent an exhaust stack of an engine or other waste heat dissipating machine. In one embodiment, the reflective resonator of FIG. **29** would be mounted on a stainless steel arm connected to the heat stack. The stainless steel would couple mechanical vibrations to the reflective resonator while thermally isolating the reflective resonator from the exhaust stack, thereby permitting even inorganic mechano-luminescent materials to be used.

[0475] When the engine began to show higher levels of vibration or vibrations at different frequencies, the intensity of the light emitted would change providing a visible light signal that the engine or machine was under stress from power loads or wear or mechanical failure.

[0476] In one embodiment of the invention, the reflective structure shown in FIG. **29** need not include the resonator and its resonating elements. In one embodiment of the invention, the reflective structure shown in FIG. **29** could be placed directly on a machine operating at a relatively cold temperature around 100° C. In this embodiment, the reflective structure need not include the resonator and its resonating elements. However, if the resonator and its resonating elements were present, a laser such as 656 nm laser could "probe" the resonator and intensify "on demand" the mechano-luminescence. In this way, early detection of developing mechanical problems could be detected.

[0477] Various mechano-luminescent materials suitable for the present invention include ZnS:Mn^{2+}, $SrAl_2O_4$:Eu^{2+}, ZnS:Cu, $SrAMgSi_2O_7$:Eu^{2+} (A=Ca, Sr, Ba), KCl, KI, KBr, NaF, NaCl, LiF, RbCl, RbBr, RbI, MgO, $SrAl_2O_4$, $CaAl_2O_4$, $Sr_{1-x}Ba_xAl_2O_4$(x=0, 0.1, 0.2, 0.4), $Sr_{0.9}Ca_{0.1}Al_2O_4$, $Zn_2Ge_{0.9}Si_{0.1}O_4$, $MgGa_2O_4$, $ZnGa_2O_4$, $ZnAl_2O_4$, ZnS, ZnTe, $(ZnS)_{1-x}(MnTe)_x$ (x<¼), CaZnOS, BaZnOS, $Ca_2MgSi_2O_7$, $Sr_2MgSi_2O_7$, $Ba_2MgSi_2O_7$, $SrCaMgSi_2O_7$, $SrBaMgSi_2O_7$, $Sr_nMgSi_2O_{5+n}$ (1≤n≤2), $Ca_2Al_2SiO_7$, $Sr_2Al_2SiO_7$, $CaYAl_3O_7$, $CaAl_2Si_2O_8$, $Ca_{1-x}Sr_xAl_2Si_2O_8$ (x<0.8), $SrMg_2(PO_4)_2$, $Ba_{1-x}Ca_xTiO_3$ (0.25<x<0.8), $Ba_{1-x}Ca_xTiO_3$, $LiNbO_3$, Sr_2SnO_4, $(Ca, Sr, Ba)_2SnO_4$, $Sr_3Sn_2O_7$, $Sr_3(Sn, Si)_2O_7$, $Sr_3(Sn, Ge)_2O_7$, $Ca_3Ti_2O_7$, $CaNb_2O_6$, $Ca_2Nb_2O_7$, $Ca_3Nb_2O_8$, $BaSi_2O_2N_2$, $SrSi_2O_2N_2$, $CaZr(PO_4)_2$, ZrO_2.

[0478] Yanim Jia, in "Novel Mechano-Luminescent Sensors Based on Piezoelectric/Electroluminescent Composites," Sensors (Basel). 2011; 11(4): 3962-396, the entire contents of which are incorporated by reference, describes a mechanoluminescent composite made of a piezoelectric material and an electroluminescent material. In this composite device, when a stress is applied to the piezoelectric layer, electrical charges will be induced at both the top and bottom faces of piezoelectric layer due to the piezoelectric effect. These induced electrical charges will result in a light output from the electroluminescent layer due to the electroluminescent effect.

[0479] Here, in one embodiment of the present invention, such composites made of a piezoelectric material and an electroluminescent material, hereinafter "composite mechano-luminescent emitters," provides a structure that, upon stimulation with mechanical or vibrational energy such as from an acoustic or ultrasonic transducer, emit light. Details of various electroluminescent materials that can be used for the composite mechano-luminescent emitters are provided in the next section where electroluminescent materials alone are placed in vicinity of the opposing resonator electrodes.

[0480] FIG. **30** is a schematic of composite mechano-luminescent emitter composed of a piezoelectric material and an electroluminescent material which, in one embodiment, could be mechano-luminescent light emitters in FIG. **29**.

[0481] In another embodiment, the composite mechano-luminescent emitters could be used without need for any resonator structure. FIG. **31** is schematic showing the composite mechano-luminescent emitters distributed across a sector of interest for generation of light therefrom. FIG. **31** shows that an ultrasonic transducer can be used for stimulation/activation of these composite mechano-luminescent emitters.

[0482] In color enhancement applications, application of ultrasonic energy could change the color emission from a surface. Such applications could be for security systems where an item would contain a pattern of the composite mechano-luminescent emitters. The pattern would not be

apparent until it was activated with ultrasonic or acoustic energy upon which time light of a predetermined wavelength would be emitted. The light emitted might be visible or infrared light depending on the type of detector used to detect the emitted light.

[0483] In a related application of these composite mechano-luminescent emitters, FIG. **32** is schematic showing the composite mechano-luminescent emitters distributed inside a medium of interest for generation of light therein or therefrom. With the present invention, light can be turned on and off with the on/off status of an ultrasonic transducer and the intensity of the light can be varied. There are no power leads to run into the medium of interest. There is no space taken up by batteries or control elements to turn power on and off. The composite mechano-luminescent emitters can be miniaturized. The composite mechano-luminescent emitters could be agglomerated in a container. In some embodiments, the container would not be completely packed permitting the tilting of the container to relocate the composite mechano-luminescent emitters within the container.

[0484] Electroluminescent and phosphorescent materials (organic and inorganic): The present invention in various embodiments with or without energy augmentators can utilize in organic fluorescent molecules or inorganic particles capable or fluorescence and phosphorescence having crystalline, polycrystalline or amorphous micro-structures for the converters (optionally including the energy augmentation structures described above).

[0485] The list of inorganic molecules that can be used in the resonating structures to enhance the color emission include but is not limited to the following inorganic electroluminescent phosphor materials:

[0486] $SrS:Ce^{3+}$

[0487] $CaGa_2S_4:Ce^{3+}$

[0488] $SrS:Cu^{+}$

[0489] $CaS:Pb^{2+}$

[0490] $BaAl_2S_4:Eu^{2+}$

[0491] $ZnS:Tb^{3+}$

[0492] $ZnMgS:Mn^{2+}$

[0493] $SrGa_2S_4:Eu^{2+}$

[0494] $CaAl_2S_4:Eu^{2+}$

[0495] $BaAl_2S_4:Eu^{2+}$

[0496] $ZnS:Mn^{2+}$

[0497] $MgGa_2O_4:Eu^{3+}$

[0498] $(Ca, Sr)Y_2S_4:Eu^{2+}$

[0499] $BaAl_2S_4:Eu^{2+}$

The organic molecules that can phosphoresce under the influence of an electric field are also of interest in the present application. The organic fluorescent compounds with high quantum yield include by way of illustration:

[0500] Naphthalene,

[0501] Pyrene,

[0502] Perylene,

[0503] Anthracene,

[0504] Phenanthrene,

[0505] p-Terphenyl,

[0506] p-Quartphenyl,

[0507] Trans-stilbene,

[0508] Tetraphenylbutadiene,

[0509] Distyrylbenzene,

[0510] 2,5-Diphenyloxazole,

[0511] 4-Methyl-7-diethylaminocoumarin,

[0512] 2-Phenyl-5-(4-biphenyl)-1,3,4-oxadiazole,

[0513] 3-Phenylcarbostyryl,

[0514] 1,3,5-Triphenyl-2-pyrazoline,

[0515] 1,8-Naphthoylene-1', 2'-bezimidazole,

[0516] 4-Amino-N-phenyl-naphthalimide.

[0517] The inorganic fluorescent and phosphorescent materials detailed here are numerous, and various examples are given by way of illustration rather than limitation. Furthermore, these materials can be doped with specific ions (activators or a combination of activators) that occupy a site in the lattice structure in the case of crystalline or polycrystalline materials and could occupy a network forming site or a bridging and/or non-bridging site in amorphous materials. These compounds could include (not ranked by order of preference or utility) the following material examples:

[0518] CaF_2, ZnF_2, $KMgF_3$, $ZnGa_2O_4$, $ZnAl_2O_4$, Zn_2SiO_4, Zn_2GeO_4, $Ca_5(PO_4)_3F$, $Sr_5(PO_4)_3F$, $CaSiO_3$, $MgSiO_3$, ZnS, $MgGa_2O_4$, $LaAl_{11}O_{18}$, Zn_2SiO_4, $Ca_5(PO_4)_3F$, $Mg_4Ta_2O_9$, CaF_2, $LiAl_5O_8$, $LiAlO_2$, $CaPO_3$, AlF_3.

[0519] Further included are alkali earth chalcogenide phosphors which are in turn exemplified by the following non-inclusive list:

[0520] $MgS:Eu^{3+}$, $CaS:Mn^{2+}$, CaS:Cu, CaS:Sb, $CaS:Ce^{3+}$, $CaS:Eu^{2+}$, $CaS:Eu^{2+}Ce^{3+}$, $CaS:Sm^{3+}$, $CaS:Pb^{2+}$, $CaO:Mn^{2+}$, $CaO:Pb^{2+}$.

[0521] The examples include the ZnS type phosphors that encompass various derivatives:

[0522] ZnS:Cu,Al(Cl), ZnS:Cl(Al), ZnS:Cu,I(Cl), ZnS:Cu, ZnS:Cu,In.

[0523] Compound IIIb-Vb phosphors which include the group IIIb and Vb elements of the periodic table are suitable for converter materials. These semiconductors include BN, BP, BSb, AlN, AlP, AlAs, AlSb, GaN, GaP, GaAs, GaSb, InN, InP, InAs, InSb and these materials have donors and acceptors that work in together to induce light emission diodes. The donors include Li, Sn, Si, Li, Te, Se, S, O, and acceptors include C, Be, Mg, Zn, Cd, Si, Ge. As an example, GaP light emitting diodes include GaP:Zn, O, GaP:NN, Gap:N and GaP which emit colors Red, Yellow, Green and Pure Green respectively.

[0524] The compounded materials further include such materials as GaAs with compositional variation of the following sort: In1-y(Ga1-xAlx)yP (provides a simple example). Silicon Carbide SiC as a luminescent platform has commercial relevancy if the blue light emitting diodes. These include the polytypes 3C—SiC, 6H—SiC, 4H—SiC with donors such as N and Al and acceptors such as Ga and B.

[0525] Multiband luminescent materials suitable for converter materials include for example the following compositions:

[0526] $(Sr, Ca, Ba)_5(PO_4)_3Cl:Eu^{2+}$, $BaMg_{2^4}Al_{16}O_{27}:Eu^{2+}$, $CeMgAl_{11}O_{19}:Ce^{3+}:Tb^{3+}$, $LaPO_4:Ce^{3+}:Tb^{3+}$, $GdMgB_5O_{10}:Ce^{3+}:Tb^{3+}$, $Y_2O_3:Eu^{3+}$, $(Ba,Ca,Mg)_5(PO_4)_3Cl:Eu^{2+}$, $2SrO_{0.84}P_2O_5.0.16B_2O_3:Eu^{2+}$, $Sr_4Al_{14}O_{25}:Eu^{2+}$.

[0527] Other materials suitable for converter materials include those materials used for fluorescent high pressure mercury discharge lamps can be excited with X-Ray and are exemplified by way of family designation as follows:

[0528] Phosphates $(Sr, M)(PO_4)_2:Sn^{2+}$, Mg or Zn activator, Germanate $4MgO.GeO_2:Mn^{4+}$, $4(MgO, MgF_2)GeO_2:Mn^{4+}$, Yttrate $Y_2O_3:Eu^{3+}$, Vanadate $YVO_4:Eu^{3+}$, $Y(P,V)O_4:Eu^{3+}$, $Y(P,V)O_4:In^{+}$, Halo-Silicate Sr2Si3O$_8$.

$2SrCl_2:Eu^{2+}$, Aluminate $(Ba,Mg)_2Al_{16}O_{24}:Eu^{2+}$, $(Ba,Mg)_2Al_{16}O_{24}:Eu^{2+},Mn^{2+}$, $Y_2O_3Al_2O_3:Tb^{3+}$.

[0529] Another grouping of materials suitable for converter materials by host compound include chemical compositions in the Halophosphates phosphors, Phosphate phosphors, Silicate phosphors, Aluminate phosphors, Borate phosphors, Tungstate phosphors, and other phosphors.

[0530] The halophosphates include by way of illustration:

[0531] $3Ca_3(PO_4)_2.Ca(F,Cl)_2:Sb^{3+}$, $3Ca_3(PO_4)_2.Ca(F,Cl)_2:Sb^{3+}/Mn^{2+}$, $Sr_{10}(PO_4)_6Cl_2:Eu^{2+}$, $(Sr,Ca)_{10}(PO_4)_6Cl_2:Eu^{2+}$, $(Sr,Ca)_{10}(PO_4)_6.nB_2O_3:Eu^{3+}$, $(Sr,Ca,Mg)_{10}(PO_4)_6Cl_2:Eu^{2+}$. The phosphate phosphors include by way of illustration $Sr_2P_2O_7:Sn^{2+}$, $(Sr,Mg)_3(PO_4)_2:Sn^{2+}$, $Ca_3(PO_4)_2.Sn^{2+}$, $Ca_3(PO_4)_2:Tl^{+}$, $(Ca,Zn)_3(PO_4)_2:Tl^{+}$, $Sr_2P_2O_7:Eu^{2+}$, $SrMgP_2O_7:Eu^{2+}$, $Sr_3(PO_4)_2:Eu^{2+}$, $LaPO_4:Ce^{3+}$, Tb^{3+}, $La_2O_3.0.2SiO_2.0.9P_2O_5:Ce^{3+}.Tb^{3+}$, $BaO.TiO_2.P_2O_5$. The silicate phosphors $Zn_2SiO_4:Mn^{2+}$, $CaSiO_3:Pb^{2+}/Mn^{2+}$, $(Ba,Sr,Mg).3Si_2O_7:Pb^{2+}$, $BaSi_2O_5:Pb^{2+}$, $Sr_2Si_3O_8.2SrCl_2:Eu^{2+}$, $Ba_3MgSi_2O_8:Eu^{2+}$, $(Sr,Ba)Al_2Si_2O_8:Eu^{2+}$.

[0532] The aluminate phosphors include:

[0533] $LiAlO_2:Fe^{3+}$, $BaAl_8O_{13}:Eu^{2+}$, $BaMg_2Al_{16}O_{27}:Eu^{2+}$, $BaMg_2Al_{16}O_{27}:Eu^{2+}/Mn^{2+}$, $Sr_4Al_{14}O_{25}:Eu^{2+}$, $CeMgAl_{11}O_{19}:Ce^{3+}/Tb^{3+}$.

[0534] The borate phosphors include:

[0535] $Cd_2B_2O_5:Mn^{2+}$, $SrB_4O_7F:Eu^{2+}$, $GdMgB_5O_{10}:Ce^{3+}/Tb^{3+}$, $GdMgB_5O_{10}:Ce^{3+}/Mn^{3+}$, $GdMgB_5O_{10}:Ce^{3+}/Tb^{3+}/Mn^{2+}$.

[0536] The tungstate phosphors include:

[0537] $CaWO_4$, $(Ca,Pb)WO_4$, $MgWO_4$. Other phosphors $Y_2O_3:Eu^{3+}$, $Y(V,P)O_4:Eu^{2+}$, $YVO_4:Dy^{3+}$, $MgGa_2O_4:Mn^{2+}$, $6MgO.As_2O_5:Mn^{2+}$, $3.5MgO.0.5MgF_2.GeO_2:Mn^{4+}$.

[0538] Activators of relevance to the various doped phosphors include the following list:

[0539] Tl^{+}, Pb^{2+}, Ce^{3+}, Eu^{2+}, WO_4^{2-}, Sn^{2+}, Sb^{3+}, Mn^{2+}, Tb^{3+}, Eu^{3+}, Mn^{4+}, Fe^{3+}.

[0540] In various embodiments, the luminescence center Tl+ can be used with a chemical composition such as:

[0541] $(Ca,Zn)_3(PO_4)_2:Tl^{+}$, $Ca_3(PO_4)_2:Tl^{+}$.

[0542] Similarly, the luminescence center Mn2+ can be used with chemical compositions such as

[0543] $MgGa_2O_4:Mn^{2+}$, $BaMg_2Al_{16}O_{27}:Eu^{2+}/Mn^{2+}$, $Zn_2SiO_4:Mn^{2+}$, $3Ca_3(PO_4)_2.Ca(F,Cl)_2:Sb^{2+}/Mn^{2+}$, $CaSiO_3:Pb^{2+}/Mn^{2+}$, $Cd_2B_2O_5:Mn^{2+}$, $CdB_2O_5:Mn^{2+}$, $GdMgB_5O_{10}:Ce^{3+}/Mn^{2+}$, $GdMgB_5O_{10}:Ce^{3+}/Tb^{3+}/Mn^{2+}$.

[0544] Further, the luminescence center Sn^{2+} can be used with chemical compositions such as:

[0545] $Sr_2P_2O_7:Sn^{2+}$, $(Sr,Mg)_3(PO_4)_2:Sn^{2+}$.

[0546] The luminescence center Eu^{2+} can also be used with chemical compositions such as:

[0547] $SrB_4O_7F:Eu^{2+}$, $(Sr,Ba)Al_2Si_2O_8:Eu^{2+}$, $Sr_3(PO_4)_2:Eu^{2+}$, $Sr_2P_2O_7:Eu^{2+}$, $Ba_3MgSi_2O_8:Eu^{2+}$, $Sr_{10}(PO_4)_6Cl_2:Eu^{2+}$, $BaMg_2Al_{16}O_{27}:Eu^{2+}/Mn^{2+}$, $(Sr,Ca)_{10}(PO_4)_6Cl_2:Eu^{2+}$.

[0548] The luminescence center Pb^{2+} can be used with chemical compositions such as:

[0549] $(Ba,Mg,Zn)_3Si_2O_7:Pb^{2+}$, $BaSi_2O_5:Pb^{2+}$, $(Ba,Sr)_3Si_2O_7:Pb^{2+}$.

[0550] The luminescence center Sb^{2+} can be used with chemical compositions such as:

[0551] $3Ca_3(PO_4)_2.Ca(F,Cl)_2:Sb^{3+}$, $3Ca_3(PO_4)_2.Ca(F,Cl)_2:Sb^{3+}/Mn^{2+}$.

[0552] The luminescence center Tb3+ can be used with chemical compositions such as:

[0553] $CeMgAl_{11}O_{19}:Ce^{3+}/Tb^{3+}$, $LaPO_4:Ce^{3+}/Tb^{3+}$, $Y_2SiO_5:Ce^{3+}/Tb^{3+}$, $GdMgB_5O_{10}:Ce^{3+}/Tb^{3+}$.

[0554] The luminescence center Eu^{3+} can be used with chemical compositions such as:

[0555] $Y_2O_3:Eu^{3+}$, $Y(V,P)O_4:Eu^{3+}$.

[0556] The luminescence center Dy^{3+} can be used with chemical compositions such as:

[0557] $YVO_4:Dy^{3+}$.

[0558] The luminescence center Fe^{3+} can be used with chemical compositions such as:

[0559] $LiAlO_2:Fe^{3+}$.

[0560] The luminescence center Mn^{4+} can be used with chemical compositions such as:

[0561] $6MgO.As_2O_5:Mn^{4+}$, $3.5MgO.0.5MgF_2.GeO_2:Mn^{4+}$.

[0562] The luminescence center Ce^{3+} can be used with chemical compositions such as:

[0563] $Ca_2MgSi_2O_7:Ce^{3+}$ and $Y_2SiO_5:Ce^{3+}$.

[0564] The luminescence center WO_4^{2-} can be used with chemical compositions such as:

[0565] $CaWO_4$, $(Ca,Pb)WO_4$, $MgWO_4$.

[0566] The luminescence center TiO_4^{4-} can be used with chemical compositions such as:

[0567] $BaOTiO_2.P_2O_5$.

[0568] In various embodiments of this invention, the phosphor chemistry utilized in X-Ray excitations can be used. Of particular interest is the k-edge of these phosphors. Low energy excitation can lead to intense luminescence in materials with low k-edge. Some of these chemistries and the corresponding k-edge are included as follows:

$BaFCl:Eu^{2+}$	37.38 keV
$BaSO_4:Eu^{2+}$	37.38 keV
$CaWO_4$	69.48 keV
$Gd_2O_2S:Tb^{3+}$	50.22 keV
$LaOBr:Tb^{3+}$	38.92 keV
$LaOBr:Tm^{3+}$	38.92 keV
$La_2O_2S:TB^{3+}$	38.92 keV
$Y_2O_2S:Tb^{3+}$	17.04 keV
$YTaO_4$	67.42 keV
$YTaO_4:Nb$	67.42 keV
ZnS:Ag	9.66 keV
(Zn, Cd)S:Ag	9.66/26.7 keV

[0569] In one embodiment of this invention, light from these materials (excited for example by high energy particles including x-rays, gamma rays, protons, and electrons) can have their emissions modulated by having those materials included in a vicinity of (including inside) the color enhancing structures described herein. For example, in medical treatments where x-ray excites phosphorescence to photostimulate reactions in a patient, simultaneous with irradiation by the high energy particles there could be applied infrared irradiation to drive resonance in the color enhancing structures/energy augmentation structures described herein, where the x-ray phosphors would have enhanced emissions when in the presence of the intensified electric fields. In another example, in medical or scientific instruments, simultaneous with irradiation by the high energy particles there could be applied electric fields to enhance emissions from these x-ray phosphors.

Cell to Cell Communication

[0570] The invention pertains to ways to induce a biological change in a medium not necessarily directly treated with an agent which can cause the biological change. As to be explained below, cell to cell communication typically involves low intensity signals which are difficult to capture or collect. The present invention's energy augmentation structures including resonators such as the folded resonators described herein are particularly useful in capturing biophotons for diagnostic purposes or for delivery of natural or artificially generated biophotons to a target site for treatment purposes. While the description below refers often to folded resonators and more particularly to % wave folded resonators, the present invention is not so limited to those particular resonators and can be practiced with other energy augmentation structures including but not limited to the fractal antenna structures, waveguide structures, and wavelength stubs described herein and other resonant structures known in the art. The present invention directed to cell to cell communication can also be practiced with or without the energy conversion materials and devices described herein.

[0571] More particularly, in one embodiment of the invention, the energy augmentation structure is a distributed energy (or flux) collector in which received light or flux at different spatial positions about a target site and is thereafter internally transmitted through total internal reflection to a central optical detector. Furthermore, in another embodiment of the invention, the energy augmentation structure is a distributed energy (or flux) collector in which received light (or flux) at different spatial positions about a target site and is thereafter detected and converted into an electrical signal which is transmitted to a central accumulator. In another embodiment of the invention, the energy augmentation structure is a distributed energy (or flux) distributor in which light (or flux) is delivered to different spatial positions about a target site for simulating or otherwise inducing a biophoton type reaction at a target site. By having the energy augmentation structures noted above (including resonators such as the folded resonators described herein) distributed, the light collected from or the light to be delivered to a target site is not as subject to attenuation by the anatomical structures about the target site had the biophotons been collected remote from a target structure.

[0572] Moreover, spatial collection/detection of photons at various positions, in one embodiment of this invention, is useful for diagnostic findings or even companion in-situ diagnostics for drugs, devices and externally applied stimulation (e.g. regeneration of specific nerves, spinal cord repair . . . etc. . . .) In one embodiment, in situ detection coupled to an external collector/logic gate permits real-time feedback.

[0573] In another embodiment, the energy augmentation structures include resonant structures which locally intensify an electric field in proximity to the resonant structure. Work by others has shown that biophoton emission from cells can be enhanced in the presence of higher strength electrical or magnetic fields. See "Enhancement of biophoton emission of prostate cancer cells by Ag nanoparticles," by Hossu et al., Cancer Nanotechnol. 2013; 4(1-3): 21-26. Published online 2013 Mar. 28. See "Nonlinear enhancement of spontaneous biophoton emission of sweet potato by silver nanoparticles," by Hossu et al., in in Journal of photochemistry and photobiology. B, Biology 99(1):44-8 Feb. 2010. See "The Relation between Magnetic Field Strength and Ultraweak Luminescence," by Li-xin Li, in Advanced Technology in Teaching. Advances in Intelligent and Soft Computing, vol 163. Springer, Berlin, Heidelberg.

[0574] Thus, by having the resonant structures proximate cells emitting biophotons, the collection and detection of the biophoton emissions maybe facilitated by the higher strength electrical and/or magnetic fields producing a higher flux of the biophotons from the target site. Conversely, if an artificial source of biophotons were being delivered to a target site to induce therein increased biophoton emission, then the induced biophoton emission may also be enhanced by having the resonant structures nearby. As noted below in more detail, field lines exist both in and outside the resonant structures. The degree to which the field lines emanate from the resonant structures will depend on the detailed construction of the particular resonator. The ¾ wavelength folded resonators described herein contain both field lines principally directed from one opposing electrode to another and field lines emanating into the surrounding medium such that biophoton enhancement can occur for biological material both between the opposing electrodes and in a vicinity of the opposing electrodes.

[0575] In various embodiments, infrared sources known to penetrate cell tissue can be applied to patient and directed to resonant structures inside the patient in proximity to a target site. In those embodiments, the resonant structures are resonant at the infrared frequency or infrared frequencies. This not only generates an intensified electric field at the IR resonant frequency, but also generates this electric field by application of frequencies that do not interfere with (or contribute noise to) the detection of UV or visible biophotons. In some embodiments, the resonant structures can be resonant at microwave frequencies and the same advantages follow.

[0576] Accordingly, one object of the present invention is to provide a method for treatment of a condition, disorder or disease in a subject which induces a change in a targeted region that is not directly exposed to an agent which can cause a biological, chemical, physical or therapeutic change. The induced change occurs in situ to treat a condition, disorder or disease. The induced change can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators described herein.

[0577] A further object of the present invention is to provide a method for treatment of a condition, disorder or disease in a subject using transmission of signals from a first or control region into a second or target region of the subject to effect a predetermined change in the target region. The induced change can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators described herein.

[0578] A further object of the present invention is to provide a method for treatment of a condition, disorder or disease using cell to cell communication to effect a predetermined change in the target region. The induced change can be assisted by the in situ or ex situ presence of energy augmentators.

[0579] A further object of the present invention is to provide various biophoton collectors and biophoton bypasses useful for implementing a variety of the method embodiments. The induced change can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators described herein.

[0580] These and other objects of the present invention, which will become more apparent in conjunction with the following detailed description of the preferred embodiments, either alone or in combinations thereof, have been satisfied by the discovery of a method of treating a subject comprising:

[0581] providing a first region of biological material coupled to the subject;

[0582] initiating a change in a cellular environment of the cells in the first region; and

[0583] due to a change in biological or chemical activity of the cells in the first region, inducing a biological change in a second region inside the subject, wherein the induced biological change is assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators described herein.

[0584] As a brief background discussion, light modulation from a deeply penetrating radiation like X-ray to a photo-catalytic radiation like UV or IR, opens the possibility for activating bio-therapeutic agents of various kinds within mammalian bodies. Other possibilities include the activation of photo-catalysts in mediums for cross-linking reactions in polymeric chains and polymer based adhesives. These examples are but two examples of a number of possibilities that can be more generally described as the use of a conversion material to convert an initiating radiation that is deeply penetrating to another useful radiation possessing the capability of promoting photo-based chemical reactions. The photo-chemistry is driven inside media of far ranging types including organic, inorganic or composited from organic and inorganic materials.

[0585] Photo-activation with no line of site required can be done in-vivo and ex-vivo such as those carried out in cell cultures. In turn, the photo activation of a select bio-therapeutic agent, and conceivably more than one agent at a time, can lead to the onset of a desirable chemical reaction, or a cascade of reactions, that in turn lead to a beneficial therapeutic outcome. As an example, the binding of psoralen compounds to DNA through the formation of monoadducts and/or crosslinked adducts is well known to engender an immune response if done properly.

[0586] Below is a description of the various anatomical cell structures present in subjects to which the techniques of the present invention disclosed below can apply by use of the resonant structures detailed herein.

[0587] Further details of anatomical structures can be found in U.S. Pat. No. 9,295,835 (the entire contents of which are incorporated herein by reference). As described in the '835 patent, humans and animals are constructed of cells. Cells are the smallest fundamental unit of life. A cell is considered to be the smallest living structure capable of performing all of the processes that define life. The human body is made up of some 100 trillion cells representing perhaps some 300 cell-types. Each cell-type performs a specific function such as operating muscles, glands, and vital organs. In addition, nerves, which are made of communicating-cells called neurons, provide electrical regulating signals to operate and adjust enormous amounts of functional activities throughout the body to maintain homeostasis (life equilibrium).

[0588] FIG. **33**A is a schematic illustrating various cellular components of an example cell **100**. The depiction shown in FIG. **33**A illustrates, for example, cellular components such as mitochondria, ribosomes, centrosome, centrioles, the nucleus, and so on.

[0589] FIG. **33**B is a depiction of a folded resonator that could be printed (or otherwise formed) on surface of a template for insertion into, on, or around cellular components such as those shown in FIG. **33**A. A sinusoidal wave representing for example an instantaneous waveform of a light wave (an incident energy flux **12**) when incident on a ¾ λ resonator, having a length of ¾ of the wavelength λ, with the open ends of the resonator "folded" together couples energy into this resonant structure. The folded ends form a region of an intensified, amplified electric field denoted by the horizontally directed arrows between the opposing open ends.

[0590] When light nominally of a wavelength λ (or harmonics thereof 2 λ, 3 λ, 4 λ, etc.) is incident on the folded antenna structure, a fraction of the light will be coupled into this structure establishing the amplified electric field. For resonators made of low loss materials, high Q-factors are obtained which, in this case, could mean that the electric field strength between the opposing electrodes may be for example 100 to 1000 times the peak amplitude of the electric field vector of the incident waveform.

[0591] While the ¾ λ folded resonator in one embodiment could be designed to resonate at blue light (λ=420 to 440 nm) for photoexcitation of drugs, the resonator could also be designed to resonate at frequencies of infrared light (e.g. λ=700 to 1000 nm) for localized heating nearby the folded resonators. The ¾ λ folded resonator in one embodiment could be designed to resonate at microwave frequencies

[0592] FIG. **33**C is diagram showing a pattern of ¾ λ folded resonators **22** distributed in space. The present invention is not limited to the regular, uniformly spaced and sized resonators shown in FIG. **33**C. There is no requirement that the distribution be regular, uniformly spaced, uniformly sized, or uniformly oriented. Differently sized, spaced, and oriented resonators may provide better utilization of the full spectrum of applied energy directed to the resonators.

[0593] In one embodiment, this pattern could be formed by lithographic or stamping processes onto a planar surface such as a glass plate or onto a curved or planar sheet type product. This pattern may also include printed therewith upconverting or downconverting materials permitting the resonant structures of this invention to for example down convert x-rays into UV emissions or upconvert infrared light into visible or ultraviolet frequencies, while at the same time presenting an intensified electric field to enhance the up conversion or down conversion or to enhance biophoton generation or interaction with biological material in the presence of the resonator's electric field.

[0594] FIG. **35** illustrates a schematic drawing of the structure of a plasma membrane **100** of the cell **100** shown in FIG. **33**A.

[0595] Cells are known to have a complex cellular wall referred to in the art as a plasma membrane, an example of which is shown in FIG. **35**. A portion **200** of the plasma membrane is shown in FIG. **35** with respect to the cell **100**. The plasma membrane separates the internal structures and operating organelles from the cell's external environment. It houses and protects the contents of the cell. It is made of a bi-layer of phospholipids and various proteins, which are attached or embedded.

[0596] The plasma membrane is a semi permeable structure that allows passage of nutrients, ions, water, and other materials into the cell. It also allows an exit pathway for waste products and for functional two-way passage of many kinds of molecules to adjust cell chemistry. The principal purpose of the cell membrane is to provide a barrier that contains all of the processes and components within the living cell and to simultaneously repel unwanted substances from invading or entering the cell.

[0597] There are some 300 types of ion pores in a plasma membrane for purposes of transporting the raw materials used by the cell to live and to perform its duties. Additionally, the plasma membrane may have (from a relatively small number of ion channels) up to approximately 200 to 400 molecular channels or more and of different dimension through which the passage of nutriments and electrolytic ions can enter the cell. The thickness of a plasma membrane is estimated to be about 7-8 nanometers. In addition, selected ion channels can rid the individual cells of waste products in a process called autophagy to transport, excrete or see to the expulsion of waste products from the cellular interior into the extracellular space. To these structures, according to one embodiment of the invention, biological change can be affected by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0598] The molecular channels within the plasma membrane have molecular sized openings for the different molecules of extracellular ions and other nutriments or materials required by the cell. An example of the materials desired by the cell to transport through these channels include, but is not limited to, sodium, potassium, magnesium, calcium ions, and water. The openings are provided for example by specifically sized pores through which ions can travel between extracellular space and cell interior. The channels are typically specific (selective) for one ion; for example, most potassium channels are characterized by 1000:1 selectivity ratio for potassium over sodium, though potassium and sodium ions have the same charge and differ only slightly in their radius. The channel pores are typically so small that ions must pass through in a single-file order. According to one embodiment of the invention, the rate at which the ions pass through can be affected by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0599] A channel may have several different states (corresponding to different conformations of a protein), with each state considered to be either open or closed. In general, closed states correspond either to a contraction of the pore—making it impassable to the ion—or to a separate part of the protein, stoppering the pore. For example, the voltage-dependent sodium channel undergoes inactivation, in which a portion of the protein swings into the pore, sealing it. This inactivation shuts off the sodium current. According to one embodiment of the invention, the sodium current can be affected by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0600] Ion channels can also be classified by how the channels respond to their environment. For example, the ion channels involved in an action potential are voltage-sensitive channels; they open and close in response to the voltage across the membrane. Ligand-gated channels form another important class; these ion channels open and close in response to the binding of a ligand molecule, such as a neurotransmitter. Other ion channels open and close with mechanical forces. Still other ion channels—such as those of sensory neurons—open and close in response to other stimuli, such as light, temperature or pressure. Light (an electromagnetic radiation) was therefore demonstrated to enable the triggering of certain cellular functions.

[0601] The passage of ions through the cellular membrane participates, generates, and/or creates a flow of electric currents within the membrane and/or on the inner surface of the plasma membrane. At points where the cytoskeleton, intermediate-filaments or microfilaments are attached to the plasma membranes, those points allow "signals" to gain entry onto the cytoskeleton so as to be able to serve as a pathway to transport the signals around the cell. Such signals may travel to trigger or adjust chemical reaction areas and to various organelles and the nucleus to trigger reactions and pass along cellular communication instructions, at a minimum. Cells were therefore demonstrated to be equipped with an enabling infrastructure to sense and react to stimuli including electrical and electromagnetic stimuli.

[0602] Since cells are electrochemical in nature, the plasma membrane is the site for generating the cells electrical signals for metabolic and other operations and to serve as a means to communicate, relay and receive signals with other cells, especially those of similar type. The nucleus and plasma membrane communicate with electrical signals. The nucleus determines how the cell functions and also determines the architecture of the cell and its contents. The plasma membrane uses electrical signaling to open passageways and ion channels to allow the intake of chemicals as well as the outflow of cellular waste products. The electric signaling exists by virtue of potential gradients and the establishment of currents that exist within cells and between cells within biological bodies. The displacement of charged species encompasses electrons, ions, anions, low, mid and high molecular weight biological polymers, which in turn includes, but is not limited to, proteins. It is well known that the displacement of charged species (current) is almost always accompanied by the establishment of magnetic fields during the transient states associated with motion. According to one embodiment of the invention, these signals and charged species (current0 (developing from the natural processes described above, can nevertheless be affected by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein, and the resultant electric field in proximity to these signals.

[0603] The outside of the cell membrane is coated with a defensive glycocalyx, which is designed and produced by the cell to protect it and allow it to be recognized. The nucleus has input into the crafting of membrane defensive characteristics. The glycocalyx can produce a negative electric surface charge in cancer cells so as to repel the body's immune system.

[0604] The cell membrane regulates the flow of materials into and out of the cell. Also, it can detect external signals and mediate interactions between other cells. Membrane carbohydrates installed on the outer surface function as cell markers to distinguish itself from other cells.

[0605] This plasma membrane contains the sites where the electrical energy is created and the cellular communication signals are formed. These signals are transmitted over the

cytoskeleton, which acts like wires, to regulate and trigger metabolic and functional processes within the cell. The cell nucleus communicates with all organelles and operating structures located within the cell. FIG. **36**, for example, illustrates a junction view **300** of the attachments between tumor cells.

[0606] Specific Target Biological Structures

[0607] Described below are a number of charge or current or signals naturally produced by living cells. According to one embodiment of the invention, biological changes can be affected by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0608] While not limited to the particular theories below, the intensified electric field existing at high frequency in a vicinity of the electrodes of a resonator may produce a number of biological changes related to the ion transport or electrical signaling. For example, the thin wall of the plasma membrane may be considered to be a dielectric barrier for electron transport. In one example, the intensified electric fields from the resonator structures may produce an asymmetric flow of charge. Lighter charge carriers such as electrons in a biological material will respond to a high frequency AC field and gain energy, while heavier ions will not have time to accelerate and gain energy before the instantaneous electric field reverses. The net effect is the electrons may preferentially gain energy and will thereby diffuse more rapidly than the heavier ions. Since charge is conserved in the system, a net positive potential (or space charge) develops. The positive charge serves to limit additional electron diffusion from the region where the electric field from the resonator exists. This space charge or net positive charge in turn would affect ion diffusion through plasma membranes exposed to the space charge.

[0609] In another example, the intensified electric fields from the resonator structures may assist in quantum tunneling. In a quantum event, wave packets representing the electrons are partially reflected and partially transmitted through a barrier. The net effect is that of tunneling of the electrons across the barrier. As above, since charge is conserved in the system, a net positive potential (or space charge) develops on the side of the barrier from where the tunneling electrons originated from. The net positive charge serves to limit additional tunneling events unless there is a field (such as an electric field from a resonator) to continue "pumping" this biological system, thereby increasing the space charge or net positive charge on the electron-originating side of the barrier. This space charge or net positive charge in turn may drive ion diffusion through plasma membranes exposed to the space charge.

[0610] Accordingly, the intensified electric field from a resonator may itself directly affect electrical signals naturally being communicated thorough the plasma membrane, or may through an induced space charge (such as for example like those described above or through other asymmetric charge transport) directly affect ion transport through the plasma membrane. See discussion below of rectifying resonant structures which could be used to affect ion transport through the plasma membrane.

[0611] Hence, regardless of the mechanisms in effect, a resonator structure of the present invention can be used to affect signaling and ion transport through a plasma membrane in vicinity of the resonator's electric fields, thereby controlling phenomena such as Ca^{+} ion transport or other respiratory or metabolic cell functions.

[0612] FIG. **38** illustrates a pictorial drawing of the internal framework **400** of a cell, such as the cell **100** shown in FIG. **33**A.

[0613] The cytoskeleton in a cell maintains the shape of all cells from the inside. It is like a geodesic structure that provides strength and internal areas for electro-chemical timed reactions. Noteworthy is that the cytoskeleton extends into other cells and links up with their cytoskeleton to maintain and form communication links into adjacent cells. This structure is made up of a network of hollow-microtubules, solid-microfilaments, and solid-intermediate filaments. The cytoskeleton is anchored to the plasma membrane and serves as the 'wiring' to transmit the cellular communication signals. The cellular environment is highly networked and the transmission of chemical and electrical information is made more efficient as a result if this interconnectivity.

[0614] The cytoskeleton is made up of actin and myosin, which are also found in muscle structures. The cytoskeleton also controls the circulation of the cytosol, which is the fluid and semi-fluid that suspends the organelles. Organelles are the functioning entities of the cell that manufacture and distribute cellular products and processes necessary for the cell to live.

[0615] The cytoplasm in a cell is a fluid, that can be rather gel-like, which surrounds the nucleus, which is considered an organelle. The nucleus contains the DNA genetic information and hence, controls both the activity of the cell and its structural nature. The nucleus is spherical and is surrounded by a double membrane, the nuclear membrane and envelope, which is perforated by a significant number of pores that allow the exchange of materials and substances with the cell's cytoplasm and the extra moist environment outside which contains the ionic minerals and chemicals that feed the cells and provides the necessary water.

[0616] The nucleus in the cell is an electrical body which contains the cell's DNA and carries programs to operate its electrical signals and the opening and closing of channels in the wall of the cell's plasma membrane. The nucleus also contains the apoptosis program for cell suicide. Depending on the duties of the cell, some use ion channels that function electrically and others are influenced by chemicals that it obtains from the extra cellular media. Ion pumps and ion channels are electrically equivalent to a set of batteries and resistors inserted in the membrane wall, and thus create voltage differences between the inner and outer sides of the membrane. Such differences in the electrical values range from −40 mV to −80 mV. Because the cell acts as a battery, it provides the power to operate molecular devices that are embedded in the plasma membrane. As described in the '835 patent, the electrical activity sends signals that communicate with adjoining cells of the tumor to regulate the cancer as an intra grail living body.

[0617] An important organelle in the cell is the mitochondrion, which serves as the power station for the cell. Mitochondria are rod or oval shaped structures functioning as respiration for the cell. A number of mitochondria are distributed within the cytoplasm and move in accordance with its flow. The product produced as a biological fuel is called adenosine triphosphate (ATP). The manufacture of ATP results from the processing of proteins, fats, and carbohydrates through the Krebs cycle. The ATP once pro-

duced is distributed to other organelles that require this bio-fuel to provide processing energy as needed.

[0618] The mechanism of energy production is known as oxidative phosphorylation. The membrane of the live biological cell and the membrane of the mitochondria are analogous to plate-like condensers with defined capacitance related to the surface area, the permittivity of the biological media and is inversely proportional to the distance between the surfaces. The pumping of ions into the intermembrane space leads to a voltage build up and the process is analogous to a metabolic pump with a defined voltage gradient and hence a power supply to drive an electromotive force.

[0619] The endoplasmic reticulum (ER) in a cell is a network of membranes that form channels that crisscross the cytoplasm utilizing its tubular and vesicular structures to manufacture various molecules. The network of membranes is dotted with small granular structures called ribosomes for the synthesis of proteins. Ribosomes are tiny spherical organelles distributed around the cell in large numbers to synthesize cell proteins. They also create amino acid chains for protein manufacture. Ribosomes are created within the nucleoli at the level of the nucleolus and then released into the cytoplasm.

[0620] Smooth ER makes fat compounds and deactivates certain chemicals like alcohol or detected undesirable chemicals such as pesticides. Rough ER makes and modifies proteins and stores them until notified by the cell communication system to send them to organelles that require the substances. Cells in humans, except erythrocytes (red blood cells), are equipped with endoplasmic reticulum.

[0621] The Golgi apparatus is made of Golgi bodies, which are located close to the nucleus and are made of flattened membranes stacked atop one another like a stack of plates. The Golgi apparatus sorts and modifies proteins and fats made by the ER, after which it surrounds and packs them in a membranous vesicle so they can be moved around the cell as needed. Similarly, there is a process to pack up cell waste products for expulsion from the cell via ports in the plasma membrane into the extra cellular spaces.

[0622] Lysosomes are the digestive system for the cell. They contain copious quantities of acids, enzymes, and phosphates to break down microbes and other undesirable substances that have entered the cell. They also digest and recycle worn-out organelles to make new cellular structures or parts.

[0623] As described in the '835 patent, the cytoskeleton is composed and constructed of intermediate sized filaments, which actually serve as the internal structure to maintain cellular shape. The filamentous structure serves to provide a highway for electrical signals to travel to sites of chemical process that reside on shelves constructed by the cytoskeleton assembly within the cell. The intermediate filaments are composed of compounds that are similar to the structures of muscles, which have their own electrical properties. The electrical signals traveling through or on the cytoskeleton most likely initiate and stop the chemical reactions, as required. The electrical signals may skip and travel along the surface of the filamentous network rather than within the central framework, again on some sort of scheduled or timed basis or in response to some event or instruction. Access to all systems within the cell by nucleus operations is made possible by electrical signals residing within the individual cells.

[0624] As described in the '835 patent, cells become more electro-negative in the course of cancerization. Cancer cells seem to reconstruct the cellular membrane access ports to allow the importation of more sodium and sugars than non-cancerous cells of the same size. The electrical potential between the inner and exterior layers of the plasma membrane serve as a sort of electrical generator to supply the power to operate the individual cancer cell.

[0625] The cytoskeleton intermediate filaments are considered to be hooked together with a sort of "Velcro" at its connection points throughout the cells interior to allow some flexing of the overall cellular structure. Importantly, the intermediate filaments continue protruding through the desmosome which allows a connection to an adjoining cancer cell. This piercing of the cell wall within the desmosome is considered to one way explaining how signals are sent and received from adjoining cells. There can be several desmosome connections on different aspects of the cell wall (plasma membrane) so as to connect to cells over, under, and beside for example a given cancerous cell, so as to provide a connected network for communication. In the alternative, other types of cellular attachment for signal transduction or transmission are likely.

[0626] Normal cells reproduce by going through a cell cycle that leads to reproduction of similar cells by a process of mitosis which is where a single cell divides and then splits into two daughter cells that are exact replications of the mother cell. Normal cells are limited as to how many times they can reproduce by mitosis, which is probably no more than 70 times.

[0627] Cancer occurs in normal cells in which birth-defected distorted chromosomes and abnormal genes can lead to the formation of a defective cell which exhibits a severe disorder of mitosis (cell division). The thrust of a cancerized cell is to continuously reproduce by splitting into similar daughter cells uncontrollably for its entire life. Some species of cancer cells can reproduce continuously every 30 minutes while others can take 24 hours or longer to multiply.

[0628] Cancer cells continue to reproduce by splitting (including the nucleus) into two daughter cells which themselves split and grow into adult cancer cells and then split again, on and on continually for the life of the malignancy. This process of cell splitting, called mitosis, only produces daughter cells, which enlarges into a massive collection of cells, which is referred to as a tumor. Designated cancer cells on the outer edges of the tumor can be released and travel to other distant sites by a process called metastasis. Once this metastatic process proceeds, the cancer spreads to critical body parts and usually heralds a poor overall outcome for the patient. Cancer cells are typically unregulated, disorganized, and engage in extremely rapid rates of mitosis. When enough cancer cells are made, they form larger tumors, which interfere with the duties and nutrition of nearby normal cells.

[0629] Cancer does its damage in complex ways that include strangling or distorting organs, blood vessels, and nerves as well as working its way into bones, brain, and muscles. Cancer cells perform no function that contributes to the homeostasis (life equilibrium) of the body in any way.

[0630] As described in the '835 patent, cancer cells have developed ways to repel or block the human body immune system by several means including erecting an electrical shield on the outer surface of the plasma membrane, which is produced by the cancer cell itself. Such a thin electrical

shield is called the glycocalyx and generates a negative charge to oppose the animal or human immune system, which is also negatively charged. Two negative bodies repel each other, which in the case of cancer mean that the immune system cannot engage the tumor to destroy it. The body's natural immune system is not effective in attacking cancer as it does in attacking invading bacteria or viruses or even malfunctioning cells that have been injured, which are usually positively charged. Positively charged microbes or ill cells are susceptible to killer T-cell and other immune system attacks because the negatively charged immune defenses can approach its target successfully.

[0631] Additionally, there is a programmed cell death called apoptosis. Apoptosis as a biomedical term that indicates that there is a state of natural or induced reprogramming of a cell to enter a suicide mode whereby the cell dies without any inflammatory process. Thereafter, the lifeless cell is phagocytized and removed by macrophages of the immune system. Apoptosis can occur in many kinds of cells such as erythrocytes as a method to rid the body of non-performing or defective cells. In general, cancer cells are thought to not have much opportunity to have preprogrammed cell death because those cells have an immortal ability to continue to reproduce and reorganize their cellular electrochemical system in a way that suits the purpose of the cancerized cell.

[0632] Some 200 ion channels or more populate all sides of the cell plasma membrane which encompasses and shelters the interior operations of the cancer cell. Cells, including malignant ones, are considered to have an internal signaling mechanism in order for them to operate the cell and remain alive as well as participating in tumor life processes of continuous reproduction of more cancer cells.

[0633] Signaling between cells of a tumor is also believed to make it possible to know when to release adult cells so that they can metastasize to other areas and begin a new tumor colony. The metastatic cancer cells travel within the blood vessels or the lymphatic system or propel themselves across an organ, nerve, gland or muscle to seed a new tumor site. For the individual cancer cells to communicate among themselves, they seemingly have to establish links to neighboring cells. These connections between the individual adjacent cancer cells are specifically tied to one another to allow for the sharing of signals. Ordinarily, cancer cells do not communicate with normal cells and are unable to affect the healthy normal cell in any way, therefore, sparing the unaffected normal cell from any direct operational assault.

[0634] An initiating cancer cell starts out as a normal cell, but develops a chromosomal and/or a genetic chaos that drives a transformation to malignancy. Prevailing cancer theory blames mutations in important regulatory genes for disturbing the normal controls on cells that are destined to become malignant. Such theory does not give credit to the damaging changes to actual chromosomes that are seen in all cancer cells. The distorted, broken or bent chromosomes can unbalance thousands of genes and are believed to be sufficient to trigger cellular instability that can lead to serious genetic disruption, transforming so-called normal cells into malignant ones. While the cancer cells may retain their electrochemical signaling and operating systems which existed when it was a normal cell, changes seemingly occur to rearrange its cellular mechanisms in new ways to eventually disconnect its communication ability from adjacent normal cells and to start rapid reproduction of more cancerous cells.

[0635] As described in the '835 patent, the first cancer cells that are adjacent to normal unaffected cells are sometimes not "wired" into the rest of the tumor. Perhaps these first cells are only a demarcation line from malignant to normal and do not have to participate in the cellular communication system. Later cells do develop the desmosome interconnection communication system that allows a way for each cell to speak to its adjacent neighbor cells. Other means of communicating between cancer cells beside desmosomes are gap junctions, direct cell connections, and tight junctions. The various junctions are connected with the intermediate filaments so as to provide the pathway to transmit messages between the various cancer cells.

[0636] It is believed that neither the normal cell nor the malignant cell can live without a functioning electrical signaling mechanism to operate the electro-chemical processes that are shelved on the cytoskeleton shelving. The cytoskeleton is the framework within the cell that provides a somewhat flexible geodesic-like framework to maintain cell shape, provide shelves for chemical or electrochemical process, and allow space for the organelles, nucleus, and protein manufacturing elements within the cell. The liquid within the cell is called cytoplasm. There is a cytoplasmic streaming process that causes directional movement of the liquid cytoplasm as a means of local transport for the semi-floating organelles (functional cell components). Likely this allows these floating structures some sort of communication between the cellular membrane and the nucleus as they come into close proximity.

[0637] As described in the '835 patent, individual cells operate themselves by electrical and chemical processes to maintain life and to perform the function for which a given cell has been constructed. Cancer cells are considered to have different electrical signals than normal cells. In one embodiment of the invention, the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein, and the resultant electric field in proximity to these signals can affect the electrical and chemical processes of cancer cells promoting cell death.

[0638] Cells generate their electrical energy and communication signals within the plasma membrane. The plasma membrane may also have electrical connections to adjacent cells of the same type. The nucleus is considered in communication with activities occurring in the plasma membrane, for that matter all other activities of the cell.

[0639] Cell signaling may be accomplished by a combination of electrical and chemical interactions. Different types of cells should require a varied level of signaling qualities. The creation or generation of a given cell signal is believed to begin in the plasma membrane where raw material and chemical ions are taken in from the extracellular matrix to both generate electricity and establish the signal format. The plasma membrane is a sort-of cell wall that takes in the required raw material via its ion channels. Ion channels open and close to allow passage into and from the cell interior. Electrical signals are likely generated in the plasma membrane before they are sent via the cytoskeleton, all about the cell to go and participate and contribute to cell operations. In one embodiment of the invention, the in situ or ex situ presence of energy augmentators including reso-

nators such as the folded resonators and rectifying resonators described herein, and the resultant electric field in proximity to the ion channels can affect the ion channels and the opening and closing thereof.

[0640] The cytoskeleton also serves as a geodesic-style dome providing a framework to shape and support the cell. In addition, the cytoskeleton serves as the pathway by which cell signals generated in their plasma membrane travel within and around the cell to do its work. In addition, communication to adjacent cancer cells could happen through connections such as desmosomes, which are extensions that bridge and allow communication between adjacent cells of a tumor.

[0641] Necrosis, apoptosis, autophagy, stasis, macroautophagy, cell starvation, tumor reduction, shut-down of mitochondria production of ATP, consuming contents of cytoplasm, incipient starvation, blebbing, cell shrinkage, nuclear fragmentation, chromatin condensation, chromosomal DNA fragmentation, pyknosis, karyolysis, karyorrhexis. Human bodies have complex daily cellular maintenance duties to dispose of some 50 million worn out cells every day. Average adult humans operate an ever-busy apoptosis and repair system. Key elements are briefed below.

[0642] Necrosis is a form of traumatic cell death that results from acute cellular injury. Necrosis death of cells can happen because of infection or fever that result in the premature death of cells in living tissue. Untreated necrosis results in a buildup of dead and decomposing cell debris in the region of actual cell death. A classic example would be gangrene. Cells dying from necrosis don't follow the usual apoptosis transduction pathways.

[0643] Apoptosis is the original programmed cell death technology that helps repair and model the body beginning with birth and continuing on throughout life. Some 50 billion cells die every day due to apoptosis. For example, the lining of the digestive tract from the stomach lining on to the colon undergoes apoptosis every 3 to 5 days to replace the entire inner lining of the digestive tubular structures. Red blood cells are programmed to replace themselves every 90 days by undergoing killing by the spleen and the bone marrow manufacturing new blood cells and releasing them back into the blood vessels to do their work of carrying oxygen and carbon dioxide.

[0644] Technical events that appear during an apoptosis event include characteristic changes that include cell shrinkage, generating heat, hypoxic events and an increase in calcium concentration which causes snappy signaling in the nucleus that triggers and orchestrates the imminent apoptotic event. In one embodiment of the invention, the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein, and the resultant electric field in proximity to the nucleus can affect the nucleus of the cells promoting cell death.

[0645] Autophagy is from the Greek definition as "self-eating." Inside a living cell's cytoplasm are organelles identified as autophagosomes which move around the cell to sweep up viruses, bacteria, and worn out materials from the cell itself. The autophagosomes bag up or concentrates the cell sludge and worn out protein and other debris to be handled by recycling organelles that float in the cytoplasm. Some of the unusable waste is forced out of designated cell ion ports by pumping it through the plasma membrane into the extra-cellular fluid surrounding the cells. Since some neurons live as long as the body they have to use autophagy to maintain the quality of the overall cell health. Autophagy and mitochondrion can work together to cause apoptosis to trigger programmed cell death to rid the cell of unwanted cell component that can't be rehabilitated. Unlike necrosis, apoptosis produces cell fragments called apoptotic bodies that phagocytic cells are able to engulf, eat, digest, and then dispose of in league with the autophagy process in a well-established method to keep the overall cellular system in order.

[0646] Pyknosis is the irreversible concentration of chromatin in the nucleus of a cell involved in necrosis or apoptosis. This is followed by condensing its nucleus before expelling it to become a reticulocyte. The maturing neutrophil will be involved in forming blebs that stay in the cell until the end of its life. Blebs are distortion of the nucleus and the cancer cell shape. It is the formation of protrusion or pimple structures of what was previously a symmetrical nucleus and overall cell shape. It is followed by fragmentation of the changing nucleus on its way to experiencing karyorrhexis. During bleb formation of the nucleus, a sort of pimple formation gives the nucleus an unhealthy appearance, which does not improve.

[0647] Karyorrhexis is the ultimate bursting of the cellular nucleus into multiple pieces that cannot be repaired. The nucleus of a cell represents and is equivalent to the brain of any creature, once it is broken into pieces it is finished.

[0648] Karyorrhexis is an important cancer killing skill, which is accomplished by fragmentation of the cancer cell nucleus into apoptotic bodies, which are then engulfed and ingested by phagocyte(s). A phagocyte is a special cell that locates and surrounds broken cellular components and then eats them. There are fixed phagocytes that live in the liver, bone marrow, and spleen. Such phagocytes are represented by neutrophils and macrophages. Also, there are freely moving phagocytes such as leukocytes (white blood cells) that circulate in the blood stream to do their clean-up work. The job of the nucleus is to control all cellular operations and to participate in communication and coordination with nearby cells. If a nucleus is fragmented, it is like fragmenting the brain of a human or animal, life cannot go on with such as injury.

[0649] Electrical signaling can function to control and regulate chemical activities, autophagy, regulates the mitochondrial production of ATP which serves as an energy source for the cell, and controls the ribosome's protein manufacturing operations. In addition, the electrical codes can serve as communication means with the adjoining cells including when to release cells for metastasis operations among other duties.

[0650] Electrical signal flow traveling throughout the many cells of the tumor may allow for the generation of instructions to select cells that are destined to metastasize to distant sites to spread colonies for the malignancy. Such cells become soft and slightly puffy as they are released into the lymph or blood circulation system to travel to distant sites to start a new metastatic colony. In one embodiment of the invention, the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein, and the resultant electric field in proximity to the tumor can affect the electrical signal flow and prevent distribution of electrical signals remote from the tumor.

[0651] Electrical signals from the plasma membrane may travel on the surface of the intermediate filaments and reach chemical processes and likely ignite or stimulate a reaction that contributes to reproduction, protein manufacture or metabolic operations. Without electrical activity and the molecular devices that operate the cell plasma membrane, the cell could not function properly. In one embodiment of the invention, the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein, and the resultant electric field in proximity to the intermediate filaments can affect the electrical signals traveling on the surface of the intermediate filaments.

[0652] The charge of the outer wall takes on a protective negative charge, especially on the very thin outermost cell coating which is called the glycocalyx. This glycocalyx in cancers is considered to have a continuous negative charge protecting the malignant structure from the immune system which is also electrically charged in a negative format to repel the immune system from attacking the cancer, while non-cancerous glycocalyx coatings are positive in their protective electrical charge. All of this allows the positive protective charge to permit the negative charged immune system to embrace the positive cell protective elements and engage undesirable invaders like viruses or bacteria. Not so for the cancer glycocalyx with its negative shield which may repel the immune killer T-cells as they approach. In one embodiment of the invention, the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein, and the resultant electric field in proximity to the protective negative charge may disperse the negative charge and thereby allow the immune killer T-cells to approach the cancers.

[0653] Many issues go wrong during the formation of tumorous mass including and not limited to uncontrolled proliferation, loss of apoptosis, tissue invasion and metastasis and Angiogenesis. Though the fundamental mechanisms are still unclear, it is safe to assume that there is information (regardless of its nature) that is originated from a group of cells, an individual cell or a sub-cellular component, this information is transmitted through some means (the transmission line) and then received by a group of cells, an individual cell or a sub-cellular components that have the ability to act on the received information. It is also safe to assume that the interruption of the information from one originator to the receptor would result in information loss and therefore interruption of the communication. The information during Cancer proliferation is more often than not viewed as chemical, genetic but not electro-magnetic. In addition to the chemical and genetic information carrier entities it has been demonstrated that electromagnetic transmission is taking place. The decoding of such information is yet to be achieved. Suffice it to say that all the fundamentals of electro-magnetic communication have been established. It is therefore useful to add the possibility of electromagnetic transmission to the existing understanding of the dynamics fueling cancer.

[0654] The membrane of biological cells and organelles act like platelike capacitors with the capacitance:

$$C = \frac{\chi \varepsilon \varepsilon 0 \rho 2}{d}$$

[0655] Where χ is the portion of the plate-like capacitor, ε and ε_0 are the permittivity of the biological media and the permittivity of free space, d the distance or space in the intermembrane and ρ is the radius of curvature of the platelet. The energy stored is related to the established voltage gradient divided by the distance. In one embodiment of the invention, the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein, and the resultant electric field in proximity to these membranes can affect the energy stored on these plate-like capacitors.

[0656] The helical coils of bio-molecules result in an inductance represented by the equation:

$$L=\mu\mu_0 d8\pi,$$

[0657] where μ is the Permeability of the biological media.

[0658] Lastly the dynamic circuitry of highly nonlinear biological interconnections which contributes to charge storage as well as resistance between the various molecules as gated by hoping of electrons or conductance of heavier charged species (ions, anions, low molecular weight species) leads to an impedance described by

$$Z=(R^2+(\omega L-1/\omega C))^{1/2}$$

[0659] The impedance Z is the smallest when Z=R where $\omega L=1/\omega C$. Under this condition and a constant electric field (as established in the metabolic pump and as exemplified by the mitochondria ions build up in the interlayer, which therefore represents a power supply condition with a well-established voltage gradient, a variety of oscillatory conditions can be established. In one embodiment of the invention, the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein, and the resultant electric field in proximity to the electrons or heavier charged species can change the electrical conductance.

[0660] These oscillatory conditions do take into account the inter-connectivity of the biological media with many constituents each sharing boundary conditions and contributing to an overall energy continuum of the collective. These biological oscillatory systems are complex, and many fundamental electromagnetic laws and thermodynamic principles need to be applied, simulated, verified gaged for their predictive effectiveness. This aside, the establishment of conditions intrinsic to the biological system leading to the charge up and storage of electrical energy and subsequently discharge and decay of the stored energy under the form of electro-magnetic energy is empirically well established. These oscillatory systems can also, in one embodiment of the invention, be affected by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein, and the resultant electric field in proximity to these oscillatory systems.

[0661] FIGS. **40**A-B are a depiction of on the left a) a conventional LRC circuit capable of resonating and releasing stored energy E in the electromagnetic energy emission at well defined frequencies and on the right (b) an equivalent type biological circuit with a metabolic pump (MP), coiled molecules (CM) with a representative inductance (L), a capacitive layer (CL) from a phospho-lipid bi-layer, and the highly interconnected biological media (BM) completing the electrical circuit. This biological circuit exhibits similar characteristics as a low energy storage (low Q) LRC and can resonate in the range of 10^{14}-10^{15} Hz range which encom-

passes the visible and the UV range. Low Q typically translates into a broad emission frequencies. These biological emitters can also, in one embodiment of the invention, be affected by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein, and the resultant electric field in proximity to the biological circuit. Indeed, in one embodiment of the present invention, the frequencies of the resultant electric field can act as a type of auxiliary pump making for a forced oscillator emission. Accordingly, in one embodiment of the invention, scanning a drive frequency activating the folded resonator can induce forced biological emissions at frequencies close to or a harmonic of the folded resonator or close to or a harmonic of the biological emitter. The folded resonator thus can stimulate biophoton type emissions by coupling energy into these biological circuits with or without stimulating luminescent type reactions.

[0662] Furthermore, taking values of μ, ε and χ that pertain to biological media, one can calculate the frequency of the resonance oscillators. These calculations yield frequencies in the range of 10^{14}-10^{15} Hz range which encompasses the visible and the UV range. These findings were the subject of publications including:

[0663] Chwirot, W. B., Dygdala, R. S. and Chwirot, S. (1985) optical coherence of white light induced photon emission form microsporocytes of Larix and Europeas Mill. Cytobios, 44, 239-249.

[0664] Frohlich, H. and Kramer, F. (1983) Cohernet exciation in biological systems. Springer Verlag, Heidelberg.

[0665] Smith, C. W., Jafary Asl, A. H., Choy, R. Y. S. and Monro, J. A., (1987) the emission of low intensity electromagnetic radiation form multiple allergy patients and other biological systems. Photon Emission from Biological Systems, Jezowska-Trsebiatowska, B. Kochel, B. Slawinski, J. and Strek, W. (eds). World Scientific, Singapore, pp. 110-126.

[0666] Tiblury, R. N. (1992) the effect of stress factors on the spontaneous photon emission from microorganisms. Eperientia, 48, 1030-1041.

[0667] It is therefore useful, in view of the empirically well-established bio-photonic energy and the sound theoretical understanding, to view the classical cancer proliferation steps and identify the presence and the possible fit and play of the of electromagnetic energy in the various proliferation steps including cell proliferation, loss of apoptosis, tissue invasion and metastasis and angiogenesis, all of which may be affected by he in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein, and the resultant electric field in proximity to the biological circuits.

[0668] Furthermore, receptors consist of three domains and extracellular Ligand binding domain a transmembrane domain and an intracellular domain as illustrated in the figure:

[0669] Binding of a ligand to the extracellular domain activates the receptor tyrosine kinase which activates other proteins by phosphorylation of adding a phosphate to the amino acid tyrosine on a protein inside the cell.

[0670] The binding of the ligand to the extracellular domain could be accompanied by the emission of light in view of the Gibbs free energy reduction that accompany a favorable chemical reaction. When a ligand binds to the receptor, a signal goes to the intracellular domain activating the associated enzyme and initiating a cascade of signals to the nucleus that tells the cell to grow and divide or to stop growing. These signals can in fact be electromagnetic in nature and therefore affected by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein, and the resultant electric field in proximity to these ligands.

[0671] A protein kinase is a kinase enzyme that modifies other proteins by chemically adding phosphate groups to them (phosphorylation). Phosphorylation usually results in a functional change of the target protein (substrate) by changing enzyme activity, cellular location, or association with other proteins. The human genome contains about 560 protein kinase genes and they constitute about 2% of all human genes. Up to 30% of all human proteins may be modified by kinase activity, and kinases are known to regulate the majority of cellular pathways, especially those involved in signal transduction. In one embodiment, the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein, and the resultant electric field in proximity to these proteins and enzymes may affect the signal transduction.

Autocrine Stimulation:

[0672] Malignant cells generate many of their own growth signals which allows them to divide with reduced external growth stimulation some cells are able to produce their own growth factors and stimulate their own growth. These growth factors are then driven or diffused to the cell membrane and release to the environment outside of the cell which stimulates certain ligands.

[0673] It is possible that the autocrine process is the results of electromagnetic radiation that results from within the cell or group of cells when under stress. The stress signal stimulates biophotons which favor the over production of certain molecules (growth factors in this case) and keeling the system off balance. For example: Glioblastomas express platelet derived growth factor or PDGF and sarcomas express tumor growth factor alpha or TGF-alpha & epidermal growth factor receptors or E-GFR. In one embodiment, the present invention can interfere with the transmission of information related to proliferation by having energy modulators that get excited by X-Ray energy and emit UV energy tuned to denature such growth factors as EGFR and PDGF described in sarcomas and glioblastomas. The growth factors are targeted by UV energy to halt the growth factor inside and outside the cell. It is conceivable to have energy modulators (of small enough size) to migrate into the cytoplasm and emit UV radiation selective to the full or partial denaturization of the growth factor. The induced change can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0674] In normal cells, the production of cell surface receptors is limited by cellular restraints on gene expression and protein translation. In tumor cells, however, mutations in the genes and coding for the receptors disrupts this finely tuned regulation and too many copies of the gene are produced in a phenomenon called gene amplification.

[0675] Excessive transcription and production of receptors leads to the fact that the more receptors expressed, the more binding sites are available for the ligands. This is a sort of runway condition. The off balance of finely tuned dynamics,

results in tumor cells that have increased potential to be triggered into a growth phase by the binding of ligands to the excess receptors that decorate the cell walls.

[0676] Gross overexpression of growth factor receptors can result in ligand independent signaling where receptors are active in the absence of stimulating molecules. Structural changes to a receptor can also lead to ligand independent activation. This structural change including a modified conformation could be triggered by light, such as truncated versions of the EGRF where much of the intracellular domain is missing or constitutively active.

[0677] EGF-Receptor (such as HER1 or ErB-1) is a member of a sub family of type one receptor tyrosine kinases. These receptors are found primarily in the membranes of normal epithelial cells from: skin, breast, colon and lungs (amongst others). EGF-Receptor and its ligand play a central role in the regulation of cell proliferation differentiation & survival. EGFR is overexpressed in tumors arising from the colon, rectum and head and neck to name a few.

[0678] When a specific ligand binds to its receptor this leads to changes in the receptor that transmit a specific signal into the cell. For example the receptor tyrosine kinase is activated and initiates a signaling pathway specific to that receptor. This phenomenon is called signal transduction. In one embodiment, the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein, and the resultant electric field in proximity to these receptors can affect the signal transduction.

[0679] Activation of a signal transduction pathway creates a complex chain of events in the cytoplasm or fluid intracellular space that eventually leads into the cell nucleus where the transcription of genes regulating cell cycle progression are stimulated resulting in cell proliferation.

[0680] One of the major cascades implicated in cancers is the Ras Raf Activated Protein MAP kinase pathway. Another interesting pathway is the phosphor type 3 kinase or PI 3K/Akt/mTOR pathway. These pathways are linked to each other and other signal transduction pathways in the cell de-regulation or loss of normal controls in any of these pathways is thought to be present in all human tumors.

[0681] Once the signal reaches the nucleus, transcription factors are activated. These factors transcribe the genes that are translated into proteins, such as growth factors, that are necessary to allow the cell to continue to proliferate. Therapies can target factors responsible for tumor growth include the ligand receptors, intracellular second messengers and nuclear transcription factors. The induced change can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators described herein.

[0682] Ligands can be neutralized before they bind to the receptors: An example of this is Avastin which is a humanized monoclonal antibody that targets circulating vascular endothelial growth factor or VEGF. The induced change can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0683] Platelet derived growth factor or PDGF, fibroblast growth factor or FGF, and other examples of ligands can be targeted for different cells in the body. Light based therapies can target the denaturization of these chemistries as exemplified before. The induced change can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0684] The receptors on the surface of normal and tumor cells can be inhibited directly. Erbitux is an example of this. It is a chimeric antibody that binds directly to the epidermal growth factor receptor and competitively inhibits the binding of EGF and other ligands such as TGF-alpha. Another way to block the receptors function is through small molecule inhibitors of receptor phosphorylation associated with them. For example, EGF receptors have a tyrosine kinase that can be blocked by molecules such as Gefitinib (Iressa) or Erlotinib (Tarceva). The induced change can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0685] Apoptosis:

[0686] Apoptosis is a mechanism by which organisms limit the growth and replication of cells. If apoptosis did not occur it would be hard to control growth and tissue homeostasis would be lost (in fact this is one of the key mechanisms behind cancer). The genetic alterations in the cancer cell not only lead to increased cellular proliferation and growth they also lead to loss of apoptosis (i.e., excessive cell growth and little cell death in malignant tissue). Apoptosis occurs in normal cells to allow for removal of damaged cells and maintaining a constant number of cells in regenerating tissues and is an important part of embryogenesis. In an average human adult 50 to 70 billion cells undergo apoptosis per day. Apoptosis is characterized by changes such as: cell shrinkage, mitochondrial cytochrome C release, and fragmentation of cell DNA into multiples of 180 base pairs. In the end, cells are broken into small apoptotic bodies which will be cleared through phagocytosis. Phagocytosis is a process where cells take in the cell fragments or microorganisms in membrane-bound vesicles. The vesicles fuse with lysosome containing proteases and the engulfed material is processed for recycling.

[0687] There are two pathways that can activate apoptosis:

[0688] 1—The first is the death receptor or extrinsic pathway. It is triggered by activation of members of the tumor necrosis factor receptor superfamily.

[0689] 2—The second is through the mitochondrial or intrinsic pathway. This is set in motion by DNA damage.

[0690] Both pathways ultimately stimulate a set of enzymes called caspases which interact with inhibitors of apoptosis proteins or IAP and a Bcl-2 family of proteins (which individually have either pro and anti-apoptotic properties). The induced change can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0691] In some malignant cells there is resistance to apoptosis due to overexpression of anti-apoptotic proteins. For example Bcl-2 is overexpressed in B-cell lymphoma as a result of the translocation of its gene. Conversely, deactivating mutations having a pro-apoptotic molecule like backs is seen in some gastrointestinal tumors and leukemias. Anticancer agents have been developed targeting anti-apoptotic molecules. For instance, short segments of DNA complementary to the RNA of Bcl-2 or antisense oligonucleotides have been designed to reduce the translation of this anti-Apoptosis protein. The induced change can be assisted by the in situ or ex situ presence of energy augmentators

including resonators such as the folded resonators and rectifying resonators described herein.

[0692] Activation of transcription factors can lead to apoptotic resistance. This occurs for example when members of the nuclear factor kappa B or (NF-kB) family of transcription factors are over expressed in certain tumors which lead to increased transcription anti-Apoptotic members of the IAP and Bcl-2 families. Ubiquitin proteasome pathway regulates the expression of transcription factors and other cell cycle proteins. Certain molecules can suppress or reduce NF-kB and IAP one activation and inhibit tumor promotion. Bortezomib is a proteasome inhibitor that has shown promising results in multiple myeloma. It inhibits the proteasome which leads to increased levels of the NF-kB inhibitor and therefore less anti-apoptotic proteins. The induced change can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0693] Tissue Invasion and Metastasis:

[0694] Normal cells grow in a controlled manner that form tissues that form organs with specific functions. Malignant cells are defined by their ability to invade adjacent structures and be disseminated or metastasize. Malignant tumors can metastasize at any point. They do so by having cells break off from the main to enter the bloodstream and/or lymphatic channels and travel to other parts of the body to initiate a new tumor. Their ability to invade eventually affects the function of the normal tissue into which they are growing. Metastasis is a multi-factorial process involving complex interactions between tumor cells.

[0695] The EGFR pathway activates and modulates metastasis. When the appropriate signals enter the cell, a complex chain of events within the cytoplasm is set in motion. These events eventually lead into the cell nucleus where the transcription of gene regulating cell cycle progression and cell growth are stimulated. One protein produced through the cell activation process is the enzyme matrix metalloproteinase or MMP. When a tumor cell metastasizes, it breaks off from the main tumor and enters the extracellular space. Tumor cells secrete MMP which degrade the collagenous extracellular matrix, or ECM, breaking through the basement membrane that surrounds the tumor allowing the tumor cells to migrate toward the blood or lymph vessels.

[0696] When the MMPs reach the vessel they break down the basement membrane surrounding the vessel through enzymatic action opening access to the epithelial cells lining the vessel. Tumor cells can then migrate into the blood and lymph by entering through the tight junctions of the epithelial cells. The tumor cells are then transported through the blood and lymph to other tissues. It is known that metastatic tumor cells tend to target some organs more than others although the reason why is poorly understood. The migration of tumor cells into the organs is very much like the recruitment of white blood cells to tissues after injury.

[0697] Initially there is weak adhesion of tumor cells to endothelial cells which allows the tumor cells to shelter along the vessel lining until stronger bonds are formed. Once the metastatic cells are securely attached to the endothelial lining, they leave the vessel and enter the tissue. They also leave an open pathway that allows less aggressive tumor cells to invade the tissue and grow. This tissue invasion and metastasis can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0698] Angiogenesis:

[0699] As the tumor grows it will eventually reach a size where it will need to have additional vasculature to sustain continued growth. To achieve this the tumor cells excrete certain proteins to stimulate blood vessel growth into and around the tumor in a process called angiogenesis. One of the major pathways involved in angiogenesis involves vascular endothelial growth factor, or VGEF, and its family of receptors. There are seven subtypes of VEGF and three receptors that each bind differently. VGEF affects the endothelial cells that line the blood vessels in a number of ways. It can cause them to proliferate by activating the extracellular kinases and MAP kinase signal transduction pathways. It can induce proteins that can break down the basement membrane to allow endothelial cells to migrate and invade these proteins including matrix metalloproteinases or MMPs, euro kinase plasminogen activator uPA and its receptor uPAR, as well as the tissue type plasminogen activator. It makes vessels more permeable allowing molecules and fluids to leak out.

[0700] When MMP is secreted into the extracellular space it degrades the extracellular matrix to allow pro-angiogenic factors to reach the vasculature. With the extracellular matrix degraded pro-angiogenic factors including VGEF can reach receptors on the endothelial cells of blood vessels surrounding the tumor, thus stimulating the angiogenic signal in the vessel. The angiogenic signal may be suppressed by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0701] VGEF also helps the new endothelial cells survive by up regulating inhibitors of apoptosis. VEGF also activates the endothelial cells to express the proteins necessary to allow the new blood vessels to form. The end result is the growth of new blood vessels into the tumor. With this growth of new vessels into the tumor, additional nourishment can be delivered to the tumor. New blood vessels in the tumor thus facilitate further tumor growth. Strategies targeting VEGF and its receptors have been used successfully in clinical practice. Avastin is an antibody that binds VEGF and prevents its binding to its receptor. Another therapy is Sutint which is a small molecule inhibitor with high binding affinity for VEGF and PDGF receptors. With psoralen compounds and UV energy modulators, it is possible to achieve the same results by binding the affinity of VEGF and PDGF. Another strategy is to target the exact frequency (derived from a UV-VIS) to cause ionization or denaturization of the VEGF and PDGF. The ionization can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0702] While much is known about these various biological processes, and much is known about the phenomenon of cell-to-cell communication/signaling, methods and techniques are needed to harness the signaling power of cells to affect and/or trigger various of these biological processes within a subject.

[0703] Assisted Cell-to-Cell Communication Using Energy Augmentators

[0704] While not limited to the following, the present invention with its natural sources of biophoton radiation and its artificial sources of biophoton radiation can alter the

structures of the cells or the functions described above including the electrical signaling, can alter the chemical pumping and ion transport processes promoting cell growth (reproduction) or cell death, and can alter the "communication" or "coupling" between various cells to thereby provide a method for treatment of a condition, disorder or disease in a subject. These induced changes can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0705] As used herein, biophoton radiation encompasses mitogenic radiation to any degree that the art considers these "radiations" or ultra weak emissions to be different. Indeed, the phenomenon of ultra weak emission from cellular systems has been a topic of various inquiries since the 1900s. This topic can be traced back to the early investigations of the Russian biologist Gurwitsch Alexander G. Gurwitsch more than seventy years ago, who speculated that ultraweak photon emission transmit information in cells [A. G. Gurwitsch, S. S. Grabje, and S. Salkind, "Die Natur des spezifischen Erregers der Zellteilung," *Arch. Entwicklungsmech. Org.* 100, 11-40, 1923]. His research was an attempt to answer a question not responded in its full scale even now: "what are the causes of cell division?" Combining several observations, Gurwitsch concluded that this event required a coincidence of two factors: (1) internal cell "preparedness" to division, and (2) external impulse, i.e., a signal coming from the outside and "switching on" the (already prepared) mitosis. He suggested that the external impulse was non-chemical (i.e., a kind of radiation), and induced "collective excitation" of special molecular receptors located on a cell surface. This work and more recent work has shown that an "induction length" (that is a distance from cell emitting biophoton radiation and the cell reacting to the biophoton radiation) is extremely short, on the order of mm's, with some finding an optimal distance to be 1-10 mm.

[0706] The invention in various embodiments encompasses methods and techniques for identifying bio-photonic electromagnetic energy and stimulating the production of such naturally produced and transmitted electromagnetic energy inside a cell (intracellular) and amongst a group of short ranged neighboring cells (intercellular) and finally between two distinct group of cells as in the case between a group of diseased cells inside a tumor and a group of non-diseased cells in the Tumor Micro Environment (TME). These induced changes can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0707] In some cases the invention relates to the stimulation or interruption of the transmission of naturally occurring bio-photonic electromagnetic energy. The stimulation or interruption may be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0708] In the 1970s, this area of research was investigated by a number of investigators. The presence of biological radiation from a variety of cells was later investigated by several research groups in Europe and Japan using low-noise, sensitive photon-counting detection systems [B. Ruth and F.-A. Popp, "Experimentelle Untersuchungen zur ultraschwachen Photonenemission biologischer Systeme," *Z. Naturforsch., A: Phys. Sci.* 31c, 741-745, 1976; T. I. Quickenden and S. S. Que-Hee, "The spectral distribution of the luminescence emitted during growth of the yeast *Saccharomyces cerevisiae* and its relationship to mitogenetic radiation," *Photochem. Photobiol.* 23, 201-204, 1976; H. Inaba, Y. Shimizu, Y. Tsuji, and A. Yamagishi, "Photon counting spectral analysing system of extra-weak chemi- and bioluminescence for biochemical applications," *Photochem. Photobiol.* 30, 169-175, 1979]. Popp and coworkers suggested the evidence of some 'informational character' associated with the ultra-weak photon emission from biological systems, often referred by Popp as "bio-photons". Other studies reported ultra-weak photon emission from various species including plant, and animals cells [H. J. Niggli, C. Scaletta, Y. Yan, F.-A. Popp, and L. A. Applegate, "Ultraweak photon emission in assessing bone growth factor efficiency using fibroblastic differentiation," *J. Photochem. Photobiol., B,* 64, 62-68, 2001;]. Results of experiments of UV-irradiated skin fibroblasts indicated that repair deficient xeroderma pigmentosum cells show an efficient increase of ultraweak photon emission in contrast to normal cells. [H. J. Niggli, "Artificial sunlight irradiation induces ultraweak photon emission in human skin fibroblasts," *J. Photochem. Photobiol., B* 18, 281-285 (1993)].

[0709] A delayed luminescence emission was also observed in biological systems [F.-A. Popp and Y. Yan, "Delayed luminescence of biological systems in terms of coherent states," *Phys. Lett. A* 293, 93-97 (2002); A. Scordino, A. Triglia, F. Musumeci, F. Grasso, and Z. Rajfur, "Influence of the presence of Atrazine in water on in-vivo delayed luminescence of acetabularium acetabulum," *J. Photochem. Photobiol., B,* 32, 11-17 (1996); This delayed luminescence was used in quality control of vegetable products [A. Triglia, G. La Malfa, F. Musumeci, C. Leonardi, and A. Scordino, "Delayed luminescence as an indicator of tomato fruit quality," *J. Food. Sci.* 63, 512-515 (1998)] or for assessing the quality or quality changes of biological tissues [Yu Yan, Fritz-Albert Popp, Sibylle Sigrist, Daniel Schlesinger, Andreas Dolf, Zhongchen Yan, Sophie Cohen, Amodsen Chotia, "Further analysis of delayed luminescence of plants", *Journal of Photochemisty and Photobiology B*: Biology 78, 235-244 (2005)].

[0710] It was reported that UV excitation can further enhance the ultra-weak emission and a method for detecting UV-A-laser-induced ultra-weak photon emission was used to evaluate differences between cancer and normal cells. [H. J. Niggli et al, Laser-ultraviolet-A-induced ultraweak photon emission in mammalian cells, *Journal of Biomedical Optics* 10(2), 024006 (2005)].

[0711] There are those that maintain that the health of the body depends on certain bioelectric vibrations that are susceptible to chemical or physical toxic factors. Frohlich notes that there are coherent electric vibrations in the frequency range 100 GHz to 1 THz, excited in cells by metabolic processes (see Frohlich H. Coherent electric vibrations in biological systems and the cancer problem, IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-26, No. 8, August, 1978, pp 613-617). This idea is based on observation of the inhibition or stimulation of the growth of yeast and bacterias functions of the applied frequency, showing very stable and repetitive resonances. If such vibrational states are indeed metabolically excited, then they should be manifested in Raman spectroscopy. Actually, their existence has been demonstrated during periods of metabolic activity of lysozyme and *E. coli* (700 GHz to 5

THz). Emissions have also been observed at lower frequencies (150 GHz or less). These vibrations occur in the tissue of higher organisms and they have been hypothesized exercise some control on cellular growth (see also S. J. Webb et al, Nature, Vol. 218, Apr. 27, 1968, pp. 374-375; and S. J. Webb et al et al, Nature Vol. 222, Jun. 21, 1969, pp. 1199-1200). Cancerization could result from a modification of these vibrations by the invasion of foreign molecules, e.g., the presence of free electrons in the condition bands of proteins. There is some evidence for the presence of double spectral lines at 1.5 and 6 THz in breast carcinoma, which may be an indication of an interaction between normal cellular vibrations and free electrons. In such coherent frequency communication between cells, it is believed that the medium through which the communication is transmitted is the water within and around the cells (see Smith, Coherent Frequencies, Consciousness and the Laws of Life, 9th International Conference CASYS '09 on *Computing Anticipatory Systems*, Liege, Belgium, Aug. 3-8, 2009).

[0712] Farhardi et al, in "Evidence for non-chemical, non-electrical intercellular signaling in intestinal epithelial cells" in Biochemistry 71 (2007) 142-148 in Science Direct (the entire contents of which are incorporated herein by reference) reported on a synchrony in which mechanically separated neighboring cells (which were not able to communicate via chemical or electrical mechanisms) nevertheless showed responses in the neighboring cells (untreated) to a treated cell undergoing apoptosis. Farhardi et al, found that "detector cells" as far as 4 cm away from the control cell (where H_2O_2 was added to induce cell death in an intestinal epithelial cell line) also showed cell death although not exposed to the hydrogen peroxide.

[0713] Matsuhashi et al, in "*Bacillus carbibiphilis* cells respond to growth-promoting physical signals from cells of homologous and heterologous bacgteris" in J. Gen. Appl. Microbiol. 42, 315-323 (1996) (the entire contents of which are incorporated herein by reference) reported that bacteria cells alone can emit signals that stimulate colony formation in neighboring cells as far away as 30 cm and even those separated by an iron plate. Matsuhashi et al concluded that sonic waves were the likely signals being propagated between cell cultures.

[0714] Attempts to measure the wavelength spectrum of biophoton radiation have reported spectra in the area from 190-250 nm in the 330-340 nm wavelength range where absorption in the natural medium would be expected, thereby limiting how far biophoton radiation would travel inside a subject. While also being weak and in the UV range, natural sources of biophoton radiation emit this radiation in short bursts of a duration of approximately 10^{-3} s at a frequency of 10 to 100 Hz.

[0715] Others have reported biophoton emission from skin cells with a spectra of photon emission detected from 500 to 700 nm, with primary and secondary emission peaks at 630-670 nm and 520-580 nm, respectively.

[0716] Shanei et al. in Detection of Ultraweak Photon Emission (UPE) from Cells as a Tool for Pathological Studies, 2016 published on line at www.jbpe.org (the entire contents of which are incorporated herein by reference) report that it is well-known that all living cells emit ultraweak photon emission (UPE), which is considered due to byproducts of chemical reactions in cell metabolisms. Shanei et al. reported that it has been shown that Reactive Oxygen Species (ROS) in the cells enhances the UPE intensity. Shanei et al. reported that the magnitude of such UPE is extremely weak (i.e. a few to 10^3 photons/(sec·cm^2)), and the detection of such ultra-weak signals is hardly possible via sensitive instruments like photomultiplier tube (PMT) that can detect single photons. Shanei et al. also reported on earlier work where UPE from tumor tissue was observed to be higher than UPE from normal tissue.

[0717] In the experiments conducted by Shanei et al., they used 9235B as a 51 mm (2") diameter, end window Photomultiplier (ET Enterprises Limited, United Kingdom) to measure photons emitted from HT-29 cells (a common cancer of digestive tract). Their detector had its maximum response at 350 nm with the quantum efficiency of 30% in detection range of 250 nm to 600 nm. Shanei et al. showed that the application of H_2O_2 to the HT-29 cells caused their death and a corresponding increase in the ultra-weak photon emission (UPE).

[0718] FIG. **34** illustrates the coupling of one region (not shown) into the region shown in FIG. **34** by way of for example "natural" biophoton radiation **102** (that is radiation from nearby living cells). In one embodiment of the invention, with the coupling of these regions together, due to a change in biological or chemical activity of the cells in a first region, a biological change in a second region inside the subject will be induced. The induced biological change in the second region may be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein in proximity to the first region and/or the second region.

[0719] Coupling as used herein refers to a number of ways that cells in one region induce a biological change in another region. This coupling can utilize mitogenic radiation, biophotonic radiation, electromagnetic radiation, ultraviolet radiation, visible radiation, and near infrared radiation. This coupling between different regions can be via the quantum entanglement of associated states, magnetic coupling, coupling via electric field propagation, coupling via bioplasma states, coupling via sonic waves, coupling via single-photon-type non-classical optics, coupling via coherent light emissions, coupling through tunneling nanotubes, coupling through satellite DNA, coupling through biological waveguides, coupling via a biophoton bypass, coupling via stimulation or simulation of biophotonic radiation, and combinations of any of these mechanisms described above and in more detail below. Regardless of the coupling mechanism, according to one embodiment of the invention, there is provided a method of treating a subject comprising: providing a first region of biological material coupled to the subject; initiating a change in a cellular environment of the cells in the first region; and due to a change in biological or chemical activity of the cells in the first region, inducing a biological change in a second region inside the subject. The induced biological change in the second region may be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein in proximity to the first region and/or the second region.

[0720] Alternatively, the phosphors **104** shown in FIGS. **34**, **37**, and **39** can mimic a "natural" biophoton radiation **102** and induce the same or similar changes that would have been induced by the natural biophoton radiation. Light emission from phosphors **104** can also be used to stimulate the "natural" biophoton radiation **102**. Light emission from

the phosphors **104** may be enhanced by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein in proximity to the phosphors, as shown in proximity to phosphors **104** in FIGS. **34**, **37**, and **39**. These figures also show the presence of a folded resonator nearby a region of the cell where biophotons are being introduced to thereby enhance the interaction of the biphotons **102** the structures of the cells such as the ion channels or to enhance bioreactions occurring in the cells and signals passing through the cells, as discussed above. The depiction of the folded resonators in FIGS. **34**, **37**, and **39** is merely illustrative, and in practice any of the folded resonator (or fractal antenna configurations) described herein can be used with arrays of resonators, arrays of folded resonators, a diode/resonator/diode structure (rectifying resonator) or arrays of the diode/resonator/diode structures all capable of being used.

The Biophoton Collector

[0721] As used herein, because the exact nature of the biophoton radiation is not known and, because it may well comprise many different kinds of radiation, the radiation collector of the present invention is a collector (or a series of different kinds of collectors) that can collect radiation from various spectra ranging from ultraviolet light through visible, infrared, and far infrared bands. Furthermore, in one embodiment, the radiation collector is designed to collect electric and/or magnetic field radiation emitted from the live biological cells. Moreover, in one embodiment, the radiation collector is designed to collect acoustic or sonic waves emitted from the live biological cells and to redirect and/or amplify those collected signals to a treatment region.

[0722] One optical device suitable for collecting biophotons would be an integrating sphere. US Pat. Application Publ. No. 2017/019867 (the entire contents of which are incorporated herein by reference) describes an integrated sphere configuration suitable for the present invention, except that the window element in the '867 application) would be replaced by a cell holding a sample of living tissue. FIG. **41** is a depiction of a biophoton collector **500** according to one embodiment of the invention.

[0723] As shown in FIG. **41**, the biophoton collector **500** includes an integrating sphere **502** with a highly reflective inner surface as described below. The biophoton collector **500** includes living cell container **504** shown in FIG. **41** at the base of the sphere **502**. The biophoton collector **500** includes an output window **506** for transmitting the biophotons from the sphere **502**. The biophoton collector **500** includes optionally a stimulation window **508** which can be used to expose cells in container **504** to radiation which can stimulate biophoton radiation. The biophoton collector **500** includes nozzle **510** for supply cells or nutrients or effluent to the container **504**. Channel **512** can be used for supply and removal of the effluents. In one embodiment of the invention, the inventive resonant structures of this invention such as the folded resonators and rectifying resonators are disposed in vicinity of container **504**. FIG. **41** shows a folded resonator integrated with container **504**.

[0724] In one embodiment of the invention, the biophoton collector **500** would likely be disposed outside a patient with a transmission optic (not shown) for transmission of the light from window **506** into a patient. The integrating sphere **502** would have its interior surfaces made of and/or coated with a highly reflective material. For example, the integrating sphere **502** can be formed from a hollow sphere, with an inner wall of the sphere is coated with a material coating layer (e.g., a barium sulfate layer or titanium dioxide, etc.). Biophoton light emitted from container **504** would be reflected on the interior surfaces and directed to an output window **506**. In one embodiment of the invention, having a thin layer of the biological material on container **504** would avoid self-absorption effects and provide a source of biophoton radiation to be transmitted to a diseased site. In one embodiment of the invention, nozzle **502** provides a way to add effluent to container **504** such as hydrogen peroxide to induce controlled cell death or nutrients to promote cell growth.

[0725] For biphoton emission of electromagnetic radiation in the radio wave or microwave spectrum, an antenna can be used. FIGS. **42**A-**42**C are depictions of an electromagnetic biophoton collector **600** of one embodiment of the present invention.

[0726] Biophoton collector **600** is similar to that described in US Pat. Application Publ. No. 20010/0032437 (the entire contents of which are incorporated herein by reference). Biophoton collector **600** includes a container **602** for storing substances. The container **602** is provided with a radio frequency antenna **604**. Circuitry **606** can include a chip **610**, circuit paths **612** forming a coil of the antennae and wires **614** for connecting the circuit paths with chip **610**.

[0727] As shown in FIGS. **42**B and **42**C, the circuitry is disposed on an exterior surface **620** of container **602** and in the embodiment shown encircles the container **602**. Inside container **602** would be live cells. In one embodiment of the invention, an effluent can be added to container **602** such as hydrogen peroxide to induce controlled cell death or nutrients to promote cell growth. In one embodiment of the invention, biphoton emission as electromagnetic radiation would be collected and transmitted from circuitry **606** to a target treatment region. In one embodiment of the invention, the inventive resonant structures of this invention such as the folded resonators and rectifying resonators are disposed in vicinity of container **602**. FIG. **42**C shows a folded resonator integrated with container **602**.

[0728] In one embodiment of the invention, biphoton emission as electromagnetic radiation would be detected and its waveform characteristics would be stored by chip **610**. In one embodiment of the invention, a radio wave or microwave generator (or another electromagnetic radiation broadcaster) could use the stored waveform characteristics to generate/simulate biphoton for transmission to a target treatment region.

[0729] FIG. **43** is a depiction of a fractal antenna that can be used in one embodiment of the invention as the antenna for electromagnetic biophoton collector **600**.

[0730] A fractal antenna uses a self-repeating design such as self-repeating design **702**, or other fractal patterns. It can maximize the length of an antennae material in a total surface area. In general, fractal antennas are compact and have a wide band of operation because a fractal antenna resonates at many different resonances, meaning it can act as an antenna for many different electromagnetic frequencies. The different resonances arise because the fractal nature of the antenna acts as a virtual network of capacitors and inductors.

[0731] In one embodiment of the invention a fractal antenna could be printed (or otherwise formed) onto the external surface **620** of container **602**. In one embodiment of

the invention a fractal antenna could be printed (or otherwise formed) on a Petri dish. In one embodiment of the invention a fractal antenna could be printed onto a biocompatible polymer supporting living cells. These fractal antennae would be used to collect biophoton electromagnetic radiation.

[0732] Regardless of the antenna used, the antenna could be connected to a spectrum analyzer to evaluate the frequency characteristics of the electromagnetic radiation captured from the biological cells. Once measured, a rf or microwave generator could be used to replicate the measured spectrum.

Antenna Design for Light Collection:

[0733] Due to the circular polarization of light, it is difficult to maximize optical fiber coupling to the source of light, especially if the source of light is small and/or the intensity of light is very weak, as is generally thought to be the case for naturally occurring sources of biophotonic radiation. In one embodiment of the present invention, the circular polarization of the electric field of non-polarized light is best captured by an optical waveguide having metallized stubs of different orientations. In one embodiment, a stub would be dimensioned about ¼ wavelength wide by ¾ wavelength long, and the stubs would be oriented in all possible concentric and spherical radiated orientations. In one embodiment of the invention, the biophotonic activity taking place is measured either in-vivo through a window chamber (described below) or in-vitro in a well plate or in a container. A planar array, multiple stub configuration provides a unique antenna for other purposes and one that is suited for collection of biophoton radiation.

[0734] In one embodiment of the invention, the collection of biophoton radiation including light can use a fractal antenna design, similar to that described above for collection of electromagnetic radiation collection at radio or microwave frequencies, but in this embodiment designed for the visible light range or frequencies about the visible light range and much shorter that the radio or microwave frequencies. In one embodiment, the repetitive patterns do not have stubs with lengths shorter than $\lambda/8$. Preferably, the antennae stubs have lengths that range from near $\lambda/4$ to near $3\lambda/4$. Accordingly, if the intended light measurements are centered around 300 nm, for example, then the stub length of interest would be between 75 nm and 225 nm.

[0735] The fabrication of the antenna can be performed using well known semiconductor processes for build-up of small metallic features, including, but not limited to, low-k SiO_2 dielectric, and high-k SiO_2 dielectric. The growth of various layers could be done through a sequential build-up process. The metallized features can be achieved through metal atomic layer deposition (ALD) or through other metal deposition processes known in the art such as sputtering or evaporation, with photo-resist processing used to pattern the deposited metal layer(s) leaving the appropriate metallized patterns of interest. The metallic pattern in one embodiment would be surrounded by a high-k dielectric in contact with the metal, and that structure embedded inside a low k dielectric to a form a sensitive optical waveguide that is capable of detecting the stimulus of a weak electric field from the bio-photonic activity.

[0736] Metallic features are considered in electromagnetic theory to have an infinite dielectric constant, and are therefore able to pick up an oscillating electric field of the biophotons. The electromagnetic energy propagates along the path of the highest dielectric constant which in this case is the metal. The light can and will propagate along a path with the the high k SiO_2 dielectric. However, due to internal scattering, the light will remain confined to the high-k SiO_2 dielectric and the metal. Any time the electromagnetic energy approaches the boundary interface between the high-k SiO_2 and the low-k SiO_2, it will bend back and confine itself to the intended waveguide area formed by the metallic path as surrounded by the high k dielectric material. FIG. **44** is a schematic showing a section of waveguide **710** with a high-k dielectric material **712**, a low-k dielectric material **714**, and a central metal **716**

[0737] The patterning can be done on a quartz wafer of appropriate dimensions. The antenna pickup area is preferably of an open concentric polarization construction **720***a* as shown in FIG. **45**.

[0738] Metal stubs **722** extend radially from a common center. Other patterns are possible and can be used, including the simpler representation of the open concentric polarization construction **720***b* also shown in FIG. **45**.

[0739] FIG. **46** depicts an array **730** of antennae **732** configured on a quartz wafer (not shown). Various patterns are possible depending on the intended use. As an example, the arrayed antennae each have pick up stubs that are concentric and planar as shown in FIG. **46**.

[0740] The antenna stubs connect with an internal column (see internal column **766** shown in FIG. **50**) made of the same materials design as FIG. **44** having a configuration with a metal core, surrounded by a high k SiO_2 dielectric and a low k SiO_2 dielectric that forms the optical waveguide. The metal can be, but is not necessarily, made of a metal enabling a photoelectric effect.

[0741] A cross section of the stub configuration **730** shown in FIG. **46** with antennae **732** interconnected together is shown in FIG. **47**.

[0742] FIG. **48** is a schematic of multi-up arrayed antenna **750**.

[0743] FIG. **49** is another schematic of the multi-up arrayed antenna **750** shown in FIG. **48** showing a top-level interconnection network **762** under the top surface of multi-up arrayed antenna **750**.

[0744] FIG. **50** is another schematic of the multi-up arrayed antenna **750** shown in FIG. **48** showing the full interconnection network including top-level interconnection network **762** and bottom-level interconnection network **764**.

[0745] FIG. **51** is a depiction of antennae that can be arrayed in different manners including a square antenna **780***a*, a rectangular antenna **780***b*, and a diamond shaped antenna **780***c*.

[0746] FIG. **52** is a depiction of a spiral-type packing arrangement **790** where each antenna petal **792** is placed at 0.618034 per turn (out of a 360° circle) allowing for the best possible exposure to cellular-light. This desirable spiral arrangement follows from what is commonly referred to as the Fibonacci sequence.

[0747] The resulting multi-up pattern has a high density and a spiral configuration similar to the one found in pine cones and sunflowers. This spiral pattern is desirable for the packing it enables.

[0748] This patterned antenna can be built on a quartz wafer of any size that can fit within semiconductor equipment capability. A quartz wafer hosting thousands of antennae (2,000 to 100,000 antennae) can be built. This quartz

wafer can be used in accordance to the window chamber model. Similarly, the quartz wafer equipped with fractal antennae can be used inside a polycarbonate well plate. The cell plating can be performed on top of the quartz wafer with embedded fractal antennae. Various experiments can be envisaged to elucidate the light-based communication inside of a single cell or amongst multiple cells. The ability to conduct photonic measurement in-vivo using fractal antennae permits one to measure biophoton radiation from living tissue in vivo or in vitro.

[0749] As in other embodiments discussed above, once measured, these signals can be transmitted from their source to a treatment site or could be duplicated to mimic biophoton radiation.

In-Vivo Measurements of Bio-Photonics:

[0750] The window chamber mouse model has gained great acceptance for conducting medical research in-vivo while maintaining the ability to see through for direct observation and monitoring. FIG. **53** is a depiction of a window chamber according to one embodiment of the invention, where the window area **795** is constructed for transmission of biophoton radiation therethrough.

[0751] For example, window chamber **793** could be equipped with fractal antennae (of the same or different designs) to permit measurements of photonic activity as well as having the ability for direct observation and monitoring. For fractal antennae, the antenna patterning in at least one portion of the window **795** can be made with antenna elements dimensioned at subwavelengths of visible light so that observation of the biological region underneath window chamber **793** is possible. The fractal antenna can be as described herein, or can be any desired fractal antenna configuration. Alternatively, the window chamber **793** could include therein a folded resonator or other resonator structures as described herein. Biophotonic emission inside the window chamber could be assisted by the presence of the folded resonators described herein. In one embodiment of the invention, the inventive resonant structures of this invention such as the folded resonators and rectifying resonators are disposed in vicinity of the window area **795**. FIG. **53** shows a folded resonator disposed on window area **795**.

[0752] FIG. **54** is a depiction of a window **795** made of a quartz wafer that has different sections that are independent of each other. This design permits the photonic activity to be measured from different sectors of the subject. In one embodiment, window **795** of FIG. **54** could be used to answer the question if there is (ON) or if there is not (OFF) photonic activity. The wavelength or spectral information could be collected and stored regardless of whether the antenna was sectioned or not.

[0753] FIG. **54** also illustrates one embodiment of the invention where the antennae are sectioned such that photonic activity (or the absence thereof) can be monitored from each section. Each fractal antenna in window **795** could be connected to separate fiber optic columns **766**, or all the fractal antennae in each section could be connected together to one common fiber optic column **766**.

The Biophoton Bypass

[0754] Complicating the literature recognized problem that biophoton radiation is weak is the further problem that these weak signals (naturally originating inside a subject) travel in a dispersive medium with scattering and absorption making it unlikely that the biophoton radiation can travel extended distances. Even the distances of mm in the in vitro test cells are remarkable. The inventive solution: bypass nature's dispersive optical pathway with an artificial conduit (hereinafter the "biophoton bypass") having little if any scatter and low absorption.

[0755] The biophoton bypass might have physical characteristics of a fiber or fiber bundle if the bio-photons needed to be transmitted over significant distances, as from outside the body into the body or from one region of the body more accessible for the control than the target region.

[0756] The biophoton bypass might have physical characteristics of an optical sheet with evanescent waves from the sheet penetrating a shallow depth into a diseased organ.

[0757] The biophoton bypass might be a simple polymeric window separating a control region from the diseased organ made along the ways described in the Yevgeny patent application U.S. Pat. Appl. Publ. No. 2009 (discussed in more detail below).

[0758] The biophoton bypass might be capillary filled with a protein solution. In prior work, a narrow capillary was filled with a dilute protein solution and exposed to MGR (another name for biophoton radiation) on one end. No radiation was detected at the other end until the protein filed capillary was aligned with an electric field. Hence, in one embodiment, the biophoton bypass of the invention could be a protein-filled conduit wherein an applied electric field which can "gate" to either turn on or turn off the transmission of biophotons along the protein-filled conduit.

[0759] In one embodiment, the biophotons emitted from one cell induce photo-assisted reactions in a nearby or proximate cell that itself produces its own biophotonic emission, thereby leading to biophoton emission from one cell to another cell, appearing as a "communication" across many cells. The biophotonic emission can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0760] In one embodiment, the biophotons are emitted from excited states of luminescing species. The set of excited states can be considered a "bioplasma." In this context, bioplasma is a term derived from bioelectronics, molecular biology and solid state plasma physics and refers to a state in which biomolecules in vivo are predominantly in a stable, collective, excited state. It is considered a "cold plasma" that forms an energetic and informational network throughout the organism involving a colloid of semi-conducting proteins as the main constituent in a redox (oxidation-reduction) chemical oscillator displaying complex dynamics. This is analogous to a low-power laser that uses chemical, electrical or magnetic energy to pump it into an excited metastable state.

[0761] Coupling between the biochemical reactions of the living state takes place electromagnetically, with a wave-like internal coordination surrounded by an electromagnetic wave externally emitted. Biological effects of exogenous electromagnetic fields are ascribed to collective resonance properties of the whole bioplasma and not just to any of its individual parts.

[0762] Accordingly, in one embodiment of the invention, the collective state of this bioplasma can be influenced by localized changes. One candidate to influence local changes would be the application of an electric field, to change the

polarization of the cells and turn off (or on) chemical reactions. The electric field can be applied by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators described herein, especially the rectifying resonator structures.

[0763] Other candidates are described in more detail elsewhere but include providing ultrasonic, microwave, or localized cooling to selected portions of cells in an organ.

[0764] Regardless of the collection technique, an energy transmitting structure (as the biophoton bypass) could carry the biophotons to a target site. An optical fiber could be used if the biophoton light were in the UV to near IR range. In one embodiment, vacuum/air would be the most reliable medium for the biophoton bypass. Accordingly, a hollow optic could be used for a biophoton bypass of the invention for transmitting biophotons in the UV to near IR range inside the hollow optic while bypassing media of the subject to be treated. FIG. **55** is a depiction of a hollow optic biophoton bypass **800** according to one embodiment of the invention. U.S. Pat. No. 8,454,669 (the entire contents of which are incorporated herein by reference) describes a similar device for UV phototherapy. In the hollow optic biophoton bypass **800** of the invention, there are walls **802** which define a hollow cavity **804** filled with air, a gas, or possibly under a vacuum for transmitting UV light into a subject could be utilized in this invention. A transparent window **812** permits biophotons to be transmitted into a target treatment region or to be received from a living cell source of the biophotons. The interior surfaces **806** would be highly reflective surface. At the distal (or exit) end **810**, there would be a light optic which could either disperse or concentrate the biophoton light flux into a treatment site. Interaction of the biophoton light flux at treatment site can be enhanced by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0765] If the biophotons are low frequency electric signals (including a DC field), then a wire or conductive trace (as the biophoton bypass) could be used to transmit the low frequency electric waves. In one embodiment of the invention, the inventive resonant structures of this invention such as the folded resonators are disposed in vicinity of the window area **812**. FIG. **53** shows a folded resonator disposed on window area **812**.

[0766] FIGS. **56**A-B are a depiction of an electrically conducting biophoton bypass **900** according to one embodiment of the invention where low frequency electric signals are transmitted therein while bypassing media of the subject to be treated. The conductors **902** shown in FIGS. **56**A-B are similar to those described in U.S. Pat. No. 7,272,427 (the entire contents of which are incorporated herein by reference) where the conductors in the '427 patent were used to measure bio-electric signals from the heart muscle while a patient was in an MRI environment. Here, in the FIGS. **56**A-B embodiment of this invention, the electrically conducting biophoton bypass **900** has an electrically conductive part **902** and a sheath part **904** arranged over conductive part **902**. The conductive part **902** and sheath part **904** are separated by a dielectric **906**. The electrically conducting biophoton bypass **900** can include multiple conductors **902** terminating on connectors **910** for attachment to a subject to be treated. Connectors **910** conductors can be attached to the living cells noted above and/or to a target region if the wire or conductive trace is being used as a biophoton bypass to deliver the low frequency electric signals from a source of the low frequency electric signals to a target site for treatment. In one embodiment, as shown in FIGS. **56**A-B, the multiple conductors **902** with multiple sheaths (not shown) are twisted together to reduce high frequency noise.

[0767] FIGS. **57**A-B are a depiction of another electrically conducting biophoton bypass **1000** according to one embodiment of the invention where the biophotons as high frequency electrical waves are transmitted therein while bypassing media of the subject to be treated. In the example of FIGS. **57**A-B, a coaxial cable **1002** is used. Waveguides (as biophoton bypasses) can also be used to transmit high frequency electrical waves. These devices (coaxial cables and waveguides) are highly selective for delivery of specific frequencies of radiation. As shown in FIGS. **57**A-B, the electrically conducting biophoton bypass **1000** includes a coaxial cable **1002** having an outer plastic sheath **1010**, a woven copper shield **1012**, an inner dielectric insulator **1014**, and a copper core **1016**. The core **1016** could be made of other metals or alloys, but copper is commonly used. A coaxial cable differs from other shielded cables because the dimensions of the cable are controlled to give a precise, constant conductor spacing, which is needed for the coaxial cable to function efficiently as a transmission line.

[0768] FIG. **58** is a depiction of a magnetic biophoton bypass **1100** according to one embodiment of the invention where the biophotons as time-varying or static magnetic fields are transmitted therein while bypassing media of the subject to be treated. As shown in FIG. **58**, magnetically permeable materials form a magnetic circuit (as the biophoton bypass) carrying the time-varying or static magnetic field from a source to a target. The magnetic biophoton bypass **1100** utilizes a dual gap design. In one gap, there is a source of the magnetic fields. As shown in FIG. **58**, in one gap, there is disposed a cell containing living tissue, that is living cell biophoton emitter **1102** which is a source of magnetic biophotons. The magnetic yokes **1104** and **1108** form a "circuit" carrying the magnetic field in the circuit from the living cell biophoton emitter **1102** through magnetic yoke **1104** to a target or treatment region **1106**, and back by magnetic yoke **1108** to the living cell biophoton emitter **1102**.

[0769] In a further embodiment of the present invention, the biophoton radiation applied to a first region is capable of triggering an altered metabolic activity in one or more cells, preferably in the 100 GHz to 10 THz region, which triggers the cell(s) to undergo altered metabolic activity, and optionally, to further trigger subsequent biophoton emissions from the cell(s). Microwave broadcasters or microwave waveguide structures can be used to apply these frequencies to a target structure.

[0770] In one embodiment, the spiral chains of DNA naturally present in biological materials are used to transmit radiation in the frequency range of 100 GHz to 5 THz or are used for charge transport or signaling along DNA traditionally thought to be "satellite" or "junk" DNA (hereinafter referred to as "signaling DNA"). This signaling DNA corresponds to approximately 98.5% of the DNA strand, with only about 1.5% of the DNA strand functioning genetically to code for proteins or RNA, etc. Traditionally believed to be merely composed of various repeating nucleotide base fragments having no function, the present inventors propose that this signaling DNA actually can (and does) function as one of the components of cell-to-cell communication or signal-

ing within humans, as well as other animals. That the signaling DNA has some form of function has also been hypothesized by others (see, e.g., Jiin-Ju (Jinzhu), "PHYSICAL PROPERTIES OF BIOPHOTONS AND THEIR BIOLOGICAL FUNCTIONS", Indian Journal of Experimental Biology, Vol. 46, May 2008).

[0771] FIG. **59** is a depiction of a DNA-based biophoton bypass **1200** according to one embodiment of the invention where the biophotons in the frequency range of 100 GHz to 5 THz are transmitted therein while bypassing media of the subject to be treated.

[0772] In FIG. **59**, the signaling DNA **1202** is included in a waveguide type outer structure **1204**. The length and diameter of the outer structure **1204** is sized according to the frequency range to be transmitted. Lithographic and printing processes can be used to generate trenches in silicon substrates that could both hold the signaling DNA and form a waveguide structure for propagation of biophotons in the frequency range of 100 GHz to 5 THz across the surface of the silicon substrate and to a treatment site. Wafer thinning processes known in the art could be used to thin the silicon wafer making the DNA-based biophoton bypass **1200** potentially a flexible biophoton bypass.

[0773] In FIGS. **55-59**, interactions of the biophotons at the target site can be enhanced by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein. FIG. **55** depicts a hollow optic biophoton bypass **800** with a resonator adjacent the transparent window **812**. In that case, one or more resonators near the living cells could enhance biophoton emissions emitted from the living cells, or could enhance interaction of the biophotons delivered to the target treatment region. FIGS. **56**A-B depict an electrically conducting biophoton bypass **900** with a resonator adjacent connectors **910**. In that case, one or more resonators near the living cells could enhance biophoton emissions emitted from the living cells, or could enhance interaction of the biophotons delivered to the target treatment region. FIGS. **57**A-B depicts a high frequency electrically conducting biophoton bypass **1000** which (although not shown) could, as with the electrically conducting biophoton bypass **900**, have one or more resonators near the living cells to enhance biophoton emissions emitted from the living cells or to enhance interaction of the biophotons delivered to the target treatment region. FIG. **58** shows a folded resonator disposed nearby one of the gaps of magnetic yoke **1108**. However, the resonator could be nearby the other gap, or there could be resonators nearby both gaps. In that case, one or more resonators near the living cells could enhance biophoton emissions emitted from the living cells, and one or more resonators at the second gap could enhance interaction of the biophotons delivered to the target treatment region. FIG. **59** depicts a high frequency DNA-based biophoton bypass **1200** which (although not shown) could, as with the electrically conducting biophoton bypass **900**, have one or more resonators near the living cells to enhance biophoton emissions emitted from the living cells or to enhance interaction of the biophotons delivered to the target treatment region. Moreover, transmission of signals along DNA can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators described herein, and the electric fields emanating therefrom.

[0774] Additionally, in one embodiment of the invention, multiple of these types of biophoton conductors can be used together for the transmission of different types of biophoton signals from one region to another. Furthermore, in one embodiment of the invention, the magnetic yoke **1108** in FIG. **58** might be used to couple a magnetic field from one region to another serving to aid in quantum coherence between separate regions and thereby assist in "communication" between these two regions with changes in one region being replicated or induced in the other because of the quantum coherence.

[0775] Accordingly, in various embodiments of the invention, the application of biophoton radiation to a target structure may directly affect a diseased region or it may enhance biophoton emissions from a first region (where cell death is being artificially induced) to a second or treatment region) This biophoton emission may act as a way of "communicating changes" in the first or control region which induce changes in the second or target region. This artificial biophoton emission may also act to enhance naturally occurring biophoton emission. This biophoton emission may also result in quantum coupling between the control and the target regions. Once again, interactions of the biophotons at the target site can be enhanced by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0776] Accordingly, in various embodiments of the present invention, the first and second regions are "coupled" to each other with a medium (whether artificial or natural or that intrinsically present in the biological materials of the first and second region) that transmits bio-photons to the target region as a way of "communicating changes" in the first or control region which induce changes in the second or target region. Interactions of the biophotons at the target site can be enhanced by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein. Further, an externally applied magnetic field can assist in quantum coherence between the two regions, and thereby assist in "communication" between these two regions with changes in one region being replicated or induced in the other because of the quantum coherence.

Living-Cell Biophoton Radiators

[0777] Accordingly, in one embodiment of the present invention, live biological cells in a container could be used as a source of biophoton radiation. A number of ways can be used to form this type of source. In one example, a Petri dish or container outside the subject could contain the live biological cells. See FIGS. **41** and **42**A-C. In one embodiment of the invention, the base of the Petri dish would contain a radiation collector in near direct contact with the living cells. The radiation collector would have (if needed) a thin passivation layer to insure that the materials of the radiation collector do not interact with the solutions in the petri dish. Biophoton radiation emitted from the biological cells would be captured by the optical collector and then transmitted to a treatment site, for example inside the subject. For example, a cancer strain (the same or similar to that of a patient) could be treated in a container with hydrogen peroxide to induce cell death. The biophoton radiation would be collected from the container and transmitted in a biophoton bypass (bypassing intervening tissue

of the patient) into the diseased region promoting cell death. Interactions of the biophotons at the target site can be enhanced by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0778] U.S. Pat. Appl. Publ. No. 2009/0203530 (the entire contents of which are incorporated herein by reference) describes a method for producing polymers having properties suitable for catalytic activity or binding activity, via evolutionary nucleic acid-mediated chemistry. As described in the '530 application and suitable for the present invention, non-biological polymers (e.g., polymers other than DNA, RNA, or protein) can be synthesized. Such polymers include, but are not limited to, peptide nucleic acid (PNA) polymers, polycarbamates, polyureas, polyesters, polyacrylate, polyalkylene (e.g., polyethylene, polypropylene), polycarbonates, polypeptides with unnatural stereochemistry, polypeptides with unnatural amino acids, and combination thereof. In certain embodiments, the polymers comprise at least 10, 25, 75, 100, 125, 150 monomer units or more. These polymers could be used to encapsulate the biological cells of the living-cell biophoton radiator in which the energy augmentators including resonators such as the folded resonators and rectifying resonators described herein can be placed.

[0779] In this embodiment, a living-cell biophoton radiator could exist outside the patient or be surgically disposed inside the patient at the diseased site. U.S. Pat. No. 8,999,376 (the entire contents of which are incorporated herein by reference) describes tissue patches comprising fibrinogen (and/or fibrin). This type of fibrin glue has been approved by the FDA and can be used to impart topical hemostasis, provide sealant properties that are suitable is some clinical applications, and promote tissue approximation. Fibrin glue mimics the final steps of the coagulation cascade. FIGS. **60**A-B are a depiction of a living-cell biophoton radiator **1300** according to one embodiment of the invention where living cells are added as a part of living cell layer **1320**.

[0780] The matrix **1310** shown in FIGS. **60**A-B can be in the form of a cylindrical disc **1350** with a substantially circular cross-sectional geometry. In other embodiments, the matrix **1310** (or the entire tissue patch) can have other cross-sectional geometries such as, for example, substantially elliptical, polygonal (e.g., including any number of sides such as in the form of a triangle, a quadrilateral (e.g., rectangular or substantially square), etc.), irregularly-shaped, or any other suitable shape.

[0781] In the present invention, these types of patches **1310** can be applied to organ tissue. For example, matrix **1310** would be attached to an organ (not shown). Living cells of a kind similar to that to be treated using biophoton radiation would be contained in living cell layer **1320**. An encapsulant layer **1330** would be applied over the living cell layer **1320**. In one embodiment of the invention, encapsulant layer **1330** would contain either a substance to promote cell growth or a substance to promote cell death which would be controllably released into the living cell layer **1320**. The induced change (cell growth or cell death) can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

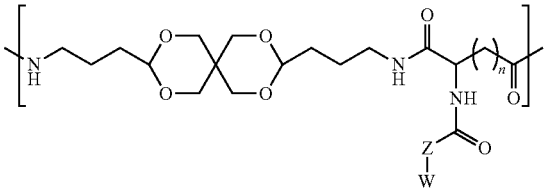
[0782] In one embodiment of the invention, the matrix **1310** would be a porous or semi-porous structure having pores **1350** in a membrane **1355** permitting biological and fluid connections from living cell layer **1320** and the organ to be made.

[0783] As the cells in the living cell layer **1320** are affected by the substances released from the encapsulant layer **1330**, biophoton radiation from living cell layer to the organ is achieved.

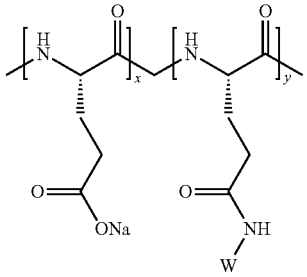
[0784] Alternatively, encapsulant layer **1330** could contain phosphors or other elements such as metals significantly heavier than carbon for preferential absorption of x-rays (with the phosphors producing ultraviolet or visible light) or for preferential absorption of microwaves (with the metals locally heating). In one embodiment, the UV or visible light or the local heating would "stress" the cells in living cell layer **1320** to thereby produce biophoton radiation. The generated biophoton radiation can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0785] U.S. Pat. Appl. Publ. No. 2010/0120117 (the entire contents of which are incorporated herein by reference) describes polymers may be used to coat living cells in cell therapy applications, and thereby would be suitable as a container used in the present invention for holding biological cells of the living-cell biophoton radiator. The '117 publication describes a polymer-coated cell construction comprising a living cell and a polymer comprising at least one recurring unit represented by a formula selected from the group consisting of formula (I), formula (II), and formula (III)

(I)

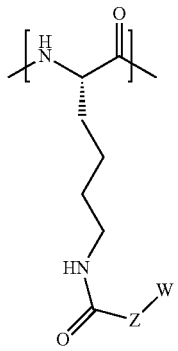


(II)



-continued

(III)



[0786] wherein n is 1 or 2; wherein x and y are each individually integers of from about 1 to about 500; wherein Z is an optional linker group comprising from about zero to about 20 carbon atoms, from about zero to about 5 oxygen atoms, from about zero to about five nitrogen atoms, from about zero to about 5 sulfur atoms, and from about zero to about five phosphorous atoms; and wherein each W is individually selected from the group consisting of biotin, a fatty acid, a fluorescent dye, an antibody, a peptide, a targeting ligand, a polysaccharide, and a negatively charged group, the polymer being non-covalently attached to at least a portion of the exterior of the living cell.

[0787] The '117 publication further describes a method for coating a living cell, comprising intermixing the living cell with a polymer which includes at least one recurring unit represented by a formula selected from formulas (I), (II), and (III) as described above, wherein the polymer is intermixed with the living cell in an amount effective to at least partially coat the exterior of the living cell.

[0788] Similar to that described in the '117 publication, in one embodiment of the present invention directed to the living cell biophoton radiator, a variety of diseased cells may be contained or carried by the polymer-coated cell construction noted above. These diseased cells may include cells exhibiting neurologic diseases (e.g. Parkinson's disease, multiple sclerosis), cardiovascular disease (myocardial ischemia, repair and regeneration of infarcted myocardium), hepatic disease (liver failure), diabetes, skin, and renal failure (chronic renal failure, acute renal failure), and cancer tissues.

[0789] In one embodiment of the invention, the target tissue to be treated with the living-cell biophoton radiator of this invention may be an organ such as heart, brain, kidney, skin, liver, muscle, spleen, lung, spinal cord and bone marrow. Tissues of this type or from these organs can be biopsied, cultured, and returned to the patient at the site of the disease. These cells may contain therapeutic agents to promote cell death or cell growth depending on the treatment under consideration. As these therapeutic agents work, biophoton emission radiates adjacent cells not contained in the polymeric coating, thereby inducing a change in the adjacent cells. Production of biophoton radiation can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators described herein. Likewise, interaction of the biophoton radiation with the adjacent cells can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0790] Conventionally, there are four basic issues for cell-based therapies. These are mobilization of the cells, homing to a target site, integration into the native tissue or organ and survival of the implanted cells. In one embodiment of this invention, the polymer coatings assist integration of cells of the living-cell biophoton radiator into native tissue and survival of implanted cells at least until biophoton radiation from the polymer encased cells can be used. By coating of the cells with the polymers, the cells may be protected in the blood for several hours. The polymer coated cells may also be protected from the immune response of the host. These coatings may protect the cell therapeutic while allowing passage of vital nutrients including oxygen.

[0791] The selection of cell type is a function of the disease which is being treated, the cell type being coated and forming part of the living-cell biophoton radiator. For example, skeletal myocytes would be injected into post-myocardial infarction scar tissue; neuronal cells would be administered to the brain of patients with Parkinson's Disease. Cell sources which may be used for the living-cell biophoton radiator of this invention include embryonic stem (ES) cells, adult stem cells, progenitor cells such as skeletal myoblasts, fetal and neonatal cariomyocytes, and chord blood.

[0792] As an example of cells contained in the above noted polymer for the living-cell biophoton radiator of this invention, cardiovascular and lung tissues may also contain progenitor or stem cells that under the correct conditions could be induced to proliferate and repair cellular damage. For instance, recent findings suggest that a sub-population of fetal proliferative alveolar epithelial stem cells is present in adult lung. In addition, other tissues such as skin, liver, brain, and muscle have progenitor or stem cell populations that may provide additional sources of cells for cellular therapies.

[0793] For neovascularization of ischemic myocardium, endothelial progenitor cells for the living-cell biophoton radiator of this invention may be injected into the target area to promote new vessel growth. The cells are isolated from the mononuclear cell fraction of bone marrow or peripheral blood. The cells may be whole isolated cells or the cells may first be expanded in culture. Other examples for the living-cell biophoton radiator of this invention include treatment of skin disease with replacement grafts. Skeletal stem cell implantation may be used for bone regeneration. Chondrocytes may be used to repair joint cartilage. Acute and chronic renal failure may be treated with stem/progenitor cells using the living-cell biophoton radiator of this invention.

[0794] The cell source for the living-cell biophoton radiator of this invention may be either an autologous source or a non-autologous source. In some embodiments, the cells may be genetically modified. In cases where an adequate supply of cells is not possible from the patient due to the disease or other condition, non-autologous sources may be used. Non-autologous cells include allogeneic and xenogeneic cells. Non-autologous sources must overcome the natural host immunologic rejection processes. The polymer coating according to the embodiments provides protection from the host immune response.

[0795] The use of autologous cells generally involves obtaining the patient's own cells, expanding the cells in vitro

in large quantities over several weeks, and reintroducing the cells in a site-specific manner.

[0796] A variety of means for administering cells for the living-cell biophoton radiators of this invention will be apparent to those of skill in the art. Such methods include injection of the cells into a target site in a subject. Cells may be inserted into a delivery device which facilitates introduction by injection or implantation into the subjects. Such delivery devices may include tubes, e.g., catheters, for injecting cells and fluids into the body of a recipient subject. In a preferred embodiment, the tubes additionally have a needle, e.g., a syringe, through which the cells of the embodiments can be introduced into the subject at a desired location. In a preferred embodiment, cells are formulated for administration into a blood vessel via a catheter (where the term "catheter" is intended to include any of the various tube-like systems for delivery of substances to a blood vessel). The cells may be prepared for delivery in a variety of different forms. For example, the cells may be suspended in a solution or gel. Cells may be mixed with a pharmaceutically acceptable carrier or diluent in which the cells of the embodiments remain viable. Pharmaceutically acceptable carriers and diluents include saline, aqueous buffer solutions, solvents and/or dispersion media. The use of such carriers and diluents is well known in the art. The solution is preferably sterile and fluid, and will often be isotonic. Preferably, the solution is stable under the conditions of manufacture and storage and preserved against the contaminating action of microorganisms such as bacteria and fungi through the use of, for example, parabens, chlorobutanol, phenol, ascorbic acid, thimerosal, and the like.

[0797] Modes of administration of the polymer coated cells include but are not limited to systemic intracardiac, intracoronary, intravenous or intra-arterial injection and injection directly into the tissue at the intended site of activity. The preparation can be administered by any convenient route, for example by infusion or bolus injection and can be administered together with other biologically active agents. Administration is preferably systemic. Most preferably, the site of administration is close to or nearest the intended site of activity. In some embodiments, the polymer coated cells will migrate or home to the tissue or organ in need of treatment in response to chemotactic factors produced due to the injury without specific modification of the polymer coated cells for targeting.

[0798] Modifications of the polymer coating can provide for housing of the cells for the living-cell biophoton radiators of this invention to the target site. Protein targeting agents such as antibodies or proteins that bind to specific membrane sites may be used to target the polymer coated cells to the target organ or tissue. In some embodiments of the methods described herein, the polymer coated cells are modified prior to implantation into the individual so as to promote their targeting to tissue or organ in need of treatment. For example, the polymer may include an antibody which binds an antigen that is abundant at the target site, that is, at the site of the tissue or organ which is diseased or in need of treatment.

[0799] For example, monoclonal antibodies are known that specifically target cancer cells. Many of these are antibodies to growth factor receptors which are preferentially expressed on the surface of cancer cells. These include the humanized monoclonal antibody trastuzumab (Herceptin) which targets the HER-2/neu oncogene (Sato, et al. (2005) Int. J. Radiation Oncology Biol. Phys. vol. 61 (1): 203-211). The HER-2/neu oncogene is found in ovarian cancer, lung cancer, gastric cancer, oral squamous cell carcinoma, breast cancer, and esophageal cancer. BLCA-38 monoclonal antibody has been shown to target prostate and bladder cancer (Russell, et al. (2004) Cancer Immunol Immunother. vol. 53:995-1004). Other monoclonal antibodies are known and it is within the level of skill in the art to select a monoclonal antibody appropriate to the cancer or other disease or injury to be treated.

[0800] Migration of polymer coated cells for the living-cell biophoton radiators of this invention to target tissues may be enhanced by genetic modification, e.g., introduction of an exogenous nucleic acid encoding a homing molecule into the cells. Examples of homing molecules include receptors specific to the target tissue such as chemokine receptors, interleukin receptors, estrogen receptors, and integrin receptors.

[0801] In various embodiments, a receptor ligand such as transferrin or epidermal growth factor can be included in the polymer for homing to cancer cells. These ligands provide specific targeting to receptors on tumor cells. Thus, delivery of the coated cells is localized to the area in need of treatment for maximum effectiveness. Any change induced at the localized area can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0802] Another method of homing a cell such as a stem cell to an injured tissue is carried out by increasing the amount of an injury-associated polypeptide, e.g., a cytokine or adhesion protein, in the injured tissue. The method increases the number of stem cells in an area of injured tissue compared to the number of stem cells in the area in the absence of an exogenous injury-associated polypeptide or nucleic acid encoding such a polypeptide. For example, identification of injury-associated polypeptides, e.g., growth factors, activate endogenous mechanisms of repair in the heart such as proliferation and differentiation of cardiac progenitor cells. These effects can give rise to biophoton radiation supplementing healing in adjacent cells. The injured tissue is contacted with a nucleic acid encoding a protein such as a cytokine or adhesion protein. Alternatively, cells such as fibroblast cells expressing exogenous nucleic acid molecules encoding the cytokine or adhesion protein are introduced to the site of injury. Any of these effects giving rise to biophoton radiation can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0803] In one embodiment for the living-cell biophoton radiators of this invention, the cells optionally can contain an exogenous nucleic acid encoding a gene product, which increases endocrine action of the cell, e.g., a gene encoding a hormone, or a paracrine action of the cell. For example, stem cells are genetically modified to contain an exogenous nucleic acid encoding a bone morphogenetic factor and engrafted into bone, cartilage, or tooth tissue, e.g., to treat periodontitis.

[0804] The cells for the living-cell biophoton radiator of this invention, optionally also include nucleic acids encoding other biologically active or therapeutic proteins or polypeptides, e.g., angiogenic factors, extracellular matrix proteins, cytokines or growth factors. For example, cells to

be engrafted into pancreatic tissue contain a nucleic acid(s) encoding insulin or insulin precursor molecules. The cells also optionally include nucleic acids encoding gene products that decrease transplant rejection, e.g., CTLA4Ig CD40 ligand, or decrease development of transplant arteriosclerosis, e.g., inducible nitric oxide synthase (iNOS).

[0805] Tissue specificity is a fundamental problem for gene therapy as proteins that are therapeutic in target cells also may be harmful to normal tissue. Thus, non cell-specific expression of a transgene has the potential for inducing metabolic and physiologic mechanisms that could result in pathology over the long term. Localized injections can provide certain degree of localized expression of the targeting vector, however, there may still be a spill over into the circulation which will affect other cells and organs. In some embodiments, transcriptionally targeted vectors may be used that can restrict the expression of the therapeutic proteins primarily to the target cells by the use of tissue-specific promoters.

[0806] Once the cells for the living-cell biophoton radiator of this invention are implanted, maintenance of the cells is dependent upon adequate nutrient and oxygen delivery to the implanted cells. The polymer cell coating according to the embodiments can allow for entry of oxygen and other nutrients into the coated cell.

[0807] In one embodiment of the present invention, a selected portion of cells in an organ can be subjected to stress. Accordingly, in this embodiment, a number of sources of stress can be used to introduce at least one of chemical and physical stresses on the selected portion of cells in the organ. For example, ultrasonic waves concentrated on a particular region of the organ could induce mechanical stresses (e.g., compression and/or elongation of the cell membranes) changing the transport of nutrients across the membrane, thereby stressing those cells to induce biophoton emission. The induced biophoton emission can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0808] In another example, localized cooling of tissues in one part of an organ would produce stress in the cells to induce biophoton emission. In another example, localized heating of tissues in one part of an organ would produce stress in the cells undergoing the local heating to induce biophoton emission. Once again, the induced biophoton emission can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0809] In this example, microwave hyperthermia treatment systems such as those described in U.S. Pat. No. 9,079,011 (the entire contents of which are incorporated herein by reference) could be used to locally heat tissues in one part of an organ, producing stress in those cells to induce biophoton emission. Conventionally, hyperthermia has been used to elevate the temperature of tissues for a variety of purposes including: (i) destroying tissues such as tumors by the application of heat, (ii) increasing the susceptibility of heated tissue to chemical or radiation therapy, and (iii) triggering heat activated or released drugs. It is generally known to use microwave electromagnetic radiation for hyperthermia treatment. The hyperthermia treatment can be assisted by the in situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein where the intensified electric field can generate localized heating owing to the electric fields being confined to a region proximate the opposing electrodes.

[0810] FIG. **61** is a depiction of a system **1400** of the present invention for application of microwave energy to a target region to locally heat the cells in the target region and thereby induce biophoton emission.

[0811] System **1400** of the present invention can have an antenna fixture **1412** supporting a plurality of antennas **1414** about a treatment volume **1415**. In one embodiment, the treatment volume may be defined by a substantially hemispherical shell **1416** whose inner surface may contain a collar **1418** receiving and supporting the top of the patient's head. The collar may be filled with de-ionized water that may be circulated through connecting hoses **1420** with a cooler/pump **1421** providing skin cooling of at approximately 15 degrees centigrade of the patient's head to minimize surface heating of the skin by microwave energy from the antennas **14**.

[0812] The antennas **1414** preferably direct microwave energy inward toward the treatment volume **1415** and may, for example, be microwave horns or patch antennas or other antennas of a type known in the art and are spaced to provide for substantially uniform separation of less than six centimeters.

[0813] Each antenna **1414** may be connected to a radiofrequency power source **1422** providing independent phase (phi) and amplitude (A) control of the radiofrequency power applied to the antenna. The radiofrequency power source **1422** may provide a separate radiofrequency amplifier/synthesizer **1424** for each antenna **1414** or may use a single radiofrequency power source with separate amplitude and phase shifters. In one embodiment, a set of discrete phases and amplitudes may be implemented in a switching fashion.

[0814] The radiofrequency power source **1422** may be controlled by a treatment controller **1428** via an interface board **1426**, for example, providing a multiplexed A/D converter outputting phase and amplitude values from the treatment controller **1428**. The treatment controller **1428** may include a processor **1430** communicating with a memory **1432** holding a stored program **1434** and treatment plan data **1436** describing a treatment schedule of changing phases and amplitudes of microwave frequency to be applied to the antennas **14** during treatment.

[0815] The treatment plan data **1436** may be developed on the treatment controller **1428** but also can be developed off-line on a separate workstation **1440** having a display **1442** for displaying treatment maps for physician input, as will be described, generated by a communicating standard desktop computer **1444** also having a processor **1446**, a stored memory **1448** holding a treatment planning program **1451** and the treatment plan data **1436**, the latter which may be transferred to treatment controller **1428**. The desktop computer **1444** may also communicate with input devices **1450** by interface **1452** according to well understood techniques for physician input as will be described. It will be appreciated that the processing and data storage required by the present invention may be freely distributed among one or more processors and different types of computers according to well-understood techniques.

[0816] Microwaves provide a number of advantages including an ability to pass though some body structures such as the skull for treatment of the brain, and an ability to be focused to permit, for example, localized treatment of a

tumor surrounded by tissue with reduced damage to the surrounding tissue. The localized treatment can be assisted by the in situ presence of energy augmentators including resonators such as the folded resonators described herein where the resultant electric field can generate localized heating owing to the electric fields being confined to a region proximate the opposing electrodes. However, in one embodiment of the invention, localized and focused heating of selected portion of cells in an organ preferentially stops short of cell death, as dead cells would not emit biophoton radiation. Rather, the treatment plan stresses living cells in the targeted region to emit biophoton radiation.

[0817] In another example, stress could be applied by UV light at a non-lethal dose level using external sources of UV light "piped" into the subject (using for example the hollow cavity waveguide described above), or using phosphors under high energy or x-ray irradiation to produce internally within an organ localized stress. Phosphor emission can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

Artificial Ex-Vivo Biophoton Radiators

[0818] On the market today is at least one commercial biophoton source, the BEP-AN15 made by Biolight, a Korean company. The Biolight source is reported to radiate ultra-weak photon emission, generating energy through modulation of visible light, and delivers the energy at a frequency similar to "biophotons by voluntary absorption."

[0819] Joohyeong Lee et al in "Oocyte maturation under a biophoton generator improves preimplantation development of pig embryos derived by parthenogenesis and somatic cell nuclear transfer." Korean J Vet Res (2017) 57 (2), pp. 89-95 (the entire contents of which are incorporated herein by reference) report the use of the artificial source of biophoton radiation noted above, the BEP-AN15 made by Biolight. Their work reported to shown that biophoton treatments during in vitro maturation improved the "developmental competence" of parthenogenesis and somatic cell nuclear transfer derived embryos. In their paper, Lee et al described that, in prior work, "leakage of a very small amount of photons from external sources has been shown to alter ultraweak photon emissions and cell-to-cell communication."

[0820] Accordingly, in one embodiment of the invention, an artificial ex vivo (or in vivo) biophoton generator is used to produce biophoton radiation or to affect ultraweak photon emissions and cell-to-cell communication.

[0821] One possible artificial source for biophoton radiation includes the device(s) described in U.S. Pat. No. 5,800,479 (the entire contents of which are incorporated herein by reference) owned by Biolight Patent Holding AB (Danderyd, S E). The '479 patent describes a device for an external medical treatment with the aid of light, including a light emitting element which is intended to lie against or be held close to a wound or sore on the body of an individual. The light emitting element included light emitting diodes or like devices and was constructed to emit infrared light in a first stage for a first predetermined length of time and thereafter to emit visible light in a second stage for a second predetermined length of time.

[0822] Another possible artificial source for biophoton radiation includes the device(s) described in U.S. Pat. No. 6,238,424 (the entire contents of which are incorporated herein by reference) owned by Biolight Patent Holding AB (Danderyd, S E). The '424 patent describes an apparatus for external medical treatment with light. A light-emitting device in the '424 patent is provided in close proximity to the body of an individual and that includes light-emitting diodes or corresponding elements that are adapted to emit monochromatic light of a first wavelength. The light emitting device is driven by a drive arrangement for causing the light-emitting device to emit the monochromatic light over a first predetermined time period in a first state, and thereafter emit selectively monochromatic light of a different wavelength than the first wavelength and over a second predetermined time period in a possible second state. The drive arrangement causes the light-emitting device to pulsate the emitted light in accordance with a predetermined pulse frequency or series of pulse frequencies over the respective time periods, and causes the light-emitting device to emit the pulsating light with a pulse length that lies within an interval of about 60% to about 90% of the time between respective start edges of two mutually sequential pulse.

[0823] Another possible artificial source for biophoton radiation includes the device(s) described in U.S. Pat. No. 6,537,303 (the entire contents of which are incorporated herein by reference) owned by Biolight Patent Holding AB (Danderyd, S E). The '303 patent describes a method for treatment of mammals by draining lymph along a lymph pathway within a mammal's body. In the '303 patent, an infrared-light-emitting device is used to emit pulsating infrared light at a low pulse repetition frequency. The light-emitting device is brought into contact with the body and is moved along a lymph pathway in a direction toward the lymphatic gland to which the pathway of the lymph vessel in question leads.

[0824] In one embodiment of the present invention, these artificial sources would be attenuated to produce weak or ultraweak light emissions with duty cycles and wavelengths that mimic natural biophoton radiators. For example, UV emitting light emitting diodes could be used along with the visible and infrared light emitting diodes described above. UV light emitting diode are described in U.S. Pat. No. 8,907,320 (the entire contents of which are incorporated herein by reference) as including an n-type semiconductor layer, an active layer disposed on the n-type semiconductor layer, a p-type semiconductor layer disposed on the active layer and formed of p-type AlGaN, and a p-type graphene layer disposed on the p-type semiconductor layer and formed of graphene doped with a p-type dopant.

[0825] In one embodiment of the invention, a target cell to be treated is analyzed first to ascertain its biophoton emission characteristics. If the target cell is a known cancer strain, representative cancer lines could be analyzed. Alternatively, biopsies could remove small regions of the cancerous tumor. These representative or biopsied samples could be subject to cell death and the natural biophoton radiation could be observed. Once characteristics (e.g., wavelengths, duty cycle, total emittance) are known or inferred or estimated, the configuration and driving of the LED array elements can be used to mimic the natural biophoton spectra. Interaction of the biophoton spectra to the biological material it is exposed to can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0826] From the literature results noted above, in one embodiment of the invention, the mimic spectra could have one or more of the following characteristics:

[0827] emissions in 190-250 nm wavelength range;

[0828] emissions in the 330-340 nm wavelength range;

[0829] a combination of emissions in the 190-250 nm and in the 330-340 nm wavelength ranges;

[0830] emissions across the range of 250 nm to 600 nm;

[0831] emissions in the infrared range;

[0832] a duration of emission in short bursts of approximately a millisecond at a repetition frequency of 10 to 100 Hz; and

[0833] a range of photon flux from a few to a 1000 photons/(sec·cm^2) or higher.

[0834] These characteristics are merely exemplary and would be designed in one embodiment as discussed above to mimic the natural biophoton spectra of a target cell to be treated.

[0835] Light from the external biophoton radiators would be coupled to the diseased or malignant site using the biophoton bypass noted above.

In Vivo Point of Use Biophoton Generator

[0836] The present invention can use any desired energy converter, including, but not limited to, organic fluorescent molecules or inorganic particles capable of fluorescence and/or phosphorescence having crystalline, polycrystalline or amorphous micro-structures.

[0837] Organic fluorescent compounds with high quantum yield include, but are not limited to:

[0838] naphthalene, pyrene, perylene, anthracene, phenanthrene, p-terphenyl, p-quaterphenyl, trans-stilbene, tetraphenylbutadiene, distyrylbenzene, 2,5-diphenyloxazole, 4-methyl-7-diethylaminocoumarin, 2-phenyl-5-(4-biphenyl)-1,3,4-oxadiazole, 3-phenylcarbostyryl, 1,3,5-triphenyl-2-pyrazoline, 1,8-naphthoylene-1', 2'-benzimidazole, 4-amino-n-phenyl-naphthalimide.

[0839] Inorganic fluorescent and/or phosphorescent materials span a wide variety of materials. Furthermore, these materials can be doped with specific ions (activators or a combination of activators) that occupy a site in the lattice structure in the case of crystalline or polycrystalline materials and could occupy a network forming site or a bridging and/or non-bridging site in amorphous materials. These compounds include, but are not limited to, (not ranked by order of preference or utility):

[0840] CaF_2, ZnF_2, $KMgF_3$, $ZnGa_2O_4$, $ZnAl_2O_4$, Zn_2SiO_4, Zn_2GeO_4, $Ca_5(PO_4)_3F$, $Sr_5(PO_4)_3F$, $CaSiO_3$, $MgSiO_3$, ZnS, $MgGa_2O_4$, $LaAl_{11}O_{18}$, Zn_2SiO_4, $Ca_5(PO_4)_3F$, $Mg_4Ta_2O_9$, CaF_2, $LiAl_5O_8$, $LiAlO_2$, $CaPO_3$, AlF_3, and $LuPO_4$:Pr^{3+}. Examples further include the alkali earth chalcogenide phosphors which are in turn exemplified by the following non-inclusive list: MgS:Eu^{3+}, CaS:Mn^{2+}, CaS:Cu, CaS:Sb, CaS:Ce^{3+}, CaS:Eu^{2+}, CaS:$Eu^{2+}Ce^{3+}$, CaS:Sm^{3+}, CaS:Pb^{2+}, CaO:Mn^2, CaO:Pb^{2+}.

[0841] Further examples include the ZnS type phosphors that encompass various derivatives: ZnS:Cu,Al(Cl), ZnS:Cl (Al), ZnS:Cu,I(Cl), ZnS:Cu, ZnS:Cu,In.

[0842] Also included are the compound IIIb-Vb phosphors which include the group IIIb and Vb elements of the periodic table. These semiconductors include BN, BP, BSb, AlN, AIP, AlAs, AlSb, GaN, GaP, GaAs, GaSb, InN, InP, InAs, InSb and these materials may include donors and acceptors that work together to induce light emission diodes. These donors include, but are not limited to, Li, Sn, Si, Li, Te, Se, S, O and acceptors include, but are not limited to, C, Be, Mg, Zn, Cd, Si, Ge. Further included are the major GaP light emitting diodes which include, but are not limited to, GaP:Zn,O, GaP:NN, Gap:N and GaP, which emit colors Red, Yellow, Green and Pure Green respectively.

[0843] The materials can further include such materials as GaAs with compositional variation of the following sort: $In_{1-y}(Ga_{1-x}Al_x)_yP$.

[0844] Also included is silicon carbide SiC, which has commercial relevancy as a luminescent platform in blue light emitting diodes. These include the polytypes 3C—SiC, 6H—SiC, 4H—SiC with donors such as N and Al and acceptors such as Ga and B.

[0845] Further examples include multiband luminescent materials include, but not limited to, the following compositions (Sr, Ca, Ba)$_5(PO_4)_3Cl$:Eu^{2+}, $BaMg_2Al_{16}O_{27}$:Eu^{2+}, $CeMgAl_{11}O_{19}$:Ce^{3+}:Tb^{3+}, $LaPO_4$:Ce^{3+}:Tb^{3+}, $GdMgB_5O_{10}$:Ce_3:Tb^{3+}, Y_2O_3:Eu^{3+}, (Ba,Ca,Mg)$_5(PO_4)_3Cl$:Eu^{2+}, $2SrO_{0.84}P2O50.16B2O3$:Eu^{2+}, $Sr_4Al_{14}O_{25}$:Eu^{2+}.

[0846] Materials typically used for fluorescent high pressure mercury discharge lamps are also included. These can be excited with X-Ray and are exemplified by way of family designation as follows: Phosphates (Sr, M)$(PO_4)_2$:Sn^{2+}, Mg or Zn activator, Germanate $4MgO.GeO_2$:Mn^{4+}, 4(MgO, MgF_2)GeO_2:Mn^{4+}, Yttrate Y_2O_3:Eu^{3+}, Vanadate YVO_4:Eu^{3+}, Y(P,V)O_4:Eu^{3+}, Y(P,V)O_4:In^+, Halo-Silicate $Sr_2Si_3O_{82}SrCl_2$:Eu^{2+}, Aluminate (Ba,Mg)$_2Al_{16}O_{24}$:Eu^{2+}, (Ba, Mg)$_2Al_{16}O_{24}$:Eu^{2+},Mn^{2+}, $Y_2O_3Al_2O_3$:Tb^{3+}.

[0847] Another grouping by host compound includes chemical compositions in the halophosphates phosphors, phosphate phosphors, silicate phosphors, aluminate phosphors, borate phosphors, tungstate phosphors, and other phosphors. The halophosphates include, but are not limited to: $3Ca_3(PO_4)_2.Ca(F,Cl)_2$:Sb^{3+}, $3Ca_3(PO_4)_2.Ca(F,Cl)_2$:Sb^{3+}/Mn^{2+}, $Sr_{10}(PO_4)_6Cl_2$:Eu^{2+}, (Sr,Ca)$_{10}(PO_4)_6Cl_2$:Eu^{2+}, (Sr, Ca)$_{10}(PO_4)_6.nB_2O_3$:Eu^{3+}, (Sr, Ca,Mg)$_{10}(PO_4)_6Cl_2$:Eu^{2+}. The phosphate phosphors include, but are not limited to: $Sr_2P_2O_7$:Sn^{2+}, (Sr,Mg)$_3(PO_4)_2$:Sn^{2+}, $Ca_3(PO_4)_2.Sn^{2+}$, $Ca_3(PO_4)_2$:Tl^+, (Ca,Zn)$_3(PO_4)_2$:Tl^+, $Sr_2P_2O_7$:Eu^{2+}, $SrMgP_2O_7$:Eu^{2+}, $Sr_3(PO_4)_2$:Eu^{2+}, $LaPO_4$:Ce^{3+}, Tb^{3+}, $La_2O_3.0.2SiO_2.0.9P_2O_5$:$Ce^{3+}$.$Tb^{3+}$, $BaO.TiO_2.P_2O_5$. The silicate phosphors Zn_2SiO_4:Mn^{2+}, $CaSiO_3$:Pb^{2+}/Mn^{2+}, (Ba, Sr, Mg).$3Si_2O_7$:Pb^{2+}, $BaSi_2O_5$:Pb^{2+}, $Sr_2Si_3O_8.2SrCl_2$:Eu^2, $Ba_3MgSi_2O_8$:Eu^{2+}, (Sr,Ba)$Al_2Si_2O_8$:Eu^{2+}.

[0848] The aluminate phosphors include, but are not limited to: $LiAlO_2$:Fe^{3+}, $BaAl_8O_{13}$:Eu^{2+}, $BaMg_2Al_{16}O_{27}$:Eu^{2+}, $BaMg_2Al_{16}O_{27}$:Eu^{2+}/Mn^{2+}, $Sr_4Al_{14}O_{25}$:Eu^{2+}, $CeMgAl_{11}O_{19}$:Ce^{3+}/Tb^{3+}.

[0849] The borate phosphors include: $Cd_2B_2O_5$:Mn^{2+}, SrB_4O_7F:Eu^{2+}, $GdMgB_5O_{10}$:Ce^{3+}/Tb^{3+}, $GdMgB_5O_{10}$:Ce^{3+}/Mn^{3+}, $GdMgB_5O_{10}$:Ce^{3+}/Tb^{3+}/Mn^2.

[0850] The tungstate phosphors include, but are not limited to: $CaWO_4$, (Ca,Pb)WO_4, $MgWO_4$. Other phosphors Y_2O_3:Eu^{3+}, Y(V,P)O_4:Eu^{2+}, YVO_4:Dy^{3+}, $MgGa_2O_4$:Mn^{2+}, $6MgO.As_2O_5$:Mn^{2+}, $3.5MgO.0.5MgF_2.GeO_2$:Mn^{4+}.

[0851] The activators to the various doped phosphors include, but are not limited to: Tl^+, Pb^{2+}, Ce^{3+}, Eu^{2+}, WO_4^{2-}, Sn^{2+}, Sb^{3+}, Mn^{2+}, Tb^{3+}, Eu^{3+}, Mn^{4+}, Fe^{3+}. The luminescence center Tl^+ is used with a chemical composition such as: (Ca,Zn)$_3(PO_4)_2$:Tl^+, $Ca_3(PO_4)_2$:Tl^+. The luminescence center Mn^{2+} is used with chemical compositions such as $MgGa_2O_4$:Mn^{2+}, $BaMg_2Al_{16}O_{27}$:Eu^{2+}/Mn^{2+}, Zn_2SiO_4:Mn^{2+}, $3Ca_3(PO_4)_2.Ca(F,Cl)_2$:Sb^{2+}/Mn^{2+}, $CaSiO_3$:Pb^{2+}/

Mn^{2+}, $Cd_2B_2O_5:Mn^{2+}$, $CdB_2O_5:Mn^{2+}$, $GdMgB_5O_{10}:Ce^{3+}/Mn^{2+}$, $GdMgB_5O_{10}:Ce^{3+}/Tb^{3+}/Mn^{2+}$. The luminescence center Sn2+ is used with chemical compositions such as: $Sr_2P_2O_7:Sn^{2+}$, $(Sr,Mg)_3(PO_4)_2:Sn^{2+}$. The luminescence center Eu^{2+} is used with chemical compositions such as: $SrB_4O_7F:Eu^{2+}$, $(Sr,Ba)Al_2Si_2O_8:Eu^{2+}$, $Sr_3(PO_4)_2:Eu^{2+}$, $Sr_2P_2O_7:Eu^{2+}$, $Ba_3MgSi_2O_8:Eu^{2+}$, $Sr_{10}(PO_4)_6Cl_2:Eu^{2+}$, $BaMg_2Al_{16}O_{27}:Eu^{2+}/Mn^{2+}$, $(Sr,Ca)_{10}(PO_4)_6Cl_2:Eu^{2+}$. The luminescence center Pb^{2+} is used with chemical compositions such as: $(Ba,Mg,Zn)_3Si_2O_7:Pb^{2+}$, $BaSi_2O_5:Pb^{2+}$, $(Ba,Sr)_3Si_2O_7:Pb^{2+}$.

[0852] The luminescence center Sb^{2+} is used with chemical compositions such as: $3Ca_3(PO_4)_2.Ca(F,Cl)_2:Sb^{3+}$, $3Ca_3(PO_4)_2.Ca(F,Cl)_2:Sb^{3+}/Mn^{2+}$.

[0853] The luminescence center Tb^{3+} is used with chemical compositions such as: $CeMgAl_{11}O_{19}:Ce^{3+}/Tb^{3+}$, $LaPO_4:Ce^{3+}/Tb^{3+}$, $Y_2SiO_5:Ce^3/Tb^{31}$, $GdMgB_5O_{10}:Ce^{3+}/Tb^{3+}$. The luminescence center Eu^{3+} is used with chemical compositions such as: $Y_2O_3:Eu^{3+}$, $Y(V,P)O_4:Eu^{3+}$. The luminescence center Dy^{3+} is used with chemical compositions such as: $YVO_4:Dy^{3+}$. The luminescence center Fe^{3+} is used with chemical compositions such as: $LiAlO_2:Fe^{3+}$. The luminescence center Mn^{4+} is used with chemical compositions such as: $6MgO.As_2O_5:Mn^{4+}$, $3.5MgO0.5MgF_2.GeO_2:Mn^{4+}$. The luminescence center Ce^{3+} is used with chemical compositions such as: $Ca_2MgSi_2O_7:Ce^{3+}$ and $Y_2SiO_5:Ce^{3+}$. The luminescence center WO_4^{2-} is used with chemical compositions such as: $CaWO_4$, $(Ca,Pb)WO_4$, $MgWO_4$. The luminescence center TiO_4^{4-} is used with chemical compositions such as: $BaO.TiO_2.P_2O_5$. Additional phosphor chemistries of interest using X-Ray excitations include, but are not limited to, the k-edge of these phosphors. Low energy excitation can lead to intense luminescence in materials with low k-edge. Some of these chemistries and the corresponding k-edge are listed below:

$BaFCl:Eu^{2+}$	37.38 keV
$BaSO_4:Eu^{2+}$	37.38 keV
$CaWO_4$	69.48 keV
$Gd_2O_2S:Tb^{3+}$	50.22 keV
$LaOBr:Tb^{3+}$	38.92 keV
$LaOBr:Tm^{3+}$	38.92 keV
$La_2O_2S:TB^{3+}$	38.92 keV
$Y_2O_2S:Tb^{3+}$	17.04 keV
$YTaO_4$	67.42 keV
$YTaO_4:Nb$	67.42 keV
ZnS:Ag	9.66 keV
(Zn, Cd)S:Ag	9.66/26.7 keV

[0854] These materials can be used alone or in combinations of two or more. A variety of compositions can be prepared to obtain the desired output wavelength or spectrum of wavelengths. Emissions from these phosphors described above can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0855] In the present invention, the phosphor selection could be chosen such that under x-ray or other high energy source irradiation, the light emitted from the phosphors would mimic the natural biophoton spectra of a target cell to be treated, similar to that described above where exemplary characteristics could include:

[0856] emissions in 190-250 nm wavelength range;

[0857] emissions in the 330-340 nm wavelength range;

[0858] a combination of emissions in the 190-250 nm and in the 330-340 nm wavelength ranges;

[0859] emissions across the range of 250 nm to 600 nm;

[0860] emissions in the infrared range;

[0861] a duration of emission in short bursts of approximately a millisecond at a repetition frequency of 10 to 100 Hz; and

[0862] a range of photon flux from a few to a 1000 photons/(sec·cm2) or higher.

[0863] Thus, in one embodiment of the invention, ultraviolet and visible emissions can be used for the inventive in vivo biophoton source. Interaction of the biophotons to the biological material it is exposed to can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0864] FIG. **62** is a depiction of an in vivo biophoton source **1500** where phosphors **1510** in proximity to the cells are excited by high energy such as x-rays or c-beams to generate biophoton radiation **1530** mimicking the characteristics known or measured from the target cells for their biophoton radiation.

[0865] In the depiction of FIG. **62**, the biophotons **1530** can penetrate the cell and interact with the interior components of the cell such as the mitochondria and bacteria in the cell. In one embodiment of the invention, the biophotons **1530** can be transmitted to the donor cell by transmission through the tunneling nanotube joining the cells. A more thorough discussion of tunneling nanotubes is given later. In one embodiment of the invention, the biophoton radiation may change the chemical and charge transport along the tunneling nanotubes by photoionization events which place charge on the interior walls of the tunneling nanotubes. Interaction of the biophotons to the biological material it is exposed to can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein, which may well affect the charge on the interior wall especially if a rectifying resonator is used.

[0866] Accordingly, in one embodiment of the invention, the photon flux from the inventive biophoton sources can be, but is not necessarily, a low photon flux source (in the range of single photons and therefore not operating as a classical light wavefront subject to scattering and absorption). Higher flux may be used with the expectation that beneficial results would still follow, especially under conditions where the natural absorption/scatter in the subject would result in appropriate photon fluxes within the treatment region.

[0867] With the in vivo point of use biophoton generator, the duty cycle of the x-ray unit would determine the duty cycle of the biophoton radiation produced, the phosphor selection or combination of phosphors would determine the wavelength emission characteristics, and external coatings on the phosphors would serve to attenuate the level of light emitted at the target site.

[0868] Moreover, since the level of light emission for biophotons is low, the x-ray dose to the patient for a biophoton radiation treatment can be significantly lower than that for other radiation treatments.

[0869] In this embodiment, a downconverting energy modulation agent (e.g., a down converting phosphor) can comprise inorganic particulates selected from the group consisting of: metal oxides; metal sulfides; doped metal oxides; and mixed metal chalcogenides. In one aspect of the

invention, the downconverting material can comprise at least one of Y_2O_3, Y_2O_2S, $NaYF_4$, $NaYbF_4$, YAG, YAP, Nd_2O_3, LaF_3, $LaCl_3$, La_2O_3, TiO_2, $LuPO_4$, YVO_4, YbF_3, YF_3, Na-doped YbF_3, ZnS; ZnSe; MgS; CaS and alkali lead silicate including compositions of SiO_2, B_2O_3, Na_2O, K_2O, PbO, MgO, or Ag, and combinations or alloys or layers thereof In one aspect of the invention, the downconverting material can include a dopant including at least one of Er, Eu, Yb, Tm, Nd, Mn Tb, Ce, Y, U, Pr, La, Gd and other rare-earth species or a combination thereof. The dopant can be included at a concentration of 0.01%-50% by mol concentration. U.S. Pat. Appl. Publ. Nos. 2017/0157418 and 2017/0239489 (the entire contents of both are incorporated herein by reference) provided details of these and other suitable phosphors.

[0870] In one aspect of the invention, the downconverting energy modulation agent can comprise materials such as ZnSeS:Cu, Ag, Ce, Tb; CaS: Ce, Sm; La_2O_2S:Tb; Y_2O_2S:Tb; Gd_2O_2S:Pr, Ce, F; $LaPO_4$. In other aspects of the invention, the downconverting material can comprise phosphors such as ZnS:Ag and ZnS:Cu, Pb. In other aspects of the invention, the downconverting material can be alloys of the ZnSeS family doped with other metals. For example, suitable materials include $ZnSe_xS_y$:Cu, Ag, Ce, Tb, where the following x, y values and intermediate values are acceptable: x:y; respectively 0:1; 0.1:0.9; 0.2:0.8; 0.3:0.7; 0.4:0.6; 0.5:0.5; 0.6:0.4; 0.7:0.3; 0.8:0.2; 0.9:0.1; and 1.0:0.0.

[0871] In other aspects of the invention, the downconverting energy modulation agent can be materials such as sodium yttrium fluoride ($NaYF_4$), lanthanum fluoride (LaF_3), lanthanum oxysulfide (La_2O_2S), yttrium oxysulfide (Y_2O_2S), yttrium fluoride (YF_3), yttrium gallate, yttrium aluminum garnet (YAG), gadolinium fluoride (GdF_3), barium yttrium fluoride ($BaYF_5$, BaY_2F_8), gadolinium oxysulfide (Gd_2O_2S), calcium tungstate ($CaWO_4$), yttrium oxide:terbium (Yt_2O_3Tb), gadolinium oxysulphide:europium (Gd_2O_2S:Eu), lanthanum oxysulphide:europium (La_2O_2S:Eu), and gadolinium oxysulphide:promethium, cerium, fluorine (Gd_2O_2S:Pr,Ce,F), YPO_4:Nd, $LaPO_4$:Pr, (Ca,Mg)SO_4:Pb, YBO_3:Pr, Y_2SiO_5:Pr, $Y_2Si_2O_7$:Pr, $SrLi_2SiO_4$:Pr,Na, and $CaLi_2SiO_4$:Pr.

[0872] In other aspects of the invention, the downconverting energy modulation agent can be near-infrared (NIR) downconversion (DC) phosphors such as $KSrPO_4:Eu^{2+}$, Pr^{3+}, or $NaGdF_4$:Eu or $Zn_2SiO_4:Tb^{3+}$, Yb^{3+} or β-$NaGdF_4$ co-doped with Ce^{3+} and Tb^{3+} ions or Gd_2O_2S:Tm or $BaYF_5$:Eu^{3+} or other down converters which emit NIR from visible or UV light exposure (as in a cascade from x-ray to UV to NIR) or which emit NIR directly after x-ray or e-beam exposure.

[0873] In one aspect of the invention, an up converting energy modulation agent can also be used such as at least one of Y_2O_3, Y_2O_2S, $NaYF_4$, $NaYbF_4$, YAG, YAP, Nd_2O_3, LaF_3, $LaCl_3$, La_2O_3, TiO_2, $LuPO_4$, YVO_4, YbF_3, YF_3, Na-doped YbF_3, or SiO_2 or alloys or layers thereof.

[0874] In one aspect of the invention, the energy modulation agents can be used singly or in combination with other down converting or up converting materials. Regardless, Emissions from these up or down converting materials described herein can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein

[0875] TABLE 1 shows a list of other suitable phosphors:

TABLE 1

#	Phosphor	Emission spectrum Peak	X-ray Absorption			Microstructure		Hygroscopic
		Emission (nm)	Emiss Eff (%)	Eff (Z)	K-edge (keV)	Specific Gravity	Crystal Structure	
1	BaFCl:⑦	380	13	49.3	37.38	4.7	Tetragonal	N
2	$BaSO_4$-:⑦	390	6	45.5	37.38	4.⑦	Rhombic	N
3	LaOBr:Tm⑦	360, 460	14	49.3	38.92	6.3	Tetragonal	N
4	$YTaO_4$	337		59.8	67.42	7.5	Monolithic	N
5	$YTaO_4$:Nb (*)	410	11	59.8	67.42	7.5	Monolithic	N
6	$CaWO_4$	420	5	61.8	69.48	6.1	Tetragonal	N
7	LaOBr:Tb⑦	420	20	49.3	38.92	6.3	Tetragonal	N
8	Y⑦O⑦S:Tb⑦	420	18	34.9	17.04	4.9	Hexgonal	N
9	ZnS:⑦	450	17	26.7	9.66	3.9	Hexgonal	N
10	(Zn⑦Cd)S:⑦	530	19	38.4	9.66/26.7	4.8	Hexgonal	N
11	Gd_2O_2S:Tb⑦	545	13	59.5	50.22	7.3	Hexgonal	N
12	La_2O_2S:Tb⑦	545	12.5	52.6	38.92	6.⑦	Hexgonal	N

⑦ indicates text missing or illegible when filed

[0876] In one embodiment of the invention, besides the $YTaO_4$, noted above, other energy modulation agents can include phosphors were obtained from the following sources. "Ruby Red" obtained from Voltarc, Masonlite & Kulka, Orange, Conn., and referred to as "Neo Ruby"; "Flamingo Red" obtained from EGL Lighting. Berkeley Heights, N.J., and referred to as "Flamingo"; "Green" obtained from EGL Lighting, Berkeley Heights, N.J. and referred to as "Tropic Green"; "Orange" obtained from Voltarc, Masonlite & Kulka. Orange, Conn., and referred to as "Majestic Orange"; "Yellow" obtained from Voltarc. Masonlite & Kulka, Orange. Conn., and referred to as "Clear Bright Yellow." The "BP" phosphors are shown in detail below in TABLE 2:

TABLE 2

Code	Phosphor Material Color	Emission Spectrum Peak Emission (nm)	X-ray Absorption Emiss Eff (%)	X-ray Absorption Eff (Z)	X-ray Absorption K-edge (keV)	Density g/cc Specific Gravity	Xtal Crystal Structure	Hygroscopic
BP1	CaWO4:Pb	425						N
BP2	Y2SiO5:Ce	410						N
BP3	YTaO4	337	10	59.8	67.42	7.5	Monolithic	N
BP3-C	YTaO4	337	10	59.8	67.42	7.5	Monolithic	N
BP4	BASF-1	460						
BP5	BASF-2	490						
BP6	YTaO4:Nb (*)	410	11	59.8	67.42	7.5	Monolithic	N
BP6-C	YTaO4:Nb (*)							
BP7-C	LaOBr:Tm3+ (coated)	360, 460	14	49.3	38.92	6.3	Tetragonal	N
BP8-C	LaF3:Ce	280						
BP9	Y2O3	365						
BP10	BaSO4–:Eu2+ (coated)	390	6	45.5	37.38	4.5	Rhombic	N
BP10-C	BaSO4–:Eu2+ (coated)	390	6	45.5	37.38	4.5	Rhombic	N
BP11	LaOCl:Tm							
BP12	Y2O2S:Tm							
BP13	BaSi2O5:Pb2+	350						N
	SrB6O10:Pb	360						N
	C⍰:Na (Coated)	338						Y
	Gd_2O_2S:Tm	Blue to Green						Y

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[0877] The "BP" phosphors are available from PhosphorTech Corporation of Kennesaw, Ga., from BASF Corporation, or from Phosphor Technology Ltd, Norton Park, Norton Road Stevenage, Herts, SG1 2BB, England.

[0878] Other useful energy modulation agents include semiconductor materials including for example TiO_2, ZnO, and Fe_2O_3 which are biocompatible, and CdTe and CdSe which would preferably be encapsulated because of their expected toxicity. Other useful energy modulation agents include ZnS, CaS, BaS, SrS and Y_2O_3 which are less toxic. Other suitable energy modulation agents which would seem the most biocompatible are zinc sulfide, ZnS:Mn^{2+}, ferric oxide, titanium oxide, zinc oxide, zinc oxide containing small amounts of Al_2O_3 and AgI nanoclusters encapsulated in zeolite. For non-medical applications, where toxicity may not be as critical a concern, the following materials (as well as those listed elsewhere) are considered suitable: lanthanum and gadolinium oxyhalides activated with thulium; Er^{3+} doped $BaTiO_3$ nanoparticles. Yb^{3+} doped $CsMnCl_3$ and $RbMnCl_3$. BaFBr:Eu^{2+} nanoparticles, cesium iodide, bismuth germanate, cadmium tungstate, and CsBr doped with divalent Eu. Table 4 below provides a list of various useful energy modulation agents

[0879] In various embodiments of the invention, the following luminescent polymers are also suitable as energy modulation agents: poly(phenylene ethynylene), poly(phenylene vinylene), poly(p-phenylene), poly(thiophene), poly (pyridyl vinylene), poly(pyrrole), poly(acetylene), poly(vinyl carbazole), poly(fluorenes), and the like, as well as copolymers and/or derivatives thereof.

[0880] As a non-limiting list, the following are also suitable energy modulation agents: Y_2O_3 ZnS; ZnSe; MgS; CaS; Mn, Er ZnSe; Mn, Er MgS; Mn, Er CaS; Mn, Er ZnS; Mn, Yb ZnSe; Mn, Yb MgS; Mn, Yb CaS; Mn, Yb ZnS:Tb^{3+}, Er^{3+}; ZnS:Tb^{3+}; Y_2O_3:Tb^{3+}; Y_2O_3:Tb^{3+}, Er^{3+}; ZnS:Mn^{2+}; ZnS:Mn,Er^{3+}; $CaWO_4$, $YaTO_4$, $YaTO_4$:Nb, $BaSO_4$:Eu, La_2O_2S:Tb, $BaSi_2O_5$:Pb, NaI(Tl), CsI(Tl), CsI(Na), CsI (pure), CsF, KI(Tl), LiI(Eu), BaF_2, CaF, CaF_2(Eu), ZnS (Ag), $CaWO_4$, $CdWO_4$, YAG(Ce) ($Y_3Al_5O_{12}$(Ce)), BGO bismuth germanate, GSO gadolinium oxyorthosilicate, LSO lutetium oxyorthosilicate. $LaCl_3$(Ce). $LaBr_3$(Ce). $LaPO_4$; Ce, Tb (doped). Zn_2SiO_4:Mn with Mn doped between 0.05-10%, and $YTaO_4$.

TABLE 3

Item #	Phospohor Color	Emission Spectrum Peak Emission (nm)	Emiss Eff (%)	Eff (Z)	Xray Absorption K-edge (keV)	Specific Gravity	Crystal Structure	Hygroscopic
24	Zn3(PO4)2:T1+	310						N
33	BaF2	310						Slightly
30	C⍰	315						N
23	Ca3(PO4)2:T1+	330						N
4	YTaO4	337		59.8	67.42	7.5	Monolithic	N
38	C⍰:Na	338						Y

TABLE 3-continued

Item #	Phospohor Color	Emission Spectrum Peak Emission (nm)	Emiss Eff (%)	Eff (Z)	Xray Absorption K-edge (keV)	Specific Gravity	Crystal Structure	Hygroscopic
14	BaS?2O5:Pb2+	350						N
27	Borosilicate	350						N
34	LaCl3(Ce)	350						Y
16	SrB4O7F:Eu2+	360						N
20	RbBr:T1+	360						?
15	(Ba, Sr, Mg)3S?2O7:Pb2+	370						N
17	YAlO3:Ce3+	370						N
37	BC-422	370					Organic	?
1	BaFCl:Eu2+	380	13	49.3	37.38	4.7	Tetragonal	N
2	BaSO4:Eu2+	390	6	45.5	37.38	4.5	Rhombic	N
19	BaFBr:Eu2+	390						?
36	BC-420	391					Organic	?
35	BC-414	392					Organic	?
25	SrMgP2O7:Eu2+	394						N
18	BaBr2:Eu2+	400						N
22	(Sr, Ba)Al2S?2O8:Eu2+	400						N
5	YT?O4:Nb (*)	410	11	59.8	67.42	7.5	Monolithic	N
21	Y2S?O5:Ce3+	410						N
6	CaWO4	420	5	61.8	69.48	6.1	Tetragonal	N
7	LaOBr:Tb3+	420	20	49.3	38.92	6.3	Tetragonal	N
8	Y2O2S:Tb3+	420	18	34.9	17.04	4.9	Hexgonal	N
13	L?2S?O5:Ce3+	420						N
26	L?1.8Y0.2S?O5:Ce	420						N
9	ZaS:Ag	450	17	26.7	9.66	3.9	Hexgonal	N
29	CdWO4	475						Slightly
28	Bi4G?3O12 (BGO)	480						N
10	(Z?, Cd)S:Ag	530	19	38.4	9.66/26.7	4.8	Hexgonal	N
11	Gd2O2S:Tb3+	545	13	59.5	50.22	7.2	Hexgonal	N
12	L?2O2S:Tb3+	545	12.5	52.6	38.92	6.5	Hexgonal	N
31	Y3Al5O12 (Ce)	550						N
3	LaOBr:Tm3+	360, 460	14	49.3	38.92	6.3	Tetragonal	N
32	CaF2(Eu)	435/300						N

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[0881] In one embodiment, phosphors used in the invention as energy modulation agents can include phosphor particles, ionic doped phosphor particles, single crystal or poly-crystalline powders, single crystal or poly-crystalline monoliths, scintillator particles, a metallic shell encapsulating at least a fraction of a surface of the phosphors, a semiconductor shell encapsulating at least a fraction of a surface of the phosphors, and an insulator shell encapsulating at least a fraction of a surface of the phosphors, and phosphors of a distributed particle size.

[0882] In one embodiment of this invention, the phosphors for the in vivo point of use biophoton generator can be coated with the '117 publication polymers noted above for homing of the phosphors for the in vivo point of use biophoton generator to the target site.

[0883] With the capability to produce in vivo or deliver in vivo, specified wavelengths of light, the present invention may utilize a hybrid process in which both biophoton radiation and "activation" radiation are available for treatment. An activation radiation would be radiation of a specific wavelength to activate a photoactivatable drug such as psoralen or coumarin.

[0884] The selection of activatable pharmaceutical agents depends on a number of factors such as the desired cellular change, the desired form of activation, as well as the physical and biochemical constraints that may apply. Exemplary activatable pharmaceutical agents may include, but are not limited to, agents that may be activated by photonic energy, electromagnetic energy, acoustic energy, chemical or enzymatic reactions, thermal energy, or any other suitable activation mechanisms. An activatable agent may be a small molecule; a biological molecule such as a protein, a nucleic acid or lipid; a supramolecular assembly; a nanoparticle; or any other molecular entity having a pharmaceutical activity once activated.

[0885] When activated, the activatable pharmaceutical agent may effect cellular changes that include, but are not limited to, apoptosis, redirection of metabolic pathways, up-regulation of certain genes, down-regulation of certain genes, secretion of cytokines, alteration of cytokine receptor responses, or combinations thereof. These cellular changes can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0886] The mechanisms by which an activatable pharmaceutical agent may achieve its desired effect are not particularly limited. Such mechanisms may include direct action on a predetermined target as well as indirect actions via alterations to the biochemical pathways. A preferred direct action mechanism is by binding the agent to a critical cellular structure such as nuclear DNA, mRNA, rRNA, ribosome, mitochondrial DNA, or any other functionally important structures. Indirect mechanisms may include releasing metabolites upon activation to interfere with normal metabolic pathways, releasing chemical signals (e.g. agonists or antagonists) upon activation to alter the targeted cellular response, and other suitable biochemical or metabolic alterations.

[0887] In one embodiment, the activatable pharmaceutical agent is capable of chemically binding to the DNA or mitochondria at a therapeutically effective amount. In this embodiment, the activatable pharmaceutical agent, preferably a photoactivatable agent, is exposed to an activating energy emitted from an energy modulation agent (e.g. a phosphor), which, in turn receives energy from an initiation energy source (e.g. an x-ray source).

[0888] The activatable agent may be derived from a natural or synthetic origin. Any such molecular entity that may be activated by a suitable activation signal source to effect a predetermined cellular change may be advantageously employed in the present invention.

[0889] Suitable photoactive agents include, but are not limited to: psoralens and psoralen derivatives, pyrene cholesteryloleate, acridine, porphyrin, fluorescein, rhodamine, 16-diazorcortisone, ethidium, transition metal complexes of bleomycin, transition metal complexes of deglycobleomycin, organoplatinum complexes, alloxazines such as 7,8-dimethyl-10-ribityl isoalloxazine (riboflavin), 7,8,10-trimethylisoalloxazine (lumiflavin), 7,8-dimethylalloxazine (lumichrome), isoalloxazine-adenine dinucleotide (flavine adenine dinucleotide [FAD]), alloxazine mononucleotide (also known as flavine mononucleotide [FMN] and riboflavine-5-phosphate), vitamin Ks, vitamin L, their metabolites and precursors, and napththoquinones, naphthalenes, naphthols and their derivatives having planar molecular conformations, porphyrins, dyes such as neutral red, methylene blue, acridine, toluidines, flavine (acriflavine hydrochloride) and phenothiazine derivatives, coumarins, quinolones, quinones, and anthroquinones, aluminum (111) phthalocyanine tetrasulfonate, hematoporphyrin, and phthalocyanine, and compounds which preferentially adsorb to nucleic acids with little or no effect on proteins. The term "alloxazine" includes isoalloxazines.

[0890] Endogenously-based derivatives include synthetically derived analogs and homologs of endogenous photoactivated molecules, which may have or lack lower (1 to 5 carbons) alkyl or halogen substituents of the photosensitizers from which they are derived, and which preserve the function and substantial non-toxicity. Endogenous molecules are inherently non-toxic and may not yield toxic photoproducts after photoradiation.

[0891] In one embodiment of the invention, a hybrid treatment is used. In one embodiment of the hybrid treatment, a control region inside a patient containing phosphors is exposed to x-rays, from which ultraviolet light and visible light of a spectrum to activate one of the activatable agents noted above. The photoactivated agents induce apoptosis, causing the cancer cells to emit naturally biophoton radiation. Simultaneously, phosphors mimicking the natural biophoton radiation are exposed with the same x-rays and emit also biophoton radiation. This hybrid treatment can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0892] In one embodiment of the invention, since cell death induced by the photoactivated agents occurs over a longer duration than the x-ray exposure, the simultaneous generation in situ of the biophoton radiation can be viewed as "signaling" adjacent cells not affected by the photoactivated agent of the cell death event. This cell death can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0893] In one embodiment of the invention, the photoactivated x-ray treatment can proceed the generation of biophotons in vivo by first dosing the diseased site with the phosphors for photoactivation and then later a second dosing the diseased site with phosphors for biophoton generation. Since the level of light for biophotons is low, the x-ray dose to the patient for biophoton radiation can be significantly lower than that for activation of the photoactivated agents. Changes occurring with the first and second dosing can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

Biophoton Stimulator

[0894] In one embodiment of the invention, a light source is used, not to mimic the natural biophoton spectra of a target cell to be treated, but rather to stimulate natural biophoton radiation. It is known that the entire range of visible light can stimulate a living system to emit a biophoton signal. It is also known that non-damaging ultraviolet radiation also stimulates living systems to emit biophoton signals. For example, it has been observed that light in the 300 to 450 nm wavelength range can induce ultraweak photon emission. The strongest emission observed occurred when the living cells were stimulated at 350 nm. In another example, "white light" also induced biophoton emission.

[0895] Thus, in this embodiment, the phosphors and combinations noted above for the in vivo biphoton generator embodiment can be remixed/reselected such the phosphor selection under x-ray or other high energy source irradiation, would emit light from the phosphors which would stimulate living tissue in a subject to generate its own natural biphoton radiation. The induced change from (or the generation of) the natural biphoton radiation can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0896] In one embodiment of the present invention, stimulated emission coherence is achieved because the living cells themselves (under stimulation) as in nature will generate coherent emissions. For example, without chemical toxins or high energy radiation, one can induce cancer cells (by exposure to "white light" or 350 nm light) to emit biophotons as if they themselves are undergoing apoptosis. The neighboring cancer cells would then respond to this "signaling" and die, and during the stress leading to death rebroadcast actual biophoton signals associated with cell death to their neighbors. Since the "rebroadcast" is from living cells, natural coherence would be obtained. The signaling can be affected by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0897] Coherence is considered advantageous if, at a distance from the coherent emission, constructive interference could promote a biological, physical, or chemical reaction. Coherence is considered advantageous if, at a distance from the coherent emission, long-range dynamic order is to be promoted and/or controlled. For example, electrically polar structures of biomolecules that contain electric charges can generate electromagnetic fields when they vibrate, thereby producing an endogenous electromagnetic field of the organism with coherent modes. The endogenous electromagnetic

field of the organism can be affected by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0898] In relation to this, the majority of proteins are electrically polar structures typically immersed in water, a highly polar liquid. When metabolic energy exceeds a critical level, these polar structures engage in a steady state of nonlinear vibration, and energy is stored in a highly ordered manner, as a coherent excitation. This order expresses itself as a long range phase correlation. The order in biological systems is considered not just spatial, but dynamic, and can include long-range coherence within the entire organism.

[0899] The cytoskeleton of living cells include microtubules, tree-like structures, throughout the cytoplasm. These microtubules are electrically polar structures that can be excited and are expected to generate an endogenous coherent electric field that could have a dominant effect directing the transport of molecules and electrons throughout the cell. Moreover, connective tissue with an extracellular matrix composed of collagen that interconnects cells throughout the body is another possible network for the collective bioplasma state. This bioplasma state can be affected by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0900] Others have predicted resonant frequencies of the biological field in the microwave region of the electromagnetic spectrum between 100-1000 GHz. Thus, in another embodiment, the biophoton stimulator of the invention is a microwave source operating in this frequency range to "drive resonance" or otherwise influence the behavior of this bioplasma collective system. This bioplasma collective system can be affected by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

Target Treatments

[0901] Exemplary conditions, disorders or diseases which may be treated with the present invention can include, but are not limited to, cancer, autoimmune diseases, cardiac ablasion (e.g., cardiac arrhythmiand atrial fibrillation), photoangioplastic conditions (e.g., de novo atherosclerosis, restinosis), intimal hyperplasia, arteriovenous fistula, macular degeneration, psoriasis, acne, hopeciareata, portwine spots, hair removal, rheumatoid and inflammatory arthrisis, joint conditions, lymph node conditions, and cognitive and behavioral conditions.

[0902] Although not intending to be bound by any particular theory or be otherwise limited in any way, the following theoretical discussion of scientific principles and definitions are provided to help the reader gain an understanding and appreciation of the present invention.

[0903] As used here, the term "subject" is not intended to be limited to humans, but may also include animals, plants, or any suitable biological organism.

[0904] As used herein, the phrase "a disease or condition" refers to a condition, disorder or disease that may include, but are not limited to, cancer, soft and bone tissue injury, chronic pain, wound healing, nerve regeneration, viral and bacterial infections, fat deposits (liposuction), varicose veins, enlarged prostate, retinal injuries and other ocular diseases, Parkinson's disease, and behavioral, perceptional and cognitive disorders. Exemplary conditions also may include nerve (brain) imaging and stimulation, a direct control of brain cell activity with light, control of cell death (apoptosis), and alteration of cell growth and division. Yet other exemplary a condition, disorder or disease may include, but are not limited to, cardiac ablasion (e.g., cardiac arrhythmiand atrial fibrillation), photoangioplastic conditions (e.g., de novo atherosclerosis, restinosis), intimal hyperplasia, arteriovenous fistula, macular degeneration, psoriasis, acne, hopeciareata, portwine spots, hair removal, rheumatoid and inflammatory arthritis, joint conditions, and lymph node conditions.

[0905] The nature of the predetermined cellular change will depend on the desired pharmaceutical outcome. Exemplary cellular changes may include, but are not limited to, apoptosis, necrosis, up-regulation of certain genes, down-regulation of certain genes, secretion of cytokines, alteration of cytokine receptor responses, regulation of cytochrome c oxidase and flavoproteins, activation of mitochondria, stimulation antioxidant protective pathway, modulation of cell growth and division, alteration of firing pattern of nerves, alteration of redox properties, generation of reactive oxygen species, modulation of the activity, quantity, or number of intracellular components in a cell, modulation of the activity, quantity, or number of extracellular components produced by, excreted by, or associated with a cell, or a combination thereof. Predetermined cellular changes may or may not result in destruction or inactivation of the target structure.

[0906] The inventive treatments may be used in one embodiment to induce an auto vaccine effect for malignant cells, including those in solid tumors. To the extent that any rapidly dividing cells or stem cells may be damaged by a systemic treatment, then it may be preferable to direct any signals, chemical agents, biological agents, or blocking agents directly into the first region, preventing damage directly to normal, healthy cells or stem cells in the second (or treatment) region can be induced by activating a chemiluminescent, phosphorescent or bioluminescent compound with an appropriate activation energy, either outside the subject or inside the subject. The activation of these luminescent materials can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0907] Candidates might be 1) in vivo stimulated regrowth of organ tissue, 2) generation of alternative pathways for nerve cell to nerve cell communication perhaps by promotion of TNTs, and 3) anti-inflammatory responses.

Assisted Photobiomodulation

[0908] Photobiomodulation, which is also traditionally known as low level laser therapy (LLLT), cold laser therapy, and laser biostimulation, is an emerging medical and veterinary technique in which exposure to low-level laser light can stimulate or inhibit cellular function leading to beneficial clinical effects. The "best" combination of wavelength, intensity, duration and treatment interval is complex and sometimes controversial with different diseases, injuries and dysfunctions needing different treatment parameters and techniques.

[0909] In one embodiment of this invention, wavelengths of biophoton radiation can be applied to or emitted from within a first region can for example, aid tissue regeneration,

resolve inflammation, relieve pain and boost the immune system. Observed biological and physiological effects to be expected include changes in cell membrane permeability, and up-regulation and down-regulation of adenosine triphosphate and nitric oxide. All of these changes in the biological material of the first region can, according to one embodiment of the invention, be responsible for inducing corresponding changes in a second or treatment region. These changes could be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0910] Clinical applications of photobiomodulation suitable for causing or initiating changes in the biological material of the first or target region of this invention include, for example, treating soft tissue and bone injuries, chronic pain, wound healing and nerve and sensory regeneration/restoration, and possibly even resolving viral and bacterial infections, treating neurological and phychiatric diseases (e.g., epilepsy and Parkinson's disease) (e.g., Zhang F., et al., Nature, 446:617-9 (Apr. 5, 2007; Han X., et al., PloS ONE, 2(3):e299 (Mar. 21, 2007); Arany P R, et al., Wound Repair Regen., 15(6):866-74 (2007); Lopes C B, et al., Photomed. Laser Surg., 25(2):96-101 (2007)). One other suitable clinical application is the treatment of inflammation, where the anti-inflammatory effect of location-and-dose-specific laser irradiation produces similar outcomes as NSAIDs, but without the potentially harmful side-effects (Bjordal J M, Couppé C, Chow R T, Tuner J, Ljunggren E A (2003). "A systematic review of low level laser therapy with location-specific doses for pain from chronic joint disorders". The Australian journal of physiotherapy 49(2): 107-16). Accordingly, in one embodiment of the present invention, biophoton irradiation from the biophoton radiation sources noted above can be applied to the biological material of the first or target region, and thereby inducing changes in the second or target region which may treat in the second region soft tissue and bone injuries, chronic pain, wound healing and nerve and sensory regeneration/restoration, and possibly even resolve viral and bacterial infections, and treat neurological and phychiatric diseases. The induced change from the biophoton radiation can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0911] An NIR light treatment has been shown to prevent cell death (apoptosis) in cultured neurons (brain) cells (Wong-Reiley M T, et al., JBC, 280(6):4761-71 (2005)). Specific wavelengths of light can promote cellular proliferation to the activation of mitochondria, the energy-producing organelles within the cell via cytochrome c oxidase. An NIR treatment can augment mitochondrial function and stimulate antioxidant protective pathways. The evidence that the NIR treatment can augment mitochondrial function and stimulate antioxidant protective pathways comes from photobiomodulation experiments carried out using a laboratory model of Parkinson's disease (PD) (cultures of human dopaminergic neuronal cells) (Whelan H., et. al., SPIE, Newsroom, pages 1-3 (2008)). Accordingly, in one embodiment of the present invention, biophoton radiation from the biophoton sources noted above and NIR light can be applied or internally generated in the biological material of the first or target region, and thereby inducing changes in the second or target region to address the disorders noted above. The induced change from the combination of biophoton radiation and NIR light can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0912] When the excitable cells (e.g., neurons, cardiomyocites) are irradiated with monochromatic visible light, the photoacceptors are also believed to be components of respiratory chain. It is clear from experimental data (Karu, T. I., (2002). Low-power laser therapy. In: CRC Biomedical Photonics Handbook, T. Vo-Dinh, Editor-in-Chief, CRC Press, Boca Raton (USA)) that irradiation can cause physiological and morphological changes in nonpigmental excitable cells viabsorption in mitochondria. Later, similar irradiation experiments were performed with neurons in connection with low-power laser therapy. It was shown in 80's that He—Ne laser radiation alters the firing pattern of nerves; it was also found that transcutaneous irradiation with HeNe laser mimicked the effect of peripheral stimulation of a behavioral reflex. These findings were found to be connected with pain therapy (Karu T I, et al., (2002)). Accordingly, in one embodiment of the present invention, low power laser therapy along with biophoton radiation from the biophoton sources noted above can be applied or internally generated in the biological material of the first or target region, and thereby inducing changes in the second or target region to address the disorders noted above.

[0913] When photoacceptors absorb photons, electronic excitation followed by photochemical reactions occurring from lower excitation states (first singlet and triplet) takes place. It is also known that electronic excitation of absorbing centers alters their redox properties. Until yet, five primary reactions have been discussed in literature (Karu T I, et al., (2002)). Two of them are connected with alteration of redox properties and two mechanisms involve generation of reactive oxygen species (ROE). Also, induction of local transient (very short time) heating of absorbing chromophores is possible. Details of these mechanisms can be found in (Karu T I, et. al., (2002); Karu T I, et al., (1998). The Science of Low Power Laser Therapy. Gordon and Breach Sci. Publ., London). Accordingly, in one embodiment of the present invention, the absorption of photons in the biological material of the first or target region (e.g., from the biophoton sources noted above) can contribute to changes in the first region, thereby inducing changes in the second or target region to alter the pathways noted above. The induced changes from the absorption of the biophotons can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0914] Photobiological action via activation of respiratory chain is believed to be a general mechanism occurring in cells. Crucial events of this type of cell metabolism activation are occurring due to a shift of cellular redox potential into more oxidized direction as well as due to ATP extra-synthesis. Susceptibility to irradiation and capability for activation depend on physiological status of irradiated cells: the cells, which overall redox potential is shifted to more reduced state (example: some pathological conditions) are more sensitive to the irradiation. The specificity of final photobiological response is determined not at the level of primary reactions in the respiratory chain but at the transcription level during cellular signaling cascades. In some cells, only partial activation of cell metabolism happens by

this mechanism (example: redox priming of lymphocytes). Accordingly, in one embodiment of the present invention, the absorption of photons in the biological material of the first or target region (e.g., from the biophoton sources noted above) can induce changes in the first region, thereby inducing changes in the second or target region to affect the respiratory chain as noted above. The induced changes from the absorption of the biophotons to affect the respiratory chain can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0915] Far red and NIR radiation have been shown to promote wound healing, e.g., infected, ischemic, and hypoxic wounds (Wong-Reley, W T T, JBC, 280(6):4761-4771 (2005)). Red-to-NIR radiation also protects the retina against the toxic actions of methanol-derived formic acid in a rodent model of methanol toxicity and may enhance recovery from retinal injury and other ocular diseases in which mitochondrial dysfunction is postulated to play a role (Eells J T., PNAS, 100(6):3439-44 (2003)). Another clinical application of photobiomodulation is repair of soft and bone tissues by IR laser irradiation (Martinez M E, et al., Laser in Med. Sci., 2007). Invasive laser assisted liposuction is a recently developed method, wherein a laser fiber is introduced through a tube into the skin and directly to the fat cells causing the cells to rapture and drain away as liquid (Kim K H, Dermatol. Surg., 32(2):241-48 (2006)). Tissue around the area is coagulated. Yet, another application of photobiomodulation is a non-surgical varicose vein treatment (an endovenous laser therapy), wherein a laser is threaded through an incision and the full length of the varicose vein (Kim H S, J. Vasc. Interv. Radiol., 18(6):811 (2007)). When the laser is slowly withdrawn, heat is applied to the vein walls, causing the vein to permanently close and disappear. Accordingly, in one embodiment of the present invention, the absorption of red and IR photons in the biological material of the first or target region along with biophoton radiation can cause changes in the first region, thereby inducing changes in the second or target region to promote wound healing, e.g., infected, ischemic, and hypoxic wounds and/or help repair soft tissue, noted above. The induced changes from the absorption of the biophotons to promote wound healing can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0916] Yet, another area of application of photobiomodulation is a direct control of brain cell activity with light. The technique is based upon NIR spectroscopy and is simpler to use and less expensive than other methods such as functional magnetic resonance imaging and positron emission tomography.

[0917] Whenever a region of the brain is activated, that part of the brain uses more oxygen. This technique works by measuring the blood flow and oxygen consumption in the brain. The light emitted by NIR laser diodes is carried through optical fibers to a person's head. The light penetrates the skull where it assesses the brain's oxygen level and blood volume. The scattered light is then collected by optical fibers, sent to detectors and analyzed by a computer. By examining how much of the light is scattered and how much is absorbed, portions of the brain and extract information about brain activity can be mapped. By measuring the scattering, it is determined where the neurons are firing. This means that scientists can simultaneously detect both blood profusion and neural activity. The technique could be used in many diagnostic, prognostic and clinical applications. For example, it could be used to find hematomas in children, to study blood flow in the brain during sleep apnea, and to monitor recovering stroke patients on a daily, or even hourly, basis (that would be impractical to do with MRI). To validate the technique, hemoglobin oxygen concentrations in the brain obtained simultaneously by NIR spectroscopy and by functional MRI, the current "gold standard" in brain studies, was compared. Both methods were used to generate functional maps of the brain's motor cortex during a periodic sequence of stimulation by finger motion and rest. Spatial congruence between the hemoglobin signal and the MRI signal in the motor cortex related to finger movement was demonstrated. The researchers also demonstrated collocation between hemoglobin oxygen levels and changes in scattering due to brain activities. The changes in scattering associated with fast neuron signals came from exactly the same locations. Accordingly, in one embodiment of the present invention, the absorption of NIR in the biological material of the first or target region coupled to brain tissue along with biophoton radiation the biophoton sources noted above can directly cause changes in the first region, thereby inducing changes in the second or target region in the actual brain tissue for control of brain cell activity, as noted above. The induced changes from the absorption of the biophotons to control or influence brain cell activity can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0918] A low-intensity laser light-oxygen cancer therapy is another application of photobiomodulation. The light-oxygen effect (LOE), which involves activation of or damage to biosystems by optical radiation at low optical doses by direct photoexcitation of molecular oxygen dissolved in a biosystem so that it is converted to the singlet state, i.e., by photogeneration of molecular singlet oxygen from O_2 dissolved in cells, similar to photodynamic effect (Zakharov S D, et al., Quantum Electronics, 29(12):1031-53 (1999)). It was shown that the He—Ne laser radiation destroys tumor cells in the presence or absence of the photosensitiser. The LOE can be activated by small optical doses, which are 4-5 orders of magnitude lower that those found if a comparison is made with the familiar analogue in the form of the photodynamic effect (PDE). Accordingly, in one embodiment of the present invention, the absorption of He—Ne laser radiation in the biological material of the first or target region coupled to cancerous tissue along with biophoton radiation the biophoton sources noted above can cause changes in the first region, thereby inducing changes in the second or target region in the actual cancerous tissue. The induced changes from the absorption of the biophotons to affect cancerous tissue can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

Assisted Photostimulation

[0919] One photostimulation technique involves chemical modification of ion channels and receptors to render them light-responsive. Some of the most fundamental signaling mechanisms in a cell involve the release and uptake of Ca^{2+} ions. Ca^{2+} is involved in controlling fertilization, differen-

tiation, proliferation, apoptosis, synaptic plasticity, memory, and developing axons. It has been shown that Ca^{2+} waves can be induced by UV irradiation (single-photon absorption) and NIR irradiation (two-photon absorption) by releasing caged Ca^{2+}, an extracellular purinergic messenger InsP3 (Braet K., et al., Cell Calcium, 33:37-48 (2003)), or ion channel ligands (Zhang F., et al., 2006).

[0920] Directly controlling a brain cell activity with light is a novel means for experimenting with neural circuits and could lead to therapies for some disorders. This accomplishment is a step toward the goal of mapping neural circuit dynamics on a millisecond timescale to see if impairments in these dynamics underlie severe psychiatric symptoms. Knowing the effects that different neurons have could ultimately help researchers figure out the workings of healthy and unhealthy brain circuits. If use of the technique can show that altered activity in a particular kind of neuron underlies symptoms, for example, this insight will allow development of targeted genetic or pharmaceutical treatments to fix those neurons. Conceivably, direct control of neuronal activity with light could someday become a therapy in itself. Here, the phosphor configurations of the invention can be programmed or instructed or configured to deliver light for direct control of neuronal activity. The light generation and subsequent absorption can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0921] In living organisms, scientists have been able to cause worms, *C. elegans*, to stop swimming while their genetically altered motor neurons were exposed to pulses of yellow light intensified through a microscope. In some experiments, exposure to blue light caused the worms to wiggle in ways they weren't moving while unperturbed. When the lights were turned off, the worms resumed their normal behavior.

[0922] Meanwhile, in experiments in living brain tissues extracted from mice, the researchers were able to use the technique to cause neurons to signal or stop on the millisecond timescale, just as they do naturally. Other experiments showed that cells appear to suffer no ill effects from exposure to the light. The mice resume their normal function once the exposure ends.

[0923] The most direct application of an optical neuron control is experimenting with neural circuits to determine why unhealthy ones fail and how healthy ones work.

[0924] In patients with Parkinson's disease, for example, researchers have shown that electrical "deep brain stimulation" of cells can help patients, but they don't know precisely why. By allowing researchers to selectively stimulate or dampen different neurons in the brain, the light stimulation techniques could help in determining which particular neurons are benefiting from deep brain stimulation. That could lead to making the electrical treatment, which has some unwanted side effects, more targeted.

[0925] Another embodiment of the present invention is the stimulation of neural communications. Because neurons communicate by generating patterns of signals-sometimes on and sometimes off like the 0s and 1s of binary computer code-flashing blue and yellow lights in these patterns could compel neurons to emit messages that correspond to real neural instructions. The present invention can be used to test and tune sophisticated neuron behaviors. The ability to artificially stimulate neural signals, such as movement instructions using the present invention may allow doctors to bridge blockages in damaged spinal columns, perhaps restoring some function to the limbs of paralyzed patients. The induced change in treating paralyzed patients can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0926] Accordingly, in one embodiment of the present invention, the absorption of photons designed for photostimulation in the biological material of the first or target region along with biophoton radiation from one of the biophoton sources noted above can cause or induce changes in the first region via photostimulation, thereby inducing changes in the second or target region for stimulation and/or control of neural communication and other neuron activities. The induced change in neural communication and other neuron activities can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0927] In Vivo or In Vitro Internal Light Sources

[0928] In one embodiment, sources of internal light can be used in this invention to stimulate bioactivity (as discussed above and elsewhere) and or to simulate natural biophoton sources. In one embodiment, the sources of internal light for use in this invention can include persistent after-glow phosphor materials emitting light in the visible to near ultraviolet and ultraviolet range. These sources of internal light can be either sources inside a patient or inside an artificial construct containing biological material to be exposed to the light where the sources comprise up converting or down converting phosphors or fluorescent agents, and preferably down converting phosphors or fluorescent agents which, upon exposure to x-rays (or other high energy waves or particles) emit ultraviolet and/or visible light at the known emission bands of these phosphors and fluorescent agents. These sources of internal light can be those described above for the in vivo point of use biophoton generator and the biophoton stimulator. Interactions of biological material with light from these internal sources can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[0929] In one embodiment, Eu-doped strontium aluminate is used as an internal light source in which deep UV light or x-ray or electron beams "charge" the photoluminescence such that these phosphors can, for example, be charged outside a patient and then injected into a target or diseased site where UV photons would be emitted. In another embodiment, gadolinium strontium magnesium aluminate is used as an internal light source in which deep UV light or x-ray or electron beams "charge" the photoluminescence such that these phosphors can, for example, be charged outside a patient and then injected into a target or diseased site where UV photons would be emitted. U.S. Pat. Appl. Publ. No. 20070221883 (the entire contents of which are incorporated herein by reference) describes specifically gadolinium-activated strontium magnesium aluminate having an excitation maximum at about 172 nm, and which emits in a narrow-band UV emission at about 310 nm. The '883 publication also describes other useful internal light sources for this invention, making note of emission spectra between 300 nm and 320 nm for a $Sr(Al,Mg)_{12}O_{19}$:Gd phosphor and two 312 nm line emitting phosphors,

$YMgB_5O_{10}$:Gd, Ce and $YMgB_5O_{10}$:Gd, Ce, Pr. WO2016200349 (the entire contents of which are incorporated herein by reference) describes long lasting yellowish-green emitting phosphorescent pigments in the strontium aluminate (SrAl2O4) system, which could serve as internal light sources in the present invention. WO 2016200348 (the entire contents of which are incorporated herein by reference) describes long lasting bluish-green emitting phosphorescent pigments in the strontium aluminate (Sr4Al14O25) system, which could serve as internal light sources in the present invention. Xiong et al in "Recent advances in ultraviolet persistent phosphors," Optical Materials X 2 (2019) (the entire contents of which are incorporated herein by reference) describes a number of ultraviolet persistent phosphors that could serve as internal light sources in the present invention. The table below provides a listing of such persistent phosphors:

SrO:Pb^{2+}	390	>1 h
$CaAl_2O_4$:Ce^{3+} Tb^{3+}	400	>10 h
$CaAl_2SiO_4$:Ce^{3+} Tb^{3+}	413	>10 h
$Sr_2Al_2SiO_7$:Ce^{3+}	400	several minutes
$SrZrO_3$	395	<1000 s
$BaZrO_3$:Mg^{2+}	400	>2400 s
$SrZrO_3$:Pr^{3+}	356	
$CdSiO_3Bi^{3+}$	360	
$CdSiO_3$:Bi^{3+} Dy^{3+}	360	
$CdSiO_3$:Bi^{3+} Gd^{3+}	344	>6 h
$Sr_2MgGe_2O_7$:Pb^{2+}	370	>12 h
$NaLuGeO_4$:Br^{3+} Eu^{3+}	400	>63 h
$CaZnGe_2O_6$:Bi^{3+}	300-700	>12 h
Cs_2NaYF_6:Pr^{3+}	250	>2 h

[0930] In one embodiment, the phosphor described by Xiong et al as $CaAl_2O_4$:Ce^{3+} having an emission peak of 400 nm and a persistent time of more than 10 h could be used, where it would be charged by x-ray irradiation outside a patient and then injected at a diseased site to provide internally generated UV light.

[0931] In one embodiment, the persistent phosphors noted could be activated ex vivo and introduced along with psoralen (or other photoactivatable drug) into the patient by exchange of a bodily fluid or for example by supplying the persistent phosphors and the photoactivatable drug into a patient's blood stream.

[0932] In one embodiment, the persistent phosphors noted could be activated in vivo by injection of the phosphors into a diseased site (or at a site to be treated) and then exposed to x-rays producing a persistent internal light source.

[0933] In another embodiment, a combined electromagnetic energy harvester molecule could be used as an internal light source, such as the combined light harvester disclosed in J. Am. Chem. Soc. 2005, 127, 9760-9768, the entire contents of which are hereby incorporated by reference. By combining a group of fluorescent molecules in a molecular structure, a resonance energy transfer cascade may be used to harvest a wide band of electromagnetic radiation resulting in emission of a narrow band of fluorescent energy. In another embodiment, a Stokes shift of an emitting source or a series of emitting sources arranged in a cascade is selected to convert a shorter wavelength energy, such as X-rays, to a longer wavelength fluorescence emission such an optical or UV-A.

[0934] In one embodiment, a lanthanide chelate capable of intense luminescence is used as an internal light source. In another embodiment, a biocompatible, endogenous fluorophore emitter can be used as an internal light source.

[0935] In one embodiment, the internal light source of this invention can include visible and UV-light emitting bioluminescent materials. In one embodiment, bioluminescent materials such as coelenterate-type luciferin analogues could be used including amide monoanion known to emit at 480 nm and oxyluciferin known to emit at 395 nm.

[0936] In another embodiment of the invention, mechano-luminescent materials can be used as internal light sources.

[0937] Mechano-luminescent materials convert ultrasonic or mechanical energy (such as vibrations naturally existing on an article such as motor or vibrations from driven by transducers) into visible light. Here, for example, the mechano-luminescent materials would be placed in a vicinity of a diseased site or at a site or sites to be treated with internally generated light.

[0938] Within the context of the present invention, the phrase "in a vicinity of", and variations thereof, includes near, adjacent, or within/inside a diseased site or site or sites to be treated.

[0939] Various mechano-luminescent materials suitable for the present invention include ZnS:Mn^{2+}, $SrAl_2O_4$:Eu^{2+}, ZnS:Cu, $SrAMgSi_2O_7$:Eu^{2+} (A=Ca, Sr, Ba), KCl, KI, KBr, NaF, NaCl, LiF, RbCl, RbBr, RbI, MgO, $SrAl_2O_4$, $CaAl_2O_4$, $Sr_{1-x}Ba_xAl_2O_4$(x=0, 0.1, 0.2, 0.4), $Sr_{0.9}Ca_{0.1}Al_2O_4$, $Zn_2Ge_{0.9}Si_{0.1}O_4$, $MgGa_2O_4$, $ZnGa_2O_4$, $ZnAl_2O_4$, ZnS, ZnTe, $(ZnS)_{1-x}(MnTe)_x$ (x<¼), CaZnOS, BaZnOS, $Ca_2MgSi_2O_7$, $Sr_2MgSi_2O_7$, $Ba_2MgSi_2O_7$, $SrCaMgSi_2O_7$, $SrBaMgSi_2O_7$, $Sr_1MgSi_2O_{5+n}$ (1≤n≤2), $Ca_2Al_2SiO_7$, $Sr_2Al_2SiO_7$, $CaYAl_3O_7$, $CaAl_2Si_2O_8$, $Ca_{1-x}Sr_xAl_2Si_2O_8$ (x<0.8), $SrMg_2(PO_4)_2$, $Ba_{1-x}Ca_xTiO_3$ (0.25<x<0.8), $Ba_{1-x}Ca_3TiO_3$, $LiNbO_3$, Sr_2SnO_4, (Ca, Sr, Ba)$_2SnO_4$, $Sr_3Sn_2O_7$, $Sr_3(Sn, Si)_2O_7$, $Sr_3(Sn, Ge)_2O_7$, $Ca_3Ti_2O_7$, $CaNb_2O_6$, $Ca_2Nb_2O_7$, $Ca_3Nb_2O_8$, $BaSi_2O_2N_2$, $SrSi_2O_2N_2$, $CaZr(PO_4)_2$, ZrO_2.

[0940] In one embodiment, a europium-holmium co-doped strontium aluminate can be used as a mechano-luminescent material (i.e., an internal light source). The europium-holmium co-doped strontium aluminate and the other mechano-luminescent materials convert sonic or acoustic energy into photon emissions which may be placed in a vicinity of a diseased site or at a site or sites to be treated with internally generated light.

[0941] Yanim Jia, in "Novel Mechano-Luminescent Sensors Based on Piezoelectric/Electroluminescent Composites," Sensors (Basel). 2011; 11(4): 3962-396, the entire contents of which are incorporated by reference, describes a mechanoluminescent composite made of a piezoelectric material and an electroluminescent material. In this composite device, when a stress is applied to the piezoelectric layer, electrical charges will be induced at both the top and bottom faces of piezoelectric layer due to the piezoelectric effect. These induced electrical charges will result in a light output from the electroluminescent layer due to the electroluminescent effect.

[0942] Here, in one embodiment of the present invention, such composites made of a piezoelectric material and an electroluminescent material, hereinafter "composite mechano-luminescent emitters," provides a structure that, upon stimulation with mechanical or vibrational energy such as from an acoustic or ultrasonic transducer, emit light to a diseased site or at a site or sites to be treated with internally generated light.

[0943] The present invention in various embodiments can utilize organic fluorescent molecules or inorganic particles capable or fluorescence and phosphorescence having crystalline, polycrystalline or amorphous micro-structures for the internal light sources of this invention generating light at a diseased site or at a site or sites to be treated with internally generated light.

[0944] The list of inorganic molecules that can be used for the electroluminescence and phosphorescent materials described below include but is not limited to the following inorganic electroluminescent phosphor materials:

[0945] $SrS:Ce^{3+}$

[0946] $CaGa_2S_4:Ce^{3+}$

[0947] $SrS:Cu^{+}$

[0948] $CaS:Pb^{2+}$

[0949] $BaAl_2S_4:Eu^{2+}$

[0950] $ZnS:Tb^{3+}$

[0951] $ZnMgS:Mn^{2+}$

[0952] $SrGa_2S_4:Eu^{2+}$

[0953] $CaAl_2S_4:Eu^{2+}$

[0954] $BaAl_2S_4:Eu^{2+}$

[0955] $ZnS:Mn^{2+}$

[0956] $MgGa_2O_4:Eu^{3+}$

[0957] $(Ca, Sr)Y_2S_4:Eu^{2+}$

[0958] $BaAl_2S_4:Eu^{2+}$

[0959] Organic molecules that can phosphoresce under the influence of an electric field are also of interest in the present application. The organic fluorescent compounds with high quantum yield include by way of illustration:

[0960] Naphthalene,

[0961] Pyrene,

[0962] Perylene,

[0963] Anthracene,

[0964] Phenanthrene,

[0965] p-Terphenyl,

[0966] p-Quartphenyl,

[0967] Trans-stilbene,

[0968] Tetraphenylbutadiene,

[0969] Distyrylbenzene,

[0970] 2,5-Diphenyloxazole,

[0971] 4-Methyl-7-diethylaminocoumarin,

[0972] 2-Phenyl-5-(4-biphenyl)-1,3,4-oxadiazole,

[0973] 3-Phenylcarbostyryl,

[0974] 1,3,5-Triphenyl-2-pyrazoline,

[0975] 1,8-Naphthoylene-1', 2'-bezimidazole,

[0976] 4-Amino-N-phenyl-naphthalimide.

[0977] The inorganic fluorescent and phosphorescent materials detailed here are numerous, and various examples are given by way of illustration rather than limitation and can be used for the internal light sources of this invention generating light at a diseased site or at a site or sites to be treated with internally generated light.

[0978] Furthermore, these materials can be doped with specific ions (activators or a combination of activators) that occupy a site in the lattice structure in the case of crystalline or polycrystalline materials and could occupy a network forming site or a bridging and/or non-bridging site in amorphous materials. These compounds could include (not ranked by order of preference or utility) the following material examples:

[0979] CaF_2, ZnF_2, $KMgF_3$, $ZnGa_2O_4$, $ZnAl_2O_4$, Zn_2SiO_4, Zn_2GeO_4, $Ca_5(PO_4)_3F$, $Sr_5(PO_4)_3F$, $CaSiO_3$, $MgSiO_3$, ZnS, $MgGa_2O_4$, $LaAl_{11}O_{18}$, Zn_2SiO_4, $Ca_5(PO_4)_3F$, $Mg_4Ta_2O_9$, CaF_2, $LiAl_5O_8$, $LiAlO_2$, $CaPO_3$, AlF_3.

[0980] Further included are alkali earth chalcogenide phosphors which are in turn exemplified by the following non-inclusive list:

[0981] $MgS:Eu^{3+}$, $CaS:Mn^{2+}$, CaS:Cu, CaS:Sb, $CaS:Ce^{3+}$, $CaS:Eu^{2+}$, $CaS:Eu^{2+}Ce^{3+}$, $CaS:Sm^{3+}$, $CaS:Pb^{2+}$, $CaO:Mn^{2+}$, $CaO:Pb^{2+}$.

[0982] The examples include the ZnS type phosphors that encompass various derivatives:

[0983] ZnS:Cu,Al(Cl), ZnS:Cl(Al), ZnS:Cu,I(Cl), ZnS:Cu, ZnS:Cu,In.

[0984] Compound IIIb-Vb phosphors which include the group IIIb and Vb elements of the periodic table are suitable phosphors. These semiconductors include BN, BP, BSb, AlN, AlP, AlAs, AlSb, GaN, GaP, GaAs, GaSb, InN, InP, InAs, InSb and these materials have donors and acceptors that work in together to induce light emission diodes. The donors include Li, Sn, Si, Li, Te, Se, S, O, and acceptors include C, Be, Mg, Zn, Cd, Si, Ge. As an example, GaP light emitting diodes include GaP:Zn, O, GaP:NN, Gap:N and GaP which emit colors Red, Yellow, Green and Pure Green respectively.

[0985] The compounded materials further include such materials as GaAs with compositional variation of the following sort: In1-y(Ga1-xAlx)yP (provides a simple example).

[0986] Silicon Carbide SiC as a luminescent platform has commercial relevancy for blue light emitting diodes and could be used as an internal light source if appropriately powered from the outside. The SiC luminescent platform could include the polytypes 3C—SiC, 6H—SiC, 4H—SiC with donors such as N and Al and acceptors such as Ga and B.

[0987] Multiband luminescent materials suitable for converter materials include for example the following compositions:

[0988] $(Sr, Ca, Ba)_5(PO_4)_3Cl:Eu^{2+}$, $BaMg_2Al_{16}O_{27}:Eu^{2+}$, $CeMgAl_{11}O_{19}:Ce^{3+}:Tb^{3+}$, $LaPO_4:Ce^{3+}:Tb^{3+}$, $GdMgB_5O_{10}:Ce^{3+}:Tb^{3+}$, $Y_2O_3:Eu^{3+}$, $(Ba,Ca,Mg)_5(PO_4)_3Cl:Eu^{2+}$, $2SrO_{0.84}P_2O_5 0.16B_2O_3:Eu^{2+}$, $Sr_4Al_{14}O_{25}:Eu^{2+}$.

[0989] Other materials suitable for the internal light sources of this invention generating light at a diseased site or at a site or sites to be treated with internally generated light include those materials typically used for fluorescent high pressure mercury discharge lamps but which can be excited with X-Ray and are exemplified by way of family designation as follows:

[0990] Phosphates $(Sr, M)(PO_4)_2:Sn^{2+}$, Mg or Zn activator, Germanate $4MgO.GeO_2:Mn^{4+}$, $4(MgO, MgF_2)GeO_2:Mn^{4+}$, Yttrate $Y_2O_3:Eu^{3+}$, Vanadate $YVO_4:Eu^{3+}$, $Y(P,V)O_4:Eu^{3+}$, $Y(P,V)O_4:In^{+}$, Halo-Silicate $Sr2Si3O_8.2SrCl_2:Eu^{2+}$, Aluminate $(Ba,Mg)_2Al_{16}O_{24}:Eu^{2+}$, $(Ba,Mg)_2Al_{16}O_{24}:Eu^{2+},Mn^{2+}$, $Y_2O_3Al_2O_3:Tb^{3+}$.

[0991] Another grouping of materials suitable for converter materials for the internal light source include chemical compositions in the Halophosphates phosphors, Phosphate phosphors, Silicate phosphors, Aluminate phosphors, Borate phosphors, Tungstate phosphors, and other phosphors.

[0992] The halophosphates include by way of illustration:

[0993] $3Ca_3(PO_4)_2.Ca(F,Cl)_2:Sb^{3+}$, $3Ca_3(PO_4)_2.Ca(F,Cl)_2:Sb^{3+}/Mn^{2+}$, $Sr_{10}(PO_4)_6Cl_2:Eu^{2+}$, $(Sr,Ca)_{10}(PO_4)_6Cl_2:Eu^{2+}$, $(Sr,Ca)_{10}(PO_4)_6.nB_2O_3:Eu^{3+}$, $(Sr,Ca,Mg)_{10}(PO_4)_6Cl_2:Eu^{2+}$. The phosphate phosphors include by way of illustration $Sr_2P_2O_7:Sn^{2+}$, $(Sr,Mg)_3(PO_4)_2:Sn^{2+}$, $Ca_3(PO_4)_2.Sn^{2+}$, $Ca_3(PO_4)_2:Tl^{+}$, $(Ca,Zn)_3(PO_4)_2:Tl^{+}$, $Sr_2P_2O_7:Eu^{2+}$, $SrMgP_2O_7:Eu^{2+}$, $Sr_3(PO_4)_2:Eu^{2+}$, $LaPO_4:Ce^{3+}$, Tb^{3+}, $La_2O_3.0.2SiO_2.0.9P_2O_5:Ce^{3+}.Tb^{3+}$, $BaO.TiO_2.P_2O_5$. The silicate phosphors $Zn_2SiO_4:Mn^{2+}$, $CaSiO_3:Pb^{2+}/Mn^{2}$, (Ba, Sr, Mg).$3Si_2O_7:Pb^{2+}$, $BaSi_2O_5:Pb^{2+}$, $Sr_2Si_3O_8.2SrCl_2:Eu^{2+}$, $Ba_3MgSi_2O_8:Eu^{2+}$, $(Sr,Ba)Al_2Si_2O_8:Eu^{2+}$.

[0994] The aluminate phosphors include:

[0995] $LiAlO_2:Fe^{3+}$, $BaAl_8O_{13}:Eu^{2+}$, $BaMg_2Al_{16}O_{27}:Eu^{2+}$, $BaMg_2Al_{16}O_{27}:Eu^{2+}/Mn^{2+}$, $Sr_4Al_{14}O_{25}:Eu^{2+}$, $CeMgAl_{11}O_{19}:Ce^{3+}/Tb^{3+}$.

[0996] The borate phosphors include:

[0997] $Cd_2B_2O_5:Mn^{2+}$, $SrB_4O_7F:Eu^{2+}$, $GdMgB_5O_{10}:Ce^{3+}/Tb^{3+}$, $GdMgB_5O_{10}:Ce^{3+}/Mn^{3+}$, $GdMgB_5O_{10}:Ce^{3+}/Tb^{3+}/Mn^{2}$.

[0998] The tungstate phosphors include:

[0999] $CaWO_4$, $(Ca,Pb)WO_4$, $MgWO_4$. Other phosphors $Y_2O_3:Eu^{3+}$, $Y(V,P)O_4:Eu^{2+}$, $YVO_4:Dy^{3+}$, $MgGa_2O_4:Mn^{2+}$, $6MgO.As_2O_5:Mn^{2+}$, $3.5MgO.0.5MgF_2.GeO_2:Mn^{4+}$.

[1000] Activators of relevance to the various doped phosphors include the following list:

[1001] Tl^{+}, Pb^{2+}, Ce^{3+}, Eu^{2+}, WO_4^{2-}, Sn^{2+}, Sb^{3+}, Mn^{2+}, Tb^{3+}, Eu^{3+}, Mn^{4+}, Fe^{3+}.

[1002] In various embodiments, the luminescence center Tl+ can be used with a chemical composition such as:

[1003] $(Ca,Zn)_3(PO_4)_2:Tl^{+}$, $Ca_3(PO_4)_2:Tl^{+}$.

[1004] Similarly, the luminescence center Mn2+ can be used with chemical compositions such as

[1005] $MgGa_2O_4:Mn^{2+}$, $BaMg_2Al_{16}O_{27}:Eu^{2+}/Mn^{2+}$, $Zn_2SiO_4:Mn^{2+}$, $3Ca_3(PO_4)_2.Ca(F,Cl)_2:Sb^{2+}/Mn^{2+}$, $CaSiO_3:Pb^{2+}/Mn^{2+}$, $Cd_2B_2O_5:Mn^{2+}$, $CdB_2O_5:Mn^{2+}$, $GdMgB_5O_{10}:Ce^{3+}/Mn^{2+}$, $GdMgB_5O_{10}:Ce^{3+}/Tb^{3+}/Mn^{2+}$.

[1006] Further, the luminescence center Sn^{2+} can be used with chemical compositions such as:

[1007] $Sr_2P_2O_7:Sn^{2+}$, $(Sr,Mg)_3(PO_4)_2:Sn^{2+}$.

[1008] The luminescence center Eu^{2+} can also be used with chemical compositions such as:

[1009] $SrB_4O_7F:Eu^{2+}$, $(Sr,Ba)Al_2Si_2O_8:Eu^{2+}$, $Sr_3(PO_4)_2:Eu^{2+}$, $Sr_2P_2O_7:Eu^{2+}$, $Ba_3MgSi_2O_8:Eu^{2+}$, $Sr_{10}(PO_4)_6Cl_2:Eu^{2+}$, $BaMg_2Al_{16}O_{27}:Eu^{2+}/Mn^{2+}$, $(Sr,Ca)_{10}(PO_4)_6Cl_2:Eu^{2+}$.

[1010] The luminescence center Pb^{2+} can be used with chemical compositions such as:

[1011] $(Ba,Mg,Zn)_3Si_2O_7:Pb^{2+}$, $BaSi_2O_5:Pb^{2+}$, $(Ba,Sr)_3Si_2O_7:Pb^{2+}$.

[1012] The luminescence center Sb^{2+} can be used with chemical compositions such as:

[1013] $3Ca_3(PO_4)_2.Ca(F,Cl)_2:Sb^{3+}$, $3Ca_3(PO_4)_2.Ca(F,Cl)_2:Sb^{3+}/Mn^{2+}$.

[1014] The luminescence center Tb3+ can be used with chemical compositions such as:

[1015] $CeMgAl_{11}O_{19}:Ce^{3+}/Tb^{3+}$, $LaPO_4:Ce^{3+}/Tb^{3+}$, $Y_2SiO_5:Ce^{3+}/Tb^{3+}$, $GdMgB_5O_{10}:Ce^{3+}/Tb^{3+}$.

[1016] The luminescence center Eu^{3+} can be used with chemical compositions such as:

[1017] $Y_2O_3:Eu^{3+}$, $Y(V,P)O_4:Eu^{3+}$.

[1018] The luminescence center Dy^{3+} can be used with chemical compositions such as:

[1019] $YVO_4:Dy^{3+}$.

[1020] The luminescence center Fe^{3+} can be used with chemical compositions such as:

[1021] $LiAlO_2:Fe^{3+}$.

[1022] The luminescence center Mn^{4+} can be used with chemical compositions such as:

[1023] $6MgO.As_2O_5:Mn^{4+}$, $3.5MgO.0.5MgF_2.GeO_2:Mn^{4+}$.

[1024] The luminescence center Ce^{3+} can be used with chemical compositions such as:

[1025] $Ca_2MgSi_2O_7:Ce^{3+}$ and $Y_2SiO_5:Ce^{3+}$.

[1026] The luminescence center WO_4^{2-} can be used with chemical compositions such as:

[1027] $CaWO_4$, $(Ca,Pb)WO_4$, $MgWO_4$.

[1028] The luminescence center TiO_4^{4-} can be used with chemical compositions such as:

[1029] $BaO.TiO_2.P_2O_5$.

[1030] In various embodiments of this invention, the phosphor chemistry utilized in x-ray excitations can be used for the internal light sources of this invention generating light at a diseased site or at a site or sites to be treated with internally generated light.

[1031] Of particular interest is the k-edge of these phosphors. Low energy excitation can lead to intense luminescence in materials with low k-edge. Some of these chemistries and the corresponding k-edge are included as follows:

$BaFCl:Eu^{2+}$	37.38 keV
$BaSO_4:Eu^{2+}$	37.38 keV
$CaWO_4$	69.48 keV
$Gd_2O_2S:Tb^{3+}$	50.22 keV
$LaOBr:Tb^{3+}$	38.92 keV
$LaOBr:Tm^{3+}$	38.92 keV
$La_2O_2S:Tb^{3+}$	38.92 keV
$Y_2O_2S:Tb^{3+}$	17.04 keV
$YTaO_4$	67.42 keV
$YTaO_4:Nb$	67.42 keV
ZnS:Ag	9.66 keV
(Zn, Cd)S:Ag	9.66/26.7 keV

[1032] In one embodiment of this invention, light from these materials (excited for example by high energy particles including x-rays, gamma rays, protons, and electrons) can have their emissions act as the internal light sources of this invention generating light at a diseased site or at a site or sites to be treated with internally generated light.

[1033] Various materials used for the electro-luminescence can be used for the internal light sources of this invention generating light at a diseased site or at a site or sites to be treated with internally generated light. The electro-luminescence materials can include but are not limited to:

[1034] 4,4',4"-Tris[phenyl(m-tolyl)amino]triphenylamine (m-MTDATA)

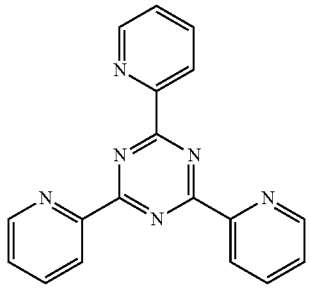
[1035] N,N'-Bis(3-methylphenyl)-N,N'-diphenylbenzidine (TPD)

[1036] 4,4',4"-Tris[phenyl(m-tolyl)amino]triphenylamine (m-MTDATA)

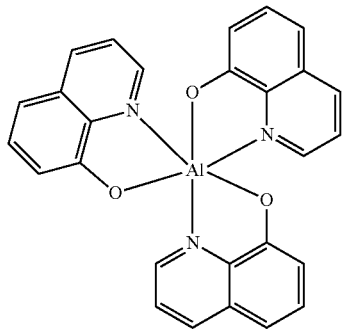
[1037] N,N'-Bis(3-methylphenyl)-N,N'-diphenylbenzidine (TPD)

[1038] Tris-(8-hydroxyquinoline)aluminum

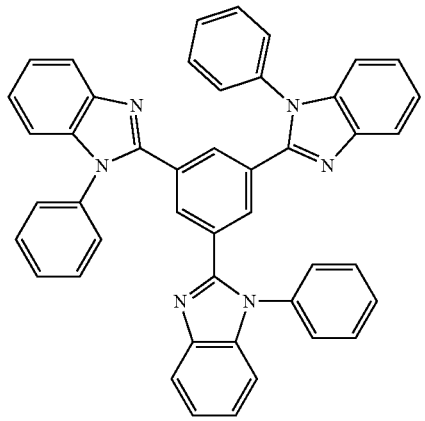
[1039] 2,4,6-Tris(2-pyridyl)-s-triazine (TPT)



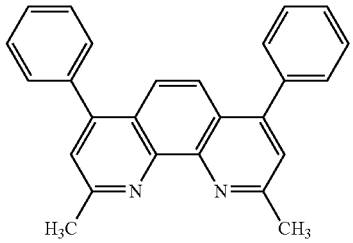
[1040] 2,2',2"-(1,3,5-Benzinetriyl)-tris(1-phenyl-1-H-benzimidazole) Alq



[1041] 2,2',2"-(1,3,5-Benzinetriyl)-tris(1-phenyl-1-H-benzimidazole) TPBI



[1042] 2,9-Dimethyl-4,7-diphenyl-1,10-phenanthroline, BCP2,9-Dimethyl-4,7-diphenyl-1,10-phenanthroline, BCP



[1043] Interactions of biological material with light from these luminescent devices and materials described in this section can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1044] Stimulated Regeneration and Phototreatment

[1045] In one embodiment of this invention, the photon radiation generated by the sources described above such as the in vivo point of use biophoton generator, the biophoton stimulator, and the in vivo and in vitro internal light sources described above (and the fluorescing materials and phosphors described herein) can be used as a source of light to stimulate bioactivity (as discussed above and elsewhere) and/or to simulate natural biophoton sources. The induced change to stimulate bioactivity can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1046] In prior work entitled "Conjugated polymers optically regulate the fate of endothelial colony-forming cells, conjugated polymers were used with visible light excitation to gain optical control of cell fate" by Lodola et al. in Science Advances 27 Sep. 2019: Vol. 5, no. 9, the entire contents of which are incorporated herein by reference, endothelial progenitor cells (EPCs) and, in particular, endothelial colony-forming cells (ECFCs) were evaluated for optical regulation. ECFCs can be mobilized from the bone marrow and vascular stem cell niche to reconstruct a vascular network destroyed by an ischemic insult and to restore local blood perfusion. ECFCs can be harvested from peripheral blood, and are known to display robust clonogenic potential, exhibit tube-forming capacity in vitro, and generate vessel-like structures in vivo.

[1047] This work by Lodola et al. demonstrated that polymer-mediated optical excitation during the first steps of ECFC growth could lead to a robust enhancement of both proliferation and tubulogenesis through the optical modulation of the Ca^{2+}-permeable transient receptor potential vanilloid 1 (TRPV1) channel and NF-κB-mediated gene expression. The material used for light absorption and phototransduction was regioregular poly(3-hexyl-thiophene) (P3HT), a thiophene-based conjugated polymer which acted as an exogenous, light-responsive actuator. This work by Lodola et al. used polymer thin films (approximate thickness, 150 nm) deposited by spin coating on top of polished glass substrates. Both polymer-coated and glass substrates have been thermally sterilized (120° C., 2 hours), coated with fibronectin, and, lastly, used as light-sensitive and control cell culturing substrates, respectively. ECFCs were seeded on top of polymer coated glass substrates.

[1048] This work by Lodola et al. provided optical excitation by a light-emitting diode (LED) source, with maximum emission wavelength at 525 nm, incident from the

substrate side. A protocol based on 30-ms excitation pulses, followed by a 70-ms dark condition, at a photoexcitation density of 40 mW/cm^2 was used to minimize heating. The whole protocol is continuously repeated for a minimum of 4 up to 36 hours, depending on the type of functional assay, at controlled temperature (37° C.) and CO_2 levels (5%). This work found that optical excitation, properly mediated by biocompatible polymer substrates, positively affects ECFC fate by spatially and temporally selective activation of the TRPV1 channel which has been shown to be expressed and drive angiogenesis in human ECFCs.

[1049] More significantly, this work postulated that the P3HT polymer upon interaction with light induced an excited state of P3HT resulting in charged oxygen state O_2^-, subsequently producing hydrogen peroxide, triggering intracellular reactive oxygen species (ROS) enhancement.

[1050] Lesions have been treated with target light-sensitive molecules called photosensitizers (PSs). When irradiated with light, PSs generate reactive oxygen species (ROS) which very rapidly react with any nearby biomolecule and can eventually kill cells through apoptosis or necrosis. The technique, called chromophore-assisted light inactivation (CALI), has been used for the treatment of precancerous lesions and superficial tumors.

[1051] In one embodiment of this invention, the stimulated activity generated by the light internally generated in the medium to be treated promotes the formation of new blood vessels using at least one of ultraviolet and/or visible light emission into the medium to be treated. Here, the internal light sources generate the ultraviolet and/or the visible light which exposes a photosensitive material (for example the P3HT polymer noted above) contained within or in a vicinity of natural or artificial tissue cells containing endothelial progenitor cells. In one embodiment, the ultraviolet and/or the visible light generated within the photosensitive material generates reactive oxygen species which can promote an angiogenesis process within the natural or artificial tissue cells containing the endothelial progenitor cells. In one embodiment, the light internally generated in the medium is generated by phosphorescence or fluorescence of light emitting materials disposed within the photosensitive material (for example the P3HT polymer noted above) when the light emitting materials are exposed to x-rays. The induced change to stimulate bioactivity by light emitting materials can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1052] In one embodiment, the phosphorescence or fluorescence light emitting materials are disposed in a biocompatible polymer that is not necessarily photosensitive. The biocompatible material is coated or else is to be located in vicinity to endothelial progenitor cells. X-ray exposure of this composite biocompatible polymer generates UV light emission from the phosphorescence or fluorescence light emitting materials which exits the composite biocompatible polymer and generates ROS in the medium about the endothelial progenitor cells, thereby stimulating blood vessel growth. The induced change to stimulate blood vessel growth can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1053] In other prior work, Andrés Garcia of the Georgia Institute of Technology and his team have made blood vessels grow by shining light on skin. In this prior work, entitled "Light-triggered in vivo activation of adhesive peptides regulates cell adhesion, inflammation and vascularization of biomaterials: published in Nature Materials volume 14, pages 352-360 (2015), the entire contents of which are incorporated herein by reference, a RGB peptide (used to signal cells to grow on new tissues) and a photo-responsive blocker were impregnated into a water-based gel, or hydrogel, which was later activated by UV light from an external source. The UV light released the blocker and cell growth was observed. However, the depth of penetration of UV light from an external source limits the utility of this approach.

[1054] In one embodiment of the present invention, a water-based gel, or hydrogel, is impregnated with a RGB peptide and a material of one of the internal light sources described above such that activation for example by x-ray exposure generates within the hydrogel the ultraviolet and/or the visible light. When UV light from the internal light source in the hydrogel is generated, the UV light causes the blocker to be released, and the RGB peptide to become active. The induced change by the UV light can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1055] In one embodiment, the hydrogel with the impregnated RGB peptide, the blocker, and the internal light source material is implanted into a patient and exposed to x-ray flux which generates within the hydrogel UV light which causes the blocker to be released, and the RGB peptide to become active within the patient. The induced change by the UV light can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1056] In another embodiment, the hydrogel with the impregnated RGB peptide, the blocker, the internal light source material, and a vascular endothelial growth factor protein that stimulates the growth of new blood vessels is implanted into a patient and exposed to x-ray flux which generates within the hydrogel UV light which causes the blocker to be released, and the RGB peptide and the vascular endothelial growth factor protein to become active. The induced change by the UV light can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1057] Thus, in one embodiment of the invention, there is provided a method for regenerative medicine using internal light sources within artificial or in vivo living cells to regrow cells of an organ in a patient in which light for the internal light sources stimulates or otherwise promote s the regrowth/regeneration of cells of the organ, for example where angiogenesis (blood vessel regrowth occurs as an example due to generation of reactive oxygen species or for example the removal of blocking proteins preventing endothelial progenitor cells from generating new cells. The induced change for blood vessel regrowth can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1058] In other prior work, Berkowitz et al. and his research team at John Hopkins in an article entitled "Melanopsin mediates light-dependent relaxation in blood vessels," in Proceedings of the National Academy of Sciences in North America, first published Nov. 17, 2014, vol. 11, no.

50 pp 17977-17982 (the entire contents of which are incorporated herein by reference) have found that delivering light to blood vessels can deter vascular disease. Accordingly, in another embodiment of the present invention, light from internal light sources inside blood vessels can stimulate blood vessels. It was learned by Berkowitz that melanopsin (opsin 4) is one group of nonimage-forming light receptors that are present in blood vessels elsewhere in the human body which help set the circadian rhythms that affect the body's daily cycle of physical, mental and behavioral changes. Berkowitz et al. reported a physiological role for Opn4 in regulating blood vessel function, particularly in the context of photorelaxation.

[1059] Berkowitz et al. further reported that opsin 4 (a classic G protein-coupled receptor) is expressed in blood vessels. Vasorelaxation was reported by Berkowitz et al. to be wavelength-specific, with a maximal response at vessels at low-intensity blue light (380-495 nm), which was reported by Berkowitz et al. to correspond to the optimal absorption wavelength for the mouse Opn4 receptor. In short, Berkowitz et al. found that exposure of the blood vessels to blue light increased blood flow.

[1060] In general, a variety of different microbial opsins and genetically modified opsins have been used and developed to date for optogenetic manipulations. In the art, the term opsin describes a light-responsive protein, independent of its chromophore type (e.g., retinal, flavin), mode of action (e.g., phosphorylation, ion conductance's), or function (e.g., phototaxis, vision).

[1061] Typically, two superfamilies are distinguished: (1) microbial opsins (type I), including opsins from prokaryotes, fungi, and algae and (2) animal opsins (type II), which are found in eumetazoans.

[1062] Although both opsin types are transmembrane proteins and may share a common origin, they differ significantly from each other. Microbial opsins are mainly light-activated ion pumps or channels, which directly transduce electromagnetic signals into electrical currents. On the other hand, all type II opsins belong to the family of G protein-coupled receptors (GPCRs), which initiates protein-protein interaction and subsequent intracellular signaling cascades.

[1063] Microbial opsins, of type I, utilize all-trans as a chromophor, which stays covalently bound to the opsins after photoisomerization, whereas type II opsins use cis to trans isomerization of retinal (retinaldehyde) to transmit light stimuli. All vertebrate tissues investigated so far already contain sufficient amounts of retinal to constitute the protein, so that no additional retinal has to be supplied.

[1064] After the establishment of channelrhodopsin 2 (ChR2), a blue light-gated cation-selective ion channel from green algae ChR2, as an excitatory optogenetic tool, the first inhibitory tool was described. NpHR, a chloride pump from *Natronomonas pharaonis*, was used to silence neurons in vitro and in vivo. NpHR has its excitation maximum around 600 nm. In addition to opsins that regulate chloride pumps, opsins that control outward proton pumps, i.e., bacteriorhodopsins, such as eBR, Arch, and Mac, have also demonstrated their ability to inhibit neuronal firing. These capabilities have raised the possibility that optogenetic therapies can treat degenerative diseases of the eyes, hearing loss, and spinal cord injuries, as well as play a role in deep brain stimulation therapies.

[1065] In general, light-gated actuators have been known to control neuronal activity. Specific light-sensitive elements in phototransduction machineries underlying animal vision were found to be membrane-embedded photopigments called rhodopsins, each rhodopsin molecule consisting of a protein called opsin (belonging to the family of G-protein-coupled receptors or GPCRs) covalently bound to a chromophore (a vitamin A-related compound called retinal or one of its derivatives). Upon illumination, the bound retinal molecule undergoes isomerization, which induces conformational changes in the opsin backbone and activates a G-protein signaling pathway. Indeed, the first light-actuated control systems were designed to modulate neuronal firing.

[1066] In this invention, the light from the internal light source materials noted above (e.g., phosphors, fluorescent agents, etc.) can be used to treat different types of diseases and disorders such as those described above, and in one embodiment can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1067] In one embodiment, the light from the internal light source materials noted above could be used to treat degenerative diseases of the eyes, hearing loss, and spinal cord injuries, as well as play a role in deep brain stimulation therapies. This treatment can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1068] In one embodiment, the light from the internal light source materials noted above could be used to treat vascular disease including peripheral artery disease, aneurysms and Raynaud's disease (a condition causing people to feel numbness and cold in their fingers and toes due to the narrowing of the small arteries that supply blood to the skin) by emission of characteristic wavelengths of light which triggers the light receptors in blood vessels. This vascular disease treatment can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1069] Specifically, in one embodiment, the endothelial cells that line blood vessels can be exposed to blue light (380-495 nm) generated from the internal light sources noted above such that, upon patient exposure to x-rays, blue light emitted from the internal light source would affect blood flow. Emission of the blue light and its affects can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1070] In one embodiment of the invention, a phosphorescent or fluorescent or light emitting material such as those described above (e.g., x-ray induced persistent phosphors) would be encased with a biocompatible coating transparent to blue light and introduced into the blood stream or into the body of the blood vessel or nearby a blood vessel. Upon exposure to x-rays, the phosphorescent or fluorescent or light emitting material would emit blue light which would be absorbed in the walls of the blood vessel to affect a change in blood flow for example by way of triggering a response in melanopsin (opsin 4) in the blood vessel walls. The induced change in blood flow can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1071] In other work, workers have sought to optically control Ca^{2+} signals. Ca^{2+} acts as a messenger to regulate a

myriad of cellular activities, ranging from short-term reactions occurring within seconds (e.g., muscle contraction and neurotransmitter release) to long-term processes that last for hours or even days (e.g., gene transcription). The location, amplitude and frequency of Ca^{2+} signals in mammalian cells undergo constant changes to maintain Ca^{2+} homeostasis while meeting the diverse requirements of different Ca^{2+}-modulated events. Activation of cell-surface receptors, such as G protein-coupled receptors (GPCRs) and receptor tyrosine kinases (RTKs), results in mobilization of Ca^{2+} release from internal Ca^{2+} stores. Upon ligand binding to these receptors, PLC is activated to hydrolyzethe PM-bound lipid, phosphatidylinositol 4,5-bisphosphate (PIP2), generating two second messengers: inositol 1,4,5-trisphosphate (IP3) and diacylglycerol (DAG). DAG is an activator of protein kinase C (PKC) and may directly activate certain types of transient release potential (TRP) channels, resulting in Ca^{2+} influx from the extracellular space. Photo-switchable DAG and its analogs based on the azobenzene photo-switch have been developed to modulate PKC dependent pathways.

[1072] In one embodiment of the present invention, the examples given above are but illustrative of the present invention's capability for use in optogenetics. More specifically, the present invention provides the capability to provide light to opsins and other light-driven actuator proteins in order to impact a number of physiological parameters ranging from membrane voltage and calcium concentration to metabolism. The induced change in physiological parameters can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

Tunneling Nanotubes

[1073] Tunneling nanotubes TNTs have been found to exist between adjacent cells. Moreover, recent studies have found TNTs to be dynamic connections between cells, providing a route for cell-to-cell communication. TNTs are considered to play a role in intercellular exchanges of signals, molecules, organelles, and pathogens. TNTs can from in a number so cell types, including neuronal cells, epithelial cells, and almost all immune cells. In myeloid cells (e.g., macrophages, dendritic cells, and osteoclasts), intercellular communication via TNT is believed to contribute to their differentiation and immune functions. TNTs are believed to be one way for myeloid cells to communicate with a targeted neighboring or distant cell, as well as with other cell types, therefore creating a complex variety of cellular exchanges. TNTs may also contribute to pathogen spread as they are believed to serve as "corridors" from a cell to another.

[1074] Vignas et al have described in "Cell Connections by Tunneling Nanotubes: Effects of Mitochondrial Trafficking on Target Cell Metabolism, Homeostasis, and Response to Therapy," in Stem Cells Int. 2017; 2017: 6917941. (the entire contents of which are incorporated herein by reference) that TNTs can be a means of communication between cells devised to allow long-distance cell-to-cell contacts. This paper reported that the formation of tunneling nanotubes (TNTs) between these cells was initially reported in the rat pheochromocytoma- (PC12-) derived cells and in immune cells. These TNTS were long tubular structures, with diameters between 50 and 1500 nm, that could span several tens to hundreds of microns, connecting two cells together. In a characteristic manner, in 2D cultures, TNTs were not tethered to the extracellular matrix, rather floating in the culture medium. This paper reported that the tunneling nanotubes allowed a continuity in plasma membrane and cytoplasm between the connecting cells, thus allowing trafficking of a number of cellular components from one cell to the other.

[1075] Furthermore, this paper reported that cells of the immune system, notably macrophages, dendritic cells (DCs), NK, and B cells, extensively use TNTs to communicate. According to this paper, the transfer of antigenic information from migratory DCs to lymph node-residing DCs through TNTs has been shown to be critical for the induction of immune responses. TNT formation was also described in neural CAD cells (mouse cell line of catecholaminergic origin) and from bone marrow-derived dendritic cells to primary neurons.

[1076] Rustom in "The missing link: does tunneling nanotube-based supercellularity provide a new understanding of chronic and lifestyle diseases?," from http://rsob.royalsocietypublishing.org/on Sep. 3, 2018 (the entire contents of which are incorporated herein by reference) describes a number of ways for TNT formation. The paper notes that, in general, oxidative stress is defined as an imbalance between the production of free radicals and reactive metabolites, such as H_2O_2 or superoxide anions, and their elimination by the antioxidative cell defense system. The list of severe diseases that have been linked to oxidative stress is long, including neurodegenerative disorders, such as Alzheimer's and Parkinson's, chronic inflammation, diabetes and cancer. The paper notes that it is well accepted that most reactive oxygen species (ROS) are generated in cells by the mitochondrial respiratory chain.

[1077] The paper noted that to counter stress, "stressed cells" will distribute "'call-for-help' signals to determine the position of unstressed cells in their surrounding." The paper describes that, while the nature of these signals is still under debate, candidate molecules are advanced glycation end products (AGEs).

[1078] In this paper, local stress leads to increasing ROS levels and AGE distribution from the stressed cell (a-1). AGE and receptor for AGE (RAGE) interaction at the target cells leads to cROS increase (a-2) and AC-TNT formation via actin-based, filopodia-like cell protrusions in order to restore redox/metabolic homeostasis by intercellular material exchange (a-3). Further increasing ROS levels lead to MT-TNT formation (b-1), allowing for efficient redox/metabolic rescue of stressed cells, e.g. via motor protein-mediated intercellular transfer of mitochondria along microtubules (b-2). Finally, exaggerated ROS levels induce apoptosis (c-1). Note that prior to apoptosis, remaining TNT connections are severed in order to isolate and remove 'degenerated' cells from the collective (c-2)—probably controlled by altered cholesterol/oxysterol homeostasis.

[1079] Accordingly, in one embodiment of the present invention, the biophotonic sources described above and/or the biophotoic bypasses could be used to stimulate formation of TNT growth. For example, the live biophotonic sources described above could be stressed (in a number of conventional ways) or selected portions of organs could be stressed as noted elsewhere. The stressed cells would then emit "call-for-help signals" (which regardless of their origin and nature would stimulate formation of TNTs. The in situ or ex situ presence of energy augmentators including reso-

nators such as the folded resonators and rectifying resonators described herein can affect the "call-for-help signals."

[1080] For example, the artificial biophotonic sources or the above-noted biophoton stimulator would emit light at a frequency and dose level which could stimulate formation of TNTs. For example, Wang et al in "Transfer of mitochondria via tunneling nanotubes rescues apoptotic PC12 cells," in Cell Death Differ. 2015 July; 22(7): 1181-1191 (the entire contents of which are incorporated herein by reference) show that UV light induced TNT formation presumably through the stress induced on the cells by the UV light. The induced change by the UV light can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1081] In one embodiment of the present invention, the network of TNTs induced by the cell communication would permit healthy cells to strengthen their interconnection with other healthy cells, thus providing resistance to infection from other diseased cells.

[1082] In one embodiment of the present invention, the network of TNTs induced would permit cancerous cells undergoing apoptosis to experience cell death at a higher rate, thus controlling tumor growth.

[1083] In one embodiment of the present invention, the network of TNTs induced would permit organs subject to inflammation to build their interconnection to other nearby cells, thus providing a mechanism for the inflammation to be reduced by permitting mesenchymal stem cells (MSCs) to be transferred. Such cells are known to contributes to tissue repair and immunosuppressive properties. Once at the inflammation site, MSCs prevent cellular destruction and damage to surrounding tissues. MSC immuno-suppression is mediated by the secretion of soluble factors like indoleamine 2,3-dioxygenase (IDO), IL-10, TSG-6 (TNF-α-stimulated gene/protein 6), prostaglandin E2 (PGE2), TGF-β-1, inducible nitric oxide synthase (iNOS) and human leukocyte antigen (HLA-G). The induced changes by the network of TNTs can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein and the influence of the electric fields from the resonators on tunneling in the TNTs.

Building Blocks of the Invention

[1084] The present invention takes advantage of several fundamental building blocks by which it can affect a physical, chemical, and/or therapeutic change or a treatment area. Below is a non-limiting and non-exclusive discussion of these building blocks provided as guidance on implementing the procedures and tools described above. The building blocks can be influenced by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1085] One building block involves the phenomenon of cell-to-cell communication discussed above in which different cells in different regions "communicate" with each other even without necessarily being in physical or fluid contact with one another. As discussed above, there are a number of mechanisms in the literature for how the cell-to-cell communication can work. One mechanism discussed above and utilized in the present invention is by omission of a biophoton also known as mitogenic radiation. Other mechanisms discussed above and utilized in the present invention is by emission of electromagnetic radiation or sonic radiation. Another mechanism discussed above and utilized in the present invention is by coupling through coherent quantum states, where the change in the state at one location produces a concomitant change in the quantum state at another location. Another mechanism discussed above and utilized in the present invention is by coupling of excited states in a cellular bioplasma.

[1086] Closely related to the last two effects is that of quantum entanglement. Experiments with green fluorescent proteins in a biological living medium have shown the photons emitted from separated molecules to be related as "entangled pairs" with the photons' polarizations entangled such that, by determining the polarization of one emitter, the polarization of the quantum entangled other emitter was known apriori. Here, the cell-to-cell communication utilized in the present invention to induce effects in neighboring cells may well be a quantum entanglement phenomenon.

[1087] Another building block involves the capability to affect the quantum or physical states of the biological structures of a cell. For example, as discussed above, cellular processes associated with membranes in a cell are controlled by factors such as pore size, the thickness of the membrane, and the polarity of the membrane. These pore sizes and thicknesses are on the nanometer scales, and therefore are susceptible to being influenced by applied radiation, by applied electromagnetic fields, and/or by applied localized electric fields which the physics of diffusion and transport even at the quantum scale can influence the transport of materials through the membranes or the attachment of antibodies to the cell membrane.

[1088] Another building block used by the present invention is the realization that photosynthesis-type reactions (occurring in the realm of plants) are also a mechanism at play inside living cells of animals. Here, light can induce not only the generation of biophotons as discussed above but also can promote reactions in the cells such as increased metabolism of a cell, cell division, or cell death.

[1089] Another building block used by the present invention is the realization that there are many pathways before communication between cells including those of physically connected pathways such as the tunneling nanotubes (TNTs) discussed above. These pathways can be used for both productive and detrimental uses. In the present invention, mechanisms to shut down selected pathways can be used to control/restrict the spread of viruses, bacteria, or cancer from one region of the body to another. In the present invention, mechanisms to promote certain pathways can be used to promote cell regeneration, for example, in the regrowth of healthy heart tissue inside a diseased heart.

[1090] Yet another building block used by the present invention is the realization of the impact of outside stimulus, such as a biophoton, on the epigenome. For example, it has been shown that identical twins having identical DNA at birth can have their DNA changed by environmental factors. Here, in vivo light or light delivered in situ such as for example biophotons can be used to interact directly with the DNA encoded in the cells to implement a therapeutic change.

[1091] As noted above, these building blocks can be influenced by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

Quantized Biology:

[1092] In one embodiment of the invention, and in other embodiments described below, photonic energy can participate and control the various metabolic processes in an individual cell or a group of cells. Control of the metabolic processes in one region (a control region) may be coupled to another region (e.g., a treatment site inside the patient, where the coupling can induce a biological, chemical, physical, or therapeutic change in the subject at the other region or the treatment site). Control of the metabolic processes can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1093] Alternatively, in one embodiment of the invention, the photonic energy (as described for example in the following) can directly cause a biological, chemical, physical, or therapeutic change at a treatment site. These induced changes can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1094] In one embodiment of the invention, $h\nu_i$ is a photonic energy that is ionizing and can therefore be responsible for catalyzing a chemical reaction. Other energies ($h\nu_j$) generated through energy converters (such as UV or other energy generated from the phosphors described herein) could create a free radical hence inducing a charge-build up in a protein of low molecular weight or on a side group of a long molecular weight protein. Once the ionization of a protein takes place, this ionization could result in a dysfunctional behavior of the protein, and subsequently the failure of the protein to achieve the intended process. For example, in one embodiment of the invention, $h\nu_i$ or $h\nu_j$ induced ionization of an epidermal growth factor receptor (EGFR) protein can denature or render the EGFR protein dysfunctional. EGFR is considered a transmembrane protein that is a receptor for members of the epidermal growth factor family (EGF family) of extracellular protein ligands. Deficient signaling of the EGFR and other receptor tyrosine kinases in humans is associated with diseases such as Alzheimer's, while over-expression is associated with the development of a wide variety of tumors. Interruption of EGFR signaling, either by blocking EGFR binding sites on the extracellular domain of the receptor or by inhibiting intracellular tyrosine kinase activity, may prevent the growth of EGFR-expressing tumors and might improve a patient's condition.

[1095] In one embodiment of the invention, $h\nu_k$ is a photonic energy responsible for signaling an aspect of a protein conformation. This photonic energy $h\nu_k$ would typically not be ionizing. In another embodiment of the invention, $h\nu_z$ is a photonic energy responsible for signaling an aspect of a protein conformation that closes an ion channel or multiple ion channels. In a further embodiment of the invention, $h\nu_x$ is a photonic energy responsible for signaling an aspect of a protein conformation that opens an ion channel or multiple ion channels.

[1096] Hence, in one aspect of this invention, photonic energy can be used to promote reactions in some cases ($h\nu_i$), promote ionization and denaturing of certain proteins ($h\nu_j$), change protein conformation ($h\nu_k$), and/or signal the closure and the opening of ion channels ($h\nu_z$, $h\nu_x$). Energy converters in one embodiment (such as the phosphors described elsewhere) can be used to convert high energy incident radiation such as x-ray into one or more of $h\nu_i$, $h\nu_j$, $h\nu_k$, $h\nu_z$, and/or $h\nu_x$ which can interact within the cell environment to promote or prohibit the functions of those cells. The use of such high energy incident radiation (such as x-ray), which can penetrate completely through the subject body, permits the implementation of the invention deep within the body in a non-invasive manner, requiring at most only injection of the desired energy converters to the desired site. The induced changes deep within the body can be assisted by the in situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1097] The following examples performed using poly(deoxyadenylic-deoxythymidylic) acid sodium salt (poly-dAdT) and 8-methoxypsoralen (8-MOP) demonstrates this aspect of the invention and shows the effects of photonic energy to promote biologically driven reactions via quantized effects.

[1098] Monoadduct (MA) Formation and Di-Adduct Formation or Cross-Linking (XL)

[1099] In the examples below, energy promoters (i.e., the phosphors designated below as BP3, BP10, and BP6) absorb X-Ray energy and emit photonic energy from the UVA to the visible range as listed below (name, emission peak):

	(BP3, 327 nm)	(BP10, 355 nm)	(BP6, 410 nm)
Properties	BP3	BP10	BP6
Peak Emission (nm)	327	390	410
hv = Photonic Energy (J)	6.075E−19	5.093E−19	4.845E−19
Intensity (AU)	15,000	5,000	22,000
Composition	$YTaO_4$	$BaSO_4$:Eu^{2+}	$YTaO_4$:Nb

[1100] FIG. **63** shows the spectral emission of the BP3, BP10, and BP6 phosphors

[1101] Phosphors BP3, BP6, and BP10 were added to a solution of 8-MOP and Poly-dAdT, and exposed to various X-ray conditions. The plates were placed at the following distances from the X-ray source: 100 mm and 200 mm. This had the effect of changing the dose rate. The X-Ray parameters included 320 kV and 10 mA for a fixed time period. This example shows that monoadduct (MA) formation can be promoted for example by UV light with the higher energy light promoting more MA formation even at a lower flux or intensity.

[1102] Photonic energy comparison:

$$h\nu_{(BP3)} > h\nu_{(BP10)} > h\nu_{(BP6)}$$

[1103] Intensity Comparison:

$$I_{(BP6)} > I_{(BP3)} > I_{(BP10)}$$

[1104] Comparison of the phosphors in terms of Mono-Adduct (MA) formation as demonstrated in detail below showed that:

$$MA_{(BP3)} > MA_{(BP10)} > MA_{(BP6)}$$

Moreover, the observed MA formation tends to follow the photonic energy ranking rather than the intensity of the energy conversion from X-Ray to UV or visible light.

[1105] Similarly, other sets of experiments were performed further demonstrating the effect of photonic energy on both MA and di-Adduct formation (e.g. cross linking (XL)). Measurements of the MA and di-adduct formation (XL) were performed using high performance liquid chro-

matography (HPLC) to identify the presence of these compounds after exposure to photonic energy.

[1106] FIG. **64** is a chart showing that photonic energy from BP3 tends to produce more MA than BP6 or BP10. FIG. **65** is a chart showing MA formation under BP3 photonic energy as a function of distance from the X-ray source and time. Somewhat surprisingly, MA formation increases as the distance from the X-ray source increases. This points out that the right reaction is sensitive to dose rate. Lower dose rates in this case could be more beneficial. Regardless, the results show MA formation under BP3 photonic energy.

[1107] FIG. **66** is a chart showing XL under BP3 photonic energy as a function of distance from the X-ray source and time. Here, XL decreases as the distance from the X-ray source increases and increases with time. It is worth noting that the XL reaction is reversible.

[1108] FIGS. **67-71** show results from other experiments corroborating MA formation and/or XL under photonic energy exposure. FIG. **72** is a chart showing a non-linear effect on MA seen by mixing two phosphors. Indeed, the mixtures of BP7 from at least 33% to 67% show higher MA formation than observed when using only BP3 or only BP7. The tables below summarize the results:

	kvp	mA	Distance mm	Time (min)	MA1	XL
			BP6			
S2	320	10	200	1	1,500	
S6	320	10	200	2	2,700	
S10	320	10	200	2	1,500	
S14	320	10	200	4	2,000	
S18	320	10	200	4	2,000	
S22	320	10	100	2	2,000	
S26	320	10	100	1	1,000	
			BP3			
S1	320	10	200	1	30,000	600
S5	320	10	200	2	40,000	1000
S9	320	10	200	2	45,000	1,000
S13	320	10	200	4	70,000	2,500
S17	320	10	200	4	70,000	3,000
S21	320	10	100	2	60,000	2,500
S25	320	10	100	1	8,000	1,000
			BP10			
S4	320	10	200	1	4,000	
S8	320	10	200	2	4,000	
S16	320	10	200	4	6,500	
S20	320	10	200	4	10,000	
S24	320	10	100	2	35,000	
S28	320	10	100	1	3,500	

[1109] Similarly, experiments have shown that phosphor combinations can promote higher XL than the individual phosphors alone.

BP3 (g)	BP7 (g)	BP3	BP7	MA	XL
0.3	0	100.0%	0.0%	3.00E+04	5.00E+02
0.2	0.1	67.0%	33.0%	5.00E+04	6.00E+02
0.15	0.15	50.0%	50	4.80E+04	5.00E+02
0.1	0.2	33.0%	67.0%	3.50E+04	4.50E+02
0	0.3	0.0%	100.0%	1.40E+03	0.00E+00

[1110] The generation of light from these phosphor or the light interaction with the biological material can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

Activation and Deactivation of a Signaling Protein

[1111] Living cells possess sophisticated molecular machinery and control systems. Living cells convert food into energy, such as ATP, which drives the millions of biochemical processes necessary for keeping us alive. The pathways used to convert substrates such as glucose into products are collectively referred to as metabolic pathways. The drivers of these metabolic pathways are enzymes that work to assist chemical reactions by building or breaking down molecules. The enzymatic protein does not drive reactions at a constant rate. The reaction rate can in fact speed up or slow down or even stop completely according to the cell's needs. The cell is considered to be self-regulated, and the supply of products does not exceed demand. If products are being created at a rate that is faster than they can be used, a slower rate or complete stoppage can take place through a process called feedback inhibition, which is part of Allosteric regulation. Allosteric regulation plays a role in many metabolic pathways and is considered to keep everything running smoothly and efficiently while maintaining homeostasis.

[1112] Allosteric Regulation: There are enzymatic and non-enzymatic proteins. Enzymes catalyze reactions, for example, such as in the case of DNA polymerase and Amylase. Non-enzymatic proteins play a large number of functions and roles, including, but not limited to, receptors/ion channels, transport, motor and antibodies.

[1113] Enzymes have active sites where substrates combine as well as allosteric sites where enzyme regulator can bind. There are two types of regulators: allosteric activators which increase enzymatic activity and allosteric inhibitors which decrease enzymatic activity. A feedback loop gets established whereby the downstream products regulate upstream reactions. An increase or decrease of enzymatic activity is therefore tailored to the specific needs of the cell.

[1114] Mutated enzymes that do not respond to allosteric regulation have been linked to disease states, such as cancer. Many processes in our bodies rely on molecular feedback inhibition to maintain homeostasis.

[1115] In the present invention, photonic energy can be used to promote allosteric activators which increase enzymatic activity and/or promote allosteric inhibitors which decrease enzymatic activity, therefore targeting diseased cells to curtail runaway growth conditions. The induced change from this photonic energy can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1116] In one embodiment, as noted above, a signaling protein can be activated and deactivated using photonic energy. In this embodiment, an energy converter such as BP3, BP6, and/or BP10 would be located nearby or inside a cell to generate photonic energy, such as UV or visible light, to promote the function or the suppression of a signaling protein. The induced change from this photonic energy can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1117] Light-activated DNA binding in a designed allosteric protein has been reported by Devin Strickland, Keith

Moffat, and Tobin R. Sosnick, Department of Biochemistry and Molecular Biology and Institute for Biophysical Dynamics, University of Chicago, 929 East 57th Street, Chicago, Ill. 60637, edited by David Baker, University of Washington, Seattle, Wash., and approved May 12, 2008 (received for review Oct. 9, 2007) in "Light-activated DNA binding in a designed allosteric protein," the entire contents of which are incorporated herein by reference.

[1118] An understanding of how allostery, the conformational coupling of distant functional sites, arises in highly evolvable systems is of considerable interest in areas ranging from cell biology to protein design and signaling networks. The rigidity and defined geometry of α-helical domain linker was reasoned to make it effective as a conduit for allosteric signals. The idea was tested by designing twelve fusions between the naturally photoactive light-oxygen-voltage-sensing domain LOV2 domain from *Avena Sativa* phototropin 1 and the *Escherichia coli* trp repressor were investigated by Strickland et al. When illuminated with photonic energy, one of the fusions selectively binds to operator DNA and protects it from nuclease digestion. The helical "allosteric lever arm" was considered by Strickland et al. to be a mechanism for coupling the function of two proteins. This is illustrated in FIG. **73**.

[1119] In FIG. **73**, the LOV domain (containing the three dots representing the three ring FMN chromophore), the TrpR domain in orange, and the operator DNA are depicted above in various states. The shared helix, H, is shown contacting the LOV domain in (A) and contacting the TrpR domain in (B)-(D). The three-ring FMN chromophore is in the ground state in (A) and (D) above and when photoexcited in (B) and (C). (A) In the dark DNA-dissociated state, the shared helix H contacts the LOV domain, populating an inactive conformation of the TrpR domain. (B) Photoexcitation disrupts contacts between the shared helix H and the LOV domain, populating an active conformation of the TrpR domain. (C) LovTAP binds DNA. (D) The LOV domains return to the dark state. LovTAP dissociates from the DNA, contacts between the shared helix H and the LOV domain are restored, and the system returns to the initial state.

[1120] Strickland et al. concluded that a successful design of an allosteric lever arm and a bistable energy surface, along with the observation of a natural analogue, suggesting the existence of a general but largely unrecognized mode of connecting modular domains into a functionally integrated whole. The α-helical structure of the linker distinguishes this mode from others in which allostery results from intramolecular binding between domains connected by linkers of undefined structure. Because a regular helix resists bending and twisting, it can function as an allosteric lever arm to transmit forces created by interdomain contacts to generate bistable systems.

[1121] FIG. **74** provides a depiction of a design of an allosteric, light activated repressor. As shown in FIG. **74**, (A) represents a conceptual model of an allosteric lever arm. Joining two domains across terminal α-helices creates a bi-stable system in which steric overlap (star) is relieved by the disruption of contacts between the shared helix and one or the other of the domains. A perturbation (Δ) such as ligand binding or photo-excitation alters the energy surface of the system (blackline) to favor a new conformational ensemble (dashed line) with different functional properties.

[1122] Here, in the present invention, photonic energy, for example from the energy converters noted above, can be used to photoexcite these types of reactions to promote light-activated DNA binding. The induced change from the photonic energy can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1123] Furthermore, in the present invention, photonic energy can be used to activate a repressor. The induced change from the photonic energy can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1124] The following references (all of which are incorporated herein in their entirety by reference) describe repressors:

[1125] Freeman, S. Hamilton, H., Hoot, S., Podgorski, G., Ryan, J. M., Smtill, S. S., & Weigle, D. S (2002). Bilogical Science (Vol 1). Upper Saddle River, N.J.: Prentice Hall.

[1126] Gerhart, J. C., & Pardee, A. B. (1962). The enzymology of control by feedback inhibition. J Biol Chem, 237, 391-896.

[1127] Tansey, J. T., Baird, T., Cox, M. M., Fox, K. M., Knight, J., Sears, D., Bell, E. (2013). Foundational concepts and underlying theories for majors in "biochemistry and molecular biology". Biochemisty and molecular bology education, 41 (5), 289-296.

[1128] Webb, B. A., Forouhar, F., Szu, F. E., Seetharaman, J., Tong, L., Barber, D. L. (2015). Structures of huma phosphofructokinase-1 and atomic basis of cancer associated mutations. Nature 523 (7558). 111-114.

[1129] Oana I Lungu, Ryan A Hallett, Eun Jung Choi, Mary J. Aiken, Klaus M Hahn, and Brian Kuhlman, Department of Biochemistry and Biophysics, Department of Pharmacology, University of North Carolina Chapel Hill, N.C. 27599, USA, published an article in Chemistry & Biology 19, 507-517, Apr. 20, 2012 entitled "Designing Photoswitchable Peptides using the AsLOV2 Domain," the entire contents of each of which are incorporated herein by reference.

[1130] Lungu et al. describes that peptides can regulate a variety of biological processes by acting as competitive inhibitors, allosteric regulators and localization signals. Photo-control of peptide activity represents a tool for precise spatial and temporal control of cellular functions.

[1131] Lungu et al. showed that genetically encoded light-oxygen-voltage-sensing domain LOV2 domain of *Avena Sativa* phototropin 1 (AsLOV2) can be used to reversibly photo-modulate the affinity of peptides for their binding partners. Sequence analysis and molecular modeling were used to embed tow peptides into the Jα helix of the AsLOV2 domain while maintaining AsLOV2 structure in the dark but allowing for binding to effector proteins when the Jα helix unfolds in the light. Caged versions of the ipaA and SsrA peptides, LOV-ipaA and LOV-SsrA, bind their targets with 49- and 8-fold enhanced affinity in the light, respectively. These switched can be used as general tools for light-dependent colocalization, which Lungu et al. demonstrated with photo-activable gene transcription in yeast.

[1132] In another reference entitled A light-triggered protein secretion system, the entire contents of which are incorporated herein by reference, by Daniel Chen, Emily S. Gibson, and Matthew J. Kennedy, Department of Pharmacology, University of Colorado Denver School of Medicine,

Aurora, Colo. 80045, Chen et al. confirmed the importance of light in various cellular functions.

[1133] Chen et al. used UVR8, a plant photoreceptor protein that forms photolabile homodimers, to engineer the first light-triggered protein secretion system. UVR8 fusion proteins were conditionally sequestered in the endoplasmic reticulum, and a brief pulse of light triggered robust forward trafficking through the secretory pathway to the plasma membrane. UVR8 was not responsive to excitation light used to image cyan, green, or red fluorescent protein variants, allowing multicolor visualization of cellular markers and secreted protein cargo as it traverses the cellular secretory pathway. Chen et al. showed that this could be used, as a tool in neurons, to demonstrate restricted, local trafficking of secretory cargo near dendritic branch points.

[1134] In general, the use of light to control basic cellular functions has transformed experimental biology. Some of the first approaches relied on photolabile small molecule analogues of second messengers, second messenger chelators, or neurotransmitters to control cellular physiology and signaling pathways with ultraviolet (UV) light. These "caged" compounds have been used for dissecting numerous molecular pathways governing cellular physiology with unprecedented spatial and temporal control. More recently, exogenously expressed photoreceptors from plants have been used to control cellular biochemistry by conditionally gating protein-protein interactions with light. This approach has emerged as a new and powerful way to control cellular processes on fast timescales with fine spatial precision without the need for small molecules. Some of the first studies describing engineered optical control of cellular functions used the plant photoreceptor phytochromeB. PhyB binds to members of the phytochrome-interacting family (PIF) of basic helix-loop-helix transcription factors when photoexcited with red (660 nm) light. Remarkably, PhyB/PIF interactions can be reversed by near-infrared (730 nm) excitation, allowing fast and local toggling of PIF binding.

[1135] However, PhyB-based systems require addition of an exogenous phycocyanobilin chromophore that is not normally present in yeast, flies, worms, or mammals, making it more difficult to implement than more recently developed systems that are entirely genetically encoded. These systems rely on blue light photoreceptor cryptochrome2 (Cry2), which binds to cryptochrome interacting basic-helix-loop-helix 1 (CIB1) in response to blue light, and the light, oxygen, voltage (LOV) domain photoreceptors, which undergo a large conformational change when photoexcited UVR8 has many unique properties that including constitutive formation of photolabile homodimers, slow reversal kinetics, and a UV-B absorption profile, which enables multicolor imaging of widely used fluorescent proteins without activating the photoreceptor. UVR8 can be used to conditionally sequester secretory cargo in the ER. Moreover, light triggers robust forward trafficking to the plasma membrane.

[1136] FIG. **75** shows the light-triggered dissociation of UVR8-tagged proteins. UVR8 fused to prenylated GFP (UVR8-memGFP) localizes to the plasma membrane where it recruits UVR8-mCh. Dissociation of the UVR8 dimer by UV-B light releases UVR8-mCh to the cytosol

[1137] Here, in the present invention, photonic energy from for example the energy converters noted above can be used to photoexcite these types of reactions. The induced photoexcited changes can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1138] In stacking up amino-acids in the right sequence, the various units constituting a given protein enter into an energetically favorable and stable configuration. The presence of water is reported to enable the correct folding through the influence of the various water molecules in the vicinity of the amino-acids to be stacked. The proper staking and folding yields biologically compatible and functional molecules. If a solvent other than water is used the folding of proteins is derailed to biologically incompatible molecules. The energetically favorable stacking and folding is accompanied by remitting of any excess energy to the microenvironment hosting the staking process (the cell in this case). The excess energy release can be in various forms including electromagnetic radiation. This could in fact explain the presence of some of the low intensity photons in the cell environment. These photons are conceivably specific to the amino-acid being staked and the configuration to which they are folded. Hence the synthesis of the various proteins could be accompanied by the emission of electromagnetic radiation. In turn this electromagnetic radiation could play a role in guiding the conformational change of other existing (already made) protein.

In-Vivo Photosynthesis (Human Photosynthesis):

[1139] It is well understood that cells, their proteins and genes are sensitive to light. A review of this area has been provided by Neves-Petersen, M. T., et al. (2012). "UV Light Effects on Proteins: From Photochemistry to Nanomedicine", Molecular Photochemistry—Various Aspects, Dr. Satyen Saha (Ed.), ISBN: 978-953-51-0446-9, InTech, the entire contents of which are incorporated herein by reference.

[1140] Just a couple of examples of photoinitiated processes in human cells include (1) the vision process, which is initiated when photoreceptor cells are activated by light (photoisomerization); and (2) near UV (290 nm) exposed prion protein fails to form amyloid fibrils (Thakur, A. K. & Mohan Rao Ch. (2008). "UV-Light Exposed Prion Protein Fails to Form Amyloid Fibrils, Plos one, Vol 3, No. 7, (July 2008), pp. E2688, eISSN 1932-6203).

[1141] Sunlight can activate the formation of vitamin D3. Interestingly, the precursor to vitamin D3 is cholesterol. Cells also produce an abundance of cholesterol sulfate the important precursor to vitamin D3. Due to the lack of depth of penetration of sunlight into the human body, the photo-induced bio-synthesis of vitamin D3 is confined to the skin area.

[1142] The benefits of vitamin D3 are actually stemming from cholesterol sulfate and lead to protection against diabetes, cardiovascular disease and certain cancers.

[1143] In view of the ability to convert X-Ray into UV light, the technology now exists to perform biosynthesis of vitamin D3 in-vivo anywhere in the human or animal body. Energy converting particles can be placed (through injection) in proximity to a cholesterol rich area and help convert such cholesterol into water soluble vitamin D3.

[1144] In one embodiment of the present invention, photonic energy from the energy converters noted above can be used to photo-excite these types of reactions to promote light-activated bio-synthesis. This can be used as a method of increasing vitamin D3 levels in a subject, lowering total

cholesterol levels in a subject, or both simultaneously. Of course, the level of vitamin D3 production could be controlled by controlling the amount of incident high energy radiation (such as x-ray) which in turn would control the amount of UV production in vivo. Vitamin D3 production can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1145] In another embodiment of the present invention, the photonic energy need not come from down-converting phosphors. Other means for generating ultraviolet or visible light in vivo may be used by injecting into the body in target regions upconverting phosphors, UV or visible light emitting diodes, light-emitting plasma capsules, etc. to photoexcite reactions promoting vitamin D3 production and/or other light-activated bio-synthesis. The promoting vitamin D3 production and/or other light-activated bio-synthesis can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1146] Nucleic acids in living cells are associated with a large variety of proteins. Ultraviolet (UV) irradiation of cells is thought to lead to reactions between DNA and the proteins that are in contact with it, such as cross-linking between the amino acids in these associated proteins and the bases in DNA, which appears to be an important process that photoexcited DNA and proteins undergo in vivo, as well as in DNA-protein complexes in vitro. Twenty two (22) common amino acids are known to bind photochemically (upon 254 nm excitation) to uracil, with the most reactive being phenylalanine, tyrosine and cysteine. The three amino acid residues having side chains that absorb in the UV range are the aromatic residues tryptophan (Trp), tyrosine (Tyr) and phenylalanine (Phe).

[1147] One photochemical mechanism in proteins involves reduction of disulphide bridges upon UV excitation of Trp and Tyr side chains. As discussed by Neves-Petersen et al (2012), UV-excitation of tryptophan or tyrosine can result in their photoionization and to the generation of solvated electrons. The generated solvated electrons can subsequently undergo fast geminate recombination with their parent molecule, or they can be captured by electrophillic species like molecular oxygen, H3O+ (at low pH), and cystines (name given to each bridged cysteine in a disulphide bridge), which can also result in the breakage of the disulphide bridge. The free thiol radicals/groups thus formed can then react with other free thiol groups to create a new disulphide bridge. As detailed by Neves-Petersen et al (2012), this phenomenon has led to a new technology for protein immobilization (LAMI, light assisted molecular immobilization) since the created thiol groups can bind thiol reactive surfaces leading to oriented covalent protein immobilization.

[1148] There are many potential pathways for the breakage of intramolecular disulphide bridges in proteins upon UV excitation of aromatic residues, even in the absence of molecular oxygen. Breakage of the disulphide bridge can lead to conformational changes in the protein, not necessarily resulting in inactivation of the protein.

[1149] Neves-Petersen et al (2012) report that the solvated electron average lifetime is shorter at acidic pH values, which is correlated with the fact that H3O+ captures the solvated electron. Furthermore, the solvated electron lifetime is significantly shorter in protein systems as compared to from Trp alone in solution, thus indicating that a protein offers other pathways involving capture of the solvated electron. Neves-Petersen et al (2012) also report that data has shown that the higher the pH the longer time it takes for the solvated electron to recombine with the parent molecule (geminate recombination) or another electron scavenger molecule, such as H3O+. The observed lifetime increase with pH can be explained since the lower the pH, the higher the concentration of H3O+ and therefore the larger the probability of recombination of the solvated electron with the hydronium ion. Furthermore, for proteins, the higher the pH of the solution, the larger the number of basic titratable residues that have lost their positive charge and became neutral (His, Lys, Arg) and the larger the number of acidic titratable residues that have acquired a negative charge (Asp, Gly, Tyr, Cys not bridged). This means that an increase of pH leads to a loss of positive charge in the protein and a gain of neutral and negative charged residues in the protein. This can lead to an increase of the areas in the protein that carry a negative electrostatic potential. Therefore, an increase in pH will decrease the efficiency of electron recombination with the molecule due to electrostatic repulsion. This can lead to an increase of the solvated electron lifetime.

[1150] The recent development of DNA microarrays has demonstrated the importance of immobilization technology, where multiple oligonucleotide or cDNA samples are immobilized on a solid surface in a spatially addressable manner. These arrays have revolutionized genetic studies by making the global analysis of gene expression in living organisms more readily possible. Similar approaches have been developed for protein analysis. The proteins bound to the microarrays can be assayed for functional or structural properties, making screening possible on a scale and with a speed previously unachievable. The simplest type of protein immobilization uses the high inherent binding affinity of surfaces to proteins in general, such as through the use of numerous weak contacts, including van der Waals and hydrogen bonding interactions. Molecules can also be immobilized on a carrier or solid surface passively through hydrophobic or ionic interactions, or covalently by attachment to surface groups. Due to the importance of immobilization for solid phase chemistry and biological screening, the analytical uses of the technology have been widely explored. The technology has found particularly broad application in different areas of biotechnology, including, but not limited to, diagnostics, biosensors, affinity chromatography and immobilization of molecules in assays such as ELISA assays.

[1151] Light-induced immobilization techniques have also been explored, leading to the use of quinone compounds for photochemical linking to a carbon-containing support (see, e.g., EP0820483). Activation occurs after irradiation with non-ionizing UV and visible light. Masks can be used to activate certain areas of the support for subsequent attachment of biomolecules. Following illumination, the photochemically active compound anthraquinone will react as a free radical and form a stable ether bond with a polymer surface. Because anthraquinone is not found in native biomolecules, appropriate ligands have to be introduced into the biomolecule. A further development of light-induced immobilization technology is disclosed in U.S. Pat. Nos. 5,412,087 and 6,406,844, each of which is incorporated herein by reference in its entirety.

[1152] Most of the known immobilization methods use one or more thermochemical/chemical steps, sometimes with hazardous chemicals, some of which are likely to have a deleterious effect on the structure and/or function of the bound protein. The available methods are often invasive, whereby foreign groups are introduced into a protein to act as functional groups, which can cause protein denaturation, as well as lower its biological activity and substrate specificity. Neves-Petersen et al (2012) have suggested this can be addressed by Light Assisted Molecular Immobilization technology (LAMI). This technology provides a photonic method for coupling a protein or a peptide on a carrier by way of stable bonds (covalent bond or thiol-Au bond) while preserving the native structural and functional properties of the coupled protein or peptide.

[1153] LAMI technology uses an inherent natural property of proteins and peptides, whereby a disulphide bridge in a protein or peptide, located in close proximity to an aromatic amino acid residue, is disrupted following excitation of aromatic amino acids. The thiol groups created by light induced disulphide bridge breakage in a protein or peptide are then used to immobilise the protein or peptide to a carrier. The formed free thiol groups in the protein can then attach the protein onto a thiol reactive surface, such as gold, thiol derivatized glass and quartz, or even plastics. The new protein immobilization technology has led to the development of microarrays of active biosensors and biofunctionalization of thiol reactive nanoparticles, aiming at engineering drug delivery systems.

[1154] This light induced disulphide bridge breakage can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

EXEMPLARY METHODS OF THE INVENTION

[1155] FIG. **76** is a flowchart of one method of the invention for treating a subject. At **2601**, this method provides a first region of biological material coupled to the subject. At **2603**, this method initiates a change in a cellular environment of the cells in the first region. At **2605**, due to a change in biological or chemical activity of the cells in the first region, this method induces a biological change in a second region inside the subject. The induced biological change can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1156] According to various embodiments of the invention, the first region can be a region inside the subject proximate the second region or it can be a region inside the subject remote from the second region. In one embodiment, the first region can be a region outside the subject coupled physically to the second region or it can be a region inside the subject overlapping the second region.

[1157] Furthermore, at **2601**, the biological material of the first region can be segregated from the second region by an artificial material. The artificial material may comprise a permeable material capable of transmission of chemical agents produced by the biological material from the first region into the second region. The artificial material may comprise a material capable of transmission of biophotons therethrough. The artificial material may comprise a material capable of transmission of sonic waves therethrough. The artificial material may comprise a material capable of transmission of ultraviolet light or visible light therethrough. The artificial material may comprise a material capable of transmission of infrared light therethrough. The artificial material may comprise a material capable of transmission of electrical signals therethrough. At **2605**, the first region and the second region can be quantum entangled regions, permitting the coupling to occur.

[1158] Furthermore, at **2603**, initiating a change can cause cell death of the biological material of the first region or initiating a change can cause cell growth of the biological material of the first region. The changes initialed can be caused by imposing an electric field in the first region to promote ion pumping through cells in the biological material of the first region, or by imposing an electric field in the first region to retard ion pumping through cells in the biological material of the first region. Furthermore, the changes initialed can be caused by changing a rate of transport of reagents through cell membranes cells in the biological material of the first region, for example by changing a probability of tunneling of the reagents through cell membranes. The induced change in rate of transport can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1159] In one example, the probability of tunneling is changed by applying an electric field to promote or retard transmission of the reagents through the cell membranes in the biological material of the first region. In another example, the probability of tunneling is changed by applying a photon flux to the reagents to increase an energy of the reagents. In another example, the probability of tunneling is changed by applying a drug which thickens the cell membranes. In another example, the probability of tunneling is changed by applying a drug which dilates or constricts pores in the cell membranes. In a specialized example, the drugs affecting the cell membranes can be isolated only to the first region so that toxicity of the drug does not affect the subject.

[1160] Furthermore, at **2603**, initiating a change can change a rate of enzymatic reactions occurring in the biological material or can change a rate of catalysis reactions occurring in the biological material. At **2603**, initiating a change can change a rate of photosynthesis occurring in the biological material. At **2603**, initiating a change can change the genomics of the biological material in the first region. This change in genomics in the first region can induce a therapeutic change in the second region. The induced therapeutic change can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1161] Furthermore, at **2605**, inducing a biological change in a second region inside the subject occurs by coupling to the second region via interactions of DNA molecules along a pathway from the first region to the second region. In this embodiment, the pathway may comprise as part or all the pathway signaling DNA. In one embodiment, coupling is provided by transporting charge along the signaling DNA. In one embodiment, inducing a biological change occurs by removing a protein that normally binds to signaling DNA in the biological material of the first region. The induced biological change can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1162] In these steps and actions above, biophotonic or mitogenic radiation from the first regions is transmitted (or otherwise coupled) to the second regions to thereby induce the change in the second region. When this coupling is via ultraviolet or visible light, the photon flux in a specialized case is that of a single photon emission and transmission, and possibly emitted and transmitted coherently with other sources of the biophoton radiation.

[1163] Optionally, in the steps and actions above, biophoton emission is stimulated by artificial sources such that living tissues in the first region produce biophoton radiation.

[1164] Optionally, in the steps and actions above, artificial or simulated biophoton emission is produced and coupled to the second or treatment region.

[1165] In these steps and actions above, a change in the viability of the cells in the first region produces a similar change in the second region of the subject. The induced changes in the first and/or second regions can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1166] Furthermore, at **2601**, the biological material of the first region is surgically defined (isolated, separated, partially removed) from a diseased organ in the subject, a treatment is applied to the first region that had been surgically defined to promote cell death (or alternatively cell growth), thereby inducing cell death (or cell growth) as the biological change in the second region (or treatment region) of the subject. With this approach, the surgically defined first region can be selectively treated to induce cell death for example by chemically inducing cell death in the surgically defined first region or by chemically inducing cell death in the surgically defined first region by radiation. One example of such radiation can include ultraviolet light. Other examples include x-rays, gamma rays, protons, or other high energy sources. The induced cell death change can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1167] FIG. **77** is a flowchart of another method of the invention for treating a subject. At **2701**, this method provides a source of biophoton or mitogenic radiation. At **2703**, this method couples the source of the biophoton radiation to a treatment site inside the patient. At **2705**, the coupling induces a biological, chemical, physical, or therapeutic change in the subject at the treatment site. The induced biological, chemical, physical, or therapeutic change can be assisted by the in situ or ex situ presence of energy augmentators including resonators such as the folded resonators and rectifying resonators described herein.

[1168] These steps or actions in FIG. **77** may occur with any of the other steps and actions set forth above with regard to FIG. **76**.

Strategies for Photonic Coupling to Diseased Tissue Via Cellular Communication:

[1169] One can identify a photonic energy $h\nu_{mp+}$ that promotes the activity of the metabolic pump (referred to as mp+ energy). Conversely, it is possible to find photonic energy that diminishes the function of the metabolic pump called $h\nu_{mp-}$ (referred to mp− energy). This makes it possible to target tumor cells and irradiate them with the appropriate "mp− energy" to limit their function and energy production. This approach is the deconstructive approach with the strategy of impeding the undesirable behavior (uncontrolled growth). This deconstructive approach has significant limitations in that insofar as apoptosis is not triggered in the tumor environment, even a small percentage of cancerous or mutated cells that are left behind can result in the formation of metastasis and relaunch of the disease. In fact, this is the problem of all of the state-of-the-art therapies. The eradication of disease is never complete and cancerous cells find a way to invade adjacent tissue and to recolonize mutated cells in different organs. The metastasis problem is one of the biggest issues facing all therapies.

[1170] Another strategy is referred to as the photonically constructive approach and comprises stimulating the biological circuitry to generate healthy bio-photonic signatures that in-turn communicate with the tumor micro environment (TME) to stay on a healthy course rather than to engage in undesirable mutations leading to cancer propagation. The ability to collect the bio-photonic signature from the healthy tissue and to compare it with a cancerous tissue would thus provide a feedback loop necessary to activate the biological circuitry to promote the right photonic signature. The biological circuitry can be stimulated by having an increase in the metabolic pump function.

[1171] By distinguishing diseased tissue from heathy tissue in any organ of the body, a regimen of photonic stimulus can be implemented periodically until the diseased cells go back to normal behavior and subsequently become regulated by the immune system. This constructive approach should be done first to limit the evasion of mutated cells from the surveillance of the immune system. Once the cells no longer have countermeasures to evade the immune system, then the disease is corrected quickly and efficiently by the existing (and complex) chain of events enabled by the immune system.

[1172] Since the biological circuitry can be stimulated by having an increase in the metabolic pump function, this makes it possible to stimulate the proteins gating the doorways to ion channels and to cause an increase in the uptake of ions ever so slightly to build up more voltage (hence more energy storage) which results in the decay and dissipation of said stored energy via photonic energy.

[1173] The photonic energy at the cellular level coupled with the ability to measure ultraweak photons is one preferred embodiment of the present invention. It is also recognized that photonic signatures can carry information of types not described herein. However, the ability to interact at the cellular level using photons opens a myriad of medical possibilities and novel therapies based on cellular light communication.

[1174] Specific Tools for Inducing Biological Changes

[1175] Hybrid Light Collector

[1176] The augmentation of light or the concentration of the energy carried by a photon is of interest, especially in the field of cell to cell communication. FIGS. **78**A, **78**B, **79**A, **79**B, **80**A, and **80**B depict cross sections and longitudinal views of a hybrid device including an augmentation antenna **1** and a metallized optical coupling pad **2** connected to a tapered metallic core optical fiber **3**. Accordingly, there is provided in one embodiment of the invention, a biophoton collector and conduit for collecting or delivering biophotons from or into a biological medium. This collector and conduit utilizes a) one or more augmentation antennas configured to collect or provide an electric field in proximity to a region of the biological medium, b) an optical coupling pad coupled

to at least one of the augmentation antennas in the region of the biological medium; c) the optical coupling pad comprising a dielectric cladded metal core extending from the region of the biological medium to a tapered end, and d) an optical fiber coupled to the tapered end.

[1177] As depicted, this hybrid biophoton collector and conduit device makes use of a ¾ wavelength antenna configuration in juxtaposition to a folded (augmentation) antenna **1**. While the folded augmentation antenna has and can follow the configurations described elsewhere in this specification for the % wave folded resonators, here as part of the "collection" function, the folded augmentation antenna is not powered by an outside source but rather is a passive antenna device picking up signals from the biological medium. Signals from the biological medium that are at the same frequency or close to the same frequency as the resonant frequency will be better coupled to the optical coupling pad.

[1178] As illustrated in FIG. **79**B, the tip of optical coupling pad **2** (i.e., the tip of the ¾ wavelength antenna) is embedded inside the parallel folded portion of the augmentation antenna **1**. The ¾ wavelength antenna is coupled to a tapered metallic core optical fiber **3**, which, as illustrated in FIG. **80**A, turns out of the plane of the folded antenna **1**, although such a turn is not necessary. (The tapered section not shown in FIG. **80**A exists at a position out of the plane of augmentation antenna **1**.) The metallic core is surrounded by one or more dielectrics, preferably concentric dielectrics. The outer dielectric **7** has the lowest dielectric constant, the thin metallic core **5** has an infinite dielectric constant, and the middle dielectric **6** has an interim value (higher than the low dielectric constant material).

[1179] While not drawn on FIGS. **78**A, **78**B, **79**A, **79**B, **80**A, and **80**B, between the folded electrodes of antenna **1** exist an electric field extending from one electrode to the opposing electrode. This electric field includes a field line directly extending from one electrode to the opposing electrode and fringing (diverging and converging) field lines extending form one electrode to the opposing electrode. Viewed differently, there are electric field lines which emanate from the electrodes of the folded resonator and which extend into a vicinity of the medium around the electrodes.

[1180] This hybrid biophoton collector and conduit device can be used to transport biophotons from a source into the biological medium in vicinity of the resonator, or to transport biophotons from and away from biological medium nearby antenna **1**. Since folded antenna **1** is a resonant structure with the highest electrical field between the opposing electrodes, this intensified electric field can assist in the generation of biophotons from the biological medium in vicinity of folded antenna **1**, and its intensified electric field can assist in the interaction of biophotons delivered to the biological medium.

[1181] FIGS. **81**A, **81**B, and **81**C depict different views of the tapered metallic optical fiber included with the hybrid device. Specifically, FIG. **81**B is a sectional view along B-B in FIG. **81**A. It shows the metal core surrounded by a high-K dielectric SiO_2 material, surrounded by a low-K SiO_2 material. FIG. **81**C is a sectional view along C-C in FIG. **81**A. It shows the tapered nature of the metal core **5**. Referring first to FIG. **80**A, since the tip of optical coupling pad **2** is embedded inside the parallel folded portion of the augmentation antenna **1**, biophotons emitted from the biological material which enter the dielectric will be internally reflected by the low-K, high-K, metallic core structure and transmitted out of the region near augmentation antenna **1**. The biophotons would be guided along the optical fiber toward the tapered metal end. Referring to FIG. **81**C, the photons would then exit the tapered metal end and be carried in the high-K material optical fiber away from the tapered metal end to a destination. Conversely, biophotons from an external source can be transmitted in the high-K material optical fiber away toward the tapered metal end, and thereon to the region proximate the antenna **1** for delivery into a biological material.

[1182] FIG. **82** is a depiction of an array of inward folding antennas **1** coupled to one common tapered metallic core optical fiber. FIG. **82** illustrates this coupling by four ¾ wavelength antennas **2** coupled to a common optical fiber with a tapered metallic core **3**. Each of the ¾ wavelength antennas is equipped with an augmentation antenna **1** at the tip of the wavelength antenna. Each augmentation antenna **1** has inward folding parallel ends.

[1183] FIG. **83** is a depiction of an array of four outward folding antennas coupled to one common tapered metallic core optical fiber. FIG. **82** illustrates this coupling by four ¾ wavelength antennas **2** coupled to a common optical fiber with a tapered metallic core **3**. Each of the ¾ wavelength antennas is equipped with an augmentation antenna **1** at the tip of the wavelength antenna. Each augmentation antenna **1** has outward folding parallel ends.

[1184] FIG. **84** is a depiction of an array of eight outward folding antennas coupled to one common tapered metallic core optical fiber. FIG. **84** illustrates this coupling by eight ¾ wavelength antennas **2** coupled to a common optical fiber with a tapered metallic core **3**. Each of the ¾ wavelength antennas is equipped with an augmentation antenna **1** at the tip of the wavelength antenna.

[1185] FIG. **85** is a depiction of hexagonal close packing using sets of the eight outward folding antennas coupled to one common tapered metallic core optical fiber. Each of the ¾ wavelength antennas is equipped with an augmentation antenna at its tip. Each augmentation antenna has outward folding parallel ends. Multiple of these antenna configurations can form an array of antennas for light capture.

[1186] Rectifying Resonator Structures

[1187] FIG. **86** is a depiction of a rectifying folded resonator array according to one embodiment. When the resonators of this invention are coupled to a diode, the alternating wave received by the resonator legs can inject charge through the diode onto a voltage grid isolated from an opposing ground grid. In the embodiment shown in FIG. **86**, the voltage grid and ground grid partially overlap each other.

[1188] Through the diode action, charge will build on the voltage grid, thereby converting the AC waveform into a DC-type field existing between the voltage grid and the ground grid. This permits a resonator structure such as the folded resonators discussed herein to convert IR or microwave energy (or other AC radiation transmittable through a patient) into a DC-type electric field. In one embodiment, a biological target is disposed between the voltage grid and the ground grid, or conversely the voltage grid and the ground grid are disposed around the biological target. Charge carriers in biological material such as positive ions, negative ions, electrons will respond to the DC-type electric field by moving in their respective electric field directions.

[1189] FIG. **87** is a depiction of another rectifying folded resonator according to one embodiment of the invention. In

the embodiment shown in FIG. **87**, the voltage grid and ground grid overlap each other. Regardless of overlap, as discussed above, there are a number of charge carriers in the body and a number of conduits for conduction of ions or electrical signals. In one embodiment of the present invention, these charge carriers or signals could be influenced by exposure to this DC-type electric field.

[1190] In another embodiment, the intensified field from the folded resonator (regardless of rectification) can "pump energy" into a bioelectron, driving its excitation or its capture in an upper energy state of a cell constituent including the aqueous contents thereof, with resultant biophoton emission once the upper energy state of the cell constituent relaxes. The emitted photon (i.e., a biophoton) could then in turn drive photoexcited reactions in the cell.

[1191] Normally, there would be no expected way to drive the electron into an excited state except through perhaps exothermic reactions inside the body. Thus, this process of electron capture/biophoton emission/photoexcitation would be limited by whatever natural process would couple energy into the bioelectrons.

[1192] Yet, here in various embodiments, the folded resonator may act as an energy pump whereby its electric fields couple energy to the bioelectrons and pump this process (or other processes) resulting in biophoton emission.

[1193] In a further embodiment, the present invention relates to a method of treating a subject comprising:

[1194] providing a first region of biological material coupled to the subject;

[1195] initiating a change in a cellular environment of the cells in the first region; and

[1196] due to a change in biological or chemical activity of the cells in the first region, inducing a biological change in a second region inside the subject with assistance of an intensified electric field from a resonant structure in proximity to the first region or the second region.

[1197] The resonant structure may be a fractal antenna. The resonant structure may a folded resonator such the ¾ wavelength resonators described herein. The resonant structure may be a rectifying resonant structure generating an electric field having a net DC field component greater than zero (referred herein as a DC-type field). Regardless of the exact resonant structure selected, the resonance causes an electric field to exist at resonance which would be greater in field strength than when the resonant structure was operated off resonance, thus an intensified electric field. The intensified field can assist in biophoton production, assist in the interaction of biophotons with a biological medium, and affect a variety of biological mechanisms such ion current through the cell membrane wall and intra and extra cellular electrical signaling. These effects may be assisted by the presence of an applied magnetic field linking two regions together via quantum coherence such that a change in a property of one may be coupled to the other region.

[1198] Implementation Structures

[1199] In one embodiment of the invention, a method of treating a subject induces biological change in cells of a target region with the assistance of an electric field from a resonant structure in proximity to target region. Since the resonant structure has dimensions commensurate with the resonant frequency which can range over many orders of magnitude depending on excitation source being chosen, implementing the resonant structures is not limited to the few implementations described below. However, the implementations illustrated below serve as general guidance on how to construct and implement the resonators of the present invention in medical applications.

[1200] For ¾ wavelength folded resonators or other resonators designed for resonance in the microwave and infrared frequencies, the wavelengths of resonance vary from 30 cm (at microwave) to 700 nm (at infrared). For the longer wavelength resonators, the resonators may be disposed ex situ for example on sheet products "wrapped around" a limb or torso of the body. Because of fringing fields, folded ¾ wavelength resonators disposed around the limb or torso produce electric fields inside the body and can thereby enhance a chemical, biological, or physical effect inside the body in a target area between the resonators. In some embodiments, an external electrode type ¾ wavelength folded resonator design may be used where at least one of the external electrodes is disposed (for example by catheter or surgical insertion into the body) to be positioned nearby a target site to be treated. The remaining opposing electrode and the "loop" connection back to the inserted electrode could be ex situ. The ex situ components would be particularly adept at collecting microwave or infrared radiation from an external source irradiating the ex situ components,

[1201] For shorter wavelengths, the resonators may be disposed entirely within the human body. In this case, IR frequencies may be used to couple energy into the resonators creating an intensified electric field more local to a site to be treated than for the longer wavelength resonators. The IR frequencies could penetrate into the body, and then be collected and intensified (through resonance) at the site to be treated. Here, flexible sheets of the resonators could be surgically implanted around a diseased site such as a tumor. On the other hand, the folded resonators need not exist on flexible sheets, but could also exist on more rigid substrates that hold one or more the folder resonators in place. A surgeon could implant the rigid substrates next to a diseased or target site for treatment thereof. Regardless of the mechanism of disposing the folder resonator in place, once positioned, the resonator would be activated by an infrared source of energy which would create an electric field nearby the diseased or target site.

[1202] With still shorter wavelengths, entering into the visible light wavelength range of 400 to 600 nm, folded resonators could be fabricated lithographically as nanostructures on substrates or even on the surfaces of "particles" such as phosphors or non-light emitting particles. These small substrates or the particles could then be injected by syringe into a diseased organ where they would reside and could be activated.

[1203] In one embodiment, the resonators could be fabricated lithographically and then released from the substrate to become free-standing resonators. In this process, for example, a release layer formed of a dissolvable resin would be coated across the surface of an original substrate such as a glass plate or a silicon substrate, A gold or silver layer would then be formed on the resin with the thickness of the gold or silver being sufficient to form an electrical conductor of low loss. For cost saving measures, a support material such as silicon or silicon nitride or silicon oxide as an option could be deposited on the gold or sliver layer. A photoresist layer would be formed on the support material if it existed. This structure would be subject to lithography to define an image of the folded resonators on the photoresist. This image would be developed to form a photoresist pattern, and

afterwards chemical etching or reactive ion etching through the holes in the photoresist pattern would dissolve the support material leaving the resonator pattern, exposing the gold or silver layer underneath the support material. Once again or if the optional support material had not been used, chemical etching or reactive ion etching would dissolve the gold or silver material, leaving behind resonators in the gold or silver material (also including the optional support material) existing on the release layer. Dissolution of the release layer then would release the folded resonators from the original substrate producing free standing resonators.

[1204] Other techniques using positive or negative resist and/or using e-beam, extended UV, or soft x-rays to produce well defines metallic patterns could used.

[1205] In one embodiment of the invention, a biodegradable path could serve as the "substrate" for formation of the resonators thereon. U.S. Pat. No. 9,072,681 (the entire contents of which are incorporated herein by reference) describes a free-standing biodegradable patch suitable for medical applications, especially intravascular, minimally-invasive and intraoperative surgical applications, wherein the patch comprises a free-standing film having a mixture of a solid fibrinogen component and a solid thrombin component that, when exposed to an aqueous environment, undergoes polymerization to form fibrin. In alternative embodiments the patch may comprise a solid fibrinogen component, with or without an inorganic calcium salt component. The patch may take a non-adherent form during delivery to a target location within a vessel or tissue, and thereafter may be activated to adhere to vessel wall or tissue, and may include a number of additives, including materials to improve the mechanical properties of the patch, or one or more therapeutic or contrast agents. In the present invention, such biodegradable patches would have the resonators of the present invention formed thereon providing a carrier of the resonators for placement at a diseased organ or other target site in the body of a patient.

[1206] U.S. Pat. Appl. No. 20160201233 (the entire contents of which are incorporated herein by reference) describes a gauze fabric including a surface layer composed of twisted yarns, a back layer composed of twisted yarns, and a middle layer composed of twisted yarns. The middle layer is provided between the surface layer and the back layer. The surface layer and the back layer are directly and/or indirectly joined with each other. The twisted yarns in the surface layer are twisted yarns having twisting coefficient of 3.3 or less. The twisted yarns in the back layer are twisted yarns having twisting coefficient of 3.3 or less. The twisted yarns in the middle layer are twisted yarns having twisting coefficient of 3.5 or more. In the present invention, such gauze fabrics would have the resonators of the present invention formed thereon providing a carrier of the resonators for placement at a diseased organ or other target site in the body of a patient.

[1207] U.S. Pat. No. 9,872,758 (the entire contents of which are incorporated herein by reference) describes a stent for transluminal implantation comprises a first, second and third stent section for splinting and/or keeping open a hollow organ which are connected to each other via elastic tubular sections. The stent combines at least three different stent designs in one stent and can therefore be adjusted to the motion behavior of a hollow organ in an improved fashion. In the present invention, such stents would have the resonators of the present invention formed thereon providing a carrier of the resonators for placement at a diseased organ or other target site in the body of a patient. These stents in the present invention would not necessarily be used for splinting and/or keeping open a hollow organ.

[1208] U.S. Pat. No. 9,694,107 (the entire contents of which are incorporated herein by reference) describes a synthetic tissue or complex which can be produced by culture and has a high level of differentiation ability, and describes an implantable synthetic tissue which cn form a three-dimensionally structured synthetic tissue. In the present invention, such implantable synthetic tissues would have the resonators of the present invention formed thereon providing a carrier of the resonators for placement at a diseased organ or other target site in the body of a patient.

[1209] U.S. Pat. No. 6,139,867 (the entire contents of which are incorporated herein by reference) describes a medical adhesive sheet comprising a support having a laminate structure comprising a non-porous sheet and a porous-sheet, and a pressure-sensitive layer comprising an acrylic polymer prepared by polymerizing an alkyl (meth) acrylate as a main component monomer, and an organic liquid component which is compatible with the acrylic polymer, formed on the porous sheet side of the support, the layer being subjected to a crosslinking treatment, wherein the pressure-sensitive adhesive layer is embedded in the porous sheet, reaching the laminate interface between the non-porous sheet and the porous sheet. In the present invention, such medical adhesive sheets would have the resonators of the present invention formed thereon providing a carrier of the resonators for placement at a diseased organ or other target site in the body of a patient and especially for placement on the skin of a patient.

[1210] U.S. Pat. No. 7,326,659 (the entire contents of which are incorporated herein by reference) describes a biodegradable extruded netting having a plurality of interconnected strands with at least some of the strands comprising a biodegradable composition comprising polylactic acid polymer and biodegradable plasticizer. At least 10% of the strands are preferably made of the biodegradable composition. In the present invention, such biodegradable netting would have the resonators of the present invention formed thereon providing a carrier of the resonators for placement at a diseased organ or other target site in the body of a patient.

[1211] U.S. Pat. Appl. No. 20040054393 (the entire contents of which are incorporated herein by reference) describes a medical electrode for obtaining biopotentials from the skin of a subject or electrically stimulating the subject's skin and deeper tissue layers. The electrode has a carrier base member from which project a plurality of spikes arranged in an array on one surface of the base member. In the present invention, such medical electrodes would have the resonators of the present invention formed especially on the base providing a carrier of the resonators for placement at a diseased organ or other target site in the body of a patient and especially for placement on the subject's skin and deeper tissue layers.

[1212] Accordingly, the energy augmentation structures of the present invention can be used in conjunction with the energy converters described herein in a wide variety of applications, including but not limited to, medical treatments using energy generated in situ within a subject being treated (whether using an energy converter or not), solar cells, adhesives and other resins, sterilization treatment for various

materials (such as wastewater, beverages, etc). The use of energy converters in such applications has been described in the following: US Published Application No. 2008/0248001; US Published Application No. 2009/0104212; US Published Application No. 2009/0294692; US Published Application No. 2010/0003316; US Published Application No. 2010/0016783; US Published Application No. 2010/0261263; US Published Application No. 2010/0266621; US Published Application No. 2011/0021970; US Published Application No. 2011/0117202; US Published Application No. 2011/0126889; US Published Application No. 2011/0129537; US Published Application No. 2011/0263920; US Published Application No. 2012/0064134; US Published Application No. 2012/0089180; US Published Application No. 2013/0102054; US Published Application No. 2013/0129757; US Published Application No. 2013/0131429; US Published Application No. 2013/0156905; US Published Application No. 2013/0171060; US Published Application No. 2013/0240758; US Published Application No. 2014/0134307; US Published Application No. 2014/0163303; US Published Application No. 2014/0166202; US Published Application No. 2014/0222117; US Published Application No. 2014/0242035; US Published Application No. 2014/0243934; US Published Application No. 2014/0272030; US Published Application No. 2014/0323946; US Published Application No. 2014/0341845; US Published Application No. 2014/0343479; US Published Application No. 2015/0182934; US Published Application No. 2015/0202294; US Published Application No. 2015/0246521; US Published Application No. 2015/0251016; US Published Application No. 2015/0265706; US Published Application No. 2015/0283392; US Published Application No. 2015/0290614; US Published Application No. 2016/0005503; US Published Application No. 2016/0067524; US Published Application No. 2016/0159065; US Published Application No. 2016/0243235; US Published Application No. 2016/0263393; US Published Application No. 2016/0325111; US Published Application No. 2016/0331731; US Published Application No. 2016/0354467; US Published Application No. 2016/0362534; US Published Application No. 2017/0027197; US Published Application No. 2017/0043178; US Published Application No. 2017/0050046; US Published Application No. 2017/0096585; US Published Application No. 2017/0113061; US Published Application No. 2017/0121472; US Published Application No. 2017/0154866; US Published Application No. 2017/0157418; US Published Application No. 2017/0162537; US Published Application No. 2017/0173350; US Published Application No. 2017/0186720; US Published Application No. 2017/0190166; US Published Application No. 2017/0196977; US Published Application No. 2017/0239489; US Published Application No. 2017/0239637; US Published Application No. 2017/0240717; US Published Application No. 2017/0258908; US Published Application No. 2017/0319868; US Published Application No. 2017/0319869; US Published Application No. 2018/0036408; US Published Application No. 2018/0154171; US Published Application No. 2018/0154178; US Published Application No. 2018/0169433; US Published Application No. 2018/0170028; US Published Application No. 2018/0269174; US Published Application No. 2018/0271121; US Published Application No. 2018/0304225; US Published Application No. 2018/0311355; US Published Application No. 2018/0317307; US Published Application No. 2018/0344850; US Published Application No. 2018/0358327; US Published Application No. 2019/0016869; US Published Application No. 2019/0022221; US Published Application No. 2019/0100680; US Published Application No. 2019/0134419; US Published Application No. 2019/0134595; US Published Application No. 2019/0134596; US Published Application No. 2019/0157234; US Published Application No. 2019/0168015; US Published Application No. 2019/0184190; US Published Application No. 2019/308030; US Published Application No. 2019/0336605; US Published Application No. 2019/0336785; US Published Application No. 2019/0336786; US Published Application No. 2019/0341364; U.S. application Ser. No. 16/074,707, filed Aug. 1, 2018; U.S. application Ser. No. 16/516,463, filed Jul. 19, 2019; U.S. application Ser. No. 16/554,831, filed Aug. 29, 2019 U.S. application Ser. No. 16/599,732, filed Oct. 11, 2019; U.S. application Ser. No. 16/674,435, filed Nov. 5, 2019; and U.S. application Ser. No. 16/728,803, filed Dec. 27, 2019; the contents of each of which are hereby incorporated by reference in their entireties. The energy augmentation structures and/or energy converters described herein have uses with the subject matter in the above noted published and unpublished US patent applications.

[1213] The following are exemplary embodiments of the present invention:

[1214] Embodiment 1. An energy emitter comprising:

[1215] at least one energy augmentation structure; and

[1216] an energy converter capable of receiving energy from an energy source, converting the energy and emitting therefrom an emitted light of a higher or lower energy than the received energy, and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted light is emitted with an intensity larger than if the energy converter were remote from the at least one energy augmentation structure, or if the energy augmentation structure were not present.

[1217] Embodiment 2. The emitter of Embodiment 1, wherein the at least one energy augmentation structure comprises a structure in which a locally intensified electric field exists in one part of the structure when the structure receives electromagnetic energy.

[1218] Embodiment 3. The emitter of Embodiment 1 or 2, wherein the at least one energy augmentation structure comprises at least one resonator dimensioned to be resonant with the applied electromagnetic energy.

[1219] Embodiment 4. The emitter of any one of Embodiments 1-3, wherein the resonator comprises a folded resonator.

[1220] Embodiment 5. The emitter of Embodiment 4, wherein the folded resonator comprises electrical conductors configured as a fractal pattern.

[1221] Embodiment 6. The emitter of Embodiment 4, wherein the folded resonator comprises a ¾ wavelength resonator having opposing ends folded inwards from a center of the folded resonator with a gap in between the opposing ends.

[1222] Embodiment 7. The emitter of Embodiment 6, wherein the locally intensified electric field exists in a vicinity of the opposing ends.

[1223] Embodiment 8. The emitter of Embodiment 4, wherein the folded resonator comprises a ¾ wavelength resonator having opposing ends folded outwards from a center of the folded resonator with a gap in between the opposing ends.

[1224] Embodiment 9. The emitter of Embodiment 8, wherein the locally intensified electric field exists in a vicinity of the opposing ends.

[1225] Embodiment 10. The emitter of Embodiment 4, wherein the resonator comprises a fractal pattern.

[1226] Embodiment 11. The emitter of Embodiment 10, wherein the fractal pattern comprises a three-dimensional fractal pattern.

[1227] Embodiment 12. The emitter of Embodiment 4, wherein the at least one resonator comprises a plurality of resonators.

[1228] Embodiment 13. The emitter of Embodiment 12, wherein the resonators are disposed on a sheet.

[1229] Embodiment 14. The emitter of Embodiment 13, wherein the sheet comprises a sheet for disposal within a medium to be treated.

[1230] Embodiment 15. The emitter of Embodiment 13, wherein the sheet comprises a flexible sheet for disposal within a medium to be treated.

[1231] Embodiment 16. The emitter of Embodiment 13, wherein the sheet comprises a rigid sheet for disposal within a medium to be treated.

[1232] Embodiment 17. The emitter of Embodiment 13, wherein the plurality of resonators comprises an array of the resonators disposed on a sheet.

[1233] Embodiment 18. The emitter of Embodiment 12, wherein each of the resonators comprises a free-standing resonator.

[1234] Embodiment 19. The emitter of Embodiment 18, wherein the free-standing resonator is disposed within a medium to be treated.

[1235] Embodiment 20. The emitter of any one of Embodiments 1 to 19, wherein the at least one energy augmentation structure comprises a first level of metallic patterns and a second level of metallic patterns offset in in at least one of a lateral or axial direction from the first level of metallic patterns.

[1236] Embodiment 21. The emitter of Embodiment 20, wherein at least one of the metallic patterns comprises a first resonator dimensioned to be resonant with an applied electromagnetic energy.

[1237] Embodiment 22. The emitter of Embodiment 21, wherein

[1238] the at least one of the metallic patterns comprises a folded resonator having opposing electrodes with electric fields directed in between, and

[1239] the energy converter is positioned between the opposing electrodes or within fringing electric field of the opposing electrodes.

[1240] Embodiment 23. The emitter of Embodiment 22, wherein the opposing electrodes are directed external to the folded resonator and parallel to one another.

[1241] Embodiment 24. The emitter of Embodiment 22, wherein the opposing electrodes are directed internal to the folded resonator and parallel to one another.

[1242] Embodiment 25. The emitter of any one of Embodiments 22-24, wherein the folded resonator comprises a ¾ ƛ folded resonator.

[1243] Embodiment 26. The emitter of Embodiment 20, wherein the at least one of the metallic patterns comprises a plurality of the folded resonators concentrically arranged and optionally co-planar to one another, such that the external opposing electrodes of each folded resonator do not overlap spatially with the external opposing electrodes of the other of the plurality of folded resonators.

[1244] Embodiment 27. The emitter of Embodiment 20, wherein the at least one of the metallic patterns comprises a plurality of the folded resonators concentrically arranged and optionally co-planar to one another, such that the external opposing electrodes of each folded resonator overlap spatially with the external opposing electrodes of one or more of the other of the plurality of folded resonators.

[1245] Embodiment 28. The emitter of any one of Embodiments 1 to 27, wherein the at least one energy augmentation structure comprises at least one of Au, Ag, Cu, Al, transparent metal oxides or refractory metals.

[1246] Embodiment 29. The emitter of any one of Embodiments 1 to 28, further comprising an antireflection film disposed on the at least one energy augmentation structure or the energy converter.

[1247] Embodiment 30. The emitter of any one of Embodiments 1 to 29, wherein the at least one energy augmentation structure is disposed in vicinity of a down conversion material comprising the energy converter.

[1248] Embodiment 31. The emitter of any one of Embodiments 1 to 29, wherein the at least one energy augmentation structure is disposed in vicinity of an up-conversion material comprising the energy converter.

[1249] Embodiment 32. The emitter of any one of Embodiments 1 to 29, wherein the at least one energy augmentation structure is disposed in vicinity of a phosphor comprising the energy converter.

[1250] Embodiment 33. The emitter of any one of Embodiments 1 to 29, wherein the at least one energy augmentation structure is disposed in vicinity of a piezoelectric device comprising the energy converter.

[1251] Embodiment 34. The emitter of Embodiment 33, wherein the piezoelectric device is configured to receive sonic or acoustic energy and emit at least one of ultraviolet or visible light in response to absorbing the sonic or acoustic energy.

[1252] Embodiment 35. The emitter of any one of Embodiments 1 to 29, wherein the at least one energy augmentation structure is disposed in vicinity of a mechanoluminescent device comprising the energy converter.

[1253] Embodiment 36. The emitter of Embodiment 35, wherein the mechanoluminescent device is configured to receive sonic or acoustic energy and emit at least one of ultraviolet or visible light in response to absorbing the sonic or acoustic energy.

[1254] Embodiment 37. The emitter of any one of Embodiments 1 to 36, wherein the at least one energy augmentation structure is disposed inside a plasma capsule device comprising the energy converter.

[1255] Embodiment 38. The emitter of Embodiment 37, wherein the plasma capsule device is configured to receive radio frequency or microwave energy and emit at least one of ultraviolet or visible light in response to absorbing the radio frequency or microwave energy.

[1256] Embodiment 39. The emitter of any one of Embodiments 1 to 29, wherein the at least one energy augmentation structure is disposed in vicinity of an x-ray stimulated phosphor comprising the energy converter.

[1257] Embodiment 40. The emitter of Embodiment 39, wherein the x-ray stimulated phosphor emits one of ultraviolet or visible light in response to absorbing x-rays.

[1258] Embodiment 41. The emitter of Embodiment 40, wherein the x-ray stimulated phosphor emits the one of ultraviolet or visible light for at least a time of 1 minute after x-ray stimulation.

[1259] Embodiment 42. The emitter of Embodiment 40, wherein the x-ray stimulated phosphor emits the one of ultraviolet or visible light for at least a time of 10 minutes after x-ray stimulation.

[1260] Embodiment 43. The emitter of Embodiment 40, wherein the x-ray stimulated phosphor emits the one of ultraviolet or visible light for at least a time of 60 minutes after x-ray stimulation.

[1261] Embodiment 44. The emitter of Embodiment 39, wherein the x-ray stimulated phosphor emits lower energy x-rays in response to absorbing higher energy x-rays.

[1262] Embodiment 45. The emitter of any one of Embodiments 1 to 44, wherein the energy received from the energy source is one or more selected from acoustic waves, sound waves, radio waves, microwaves, far infrared, near infrared, visible light, UV, x-rays, gamma rays, electron beams, and proton beams.

[1263] Embodiment 46. The emitter of any one of Embodiments 1 to 45, wherein the energy converter being disposed in a vicinity of the at least one energy augmentation structure comprises a conductive coupling of the energy converter to the at least one energy augmentation structure.

[1264] Embodiment 47. The emitter of Embodiment 46, wherein the conductive coupling comprises a physical conductive connection between the energy converter and the at least one energy augmentation structure.

[1265] Embodiment 48. The emitter of any one of Embodiments 1 to 29, wherein the energy converter comprises either one or both of (i) a down converter converting ultraviolet or blue light into red, yellow, or green light, or (ii) an up converter converting infrared or red light into yellow, green light, or blue light.

[1266] Embodiment 49. The emitter of any one of Embodiments 1 to 29, wherein the at least one energy augmentation structure comprises a plurality of energy collectors.

[1267] Embodiment 50. The emitter of Embodiment 49, wherein the energy converters are positioned to convert energy being internally scattered within the energy collectors.

[1268] Embodiment 51. The emitter of Embodiment 49, wherein the energy collectors comprise a metal core cladded with a high-K dielectric and a subsequent cladding of a low-K dielectric.

[1269] Embodiment 52. The emitter of Embodiment 49, wherein the energy collectors comprise a radial pattern of collectors.

[1270] Embodiment 53. The emitter of Embodiment 7, wherein the energy collectors comprise a fractal pattern.

[1271] Embodiment 54. The emitter of Embodiment 53, wherein the fractal pattern is embedded within a dielectric material.

[1272] Embodiment 55. The emitter of any one of Embodiments 1 to 54, wherein the at least one energy augmentator comprises metallic conductors including at least one of Au, Ag, Cu, Ni, Pt, Pd, Co, Ru, Rh, Al, Ga, or a combination or alloys or layers thereof.

[1273] Embodiment 56. The emitter of any one of Embodiments 1 to 54, wherein the energy converter comprises at least one of Y2O3, Y2O2S, NaYF4, NaYbF4, YAG, YAP, Nd2O3, LaF3, LaCl3, La2O3, TiO2, LuPO4, YVO4, YbF3, YF3, Na-doped YbF3, or SiO2 or alloys or layers thereof.

[1274] Embodiment 57. The emitter of Embodiment 56, wherein the energy converter further comprises a dopant including at least one of Er, Eu, Yb, Tm, Nd, Tb, Ce, Y, U, Pr, La, Gd and other rare-earth species or a combination thereof.

[1275] Embodiment 58. The emitter of Embodiment 57, wherein the dopant is included at a concentration of 0.01%-50% by mol concentration.

[1276] Embodiment 59. The emitter of any one of Embodiments 1 to 54, wherein the energy converter comprises a down converter including at least one of Y2O3; ZnS; ZnSe; MgS; CaS; Mn, Er ZnSe; Mn, Er MgS; Mn, Er CaS; Mn, Er ZnS; Mn, Yb ZnSe; Mn, Yb MgS; Mn, Yb CaS; Mn, Yb ZnS:Tb^{3+}, Er3+; ZnS:Tb3+; Y2O3:Tb3+; Y2O3:Tb^{3+}, Er3+; ZnS:Mn2+; ZnS:Mn,Er3+.

[1277] Embodiment 60. The emitter of any one of Embodiments 1 to 54, wherein the energy converter comprises an up converter including at least one of Y2O3, Y2O2S, NaYF4, NaYbF4, YAG, YAP, Nd2O3, LaF3, LaCl3, La2O3, TiO2, LuPO4, YVO4, YbF3, YF3, Na-doped YbF3, or SiO2 or alloys or layers thereof.

[1278] Embodiment 61. The emitter of any one of Embodiments 1 to 54, wherein the energy converter comprises an up converter including at least one of Tm3+ doped flourozirconate glasses, LuPO4:Yb3+, Tm3+, and YbPO4:Er3+ nanocrystals, tellurium and germanium oxides, tellurium and germanium oxides doped with at least one Tm, Yb, Ho, Er, or Pr, Yb3+ doped BaZrO3, Nd3+:Cs2NaGdCl6, Nd3+, Yb3+:Cs2NaGdCl6, Nd3+ and Ho3+ co-doped-based ZrF4 fluoride glasses, Tm3+/Yb3+-codoped TeO2-Ga2O3-R2O (R=Li, Na, K) glasses, and metal-to-ligand charge transfer (MLCT) transition materials, and MLCT transition materials including [Ru(dmb)3]2+ (dmb=4,4-dimethyl-2,2-bipyridine).

[1279] Embodiment 62. An energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property.

[1280] Embodiment 63. The energy augmentation emitter of Embodiment 62, wherein the energy augmentation structure is at least one non-plasmonic member selected from the group consisting of resonators, fractal antennas, electrical grid patterns, antennas, cavities, etalons, nanoparticles, microparticles, nanostructures, and microstructures.

[1281] Embodiment 64. The energy augmentation structure of Embodiment 62, comprising a folded resonator having opposing electrodes with electric fields directed in between.

[1282] Embodiment 65. The energy augmentation structure of Embodiment 64, wherein the opposing electrodes are directed external to the folded resonator and parallel to one another.

[1283] Embodiment 66. The energy augmentation structure of Embodiment 64, wherein the opposing electrodes are directed internal to the folded resonator and parallel to one another.

[1284] Embodiment 67. The energy augmentation structure of any one of Embodiments 64 to 66, wherein the folded resonator comprises a ¾ ƛ folded resonator.

[1285] Embodiment 68. The energy augmentation structure of Embodiment 64, wherein the folded resonator is a

plurality of the folded resonators concentrically arranged and optionally co-planar to one another, such that the external opposing electrodes of each folded resonator do not overlap spatially with the external opposing electrodes of the other of the plurality of folded resonators.

[1286] Embodiment 69. The energy augmentation structure of Embodiment 64, wherein the folded resonator is a plurality of the folded resonators concentrically arranged and optionally co-planar to one another, such that the external opposing electrodes of each folded resonator overlap spatially with the external opposing electrodes of one or more of the other of the plurality of folded resonators.

[1287] Embodiment 70. An energy collector comprising at least one energy augmentation structure; and at least one energy converter capable of receiving an applied electromagnetic energy, converting the applied electromagnetic energy and emitting therefrom an emitted electromagnetic energy shifted in wavelength or energy from the applied electromagnetic energy and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted electromagnetic energy is emitted with at least one augmented property compared to if the energy converter were remote from the at least one energy augmentation structure.

[1288] Embodiment 71. The energy collector of Embodiment 70, wherein the at least one energy converter is at least one member selected from the group consisting of phosphors, lumiphors, electroluminescent particles, up-converters, down-converters, and scintillators.

[1289] Embodiment 72. The energy collector of Embodiment 70 or 71, wherein the energy augmentation structure is at least one non-plasmonic member selected from the group consisting of resonators, fractal antennas, electrical grid patterns, antennas, cavities, etalons, nanoparticles, microparticles, nanostructures, and microstructures.

[1290] Embodiment 73. The energy collector of any one of Embodiments 70 to 72, wherein having the energy converter disposed in a vicinity of the at least one energy augmentation structure comprises conductively coupling the at least one energy converter to the at least one energy augmentation structure.

[1291] Embodiment 74. The energy collector of Embodiment 73, wherein conductively coupling comprises having the at least one energy converter be proximate the at least one energy augmentation structure, physically located within the at least one energy augmentation structure, or located within a generated electric field of the at least one energy augmentation structure.

[1292] Embodiment 75. The energy collector of Embodiment 73, wherein conductively coupling comprises a physical conductive connection between the at least one energy converter and the at least one energy augmentation structure.

[1293] Embodiment 76. The energy collector of Embodiment 70, wherein the applied electromagnetic energy is selected from radio waves, microwaves, far infrared, near infrared, visible light, UV, x-rays, gamma rays, electron beams, and proton beams.

[1294] Embodiment 77. The energy collector of Embodiment 70, wherein the at least one energy augmentation structure comprises a first resonator dimensioned to be resonant with the applied electromagnetic energy, said first resonator optionally comprising a fractal pattern.

[1295] Embodiment 78. The energy collector of Embodiment 70, wherein the energy augmentation structure comprises a folded resonator having opposing electrodes with electric fields directed in between.

[1296] Embodiment 79. The energy collector of Embodiment 76, wherein the opposing electrodes are directed external to the folded resonator and parallel to one another.

[1297] Embodiment 80. The energy collector of Embodiment 76, wherein the opposing electrodes are directed internal to the folded resonator and parallel to one another.

[1298] Embodiment 81. The energy collector of any one of Embodiments 78-80, wherein the folded resonator comprises a ¾ ƛ folded resonator.

[1299] Embodiment 82. The energy collector of Embodiment 78, wherein the folded resonator is a plurality of the folded resonators concentrically arranged and optionally co-planar to one another, such that the external opposing electrodes of each folded resonator do not overlap spatially with the external opposing electrodes of the other of the plurality of folded resonators.

[1300] Embodiment 83. The energy collector of Embodiment 78, wherein the folded resonator is a plurality of the folded resonators concentrically arranged and optionally co-planar to one another, such that the external opposing electrodes of each folded resonator overlap spatially with the external opposing electrodes of one or more of the other of the plurality of folded resonators.

[1301] Embodiment 84. A method of treating a subject comprising:

[1302] providing a first region of biological material coupled to the subject;

[1303] initiating a change in a cellular environment of the cells in the first region; and

[1304] due to a change in biological or chemical activity of the cells in the first region, inducing a biological change in a second region inside the subject with assistance of an electric field from (i) at least one energy emitter of any one of Embodiments 1-61, (ii) at least one energy augmentation structure of any one of Embodiments 62-69, or (iii) at least one energy collector of any one of Embodiments 70-83, in proximity to the first region or the second region.

[1305] Embodiment 85. The method of Embodiment 84, further comprising defining for the first region a region inside the subject proximate the second region.

[1306] Embodiment 86. The method of Embodiment 85, wherein the region inside the subject is formed of the subject's own tissue.

[1307] Embodiment 87. The method of Embodiment 85, wherein the region inside the subject is an implanted biological material inside the subject and includes therewith the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector, in proximity to the implanted biological material.

[1308] Embodiment 88. The method of Embodiment 84, further comprising defining for the first region a region inside the subject remote from the second region.

[1309] Embodiment 89. The method of Embodiment 88, wherein the region inside the subject is formed of the subject's own tissue and optionally includes the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector.

[1310] Embodiment 90. The method of Embodiment 88, wherein the region inside the subject is an implanted biological material and includes therewith the (i) at least one energy emitter, (ii) at least one energy augmentation struc-

ture, or (iii) at least one energy collector, in proximity to the implanted biological material.

[1311] Embodiment 91. The method of Embodiment 84, further comprising defining for the first region a region outside the subject coupled physically to the second region.

[1312] Embodiment 92. The method of Embodiment 84, further comprising defining for the first region a region inside the subject overlapping the second region.

[1313] Embodiment 93. The method of Embodiment 84, wherein providing comprises segregating the biological material of the first region from the second region by an artificial material including therewith the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector.

[1314] Embodiment 94. The method of Embodiment 93, wherein the artificial material comprises a permeable material capable of transmission of chemical agents produced by the biological material from the first region into the second region.

[1315] Embodiment 95. The method of Embodiment 93, wherein the artificial material comprises a material capable of transmission of biophotons therethrough.

[1316] Embodiment 96. The method of Embodiment 93, wherein the artificial material comprises a material capable of transmission of sonic waves therethrough.

[1317] Embodiment 97. The method of Embodiment 93, wherein the artificial material comprises a material capable of transmission of ultraviolet light therethrough.

[1318] Embodiment 98. The method of Embodiment 93, wherein the artificial material comprises a material capable of transmission of infrared light therethrough.

[1319] Embodiment 99. The method of Embodiment 93, wherein the artificial material comprises a material capable of transmission of electrical signals therethrough.

[1320] Embodiment 100. The method of Embodiment 84, wherein the first region and the second region are quantum entangled regions.

[1321] Embodiment 101. The method of Embodiment 84, wherein initiating a change comprises causing cell death of the biological material of the first region.

[1322] Embodiment 102. The method of Embodiment 84, wherein initiating a change comprises causing cell growth of the biological material of the first region.

[1323] Embodiment 103. The method of Embodiment 84, wherein initiating a change comprises imposing an electric field by the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector in the first region to promote ion pumping through cells in the biological material of the first region.

[1324] Embodiment 104. The method of Embodiment 84, wherein initiating a change comprises imposing an electric field by the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector in the first region to retard ion pumping through cells in the biological material of the first region.

[1325] Embodiment 105. The method of Embodiment 84, wherein initiating a change comprises the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector changing a rate of transport of reagents through cell membranes cells in the biological material of the first region.

[1326] Embodiment 106. The method of Embodiment 105, wherein changing a rate of transport the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector comprises changing a probability of tunneling of the reagents through cell membranes.

[1327] Embodiment 107. The method of Embodiment 106, wherein changing a probability of tunneling comprises applying an electric field by the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector to promote or retard transmission of the reagents through the cell membranes in the biological material of the first region.

[1328] Embodiment 108. The method of Embodiment 106, wherein changing a probability of tunneling comprises applying a photon flux to the reagents to increase an energy of the reagents.

[1329] Embodiment 109. The method of Embodiment 106, wherein changing a probability of tunneling comprises applying a drug which thickens the cell membranes.

[1330] Embodiment 110. The method of Embodiment 106, wherein changing a probability of tunneling comprises applying a drug which dilates or constricts pores in the cell membranes.

[1331] Embodiment 111. The method of Embodiment 109, wherein the drug is isolated only to the first region so that toxicity of the drug does not affect the subject.

[1332] Embodiment 112. The method of Embodiment 110, wherein the drug is isolated only to the first region so that toxicity of the drug does not affect the subject.

[1333] Embodiment 113. The method of Embodiment 84, wherein initiating a change comprises the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector changing a rate of enzymatic reactions occurring in the biological material.

[1334] Embodiment 114. The method of Embodiment 84, wherein initiating a change comprises the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector changing a rate of catalysis reactions occurring in the biological material.

[1335] Embodiment 115. The method of Embodiment 84, wherein initiating a change comprises the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector changing a rate of photosynthesis occurring in the biological material.

[1336] Embodiment 116. The method of Embodiment 84, wherein initiating a change comprises the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector changing genomics of the biological material in the first region.

[1337] Embodiment 117. The method of Embodiment 116, wherein the changing genomics in the first region induces the therapeutic change in the second region.

[1338] Embodiment 118. The method of Embodiment 84, further comprising coupling to the second region via interactions of DNA molecules along a pathway from the first region to the second region.

[1339] Embodiment 119. The method of Embodiment 118, where coupling comprises having the pathway comprise signaling DNA.

[1340] Embodiment 120. The method of Embodiment 118, where coupling comprises the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector transporting charge along the signaling DNA.

[1341] Embodiment 121. The method of Embodiment 119, where coupling comprises the (i) at least one energy

emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector transporting charge along the signaling DNA.

[1342] Embodiment 122. The method of Embodiment 84, wherein initiating a change comprises removing a protein that normally binds to signaling DNA in the biological material of the first region.

[1343] Embodiment 123. The method of Embodiment 84, wherein the change in the viability of the cells in the first region produces a similar change in the second region of the subject.

[1344] Embodiment 124. The method of Embodiment 84, wherein providing comprises:

[1345] surgically defining the first region from a diseased organ in the subject in which the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector is disposed;

[1346] applying a treatment to the first region to promote cell death; and

[1347] thereby inducing cell death as the biological change in the second region of the subject.

[1348] Embodiment 125. The method of Embodiment 124, wherein applying a treatment comprises:

[1349] selectively treating the surgically defined first region to induce cell death.

[1350] Embodiment 126. The method of Embodiment 125, wherein the selectively treating comprises chemically inducing cell death in the surgically defined first region.

[1351] Embodiment 127. The method of Embodiment 125, wherein the selectively treating comprises inducing cell death in the surgically defined first region by radiation.

[1352] Embodiment 128. The method of Embodiment 127, wherein the radiation is ultraviolet light.

[1353] Embodiment 129. The method of Embodiment 127, wherein the radiation is x-rays, gamma rays, protons, or other high energy sources.

[1354] Embodiment 130. The method of Embodiment 84, wherein the biological change in the second region comprises a change in neuron activity.

[1355] Embodiment 131. The method of Embodiment 130, wherein the change in neuron activity is stimulation and/or control of neural communication.

[1356] Embodiment 132. A biophoton collector comprising:

[1357] a living cell container for holding live cells which are capable of emitting biophotons;

[1358] an integrating sphere surrounding the living cell container for collection of the biophotons;

[1359] an exit window for transmission of the biophotons from the integrating sphere; and

[1360] (i) at least one energy emitter of any one of Embodiments 1-61, (ii) at least one energy augmentation structure of any one of Embodiments 62-69, or (iii) at least one energy collector of any one of Embodiments 70-83, configured to provide an electric field in proximity to the living cell container.

[1361] Embodiment 133. The collector of Embodiment 132, further comprising a stimulation window for providing radiation to the live cells for stimulation of biophotonic radiation of the biophotons.

[1362] Embodiment 134. The collector of Embodiment 132, further comprising a nozzle for supply of an effluent to the living cell container.

[1363] Embodiment 135. A biophoton collector comprising:

[1364] a living cell container for holding live cells which are capable of emitting biophotons;

[1365] (i) at least one energy emitter of any one of Embodiments 1-61, (ii) at least one energy augmentation structure of any one of Embodiments 62-69, or (iii) at least one energy collector of any one of Embodiments 70-83, configured to provide an electric field in proximity to a first region where the live cells exist or a second region of a biological material to be treated.

[1366] an antenna surrounding the living cell container for collection of electromagnetic radiation as the emitted biophotons.

[1367] Embodiment 136. The collector of Embodiment 135, further comprising a microprocessor for storing waveform characteristics of the electromagnetic radiation.

[1368] Embodiment 137. The collector of Embodiment 135, wherein the antenna comprises a fractal antenna.

[1369] Embodiment 138. A biophoton bypass comprising:

[1370] a hollow cavity optic for transmitting biophotons from a source of the biophotons to a treatment site while bypassing media of the subject to be treated;

[1371] an exit optic attached to an end of the hollow cavity optic, the exit optic dispersing the biophotons from the hollow cavity optic into the media of the subject to be treated; and

[1372] (i) at least one energy emitter of any one of Embodiments 1-61, (ii) at least one energy augmentation structure of any one of Embodiments 62-69, or (iii) at least one energy collector of any one of Embodiments 70-83, configured to provide an electric field in proximity to a first region where the source of the biophotons exists or a second region of a biological material to be treated.

[1373] Embodiment 139. The bypass of Embodiment 138, wherein the hollow cavity optic is filled with a gas or is under a vacuum.

[1374] Embodiment 140. The bypass of Embodiment 138, wherein the hollow cavity optic comprises reflective interior walls.

[1375] Embodiment 141. An electrically conducting biophoton bypass comprising:

[1376] a conductor for transmitting low frequency electric signals from a source of the biophotons to a treatment site while bypassing media of the subject to be treated;

[1377] a sheath covering the conductor and isolated from the conductor by a dielectric spacer;

[1378] a connector attached to the conductor for connecting the conductor to the media of the subject to be treated; and

[1379] (i) at least one energy emitter of any one of Embodiments 1-61, (ii) at least one energy augmentation structure of any one of Embodiments 62-69, or (iii) at least one energy collector of any one of Embodiments 70-83, configured to provide an electric field in proximity to a first region where the source of the biophotons exist or a second region of a biological material to be treated.

[1380] Embodiment 142. The bypass of Embodiment 141, wherein the conductor comprises multiple conductors each having respective sheaths.

[1381] Embodiment 143. The bypass of Embodiment 141, wherein the multiple conductors with the respective sheaths are twisted together to reduce high frequency noise.

[1382] Embodiment 144. An electrically conducting biophoton bypass comprising:
[1383] a conductor for transmitting high frequency electrical signals from a source of the biophotons to a treatment site while bypassing media of the subject to be treated;
[1384] a sheath covering the conductor and equidistantly spaced apart from the conductor by a dielectric spacer:
[1385] a connector attached to the conductor for connecting the conductor to the media of the subject to be treated; and
[1386] (i) at least one energy emitter of any one of Embodiments 1-61, (ii) at least one energy augmentation structure of any one of Embodiments 62-69, or (iii) at least one energy collector of any one of Embodiments 70-83, configured to provide an electric field in proximity to a first region where the live cells exist or a second region of a biological material to be treated.
[1387] Embodiment 145. A magnetic yoke biophoton bypass comprising:
[1388] a magnetic yoke for transmitting magnetic signals from a source of the biophotons to a treatment site while bypassing media of the subject to be treated;
[1389] a dual gap construction comprising a first gap for introduction of the magnetic signals into the magnetic yoke and a second gap for exposing the treatment site to the magnetic signals, wherein (i) at least one energy emitter of any one of Embodiments 1-61, (ii) at least one energy augmentation structure of any one of Embodiments 62-69, or (iii) at least one energy collector of any one of Embodiments 70-83, is in proximity to the first gap or the second gap.
[1390] Embodiment 146. An in vivo biophoton generator comprising:
[1391] one or more phosphors disposed in an organ or at treatment site;
[1392] at least one energy augmentation structure of any one of Embodiments 62-69 configured to provide an electric field in proximity to the one or more phosphors, and
[1393] a controller configured to control high energy excitation of the phosphors to produce light emission from the phosphors mimicking biophoton emission from cells in the organ or at the treatment site.
[1394] Embodiment 147. The generator of Embodiment 146, wherein the controller controls e-beam or x-ray flux to the phosphors.
[1395] Embodiment 148. A living cell biophoton generator comprising:
[1396] a living cell layer comprising live cells;
[1397] a matrix for attaching the living cell layer to an organ or treatment site;
[1398] an encapsulant layer sealing the living cell layer; and
[1399] (i) at least one energy emitter of any one of Embodiments 1-61, (ii) at least one energy augmentation structure of any one of Embodiments 62-69, or (iii) at least one energy collector of any one of Embodiments 70-83, configured to provide an electric field in proximity to a region of the live cells.
[1400] Embodiment 149. The generator of Embodiment 148, wherein the encapsulant layer is configured to provide a controlled release substance to the living cell layer.
[1401] Embodiment 150. The generator of Embodiment 148, wherein the encapsulant layer comprises phosphors or metals.
[1402] Embodiment 151. A DNA-based biophoton bypass comprising:
[1403] a signaling DNA capable of transmitting electromagnetic signals as biophotons from a source of the biophotons to a treatment site while bypassing media of the subject to be treated;
[1404] (i) at least one energy emitter of any one of Embodiments 1-61, (ii) at least one energy augmentation structure of any one of Embodiments 62-69, or (iii) at least one energy collector of any one of Embodiments 70-83, configured to provide an electric field in proximity to the treatment site; and
[1405] a waveguide structure housing the signaling DNA,
[1406] wherein the signaling DNA and the waveguide structure transmit the electromagnetic signals a treatment site.
[1407] Embodiment 152. A living cell biophoton generator comprising:
[1408] a system for locally heating cells in an organ or treatment site;
[1409] (i) at least one energy emitter of any one of Embodiments 1-61, (ii) at least one energy augmentation structure of any one of Embodiments 62-69, or (iii) at least one energy collector of any one of Embodiments 70-83, configured to provide an electric field in proximity to the cells; and
[1410] a controller configured to control the local heating to an amount that induces stress in the cells and thereby induces biophoton emission from the cells in stress.
[1411] Embodiment 153. The generator of Embodiment 152 wherein the system comprises a microwave hyperthermia treatment system.
[1412] Embodiment 154. A method for in vivo biosynthesis of Vitamin D3 in a subject, comprising:
[1413] contacting a cholesterol rich region of the subject with one or more energy converters capable of converting an applied initiation energy into UV;
[1414] irradiating the cholesterol rich region of the subject and the one or more energy converters with the applied initiation energy, wherein the applied initiation energy is at least one member selected from the group consisting of x-rays, gamma rays, and particle beams, wherein at least one energy augmentation structure of any one of Embodiments 62-69 is configured to provide an electric field in proximity to the energy converters;
[1415] wherein the applied initiation energy is converted by the one or more energy converters into UV energy, which interacts with cholesterol in the cholesterol rich region, thereby converting the cholesterol into Vitamin D3.
[1416] Embodiment 155. The method of Embodiment 154, wherein the contacting is performed by injection of the one or more energy converters into the cholesterol rich region of the subject.
[1417] Embodiment 156. The method of Embodiment 154, wherein the contacting is performed by systemically infusing the one or more energy converters into a blood vessel of the subject, wherein the cholesterol rich region of the subject is the bloodstream of the subject.
[1418] Embodiment 157. A method for regenerative medicine, comprising:
[1419] internally generating light in a subject in need thereof at one or more wavelengths sufficient to cause regrowth/regeneration of cells or tissue in the subject in vicinity of (i) at least one energy emitter of any one of

Embodiments 1-61, (ii) at least one energy augmentation structure of any one of Embodiments 62-69, or (iii) at least one energy collector of any one of Embodiments 70-83, providing an electric field in proximity to the cells or tissue.

[1420] Embodiment 158. The method of Embodiment 157, wherein the light is internally generated by administration of at least one energy modulation agent in a vicinity of the area for regrowth/regeneration of cells or tissue, and applying an initiation energy to the subject which is converted internally within the subject by the at least one energy modulation agent into the one or more wavelengths.

[1421] Embodiment 159. The method of Embodiment 157, wherein the light is internally generated by activation of a long-lived persistent phosphor external to the subject, and administering the activated long-lived persistent phosphor to the subject in a vicinity of the area for regrowth/regeneration of cells or tissue.

[1422] Embodiment 160. The method of any one of Embodiments 157-159, wherein the regrowth/regeneration of cells or tissue comprises angiogenesis.

[1423] Embodiment 161. The method of any one of Embodiments 157-160, further comprising administering to the subject a hydrogel impregnated with a RGB peptide coupled with a photo-responsive blocker, such that upon internally generating light in the subject, the photo-responsive blocker is released by the internally generated light, thus activating the RGB peptide to cause regrowth/regeneration of cells or tissue.

[1424] Embodiment 162. The method of Embodiment 161, wherein the RGB peptide coupled with a photo-responsive blocker further comprises a vascular endothelial growth factor protein complexed thereto, such that upon release of the photo-responsive blocker, each of the RGB peptide and vascular endothelial growth factor protein are activated within the subject.

[1425] Embodiment 163. A biophoton collector and conduit device for collecting or delivering biophotons from or into a biological medium, comprising:

[1426] (i) at least one energy emitter of any one of Embodiments 1-61, (ii) at least one energy augmentation structure of any one of Embodiments 62-69, or (iii) at least one energy collector of any one of Embodiments 70-83, configured to collect or provide an electric field in proximity to a region of the biological medium;

[1427] an optical coupling pad coupled to at least one of the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector in the region of the biological medium;

[1428] the optical coupling pad comprising a dielectric cladded metal core extending from the region of the biological medium to a tapered end;

[1429] an optical fiber coupled to the tapered end.

[1430] Embodiment 164. The method of any one of Embodiments 84-131, wherein the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector comprises one or more resonant structures.

[1431] Embodiment 165. The biophoton collector of any one of Embodiments 132-134, wherein the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector comprises one or more resonant structures.

[1432] Embodiment 166. The biophoton collector of any one of Embodiments 135-137, wherein the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector comprises one or more resonant structures.

[1433] Embodiment 167. The biophoton bypass of any one of Embodiments 138-140, wherein the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector comprises one or more resonant structures.

[1434] Embodiment 168. The electrically conducting biophoton bypass of any one of Embodiments 141-143, wherein the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector comprises one or more resonant structures.

[1435] Embodiment 169. The electrically conducting biophoton bypass of Embodiment 144, wherein the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector comprises one or more resonant structures.

[1436] Embodiment 170. The magnetic yoke biophoton bypass of Embodiment 145, wherein the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector comprises one or more resonant structures.

[1437] Embodiment 171. The in vivo biophoton generator of any one of Embodiments 146-147, wherein the at least one energy augmentation structure comprises one or more resonant structures.

[1438] Embodiment 172. The living cell biophoton generator of any one of Embodiments 148-150, wherein the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector comprises one or more resonant structures.

[1439] Embodiment 173. The DNA-based biophoton bypass of Embodiment 151, wherein the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector comprises one or more resonant structures.

[1440] Embodiment 174. The living cell biophoton generator of any one of Embodiment 152-153, wherein the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector comprises one or more resonant structures.

[1441] Embodiment 175. The method of any one of Embodiments 154-156, wherein the at least one energy augmentation structure comprises one or more resonant structures.

[1442] Embodiment 176. The method of any one of Embodiments 157-162, wherein the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector comprises one or more resonant structures.

[1443] Embodiment 177. The biophoton collector and conduit device of Embodiment 163, wherein the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector comprises one or more resonant structures.

[1444] Embodiment 178. A method of producing a photoactivated reaction inside an animal or human patient, comprising:

[1445] introducing to a treatment site of the patient a mechanoluminescent emitter;

[1446] providing ultrasonic, vibrational, or acoustic energy to the treatment site, and

[1447] emitting at least one of ultraviolet light and visible light from the mechanoluminescent emitter at the treatment site, wherein the ultraviolet light or visible light induces the photoactivated reaction.

[1448] Embodiment 179. The method of Embodiment 178, wherein the mechanoluminescent emitter comprises a europium-holmium co-doped strontium aluminate.

[1449] Embodiment 180. The method of Embodiment 178, wherein the mechanoluminescent emitter comprises a composite made of a piezoelectric material and an electroluminescent material.

[1450] Embodiment 181. The method of any one of Embodiments 178-180, wherein the photoactivated reaction comprises inducing emission of biophotons from a cell or cellular component.

[1451] Embodiment 182. An electron emitter comprising:

[1452] an electron source for emission of electrons into a vacuum or an ambient of the electron source;

[1453] at least one (i) energy emitter of any one of Embodiments 1-61, (ii) energy augmentation structure of any one of Embodiments 62-69, or (iii) energy collector of any one of Embodiments 70-83, in proximity to the first region or the second region;

[1454] disposed in a vicinity of the electron source which, under resonant conditions, generates an intensified electric field at a point of electron emission from the source, whereby electron emission in the presence of the intensified electric field is enhanced more than if the electron emitter were remote from the at least one (i) energy emitter, (ii) energy augmentation structure, or (iii) energy collector, or if the at least one (i) energy emitter, (ii) energy augmentation structure, or (iii) energy collector were not present.

[1455] Embodiment 183. A light-emitting plasma capsule containing the electron emitter of 182, wherein electron emission into a gas in the plasma capsule generates or sustains a light-emitting plasma within the capsule.

[1456] Having generally described this invention, a further understanding can be obtained by reference to certain specific examples which are provided herein for purposes of illustration only and are not intended to be limiting unless otherwise specified.

[1457] Numerous modifications and variations of the invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

1. A method of treating a subject comprising:

providing a first region of biological material coupled to the subject;

initiating a change in a cellular environment of the cells in the first region; and

due to a change in biological or chemical activity of the cells in the first region, inducing a biological change in a second region inside the subject with assistance of an electric field from at least one (i) energy emitter, (ii) energy augmentation structure, or (iii) energy collector, wherein:

the at least one (i) energy emitter, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and an energy converter capable of receiving energy from an energy source, converting the energy and emitting therefrom an emitted light of a higher or lower energy than the received energy, and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted light is emitted with an intensity larger than if the energy converter were remote from the at least one energy augmentation structure, or if the energy augmentation structure were not present;

the at least one (ii) energy augmentation structure, when present, is capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property;

the at least one (iii) energy collector, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and at least one energy converter capable of receiving an applied electromagnetic energy, converting the applied electromagnetic energy and emitting therefrom an emitted electromagnetic energy shifted in wavelength or energy from the applied electromagnetic energy and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted electromagnetic energy is emitted with at least one augmented property compared to if the energy converter were remote from the at least one energy augmentation structure;

in proximity to the first region or the second region.

2-48. (canceled)

49. A biophoton collector comprising:

a living cell container for holding live cells which are capable of emitting biophotons;

an integrating sphere surrounding the living cell container for collection of the biophotons;

an exit window for transmission of the biophotons from the integrating sphere; and

at least one (i) energy emitter, (ii) energy augmentation structure, or (iii) energy collector, wherein:

the at least one (i) energy emitter, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and an energy converter capable of receiving energy from an energy source, converting the energy and emitting therefrom an emitted light of a higher or lower energy than the received energy, and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted light is emitted with an intensity larger than if the energy converter were remote from the at least one energy augmentation structure, or if the energy augmentation structure were not present;

the at least one (ii) energy augmentation structure, when present, is capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property;

the at least one (iii) energy collector, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and at least one energy converter capable of receiving an applied electromagnetic energy, converting the applied electromagnetic energy and emitting therefrom an emitted electromagnetic energy shifted in wavelength or energy from the applied electromagnetic energy and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted electromagnetic energy is emitted with at least one augmented property compared to if the energy converter were remote from the at least one energy augmentation structure;

configured to provide an electric field in proximity to the living cell container.

50-51. (canceled)

52. A biophoton collector comprising:

a living cell container for holding live cells which are capable of emitting biophotons;

at least one (i) energy emitter, (ii) energy augmentation structure, or (iii) energy collector, wherein:

the at least one (i) energy emitter, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and an energy converter capable of receiving energy from an energy source, converting the energy and emitting therefrom an emitted light of a higher or lower energy than the received energy, and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted light is emitted with an intensity larger than if the energy converter were remote from the at least one energy augmentation structure, or if the energy augmentation structure were not present;

the at least one (ii) energy augmentation structure, when present, is capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property;

the at least one (iii) energy collector, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and at least one energy converter capable of receiving an applied electromagnetic energy, converting the applied electromagnetic energy and emitting therefrom an emitted electromagnetic energy shifted in wavelength or energy from the applied electromagnetic energy and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted electromagnetic energy is emitted with at least one augmented property compared to if the energy converter were remote from the at least one energy augmentation structure;

configured to provide an electric field in proximity to a first region where the live cells exist or a second region of a biological material to be treated.

an antenna surrounding the living cell container for collection of electromagnetic radiation as the emitted biophotons.

53-54. (canceled)

55. A biophoton bypass comprising:

a hollow cavity optic for transmitting biophotons from a source of the biophotons to a treatment site while bypassing media of the subject to be treated;

an exit optic attached to an end of the hollow cavity optic, the exit optic dispersing the biophotons from the hollow cavity optic into the media of the subject to be treated; and

at least one (i) energy emitter, (ii) energy augmentation structure, or (iii) energy collector, wherein:

the at least one (i) energy emitter, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and an energy converter capable of receiving energy from an energy source, converting the energy and emitting therefrom an emitted light of a higher or lower energy than the received energy, and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted light is emitted with an intensity larger than if the energy converter were remote from the at least one energy augmentation structure, or if the energy augmentation structure were not present;

the at least one (ii) energy augmentation structure, when present, is capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property;

the at least one (iii) energy collector, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and at least one energy converter capable of receiving an applied electromagnetic energy, converting the applied electromagnetic energy and emitting therefrom an emitted electromagnetic energy shifted in wavelength or energy from the applied electromagnetic energy and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted electromagnetic energy is emitted with at least one augmented property compared to if the energy converter were remote from the at least one energy augmentation structure;

configured to provide an electric field in proximity to a first region where the source of the biophotons exists or a second region of a biological material to be treated.

56-57. (canceled)

58. An electrically conducting biophoton bypass comprising:

a conductor for transmitting low frequency electric signals from a source of the biophotons to a treatment site while bypassing media of the subject to be treated;

a sheath covering the conductor and isolated from the conductor by a dielectric spacer;

a connector attached to the conductor for connecting the conductor to the media of the subject to be treated; and

at least one (i) energy emitter, (ii) energy augmentation structure, or (iii) energy collector, wherein:

the at least one (i) energy emitter, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and an energy converter capable of receiving energy from an energy source, converting the energy and emitting therefrom an emitted light of a higher or lower energy than the received energy, and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted light is emitted with an intensity larger than if the energy converter were remote from the at least one energy augmentation structure, or if the energy augmentation structure were not present;

the at least one (ii) energy augmentation structure, when present, is capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property;

the at least one (iii) energy collector, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and at least one energy converter capable of receiving an applied electromagnetic energy, converting the applied electromagnetic energy and emitting therefrom an emitted electromagnetic energy shifted in wavelength or energy from the applied electromagnetic energy and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted electromagnetic energy is emitted with at least one augmented property compared to if the energy converter were remote from the at least one energy augmentation structure;

configured to provide an electric field in proximity to a first region where the source of the biophotons exist or a second region of a biological material to be treated.

59-60. (canceled)

61. An electrically conducting biophoton bypass comprising:

a conductor for transmitting high frequency electrical signals from a source of the biophotons to a treatment site while bypassing media of the subject to be treated;

a sheath covering the conductor and equidistantly spaced apart from the conductor by a dielectric spacer;

a connector attached to the conductor for connecting the conductor to the media of the subject to be treated; and

at least one (i) energy emitter, (ii) energy augmentation structure, or (iii) energy collector, wherein:

the at least one (i) energy emitter, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and an energy converter capable of receiving energy from an energy source, converting the energy and emitting therefrom an emitted light of a higher or lower energy than the received energy, and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted light is emitted with an intensity larger than if the energy converter were remote from the at least one energy augmentation structure, or if the energy augmentation structure were not present;

the at least one (ii) energy augmentation structure, when present, is capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property;

the at least one (iii) energy collector, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and at least one energy converter capable of receiving an applied electromagnetic energy, converting the applied electromagnetic energy and emitting therefrom an emitted electromagnetic energy shifted in wavelength or energy from the applied electromagnetic energy and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted electromagnetic energy is emitted with at least one augmented property compared to if the energy converter were remote from the at least one energy augmentation structure;

configured to provide an electric field in proximity to a first region where the live cells exist or a second region of a biological material to be treated.

62. A magnetic yoke biophoton bypass comprising:

a magnetic yoke for transmitting magnetic signals from a source of the biophotons to a treatment site while bypassing media of the subject to be treated;

a dual gap construction comprising a first gap for introduction of the magnetic signals into the magnetic yoke and a second gap for exposing the treatment site to the magnetic signals, wherein at least one (i) energy emitter, (ii) energy augmentation structure, or (iii) energy collector, wherein:

the at least one (i) energy emitter, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and an energy converter capable of receiving energy from an energy source, converting the energy and emitting therefrom an emitted light of a higher or lower energy than the received energy, and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted light is emitted with an intensity larger than if the energy converter were remote from the at least one energy augmentation structure, or if the energy augmentation structure were not present;

the at least one (ii) energy augmentation structure, when present, is capable of capturing one or more

wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property;

the at least one (iii) energy collector, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and at least one energy converter capable of receiving an applied electromagnetic energy, converting the applied electromagnetic energy and emitting therefrom an emitted electromagnetic energy shifted in wavelength or energy from the applied electromagnetic energy and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted electromagnetic energy is emitted with at least one augmented property compared to if the energy converter were remote from the at least one energy augmentation structure;

is in proximity to the first gap or the second gap.

63. An in vivo biophoton generator comprising:

one or more phosphors disposed in an organ or at treatment site;

at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property configured to provide an electric field in proximity to the one or more phosphors, and

a controller configured to control high energy excitation of the phosphors to produce light emission from the phosphors mimicking biophoton emission from cells in the organ or at the treatment site.

64. (canceled)

65. A living cell biophoton generator comprising:

a living cell layer comprising live cells;

a matrix for attaching the living cell layer to an organ or treatment site;

an encapsulant layer sealing the living cell layer; and

at least one (i) energy emitter, (ii) energy augmentation structure, or (iii) energy collector, wherein:

the at least one (i) energy emitter, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and an energy converter capable of receiving energy from an energy source, converting the energy and emitting therefrom an emitted light of a higher or lower energy than the received energy, and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted light is emitted with an intensity larger than if the energy converter were remote from the at least one energy augmentation structure, or if the energy augmentation structure were not present;

the at least one (ii) energy augmentation structure, when present, is capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property;

the at least one (iii) energy collector, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and at least one energy converter capable of receiving an applied electromagnetic energy, converting the applied electromagnetic energy and emitting therefrom an emitted electromagnetic energy shifted in wavelength or energy from the applied electromagnetic energy and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted electromagnetic energy is emitted with at least one augmented property compared to if the energy converter were remote from the at least one energy augmentation structure;

configured to provide an electric field in proximity to a region of the live cells.

66-67. (canceled)

68. A DNA-based biophoton bypass comprising:

a signaling DNA capable of transmitting electromagnetic signals as biophotons from a source of the biophotons to a treatment site while bypassing media of the subject to be treated;

at least one (i) energy emitter, (ii) energy augmentation structure, or (iii) energy collector, wherein:

the at least one (i) energy emitter, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and an energy converter capable of receiving energy from an energy source, converting the energy and emitting therefrom an emitted light of a higher or lower energy than the received energy, and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted light is emitted with an intensity larger than if the energy converter were remote from the at least one energy augmentation structure, or if the energy augmentation structure were not present;

the at least one (ii) energy augmentation structure, when present, is capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property;

the at least one (iii) energy collector, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and at least one energy converter capable of receiving an applied electromagnetic energy, converting the applied electromagnetic energy and emitting therefrom an emitted electromagnetic energy shifted in wavelength or energy from the applied electromagnetic energy and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted electromagnetic energy is emitted with at least one augmented property compared to if the

energy converter were remote from the at least one energy augmentation structure;

configured to provide an electric field in proximity to the treatment site; and

a waveguide structure housing the signaling DNA,

wherein the signaling DNA and the waveguide structure transmit the electromagnetic signals a treatment site.

69. A living cell biophoton generator comprising:

a system for locally heating cells in an organ or treatment site;

at least one (i) energy emitter, (ii) energy augmentation structure, or (iii) energy collector, wherein:

the at least one (i) energy emitter, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and an energy converter capable of receiving energy from an energy source, converting the energy and emitting therefrom an emitted light of a higher or lower energy than the received energy, and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted light is emitted with an intensity larger than if the energy converter were remote from the at least one energy augmentation structure, or if the energy augmentation structure were not present;

the at least one (ii) energy augmentation structure, when present, is capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property;

the at least one (iii) energy collector, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and at least one energy converter capable of receiving an applied electromagnetic energy, converting the applied electromagnetic energy and emitting therefrom an emitted electromagnetic energy shifted in wavelength or energy from the applied electromagnetic energy and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted electromagnetic energy is emitted with at least one augmented property compared to if the energy converter were remote from the at least one energy augmentation structure;

configured to provide an electric field in proximity to the cells; and

a controller configured to control the local heating to an amount that induces stress in the cells and thereby induces biophoton emission from the cells in stress.

70. (canceled)

71. A method for in vivo biosynthesis of Vitamin D3 in a subject, comprising:

contacting a cholesterol rich region of the subject with one or more energy converters capable of converting an applied initiation energy into UV;

irradiating the cholesterol rich region of the subject and the one or more energy converters with the applied initiation energy, wherein the applied initiation energy is at least one member selected from the group consisting of x-rays, gamma rays, and particle beams, wherein at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property is configured to provide an electric field in proximity to the energy converters;

wherein the applied initiation energy is converted by the one or more energy converters into UV energy, which interacts with cholesterol in the cholesterol rich region, thereby converting the cholesterol into Vitamin D3.

72-73. (canceled)

74. A method for regenerative medicine, comprising:

internally generating light in a subject in need thereof at one or more wavelengths sufficient to cause regrowth/regeneration of cells or tissue in the subject in vicinity of at least one (i) energy emitter, (ii) energy augmentation structure, or (iii) energy collector, wherein:

the at least one (i) energy emitter, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and an energy converter capable of receiving energy from an energy source, converting the energy and emitting therefrom an emitted light of a higher or lower energy than the received energy, and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted light is emitted with an intensity larger than if the energy converter were remote from the at least one energy augmentation structure, or if the energy augmentation structure were not present;

the at least one (ii) energy augmentation structure, when present, is capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property;

the at least one (iii) energy collector, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and at least one energy converter capable of receiving an applied electromagnetic energy, converting the applied electromagnetic energy and emitting therefrom an emitted electromagnetic energy shifted in wavelength or energy from the applied electromagnetic energy and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted electromagnetic energy is emitted with at least one augmented property compared to if the energy converter were remote from the at least one energy augmentation structure;

providing an electric field in proximity to the cells or tissue.

75-79. (canceled)

80. A biophoton collector and conduit device for collecting or delivering biophotons from or into a biological medium, comprising:

at least one (i) energy emitter, (ii) energy augmentation structure, or (iii) energy collector, wherein:

the at least one (i) energy emitter, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and an energy converter capable of receiving energy from an energy source, converting the energy and emitting therefrom an emitted light of a higher or lower energy than the received energy, and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted light is emitted with an intensity larger than if the energy converter were remote from the at least one energy augmentation structure, or if the energy augmentation structure were not present;

the at least one (ii) energy augmentation structure, when present, is capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property;

the at least one (iii) energy collector, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and at least one energy converter capable of receiving an applied electromagnetic energy, converting the applied electromagnetic energy and emitting therefrom an emitted electromagnetic energy shifted in wavelength or energy from the applied electromagnetic energy and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted electromagnetic energy is emitted with at least one augmented property compared to if the energy converter were remote from the at least one energy augmentation structure;

configured to collect or provide an electric field in proximity to a region of the biological medium;

an optical coupling pad coupled to at least one of the (i) at least one energy emitter, (ii) at least one energy augmentation structure, or (iii) at least one energy collector in the region of the biological medium;

the optical coupling pad comprising a dielectric cladded metal core extending from the region of the biological medium to a tapered end;

an optical fiber coupled to the tapered end.

81-94. (canceled)

95. A method of producing a photoactivated reaction inside an animal or human patient, comprising:

introducing to a treatment site of the patient a mechanoluminescent emitter;

providing ultrasonic, vibrational, or acoustic energy to the treatment site, and

emitting at least one of ultraviolet light and visible light from the mechanoluminescent emitter at the treatment site, wherein the ultraviolet light or visible light induces the photoactivated reaction.

96-98. (canceled)

99. An electron emitter comprising:

an electron source for emission of electrons into a vacuum or an ambient of the electron source;

at least one (i) energy emitter, (ii) energy augmentation structure, or (iii) energy collector, wherein:

the at least one (i) energy emitter, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and an energy converter capable of receiving energy from an energy source, converting the energy and emitting therefrom an emitted light of a higher or lower energy than the received energy, and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted light is emitted with an intensity larger than if the energy converter were remote from the at least one energy augmentation structure, or if the energy augmentation structure were not present;

the at least one (ii) energy augmentation structure, when present, is capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property;

the at least one (iii) energy collector, when present, comprises at least one energy augmentation structure capable of capturing one or more wavelengths of electromagnetic energy, and augmenting the one or more wavelengths of electromagnetic energy in at least one property; and at least one energy converter capable of receiving an applied electromagnetic energy, converting the applied electromagnetic energy and emitting therefrom an emitted electromagnetic energy shifted in wavelength or energy from the applied electromagnetic energy and the energy converter being disposed in a vicinity of the at least one energy augmentation structure such that the emitted electromagnetic energy is emitted with at least one augmented property compared to if the energy converter were remote from the at least one energy augmentation structure;

in proximity to the first region or the second region;

disposed in a vicinity of the electron source which, under resonant conditions, generates an intensified electric field at a point of electron emission from the source, whereby electron emission in the presence of the intensified electric field is enhanced more than if the electron emitter were remote from the at least one (i) energy emitter, (ii) energy augmentation structure, or (iii) energy collector, or if the at least one (i) energy emitter, (ii) energy augmentation structure, or (iii) energy collector were not present.

100. (canceled)

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