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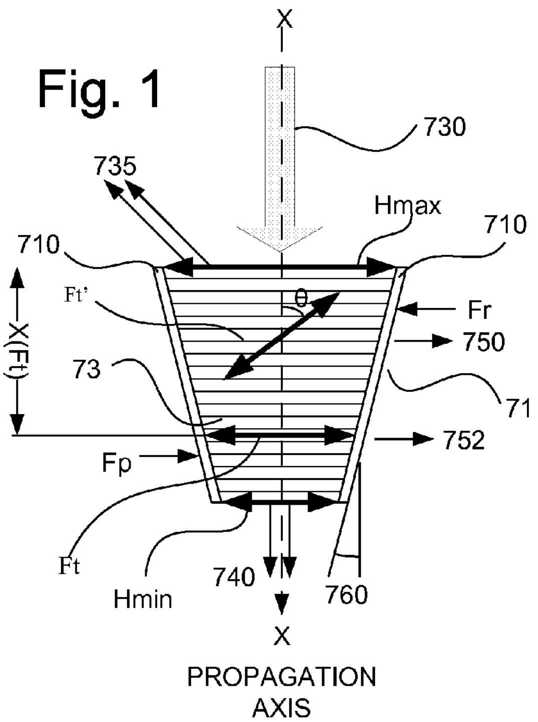
[Continued on next page]

(54) Title: OBJECT AUTHENTICATION DEVICES, KEY-LOCK MECHANISM AND FACILITATING EQUIPMENT

Fig. 1



(57) Abstract: A radiant energy based key-lock and apparatus for authenticating an object, both using radiant energy emitting and sensing arrangement is disclosed. In certain embodiments Continuous Resonant Trap Refractors (CRTRs) are used. Furthermore, as the aspects of the invention may benefit from a variable collimator, several tunable collimation arrangements are disclosed, for use with other devices disclosed herein, or with any application where tunable collimators may be beneficial.

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Object Authentication devices, key-lock mechanism and facilitating equipment

Related applications

[0001] Aspects relating to the present invention were disclosed in US Patent Applications: US 61/718,181, entitled “Nano-Scale Continuous Resonance Trap Refractor”, filed 24 October 2012; US 61/723,832, entitled “Pixel Structure Using Tapered Light Waveguides, Displays, Display Panels, and Devices Using Same”, filed 8 November 2012; US 61/723,773, entitled “Optical Structure for Banknote Authentication”, filed 7 November 2012; 13/831,575 entitled “Waveguide Based Energy Converters, and energy conversion cells using same” filed March 15, 2013; 61/786,357 titled “Methods of Manufacturing of Continuous Resonant Trap Structures, Supporting Structures Thereof, and Devices Using Same” filed March 15, 2013, 61/801,619 titled “Tapered Waveguide for Separating and Combining Spectral Components of Electromagnetic Waves” filed March 15, 2013, US 61/801,431 titled “Continues Resonant Trap Refractors, lateral waveguides, and devices using same” filed March 15, 2013, all to Andle and Wertsberger; and 61/724,920, entitled “Optical Structure for Banknote Authentication, and Optical Key Arrangement for Activation Signal Responsive to Special Light Characteristics”, filed 10 November 2012, to Wertsberger.

Field of the invention

[0002] The present invention relates generally to nanostructures and devices for refracting and spatially separating, reflecting, or combining, radiant energy, and more particularly to devices using same in varied applications regarding security and authentication.

Background

[0003] Various areas of security, whether relating to identification, access to certain locations and/or documents, or prevention of documents forgery, are fields which can benefit from devices and applications which utilize the large number of combinations of different spectral components in the radiant energy spectrum. Devices that can spatially separate radiant energy into its spectral components such as frequency and/or polarization, allow selecting a signature from amongst extremely large number of combinations. In an opposite but sometimes complimentary aspect, combining a plurality of ‘narrower’ spectral components into a ‘broader’ radiant energy is also useful, whether carried out by an apparatus or by the human eye.

[0004] In its most basic form, the term ‘refraction’ means the change of direction of a ray of light, sound, heat, radio waves, and other forms of wave energy, as it passes from one medium to another. Generally waves of different frequencies would refract at different angles and thus refraction tends to spatially separate multispectral radiation into its component frequencies.

[0005] Radiant energy extends over a very broad radiation spectrum, and the spectrum to which different aspects of the invention may be applicable ranges from the Ultra Violet (UV), via the visible light portion of the spectrum, to Infra Red (IR) and beyond into the millimeter wave range, also known as Extremely High Frequency (EHF) and microwave. Many applications would need to cover only portions of this spectrum. It is seen therefore that the application at hand determines the spectral range of interest, and that a spectral range of interest may differ by application, an apparatus, or a portion thereof. Regarding lateral waveguides, yet another aspect described below, each waveguide may have its own spectrum of interest, which may differ from the spectral range of interest of an adjacent waveguide. Therefore, the spectral range of interest is defined herein as relating to any portion or portions of the total available spectrum of frequencies which is being utilized by the application, apparatus, and/or portion thereof, at hand, and which is desired to be detected and/or emitted utilizing the technologies, apparatuses, and/or methods of the invention(s) described herein, or their equivalents.

[0006] Structure to facilitate conversion of radiant energy to electricity or electrical signals (hereinafter “LE”), or conversion of electrical signals into radiant energy such as light (hereinafter “EL”) are known. Collectively, objects, materials, and structures, which perform conversion between two forms of energy, or adjust and control flow of energy, are known by various names which denote equivalent structures, such as converters, transducers, absorbers, detectors, sensors, and the like. To increase clarity, such structures will be referred to hereinunder as ‘transducers’. By way of non-limiting examples, the term “transducer” relates to light sources, light emitters, light modulators, light reflectors, laser sources, light sensors, photovoltaic materials including organic and inorganic transducers, quantum dots, photonic structures, and the like, CCD and CMOS structures, LEDs, OLEDs, liquid crystals (such as those used by Liquid Crystal Displays (LCD)), receiving and/or transmitting antennas and/or rectennas, phototransistors photodiodes, diodes, electroluminescent devices, fluorescent devices, gas discharge devices, electrochemical transducers, and the like.

[0007] A transducer of special construction is the RL transducer, which is a reflective transducer. Reflective transducers controllably reflect radiant energy. Such transducers may comprise micro-mirrors, light gates, liquid crystal, and the like, positioned to selectively block the passage of radiant energy, and reflect it into a predetermined path, which is often but not always, the general direction the energy arrived from. Certain arrangements of semiconductor and magnetic arrangements may act as RL transducers by virtue of imparting changes in propagation direction of the radiant energy, and thus magnetic forces or electrical fields may bend a radiant frequency beam to the point that in effect, it may be considered as reflected. RL transducers may be fixed, or may be used to modulate the energy direction over time.

[0008] A common structures for LE type conversion are photovoltaic (PV) which generally uses layers of different materials, primarily for energy harvesting. In a PN based transducer, a PN junction is formed at the interface of a positive and negative doped semiconductor materials to form photoactive semiconductor based PN junction devices. When exposed to a photon having energy equaling or higher than the band gap between the junction materials, the photon energy causes formation of electron-hole groups, which are separated and collected on both sides of the junction depletion zone. Those transducers are colloquially known as inorganic transducers. Organic transducers utilize somewhat different mechanisms, generally with hetherojunctions of polymers and/or small molecules, however the skilled in the art would recognize the similarity between those transducer types and relate to them equivalently as applied to certain aspects of the present invention.

[0009] Certain PN junction based transducers are capable of emitting radiant energy when energized by electrical current, thus acting as EL type transducers. Common examples include semiconductor lasers, LED and OLED. Passive transducers such as liquid crystal and micromirrors fall into the reflective device when used to reflect incoming energy, but when used in conjunction with at least one light source may be considered LE type transducers. Charge Coupled Devices (CCD), and Complementary Metal Oxide Semiconductor (CMOS) are two common LE type of image sensing technology.

[0010] Tapered waveguide directed at trapping radiant energy, as opposed to emitting energy via the cladding, have been disclosed by Min Seok Jang and Harry Atwater in "Plasmionic Rainbow Trapping Structures for Light localization and Spectrum Splitting" (Physical Review Letters, RPL 107, 207401 (2011), 11 November 2011, American Physical Society©). The article "Visible-band dispersion by a tapered air-core Bragg waveguide", (B. Drobot, A. Melnyk, M. Zhang, T.W. Allen, and R.G. DeCorby, 8 October 2012 / Vol. 20, No. 21 / OPTICS EXPRESS 23906, ©2012 Optical Society of America_ "Visible-band dispersion by a tapered air-core Bragg waveguide" B. Drobot, A. Melnyk, M. Zhang, T.W. Allen, and R.G. DeCorby, 8 October 2012 / Vol. 20, No. 21 / OPTICS EXPRESS 23906, ©2012 Optical Society of America) describes out-coupling of visible band light from a tapered hollow waveguide with TiO_2/SiO_2 Bragg mirrors. The mirrors exhibit an omnidirectional band for TE-polarized modes in the ~490 to 570 nm wavelength range, resulting in near-vertical radiation at mode cutoff positions. Since cutoff is wavelength-dependent, white light is spatially dispersed by the taper.

[0011] A Continuous Resonant Trap Refractor (CRTR) is the name used in these specification to denote a novel structure which is utilized in many aspects of the present invention. As such, a simple explanation of the principles behind its operation is appropriate at this early stage in these specifications, while further features are disclosed below.

[0012] A simplified view of a CRTR operating in splitter mode is provided in Fig. 1. A CRTR 71 is a structure based on a waveguide having a tapered core 73, the core having a wide base face H_{max} forming an aperture, and a narrower tip H_{min} which may narrow taper to a point, or any other desired shape (not shown in Fig. 1). The core is surrounded at least partially by a cladding 710 which is transmissive of radiant energy under certain conditions. The axis X-X extending between the aperture and the tip is the CRTR depth axis, which increases in a direction from the aperture towards the tip. The CRTR may be operated in splitter mode, in a mixer/combiner mode, in reflective mode, or in a hybrid mode providing combination of the other modes. In splitter mode the radiant energy 730 wave is admitted into the CRTR via the aperture, and travels along the depth direction. The width of a two dimensional CRTR is transverse to the depth direction, while for a three dimensional CRTR, at any depth the CRTR has a plurality of widths transverse to the depth direction. The different widths for a single depth form a width plane, which is transverse to the depth direction, and the term 'in at least one direction' as related to CRTR width, relate to directions on the width plane or parallel thereto. Any given depth correspond with its width plane, and thus there are infinite number of parallel width planes. . The tapered core width varies in magnitude so as to be greater at the first end than at the second end in at least one width dimension.

[0013] The tapered core is dimensioned such that in splitter and reflective modes at least some of the admitted spectral components will reach a state where they will penetrate the cladding, and be emitted therefrom. This state is referred to as Cladding Penetration State (CPS), and is reached when energy of a certain frequency approaches a critical width of the waveguide for that frequency. The mechanism at which cladding penetration state occurs may vary, such as by tunneling penetration, skin depth penetration, a critical angle of incidence with the cladding and the like. Generally CPS will occur in proximity to or at the width, where the wave reaches a resonance, known as the critical frequency for that width, and conversely at the critical width for the frequency of the wave. Regardless of the mechanism, a CPS is characterized by the wave reaching a frequency dependent depth within the CRTR where it is emitted via the cladding. The decreasing width of the core will dictate that a lower frequency wave will reach CPS before higher frequency waves, and will penetrate the cladding and exit the waveguide at a shallower depth than at least one higher frequency wave. As waves of differing frequencies will be emitted via the cladding at differing depths, the CRTR will provide spatially separated spectrum along its cladding. Notably, in certain CRTR embodiments some frequency components of the incoming energy may be emitted via the tip, in non-sorted fashion

[0014] The size H_{max} limits the lowest cutoff frequency F_{min}. At the tip the tapered core width H_{min} dictate a higher cutoff frequency Fmax. Between the aperture wide inlet and the narrower tip, the cutoff frequency is continually increased due to the reduced width. Waves having a lower frequency than the cutoff frequency Fmin are reflected 735. Waves 740 having frequency higher than F_{max} exit through the CRTR core, if an exit exists. Waves having frequencies between F_{min} and F_{max} will reach their emission width, and thus their cladding penetration state, at some distance (emission width) from the inlet of the waveguide depending on their frequency.

[0015] Thus, examining the behavior of a wave of arbitrary frequency F_t , where $F_{min}<F_t<F_{max}$, which enters into the CRTR core at its aperture at an incidence angle within an acceptance cone centered about the propagation axis X-X, the angle θ between the wave and X-X will vary as the wave propagates along the X-X axis due to the narrowing of the CRTR waveguide and increase of the cutoff frequency, as depicted schematically by Ft'. As the wave approaches depth $X(F_t)$ where either the tapered waveguide cutoff frequency equals or nearly equals F_t, or the angle θ approaches the critical angle θ_C, at which the wave can not propagate any further within the CRTR core. The wave F_t is thus either radiated through the dielectric cladding of the CRTR as shown symbolically by 750, or is trapped in resonance at depth $X(F_t)$ in a thin metal clad CRTR, and is emitted through the cladding at that depth, as shown by 752. At that point 750 or 752 the wave of frequency Ft reached its cladding penetration state at the emission depth dictated by the emission width of the tapered CRTR core. For a continuum of entering waves of different frequencies $F_{min}<F_1, F_2, \dots F_x<F_{max}$, entering the base of the tapered waveguide 71, The tapered core waveguide becomes a Continuous Resonant Trap Refractor (CRTR) in which the different frequency waves become standing waves, trapped at resonance along the X-X axis in accordance to their

frequency. Such trapped waves are either leaked through the cladding by the finite probability of tunneling though the cladding or are lost to absorption in the waveguide. Note that a CRTR will also cause admitted rays to be refracted or otherwise redirected so that the component(s) produced by splitting exit the CRTR at an angle to the CRTR depth axis. This will make it possible to employ a CRTR that has been embedded within stacked waveguides in such a manner that the CRTR directs spectral components of the incoming multispectral radiation to predetermined waveguides.

[0016] Conversely, when operated in mixer/combiner mode, a wave coupled to the core via the cladding at or slightly above a depth where it would have reached CPS in splitter mode, will travel from the emission depth towards the aperture, and different spectral components coupled to the core through the cladding will be mixed and emitted through the aperture. Coupling light into the CRTR core from the cladding, will be referred to as 'injecting' or 'inserting' energy into the CRTR. The depth at which the wave would couple into the tapered core is somewhat imprecise, as at the exact depth of CPS the wave may not couple best into the core. Thus the term 'slightly above' as referred to the coupling of light into the tapered core in combiner/mixer mode should be construed as the depth at which energy injected into the tapered core via the cladding would best couple thereto to be emitted via the aperture, within certain tolerances stemming from manufacture considerations, precision, engineering choices and the like.

[0017] Thus functionally, a CRTR is a device which allows passage of radiant energy therethrough, while

a. imparting a change in the direction of propagation of incoming energy;

b. in one mode a CRTR is operational to spatially disperses incoming energy into spatially separated spectral components thereof, which are outputted via the CRTR cladding, the mode is equivalently referred to as disperser, splitter, or dispersion mode;

c. in another mode a CRTR is operational to combine a plurality of incoming spectral components into emitted energy comprising the components and emitted via the aperture, the mode equivalently referred to as combiner, mixer, or mixing mode; and,

d. in another mode the CRTR is operational to controllably reflect at least a portion of the spectral components admitted via the aperture, the reflected components being reflected via the aperture, thus controllable changing the effective reflectance of the CRTR at selected spectral components, the mode equivalently referred to as reflective mode or reflectance mode.

[0018] A CRTR is considered to operate in hybrid mode when energy is both admitted and emitted via the aperture. In certain embodiment this mode involves energy being admitted via the aperture and at least portions thereof being emitted via the cladding or being selectively reflected, while other energy is being injected via the cladding and emitted via the aperture.

[0019] A round cross section of the tapered core will be polarization neutral under most circumstances. Certain non-symmetrical or multi-faceted symmetrical tapered core forms will however cause separation of the aperture-admitted radiant energy to be polarization sensitive. Fig. 1A shows an example of a combination of frequency and polarization detection or mixing using CRTR with square multifaceted tapered core. While the CRTR 1050 operates in splitter mode, radiant energy is admitted to the CRTR core 1050 via the aperture and travels along the depth direction towards the tip. The energy is divided between the different transducers groups 1052 (R, G, and B), 1054(R, G, and B), such that each transducer receives a spectral component separated by polarization as well as by frequency. Thus by way of example, the pair 1052r and 1054r would each receive a spectral component of a red frequency, but of differing polarization, and similarly transducers 1052g and 1054g would receive a spectral component of a green frequency but with differing polarization, and transducers 1052b and 1054b will have the same with blue frequency. Clearly, if desired a single frequency band may be detected by including only a pair of transducers, or polarization only may be detected for a wider range of frequencies by directing the multi-frequency spectral components emitted from varying depths into a single transducer for each polarization. Mixing will operate in opposite fashion, emitting controllably polarized radiant from the aperture which is the sum of spectral components injected to the core, while maintaining polarization according to the direction in which the energy was injected.

[0020] Asymmetrical tapered core cross-sections operate similar to multifaceted cores, where energy is sorted by polarization according to the shape axes. Not every asymmetrical cross-section would result in usable polarization dependent spectral separation, but generally shapes having a plurality of axes, and especially shapes having symmetry about at least one of the axes while not about all axes, will tend to exhibit polarization selectivity. However for brevity it is assumed that when ‘multi-faceted symmetry’ core is used, unless clear form the context, the term extends to include asymmetrical core shapes that function to provide polarization selectivity.

[0021] For a given CRTR spectral range of interest Si, ranging between λmax to λmin which represent respectively the longest and shortest wavelengths of the spectral range of interest as measured in the core material, wherein λ’ is at least one wavelength in Si, the dimensions of a frequency splitting CRTR taper are bounded such that

a. the aperture size ψ must exceed the size of one half of λmax;

b. the CRTR core size must also be reduced at least in one dimension, to at least a size ζ which is smaller than or equal to one half of wavelength λ’.

[0022] Thus the CRTR dimensions must meet at least the boundary of $\{ \zeta \le \lambda'/2 < \lambda max /2 \le \psi \}$ where the CRTR sizes defined above relate to a size in at least one dimension in a plane normal to the depth dimension. In Fig. 1 the aperture size ψ=hmax. It is noted however that not all waves in Si must meet the condition b. above. By way of example, certain waves having shorter wavelengths than Hmin/2 may fall outside the operating range of the CRTR. Such waves which enter the CRTR will either be emitted 740 through the tip, reflected back through the aperture, or absorbed by some lose mechanism.

[0023] Notably if a third spectral component λ” is present, and has a higher frequency than λ’, it may be emitted at greater depth than λ’ or be emitted or reflected via the tip, if the tip is constructed to pass a spectral component of frequency λ”.

[0024] CRTRs are often disposed within a stratum. Stratums comprise either a slab of material that is transmissive of the radiant energy spectral range of interest, or a plurality of superposed waveguides equivalently referred to as superposed waveguides, stacked waveguides, or lateral waveguides. The CRTRs are disposed such that the CRTR depth direction is substantially perpendicular to the local plane of the stratum. Radiant energy emitted from the cladding is coupled to transducers within the stratum or via the stratum, and radiant energy from EL transducers within the stratum is coupled to the CRTR via the cladding.

[0025] In many embodiments that utilize lateral waveguide based stratum, transducers are embedded within the lateral waveguide.

[0026] The term “about the cladding” or equivalently about the CRTR or its core, should be construed to mean being coupled to via energy path, which implies that the transducer is disposed about the cladding not only by being physically adjacent to the cladding, but also when an energy path such as beam propagation, waveguide, and the like, exists between the location where energy is transferred in or out of the cladding, and the transducer. Similarly, the disposition about the cladding is set by the location at which the energy exists or enters the cladding. Thus, by way of example if the transducer is coupled to the cladding via a waveguide such that the energy couples at depth A of the CRTR, the transducer is considered to be disposed at depth A regardless of its physical location relative to the RCTR.

[0027] A common application of emitting pixels is a display within the visual range, but the spectral content of the radiation emitted by the pixel may range beyond the visual range, ranging from mm wave to UV. Static images may be provided through constant weighting of energy sources in the primary colors range, while photographic, video, and patterns may be provided by actively varying the weights of energy sources in an array of pixels. Thus the emitting pixel is a combination of a CRTR and at least one EL transducer. Optionally an emitting pixel may also harvest some incoming energy for powering related circuitry, and/or sense energy in certain bands..

[0028] Pixels may also have variable weighted reflectors located on one or more channelized ports such that at least a portion of the light incident on the CRTR based pixel aperture, at the associated channel frequencies is programmably reflected. The reflectors form the RL type transducers disclosed above.

[0029] The path which a spectral component takes between the CRTR and its respective transducer constitute the channel. Channels may take many forms, such as lateral waveguides, paths within a slab stratum, other waveguides, and the like. A channel may also constitute a path between the CRTR core and a RL transducer even if such path is of minute length. In certain application the channel may be to an absorber which absorb the energy for storage, dispensing, as heat, and the like.

[0030] Document security and authentication is an ongoing problem where issuers of documents like passports, identification documents, stocks, and other valuable documents fight against forgers. Banknotes have been the most visible and perhaps the oldest subject of forgery, and governments spend inordinate efforts to avoid those problems. There is an ongoing need for improved authentication mechanisms.

[0031] Locks and keys, have been used for thousands of years to control access to locations and devices.

There is also an ongoing need to improved key/lock mechanisms.

[0032] Yet another need is for electrically controllable collimator, which may be beneficially used with the present invention, however the disclosed solutions to this problem may be applied to other field of endeavor where tunable collimators are required.

Summary

[0033] Different aspects of the present invention utilize different capabilities of CRTR and arrays thereof, which may be operated as a multispectral capable photonic pixel which is capable of acting as a reversible channelized filter/combiner, capable of operating from the far IR and mm wave radar regime of the electromagnetic spectrum, to the deep Ultra Violet (UV) range. As such it is an object of the invention to provide CRTR based devices and systems that will improve existing radiant energy absorbing and emitting structures, and provide new uses therefore.

[0034] Yet another aspect of the invention discloses a collimator that is usable as an independent apparatus in combination with other radiant energy detectors and/or emitters, but which may be beneficially combined with CRTR based devices.

[0035] In some embodiments, the CRTR is embedded in a stack of lateral waveguides, each containing transducers, or acting as energy guides to transducers. The transducers may be optimized to the type of radiant energy received.

[0036] In an aspect of the invention there is provided an authentication system for authenticating a banknote or a document, the system comprises a power harvester embedded within a first zone of the document or banknote, and a plurality of light sources embedded within a second zone of the document, wherein the light sources are being coupled to the energy harvester. Optionally, the emitting transducers are arranged in a pattern. While any power harvesting device may be utilized, in at least some embodiments, the power harvester comprises at least one CRTR coupled to LE type transducer. Similarly, while any light source type may be used, in at least some embodiments at least one of the plurality of light sources comprises a CRTR coupled to a EL and/or RL transducer. Optionally in such embodiments the at least one CRTR emits light having at least one spectral component comprising asymmetrical polarization.

[0037] In another aspect of the invention there is provided a document or banknote authentication system. In one embodiment The system comprises a plurality of optical waveguides embedded within the document or banknote, which have substantially parallel faces. Each of the plurality of waveguides have an aperture at respective ends of the waveguide, the apertures being constructed to accept radiant energy from a face of the banknote or document into the respective waveguide, and emit such light from the second aperture of the respective waveguide. The waveguides are arranged within the banknote or document such that the first apertures of the plurality of waveguides are disposed at first zone and the respective second apertures of the waveguides are arranged in a pattern at a second zone. Optionally, the first and second apertures of the waveguides are disposed on respectively opposing faces of the banknote or document.

[0038] An aspect of the invention is directed at a key-lock mechanism comprising at least one radiant energy spectral splitter having an aperture, and a first and a second channelized outputs, the channelized output emitting different spectral components to respective transducers, when multi-spectral radiant energy in admitted via the aperture; the mechanism further comprising logic having inputs and a locked and unlocked states responsive to the inputs, the transducers being coupled to the inputs. Preferably the logic transitions from locked to unlocked state only when a XOR state exists between at least two of the inputs. In some embodiments the logic includes at least one XOR function. Optionally the spectral splitter is a CRTR.

[0039] Another aspect of the invention is directed to a key-lock mechanism comprising a plurality of radiant energy transducers disposed at spatial relationship therebetween, the mechanism further comprising logic having inputs and a locked and unlocked states responsive to the inputs, the transducers being coupled to the inputs. Preferably the logic transitions from locked to unlocked state only when a XOR state exists between at least two of the inputs. In some embodiments the logic includes at least one XOR function.

[0040] The logic may comprise hardware, software and any combination thereof.

[0041] There is also provided a key configured for providing radiant energy that will cause the logic to transition between the locked and unlocked states.

[0042] In some embodiment there is provided a tunable collimator comprising a collimation plate having a top and a bottom surfaces, the plate having at least one cavity having walls defined thereby, the cavity having walls extending between the top and the bottom layers, and comprising at least one radiant energy modulator.

[0043] In some embodiments, the plate may comprise a photo-reflective or photo-absorptive material. In some embodiments, the modulator comprises liquid crystal.

[0044] In an alternate collimator construction there is provided a plate comprising a poled ferroelectric material having a changing dielectric constant dependent on a biasing electric field, the plate having a top and bottom surfaces, and at least one cavity extending between the top and bottom surfaces. In yet another alternative embodiment the collimator is constructed with a plate which comprises piezoelectric or electrostrictive regions such that a length dimension varies with applied electric field, and wherein the cavity extends along the length dimension, which is the dimension extending between the top and bottom surfaces of the plate.

[0045] In yet another alternate constructions, a collimator is formed between a bottom conductive membrane and a generally superposed top conductive membrane, having a compliant material disposed therebetween, at least one cavity extending between the top and bottom membranes, such that the electrostatic attractive or repulsive forces applied to the membranes alter a distance therebetween. Optionally the compliant material comprises a vacuum, or a fluid such as air, gas, or other compressible fluid.

Brief description of the drawings

[0046] The summary, above, and the following detailed description will be better understood in view of the enclosed drawings which depict details of preferred embodiments. It should however be noted that the invention is not limited to the precise arrangement shown in the drawings and that the drawings are provided merely as examples.

[0047] Fig. 1 depicts a simplified view of a CRTR.

[0048] Fig. 1A depicts one example of polarizing CRTR using symmetrical multifaceted core.

[0049] Fig 2 depicts a simplified diagram of a lock arrangement utilizing light or similar radiant energy.

[0050] Fig. 3 is a simplified diagram of an embodiment of a lock arrangement utilizing CRTRs

[0051] Fig. 4 is a diagram of a lock and matching key.

[0052] Fig. 5 depicts a simplified system of system for authentication of documents

[0053] Fig. 6 depict a cross section view of a document or banknote utilizing CRTRs.

[0054] Fig. 7 depicts yet another authentication system embodiment using CRTRs on opposite sides of a document to be authenticated.

[0055] Fig. 8 comprises a top view of an optional embodiment of the authentication system

[0056] Fig. 9 depicts an embodiment of a tunable collimator which is disposed over optional CRTRs

[0057] Fig. 10 depicts an alternative construction of a controllable collimator.

Detailed description

[0058] Certain figures and embodiments of the invention will now be described by way of example to increase the understanding of different aspects of the invention.

[0059] An aspect of the invention is a key lock function. Generally such arrangement comprises a plurality of light sensitive transducers, coupled to logic which includes at least one XOR function, such that when the transducers receive at least one spectral component, but do not receive another spectral component, the lock is activated. A simplified example of such mechanism is depicted in Fig. 9A. Transducers 811, 812, and 813 may be of any desired type, such as photocells, phototransistors, photodiodes, CCD, CMOS, photovoltaic, rectennas, and the like. A radiant energy limiter F1, F2, F3 is disposed between the transducers and the key. Any light limiter technology may be utilized, such a dichroic mirrors, prisms, gratings, and the like. The limiter task is to direct specific spectral component to the matching transducer, while preventing or limiting other radiant energy from reaching thereto. Limiters F1, F2, and F3, and respective transducers 811, 812, and 813 form a detector.

[0060] The limiters shown in Fig. 2 comprises of light filters F1, F2, and F3 of desired colors and/or polarization. Each of the transducers is constructed to produce sufficient output to assert a logic state only when the energy 141 contains a spectral component of proper characteristics to be passed by the respective limiter, and with sufficient energy to be detected to assert a digital state, either directly, or via an optional shaping circuitry 811A, which may be required for one or more transducers, to convert the respective transducer output into an output fit for digital logic activation. Shaping circuitry may be a Schmidt trigger, amplifier, CMOS gate, and the like.

[0061] Fig. 2 depicts a simplified logic where XOR gate 815 will assert its output only if one of transducers 812 and 813 is activated. If transducer 811 is activated as well, AND gate 820 will assert its output, and activate the lock release signal 825. Thus the radiant energy 141 coming from the key must include the spectral component that passes F1, and only one of spectral components that will pass F2 or F3. By way of example F1 is a red filter, F2 is a green filter F3 is a blue filter, the lock release signal 825 will be activated only when the incoming radiant energy 141 comprises a red spectral component, and either a blue or a green spectral component, but not both. It will be clear that the figures contain only simple logic, and the logic may be modified as a matter of engineering choice. Notably, even AND gate 820 is not required but was added to exemplify that more than the simple XOR function may be utilized. The logic may be as complex as desired, and may be implemented by any desired means, such as a CPU, an ASIC, discrete, or any other logic.

[0062] The lock release signal 825 of the lock may activate any desired apparatus or logic, for an indication, and the like. By way of example the lock release signal may activate a lock release mechanism, activate a machine, provides logic signal confirming an identity, activate or de-activate an alarm, confirm the identity of a user, and the like.

[0063] Optionally, power for the lock embodiment may be obtained by photovoltaic transducer.

[0064] CRTR's are capable of discerning a signal amongst a broad range of frequencies and polarization. Therefore a CRTR may be utilized as an electronic 'lock' which will only respond to light of specific frequency and/or polarization combination being shone on a receptor area. The CRTR will simplify the detector, as it will act as the limiters F1-F3 in Fig. 2. Therefore, in a CRTR based lock mechanism, the detector comprises a CRTR 871 and a plurality of transducers 811-813. Several such detectors may be combined to provide a very large range of possible lock/key combinations.

[0065] Fig. 3 provides an example of an optional embodiment of a locking mechanism utilizing a CRTR. CRTR 871 has three transducers 811, 812, and 813, positioned to couple to specific spectral components such as bands of frequencies and/or polarizations. Each of those transducers is constructed to produce sufficient output to assert a logic state only when the energy 141 admitted via the aperture contains a spectral component of sufficient energy in the transducer corresponding spectral band. Logic coupled to the transducers activates a lock release signal 825. Similarly to the embodiment in Fig. 2, shaping circuitry may be required (not shown).

[0066] Optionally ,the transducers are disposed in narrow lateral waveguide(s) located at least functionally about the CRTR (not shown). Such construction will allow more precise and efficient detection of the different spectral components. Polarization sensitive CRTRs may be utilized to provide a larger selection of key combinations, by allowing spectral components to be based on combinations of polarizations as well as frequencies.

[0067] A matching radiant energy source is required to activate the lock. Such light sources may comprise matching CRTR's, specialized light sources, or light sources using specific filters.

[0068] In this simple example the 'open' signal will only be asserted if transducer 811 is asserted, and only one of transducers 812 and 813 is asserted. Therefore, those conditions must be supplied by the "key" light source (not shown). The key may employ discrete light sources, filters, CRTRs and the like.

[0069] A plurality of such detectors, whether CRTR based or not, may also be employed. In certain cases the 'key' may fit precisely into a physical lock and emitters in the key would physically align with sensors in the lock. The key may be fed power by the lock if desired. Alternatively the key just need to be transmitting radiant energy in the vicinity of the lock to activate the lock. Polarization may be sensed relative to other detectors, to provide additional combination options.

[0070] The number of color/rotational polarization combinations is so large that even one detector may provide sufficient complexity to act as a secured lock. However more than one detectors may be advantageously operated and the number of possible combinations is essentially limitless.

[0071] If the key contains its own logic the system may implement more complex operations, such as changing the coding at given intervals or in response to lock activation (colloquially known as 'rolling code', or following other corresponding algorithms in the key and the lock, as known. Furthermore, a single key may store a large numbed of codes for a plurality of locks.

[0072] Fig. 4 depicts an example of a lock 901 and a matching key 915, utilizing a plurality of emitters 925, disposed such that when the key and the lock are in registration the emitters will be opposite their corresponding detectors 925'. Emitters 925 may emit infrared or visible light which is detected by corresponding detectors 925' only when the proper face-to-face relationship is formed between the key and lock. At least some of the emitters may emit a predefined spectral combination. Thus by way of example one of the two emitters 925 may emit infrared light in the 1500 and the 600 nm range, while the other may emit light at 550nm with vertical polarization only. Such emission may be obtained by proper filters, by utilizing CRTR's or by the light sources used. Detectors 925' are arrange to assert their output only in response to the corresponding emitter predefined spectral combination. The output of the lock as a whole 930 is asserted when the proper radiant energy patterns are detected by the plurality of detector/emitter pairs.

[0073] Fig. 4 also depicts an optional feature where the key receives its operational power from the lock. When emitter 920 is in sufficient registration with detector 920' the energy transmitted by the lock via the emitter 920 is detected and harvested by the key for operating other emitters in the key. Additional detector/emitter pairs may be used. Similarly, any detector/emitter pair may be used for establishing digital communication between the key and the lock.

[0074] Notably, it is not necessary the key and lock not have to be in physical contact with each other, and whether or not such contact is required is a matter of technical choice.

[0075] Therefore, in one embodiment there is provided a key-lock mechanism comprising a radiant energy separator constructed to separate radiant energy directed thereat to a plurality of spectral components, and to direct the spectral components to corresponding LE transducers, the transducers being coupled to logic and the logic constructed to assert an output signal only if the transducers output a predetermined set of outputs, the set of outputs having at least one output which indicate the absence of a predetermined spectral component from the light directed at the light separator. The set of outputs may vary responsive to time. The spectral component may comprise radiant energy of predetermined frequency or frequency band, a predetermined polarization, or a combination thereof. The directed radiant energy may be of any desired frequency, such as, by way of example, infrared light, visible light , UV light, millimeter waves, or any combination thereof. In some embodiments the radiant energy separator comprises a CRTR. In some embodiments the radiant energy separator comprises a plurality of filters. There is also provided a lock utilizing a plurality of separators/transducer combinations, dispersed spatially about an object. By way of example, a plurality of CRTRs acting as light separators in combination with a plurality of detectors may be dispersed on a surface, the relative position of at least two of the CRTRs being matched by the lock.

[0076] Counterfeit banknotes cause significant damage to any economy, while counterfeit documents may be used not only for simple criminal activities, but also present a major security risk. An aspect of the invention provides cover and/or overt method and apparatus offering authentication features for authenticating objects such as documents, banknotes, credit cards, and the like, and preventing counterfeit thereof. The authentication features may be embedded in documents and in banknotes, and for brevity will be described as applied to banknotes, while the skilled in the art will recognize that the features provided herein, separately or in combination, may be incorporated in sheet-like document, such as passports, stock certificates, banknotes, identification documents, awards, credit cards, and the like. When radiant energy is directed at one part of the of the object to be protected, either a visible pattern is shone therefrom, or radiant energy is emitted in certain known patterns that will offer identification.

[0077] Fig. 5 depicts a simplified apparatus for authentication of documents. A portion of a document 1600 is depicted showing elements of the apparatus. An energy harvester 1610 is disposed in the energy harvesting area, the energy harvester may be any convenient energy harvesting device such as a photo cell, a solar cell, an antenna, a magnetic coil, and the like. In one embodiment the energy harvester may be a piezoelectric device, which receives stress energy rather than radiant energy. A CRTR based energy harvester as described elsewhere in these specifications is particularly advantageous, but is not mandated. As energy in the IR range easily passes through paper, a harvester for the IR frequency range is also advantageous, and use thereof allows easy covering of the harvesting area.. The energy harvester 1611 is electrically coupled 1620 to a plurality of EL type transducers 1625 which form a pattern of emitted radiant energy. For overt authentication the energy may be in the visible spectrum, while for covert authentication the emitted radiant energy may be of other portion of the spectrum. When energy is provided to the energy harvester, such as by exposing the area in which the energy harvester is disposed, to proper radiant energy, the energy is harvested and transmitted to the transducers which convert it to radiant energy. If the emitted energy is visible a known pattern will be visible, while if the energy is outside the visible spectrum it may be detected by detection devices. Therefore, in its simplest form, this aspect of the invention comprises a energy harvester coupled to a plurality of radiant energy sources embedded within the document to authenticated, or permanently attached thereto.

[0078] Notably, a portion of, or the whole arrangement, shown in Fig. 11 may be embedded in a substrate 1605, which may in turn be embedded in the document or banknote to be authenticated. By way of example such apparatus may be incorporated in the security strip of a banknote. Alternatively the arrangement or portions thereof may be completely embedded within the paper of otherwise within the document. The transducers may also be of any desired type, such as Light Emitting Diodes (LED's) antennas, organic LEDs, and the like, however transducers coupled to emitting CRTRs operated in mixer/combiner mode, are advantageous as they offer small size, high efficiency, and ability to produce different colors. Furthermore, a set of optical fibers, each having a first and a second end, may be embedded in the banknote or the document such that the first ends of the plurality of optical fibers are disposed in a first area of the banknote or the document, and the second ends are disposed in a pattern in a second area of the banknote or document. Thus light being shone at the first area will result in a visible pattern at the second area.

[0079] Fig. 6 depict a cross section view of a document or banknote 1600 showing a single pixel, of a potential plurality of pixels, which embodies an optional construction of an authenticating apparatus. A sensing CRTR 1451 and an emitting CRTR 1452 are depicted. Radiant energy 1157 is admitted via the sensing CRTR 1451 aperture, and is split according to frequency, such that different spectral components thereof are coupled to different lateral waveguides 1458, 1459 and 1460. Those spectral components are coupled to emitting CRTR 1452, which operates in mixer/combiner mode, and receives the spectral components from the lateral waveguides, combines them and emits them 1158 via the aperture. Only some of the spectral components of radiant energy admitted to the sensing CRTR are transmitted to the emitting CRTR, and thus a filtering occurs.

[0080] Fig. 7, depicts a CRTR based application in which energy 1670 is absorbed by sensing CRTR 1650 and converted by at least one transducer 1662 into electrical energy, which is coupled to circuitry 1626. Circuitry 1626 may be analog or digital and may be used to combine electrical energy from a plurality of sensing CRTRs, and distribute it to transducers 1622, 1623, 1624, which will convert the electrical energy into radiant energy which is in turn coupled into emitting CRTR 1610 and emitted as energy 1620. In many embodiments, more than one energy harvesting CRTR will be utilized to power one emitting CRTR.

[0081] Fig. 7 also depict an optional arrangement where the sensing CRTR 1650 is on an opposite side of the banknote or the document. The skilled in the art would recognize that energy harvesting may be arranged at any side relative to the document. Notably, CRTRs or other transducers arranged in the display area may emit energy in color, and an arrangement of emitting transducers may form a recognizable pattern such as a number, a drawing, text, numerals, and the like.

[0082] If covert authentication is required, energy of specific characteristics may be required to operate the sensing/emitting pixel, or a specific radiant energy pattern may be emitted by the emitting transducers. By way of example, an overt authentication feature may be activated only when light having at least one specific frequency , and lacking at least one specific frequency, is shone on the energy harvester. Such construction may be embodied by a spectral limiter place on a transducer, and/or simple XOR logic or equivalent. Alternatively or in addition, emitters of a secret pre-selected set of spectral components may be disposed in predetermined areas on the banknote or document. A relatively small number of emitters may be placed at predetermined portions of the document, and each will shine in predetermined characteristics such as specific frequency, polarization, and a combination thereof, when activated. In some embodiments activation may be done by simply shining any type of radiation on the energy harvester. However in embodiments where only a specific combination of incoming energy will activate the hidden response from the coded emitters, the number of possible combinations is vast, and a potential forger will need to spend long time trying to decode which combination of energy on the energy harvester elicits a response, and what are the specific characteristics of the response. Notably, at least one energy harvester may be hidden. Clearly, logic may be embedded in the circuitry as well, and the device may act according to principles similar to those of the key/lock aspect of the invention.

[0083] Fig. 8 depicts s a simplified diagram depicting the face of an object to be authenticated 1900 such as banknote, a credit card, a document, and the like. A plurality of optical waveguides 1625 are embedded in the object 1900. A first zone 1610 comprises an input for the plurality of the waveguides, and may be embodied as individual inlets of the waveguide, or as a single inlet, the energy admitted thereto is later divided to individual waveguides. At least some of the waveguides terminate in a display zone 1620, where energy admitted to the first zone is outputted by the outputs of the waveguides 1633. Optionally, more than one group of waveguides is utilized, such as depicted by 1630 and the respective outlets 1635, to provide response to different patterns of emitted energy, such as by way of example shining light on only a portion of the first zone. Optionally, the outlets of the waveguides will be arranged in recognizable pattern. In one embodiment the waveguides comprise optical fibers. Notably, the option of having a single inlet feed more than one outlet is shown in the arrangement of the waveguides, where waveguides 1630 feed only one outlet, but 1625 feed more than one outlet. Filters may be placed on certain inlets to provide a color pattern.

[0084] Thus, in an embodiment of the invention there is provided an object authentication system comprising a plurality of waveguides embedded within an object having two substantially parallel faces, such as a banknote, a document, a credit card, and the like. Each of the plurality of waveguides having an aperture at respective ends of the waveguide. The waveguides being constructed to accept light via one aperture from a face of the object, and emit such light from the second aperture thereof; the waveguides being arranged within the object such that the first apertures of a plurality of waveguides are disposed in a first zone of the banknotes and the respective apertures of the waveguides are arranged at a pattern at a second zone of the banknotes. This will cause light being shone on the first zone to produce visible pattern of light in the second zone. In certain embodiments each waveguide comprises a plurality of sections. In certain embodiments the respective ends of the waveguides are disposed on opposing faces of the banknote or document, and in certain embodiments the ends of the waveguides are disposed on the same side. Optionally the waveguides are optical fibers.

[0085] In another embodiment there is provided a plurality of waveguides having two ends embedded within a banknote having two substantially parallel faces, a plurality of CRTR's are arranged in a pattern and embedded in a first zone of the banknote, each CRTR being optically coupled to at least one end of one of the plurality of the waveguides, wherein the waveguide provide at least a partial optical path to a second aperture disposed in a second zone of the banknote. In some embodiments the waveguide is optically coupled to a second CRTR at a second end of the waveguide, wherein the second aperture being the aperture of the second CRTR.

[0086] In yet another embodiment there is provided an document authentication system comprising a plurality of sensing CRTR's disposed in a first zone of the banknote or document, wherein energy entering into a sensing CRTR is being coupled to at least one LE transducer, the output of the LE transducer is electrically coupled to at least one EL transducers, the output of the EL transducer is optically coupled to at least one emitting CRTR's disposed at a second zone of the object. Preferably the emitting CRTRs are arranged in a pattern.

[0087] CRTRs may often benefit from having collimators placed in front of their apertures. While such collimators may find many uses, in the present authentication and key/lock aspects provided above, such collimators will allow precise operation of line-of-sight alignment of the key/lock or of the energy source to the authenticated object. Furthermore, it is often desirable to dynamically control the effective dimensions of the collimator. Notably, the effective dimension does not necessarily relates to a physical dimension, but may relate to the dimension which tunes the collimator to act as a collimator of a different physical dimension.

[0088] Fig. 9 depicts an embodiment where collimators 1250 are formed in a collimation layer 1210 and disposed over the CRTR cores 1202 and 1203. Cavities 1250 are formed in the collimation layer 1210, using any desired technique. Collimation layer 1210 may comprise a photo-reflective or photo-absorptive material, semiconductor material, and the like, or such material may comprise such material 1240 interspersed between the cavities. Electrodes 1215 and 1220 are disposed on both sides of the collimation layer. liquid crystal or other electrically controlled light modulator 1230 is formed at least partially over the walls of the cavity. When voltage is applied between electrodes 1215 and 1220, the collimator changes the effective dimensions and thus its collimation characteristics.

[0089] In an alternate construction collimator layer 1210 comprises a poled ferroelectric material having a changing dielectric constant dependent on a biasing electric field. In other applications the collimator layer 1210 comprises piezoelectric or electrostrictive regions such that a length dimension varies with applied electric field.

[0090] In yet other alternate constructions collimator layer 1210 comprises a compliant material which could be air or vacuum between two flexible, conductive membranes such that the electrostatic attractive or repulsive forces alter a dimension of the collimator. The source of the electric field may be any convenient generator, such as a capacitive or inductive generator, static generator, and the like.

[0091] Such embodiments are depicted generally in Fig. 10 where the effective dimension of the collimating cavities 1250 is changed by the application of an electric, magnetic, electrostatic, or a combined field induced by field generator 1212.

[0092] In some embodiments there is provided a tunable collimator comprising a collimation plate comprising an insulator, having two electrodes disposed on opposite faces of the plate, and a cavity extending between the two electrodes. Change of the collimator characteristics is obtained by applying a charge between the electrodes 1215 and 1220 would sufficiently modify the characteristics of radiant energy transferred via the cavity 1250.

[0093] The selection of the different options for the construction of the collimator are dictated by the desired design parameters of the collimator.

[0094] It will be appreciated that the invention is not limited to what has been described hereinabove merely by way of example. While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various other embodiments, changes, and modifications may be made therein without departing from the spirit or scope of this invention and that it is, therefore, aimed to cover all such changes and modifications as fall within the true spirit and scope of the invention, for which letters patent is applied.

We claim

1. An authentication system for authenticating an object, the system comprises a energy harvester embedded within a first zone of the object, and a plurality of light sources embedded within a second zone of the document, wherein the light sources are being coupled to the energy harvester such that the light sources emit light responsive to radiant energy being directed at the energy harvester.
2. The authentication system as claimed in claim 1 wherein aqt least a portion of the plurality of the light sources are arranged in a pattern.
3. The authentication system of claim any of claims 1 or 2, wherein the energy harvester comprises at least one Continuous Resonant Trap refractor (CRTR) coupled to LE type transducer.
4. The authentication system of claim any preceding claim, wherein at least one of the plurality of light sources comprises a CRTR coupled to a EL and/or to a RL transducer.
5. The authentication system of claim 4, wherein the at least one CRTR emits energy having at least one spectral component comprising asymmetrical polarization.
6. A document or banknote authentication system comprising a plurality of optical waveguides embedded within the document or banknote, each of the plurality of waveguides have an aperture at respective ends of the waveguide, the apertures being constructed to accept radiant energy from a face of the banknote or document into the respective waveguide, and emit such light from the second aperture of the respective waveguide.
7. An authentication system as claimed in claim 6, wherein, the first and second apertures of the waveguides are disposed on respectively opposing faces of the banknote or document.

8. A key-lock mechanism comprising:

   at least one radiant energy spectral splitter having an aperture and a first and a second channelized outputs, the channelized output directing different spectral components to respective transducers, when multi-spectral radiant energy in admitted via the aperture;

logic having inputs and a locked and unlocked states responsive to the inputs, the transducers being coupled to the inputs;

wherein the logic transitions from locked to unlocked state only when a XOR state exists between at least two of the inputs.

9. A key-lock mechanism as claimed in claim 8, wherein the spectral splitter comprises a Continuous Resonant Trap refractor (CRTR).

10. A key-lock mechanism comprising:

a plurality of radiant energy transducers disposed at spatial relationship therebetween;

logic having inputs and a locked and unlocked states responsive to the inputs,

wherein the transducers being coupled to the inputs, and the logic transitions from locked to unlocked state only when a XOR state exists between at least two of the inputs.

11. A key-lock mechanism as claimed in any preceding claim, further comprising a key having radiant energy emitters configured for emitting energy in a pattern that wil cause the logic to transition between the locked state and the unlocked state.

12. The key-lock mechanism of any of claims 8-11, the inputs are asserted as a function of radiant energy of differing polarization.

13. A tunable collimator comprising a collimation plate having a top and a bottom surfaces, the plate having at least one cavity defined by cavity wall, the cavity having walls extending between the top and the bottom layers, the walls comprising at least one radiant energy modulator.

14. The collimator of claim 13, wherein the plate comprises photo reflective material, photo absorptive material, semiconductive material, or any combination thereof.

15. The collimator as claimed in claims 13 or 14, wherein the modulator comprises a liquid crystal.

16. A tunable collimator comprising a plate having a top and bottom surfaces, and at least one cavity extending between the top and bottom surfaces, the plate comprising a poled ferroelectric material having a changing dielectric constant dependent on a biasing electric field.

17. A tunable collimator comprising a plate having a top and a bottom surface, and at least one cavity extending therebetween, the cavity having a length dimension, wherein the plate comprising at least one piezoelectric or electrostrictive region, such that the length dimension varies in response to a biasing electric field.

18. A tunable collimator comprising:

a bottom plate;

a top plate;

compliant material disposed between the top and bottom plates, the compliant matter having at least one cavity defined therein;

the top plate and the bottom plate being susceptible to electrostatic charge such that electrostatic attractive or repulsive forces applied to the membranes alter a distance therebetween.

19. A tunable collimator comprising a collimation plate having a top and a bottom electrodes, the plate having at least one cavity defined by cavity wall, the cavity having walls extending between the top and the bottom layers, the plate comprising an insulator material.

Fig. 1

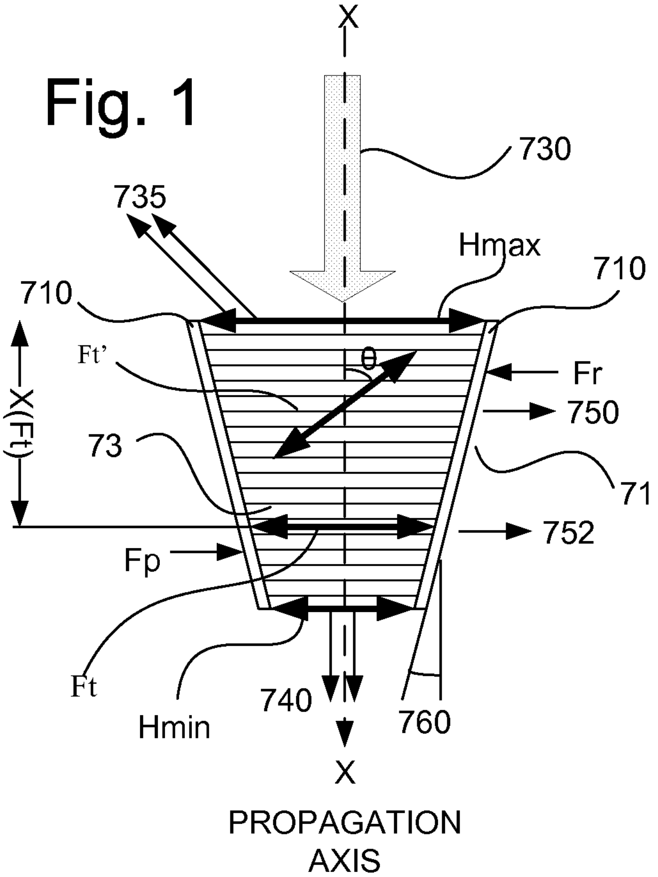


Fig. 1A

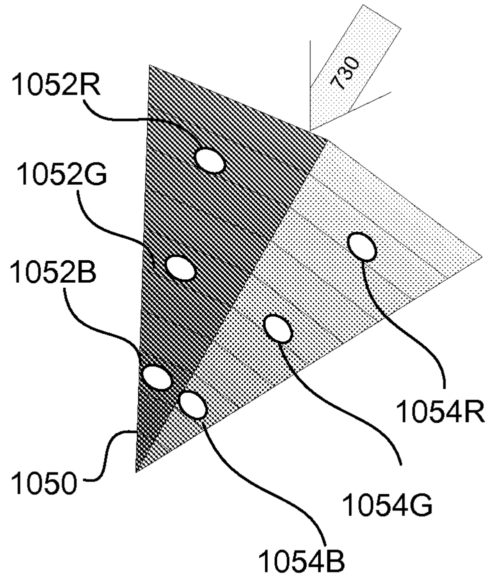


Fig. 2

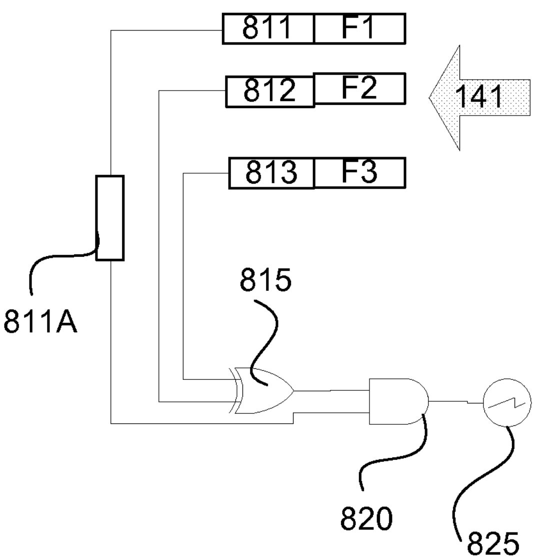
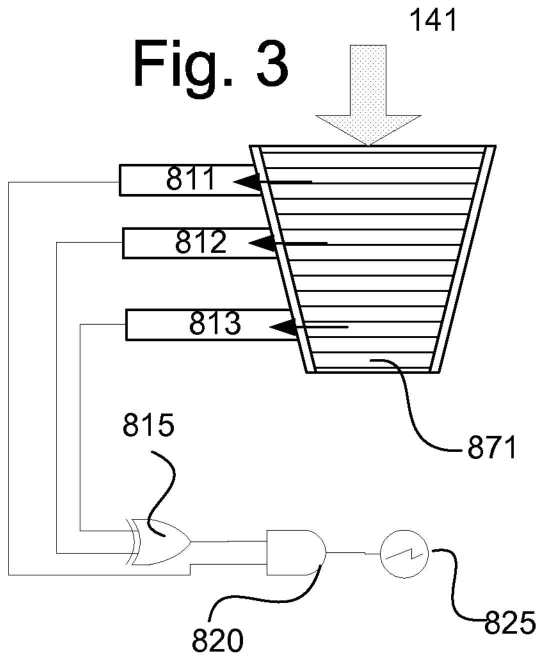


Fig. 3



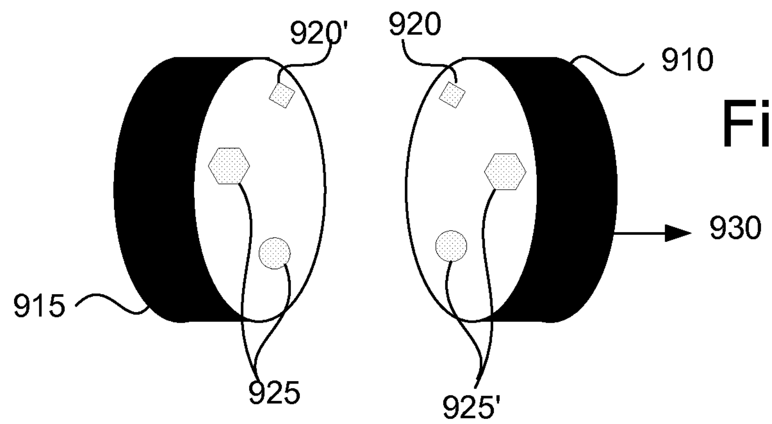


Fig. 4

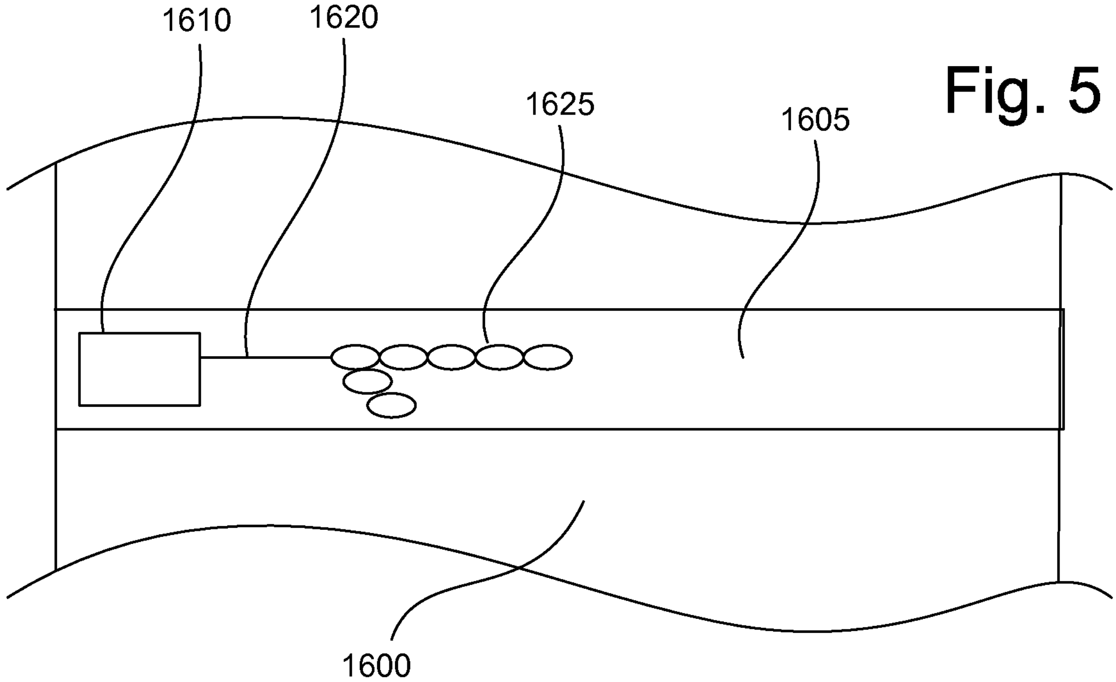


Fig. 5

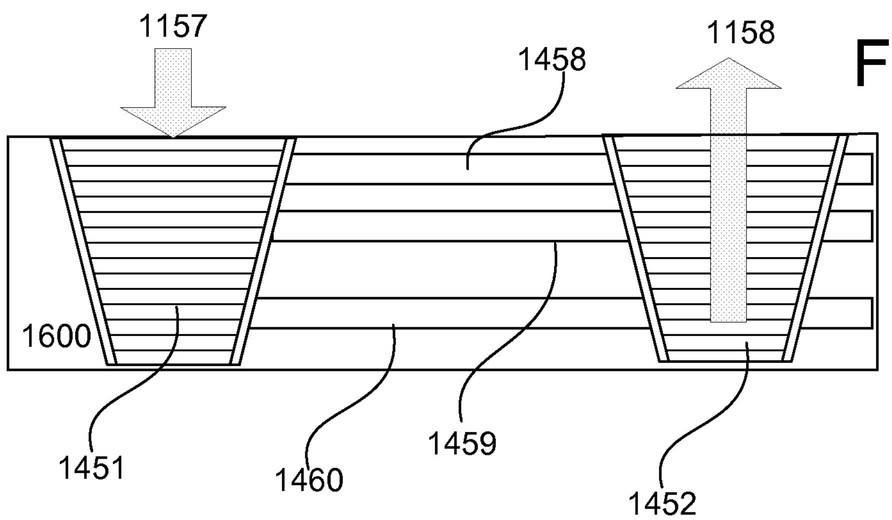


Fig. 6

Fig. 7

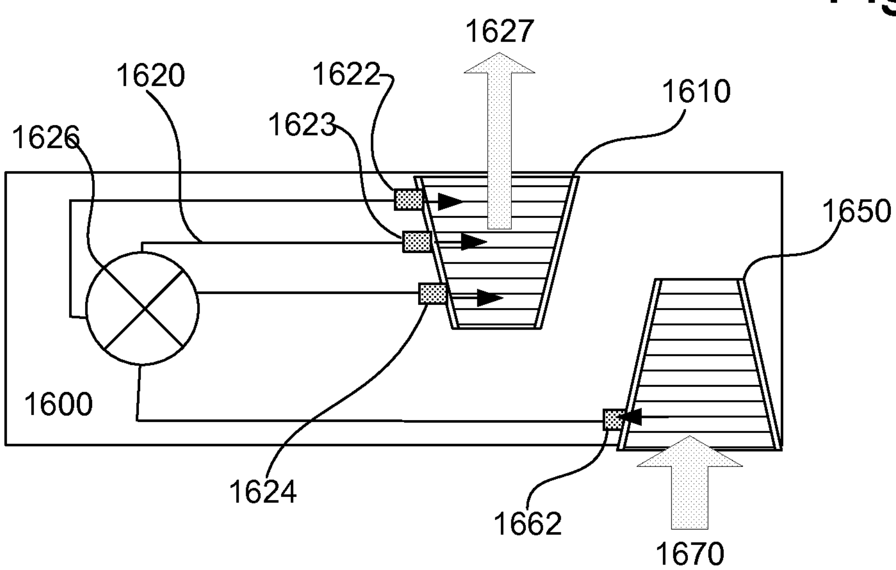

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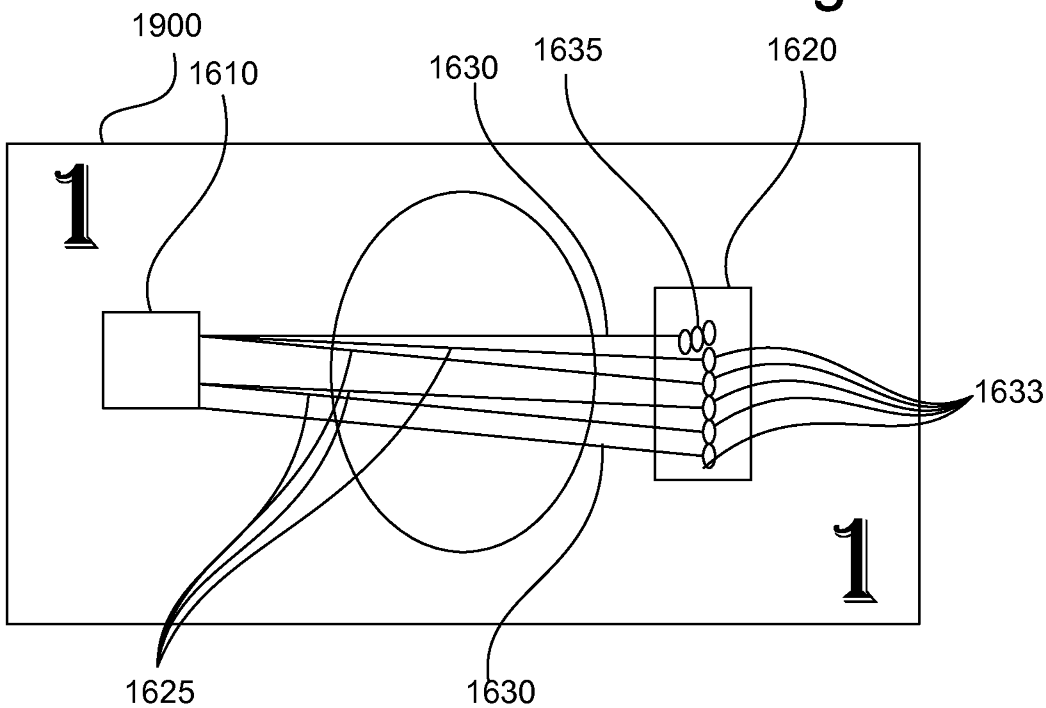
Fig. 8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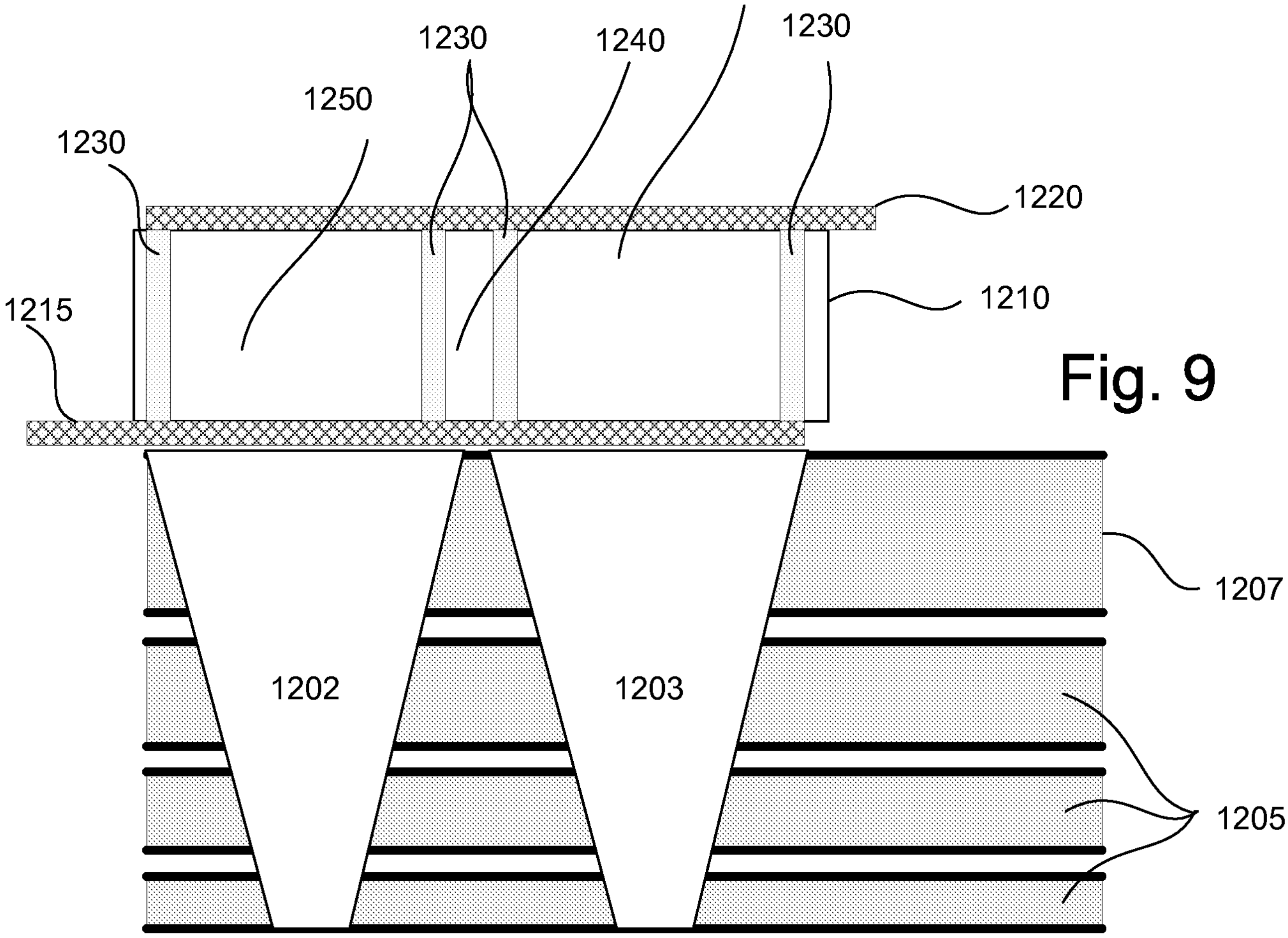
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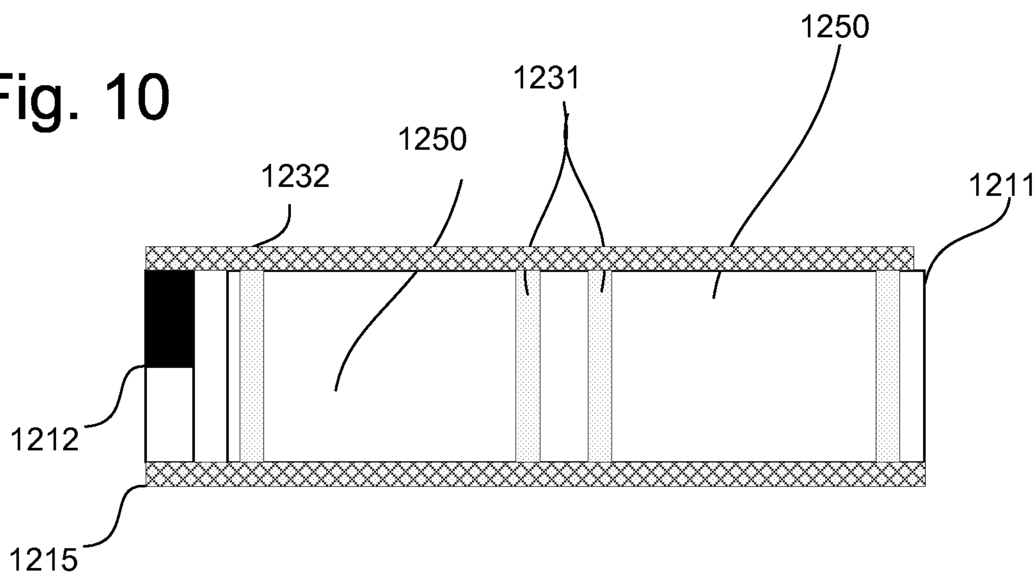
Fig. 9

Fig. 10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INTERNATIONAL SEARCH REPORT	International application No. PCT/US 2013/063741

A. CLASSIFICATION OF SUBJECT MATTER

G07D 7/12 *(2006.01)*
G02B 6/42 *(2006.01)*

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B41M 3/00, 3/10, 3/14, B42D 15/00, 15/10, G07D 7/00, 7/02, 7/06, 7/12, G09F 3/00, 3/02, G02B 6/00-6/42

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatSearch (RUPTO internal), USPTO, PAJ, Esp@cenet, DWPI, EAPATIS, PATENTSCOPE, Information Retrieval System of FIPS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	RU 2386543 C2 (ORELL FUESSLI SICHERHEITSDRUCK AG) 27.12.2008, p. 4, line 35-p. 5, line 21, p. 6, lines 9-20, p. 7, line 14-p. 8, line 9, fig. 2	1-2
A		3-5, 9
X	RU 2136048 C1 (GORBAN YURY IVANOVICH) 27.08.1999, abstract, p. 4, lines 38-42, fig. 1	6
X	US 2001/0010333 A1 (WENYU HAN et al.) 02.08.2001, [0002]-[0004], [0080], fig. 12	6-7
X	US 5633975 A (THE UNITED STATES OF AMERICA AS REPRESENTED BY THE ADMINISTRATOR OF THE NATIONAL AERONAUTICS AND SPA) 27.05.1997, abstract, col. 2, line 46-p. 3, lines 9, 60-col. 4, line 64, col. 5, line 65-col. 6, line 15, fig. 1, 4, 5	8

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT	International application No. PCT/US 2013/063741

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5206521 A (NOVEDADES ELECTRONICAS INTERNACIONALES S.A. DE C.V.) 27.04.1993, col. 3, line 1-col. 5, line 30, fig. 1A, 1B	10-12
X	US 2005/0122559 A1 (REBOA PAUL F. et al.) 09.06.2005, abstract, [0015], [0029]-[0035], [0051]-[0056], fig. 2, 4A, 4B	13-15, 19
Y		16, 18
Y	US 4576441 A (UNITED TECHNOLOGIES CORPORATION) 18.03.1986, abstract, col. 1, lines 37-42, col. 2, line 54-col. 3, line 37, fig. 2, 3	16
X	WO 2008/100154 A1 (POLIGHT AS et al.) 21.08.2008, p. 4, lines 20-23, p. 5, line 27-p. 6, line 20, fig. 1a, 1b, 2d	17
Y	US 2004/071180 A1 (WANG JIAN et al.) 15.04.2004, abstract, claims 1-6, fig. 1, [0023]-[0028]	18