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(54) **Outgoing efficiency control device, projection type display apparatus, infrared sensor and non-contact thermometer**

Vorrichtung zur Kontrolle der Ausgangsleistung, Projektionsanzeigevorrichtung, Infrarotsensor und berührungsloses Thermometer

Dispositif de commande de la puissance sortante, équipement d'affichage à projection, capteur à infrarouge et thermomètre sans contact

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(56) References cited:
EP-A- 0 547 493 WO-A-93/22694
US-A- 3 995 937 US-A- 4 856 869

- **PATENT ABSTRACTS OF JAPAN vol. 011, no. 087**
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Description

TECHNICAL FIELD

[0001] The present invention relates to an infrared sensor and a non-contact thermometer which use an output efficiency control device.

BACKGROUND ART

[0002] An optical modulator modulates the intensity of incident light and outputs it. As a conventional example, there has been an optical modulator described in U.S. Patent No. 5,311,360 and an article "Deformable Grating Optical Modulator" (Optics Letters, Vol. 17, No. 9, May 1, 1992) by O. Solgaard et al. This optical modulator modulates the intensity of light by utilizing the diffraction effect of light and has the advantage of being miniaturized and mass-produced in an IC process.

[0003] Figure 24 (a) is a plan view of an optical modulator described in the above-mentioned U.S. Patent and article, and Figure 24 (b) is a cross-sectional view taken along a line K-K' in Figure 24 (a).

[0004] The optical modulator includes a silicon substrate 1001, a spacer layer 1002 made of a silicon oxide film formed in a peripheral region of the silicon substrate 1001, and a dielectric layer 1003. The dielectric layer 1003 is patterned to a plurality of minute dielectric beams 1004, and the dielectric beams 1004 float in a hollow space with both ends supported by the spacer layer 1002. The dielectric layer 1003 is made of a silicon nitride film rich in silicon, and its residual stress is reduced to about 200 MPa. The thickness of the spacer layer 1002 and the dielectric layer 1003 is set to be equal to 1/4 of a wavelength of light whose efficiency is to be controlled, i.e., light which is incident upon the optical modulator.

[0005] Openings 1005 each having a width equal to that of each dielectric beam 1004 are formed between the dielectric beams 1004. Furthermore, an Al reflective film 1006 which also functions as an electrode is provided above the substrate 1001. The reflective film 1006 is composed of upper reflective films 1007 formed on the surfaces of the dielectric beams 1004 and lower reflective films 1008 formed on the surface of the substrate 1001 through the openings 1005. The upper reflective films 1007 and the lower reflective films 1008 form a reflection-type grating.

[0006] The optical modulation principle of a conventional optical modulator having the above-mentioned structure will be described with reference to Figures 25 (a) and (b). In these figures, components identical with those in Figure 24 are denoted by the reference numerals identical with those in Figure 24, and their description will be omitted.

[0007] Figure 25 (a) shows a state where a voltage is not applied between the reflective film 1006 and the substrate 1001. At this time, the difference in step between the upper reflective films 1007 and the lower reflective

films 1008 is 1/2 of a wavelength of the incident light, and the difference in optical path between light reflected from the upper reflective films 1007 and light reflected from the lower reflective films 1008 is one wavelength. Therefore, the phases of these light beams are matched. Thus, the reflection-type grating functions as an ordinary mirror with respect to incident light 1010 which is incident upon the grating, and the incident light 1010 becomes zero-th order diffracted light 1011 to be reflected to an incident side.

[0008] On the other hand, under the condition that a voltage is applied between the reflective film 1006 and the substrate 1001, the reflective film 1006 and the substrate 1001 forms a capacitor interposing the dielectric layer 1003 and an air layer 1012, and the reflective film 1006 is positively charged and the substrate 1001 is negatively charged. Since an electrostatic attracting force is affected between the charges, the dielectric beams 1004 are bent and attracted to the substrate 1001 until they come into contact with the substrate 1001, as shown in Figure 25 (b). At this time, the difference in step between the surfaces of the upper reflective films 1007 and those of the lower reflective films 1008 becomes 1/4 of a wavelength of the incident light, and the difference in optical path between the light reflected from the surfaces of the upper reflective films 1007 and the light reflected from the surfaces of the lower reflective films 1008 becomes a 1/2 wavelength in round travel, whereby the phases between these light beams are shifted by a half wavelength. Thus, the light reflected from the upper reflective film 1007 and the light reflected from the lower reflective film 1008 cancel each other to eliminate zero-th order diffracted light, and diffracted light other than the zero-th order diffracted light is output. For example, at this time, ± 1 st order diffracted light beams 1013a and 1013b are generated at a diffraction efficiency of 41%, respectively. As described above, the optical modulator is capable of modulating incident light by turning on/off a voltage applied to the reflective film 1006 and the substrate 1001.

[0009] However, the above-mentioned conventional optical modulator modulates incident light having a beam diameter at most with a size of the grating. Thus, in order to modulate incident light having a large diameter, it is required to increase the size of the grating. However, when the grating is increased in size, the grating is likely to adhere to the silicon substrate 1001 during the step of floating the grating by a half wavelength. Therefore, it was difficult to produce such a conventional optical modulator with a good yield.

[0010] The objective of the present invention is to provide an infrared sensor and a non-contact thermometer which use an output efficiency control device, the output efficiency control device is capable of obtaining a uniform diffraction effect.

DISCLOSURE OF THE INVENTION

[0011] An infrared sensor and a non-contact thermom-

eter of the present invention are defined in the independent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

Figure 1 is a view showing a structure of an optical modulator in Embodiment 1 **(a)** is a perspective view seen from a lower surface and **(b)** is a side view.

Figure 2 is a cross-sectional view taken along a line **A-A'** in Figure 1.

Figure 3 shows an example of diffraction-type elliptical microlenses: **(a)** is a plan view and **(b)** is a cross-sectional view of one of the microlenses in **(a)**.

Figure 4 illustrates the steps of producing an output efficiency control device in Embodiment 1.

Figure 5 is a view showing a structure of an optical modulator using a movable mirror as an output efficiency control device.

Figure 6 is a perspective view seen from a lower surface showing a structure of the optical modulator in Embodiment 2.

Figure 7 is a perspective view showing a structure of an infrared sensor using the output efficiency control device in Embodiment 3 of the present invention.

Figure 8 is a side view of the infrared sensor in Figure 7.

Figure 9 is a plan view of a lens of the infrared sensor in Figure 7.

Figure 10 is a view showing an example of a spot shape on a pyro-electric element: **(a)** shows the case where incident light is focused on the pyro-electric element using a conventional circular lens and **(b)** shows the case where a lens is in the form of a rectangle.

Figure 11 shows a structure of an output efficiency control device in Embodiment 3: **(a)** is a plan view and **(b)** is a cross-sectional view taken along a line **B-B'** in **(a)**.

Figure 12 illustrates the steps of producing the output efficiency control device in Figure 11.

Figure 13 illustrates an operation of the output efficiency control device in Figure 11.

Figure 14 is a view showing a structure of an output

efficiency control device in Embodiment 4: **(a)** is a plan view and **(b)** is a cross-sectional view taken along a line **E-E'** in **(a)**.

Figure 15 shows a structure of an output efficiency control device in Embodiment 5: **(a)** is a plan view and **(b)** is a cross-sectional view taken along a line **F-F'** in **(a)**.

Figure 16 illustrates the steps of producing the output efficiency control device in Figure 15.

Figure 17 illustrates an operation of the output efficiency control device in Figure 15.

Figure 18 is a view showing a structure of an infrared sensor in Embodiment 6 of the present invention: **(a)** is a side view and **(b)** is a view seen in a -x direction from a plane which is parallel to a y-z plane and includes a line **G-G'**.

Figure 19 is a view showing a structure of an infrared sensor in Embodiment 7 of the present invention.

Figure 20 is a view showing a structure of an output efficiency control device array in the infrared sensor in Figure 19: **(a)** is a plan view, **(b)** is a cross-sectional view taken along a line **H-H'** in **(a)**, and **(c)** is a cross-sectional view taken along a line **I-I'** in **(a)**.

Figure 21 is a view showing a structure of means for measuring a two-dimensional intensity distribution of a light source (heat source) using the output efficiency control device array in Embodiment 7.

Figure 22 is a view showing a structure of an infrared sensor in Embodiment 8 of the present invention: **(a)** is a side view and **(b)** is a view seen in a -x direction from a plane which is parallel to a y-z plane and includes a line **J-J'**.

Figure 23 is a cross-sectional view showing a structure of a non-contact thermometer in Embodiment 9 of the present invention.

Figure 24 is a view showing a structure of a conventional optical modulator: **(a)** is a plan view and **(b)** is a cross-sectional view taken along a line **K-K'** in **(a)**.

Figure 25 illustrates an optical modulation principle of a conventional optical modulator.

Figure 26 is a plan view of an array of diffraction-type elliptical microlenses.

Figure 27 is a view showing a structure of an optical modulator using an array of movable mirrors.

BEST MODE FOR CARRYING OUT THE INVENTION

(Embodiment 1)

[0013] Figures 1(a) and (b) are a perspective view seen from a lower surface showing a structure of an optical modulator in Embodiment 1 and a side view thereof, and Figure 2 is a cross-sectional view taken along a line A-A' in Figure 1.

[0014] In the optical modulator of the present embodiment, as shown in Figure 1, a microlens 3a as first focusing means and a microlens 3b as second focusing means are formed on a first surface which is a surface of a transparent substrate 1 made of glass or the like having a thickness of, for example, 2 mm. The microlenses 3a and 3b are provided adjacent to each other, having the identical shape.

[0015] A reflection-type output efficiency control device 2 is formed on a second surface opposing the first surface of the transparent substrate 1. The output efficiency control device 2 is provided with its center disposed at a crossed point of a vertical line to the plane (first surface) on which the lenses are formed, extending from the center of a straight line connecting the center of the lens 3a to the center of the lens 3b, and the plane (second surface) on which the output efficiency control device 2 is formed. In other words, in the present embodiment, the output efficiency control device 2 is disposed right below the middle point between the microlenses 3a and 3b.

[0016] In the present embodiment, circular lenses having an aperture of 1 mm were used as the microlenses 3a and 3b. Such circular lenses may be produced by any method. In the present embodiment, a resist is coated on a substrate 1, the substrate 1 is baked at a softening temperature of the resist or higher so as to cause the resist to flow, and the resist is formed into a mountain shape by surface tension.

[0017] In the present embodiment, although circular microlenses are used, the shape of the microlens is not limited thereto. For example, rectangular or elliptical lenses can be used. Furthermore, a diffraction-type microlens or an aspheric lens may be produced by a semiconductor process such as photolithography, etching, and deposition. Figure 3(a) is a plan view showing an example of diffraction-type elliptical microlenses. Figure 3(b) is a cross-sectional view of one microlens in Figure 3(a) taken along an x-z plane. A diffraction-type microlens having a binary/multi-level structure in the form of steps in cross-section as shown in Figure 3(b) can be mass-produced by repeat photolithography, etching/deposition of thin films used in an ordinary semiconductor process. Therefore, microlenses having outstanding mass-productivity and production precision can be obtained.

[0018] For example, incident light 4 having a beam diameter of 0.9 mm is incident upon the microlens 3a so that an optical axis of the incident light 4 is at an angle of θ_1 (e.g., 20.2°) with respect to in a z-axis direction

shown in Figure 1(b), travels through the substrate 1 while the optical axis thereof is at an incident angle of θ (e.g., 13.3°), and is focused onto the output efficiency control device 2. Here, the incident light 4 is reflected (reflection angle: θ , e.g., 13.3°), is collimated by the microlens 3b, and is output as outgoing light 5 with the optical axis being at an output angle of θ_1 (e.g., 20.2°).

[0019] In the present embodiment, a light-absorbing member 6 is provided in a region of the surface of the transparent substrate 1 other than the regions where the microlenses 3a and 3b and the output efficiency control device 2 are formed. The light-absorbing member 6 was produced by coating a film which has a light-absorbing function with respect to a wavelength of incident light, e.g., a carbon or phthalocyanine compound mixed with a polymer such as polyimide and PMMA. However, the structure and method for production of the light-absorbing member 6 are not limited thereto. The light-absorbing member 6 may be formed by vapor-depositing an organic film of a pigment or the like having a light-absorbing effect with respect to a wavelength of incident light. Such a light-absorbing member 6 has the effect of removing stray light in the substrate 1 and from outside of the substrate 1 and improving an S/N ratio of the outgoing light 5.

[0020] In the present embodiment, the light-absorbing member 6 is also provided on the periphery of the microlenses 3a and 3b. Such a structure has the advantage of allowing only the regions with satisfactory lens characteristics to be used as first and second focusing means, without using the periphery of the microlenses where the lens characteristics are generally likely to degrade due to the surface tension with respect to the substrate 1.

[0021] The plane structure of the output efficiency control device 2 is shown as a perspective view in Figure 1 (a), and the output efficiency control device 2 has a size of, for example, $100\ \mu\text{m} \times 100\ \mu\text{m}$. Hereinafter, referring to Figures 2 and 4, the structure and the production steps of the output efficiency control device 2 will be described. In the following description of the structure of the output efficiency control device 2, the structure is described, seen from the reverse surface (second surface) of the substrate 1, and therefore, the vertical relationship is opposite to that in Figure 2.

[0022] First, as shown in Figure 4(a), a transparent conductive film 7 which functions as a first electrode and a reflective film 8 are formed in this order on one surface of the transparent substrate 1. In the present embodiment, a glass substrate with a thickness of 2 mm is used as the substrate 1, an ITO film with a thickness of 500 Å is formed on the substrate 1 as the transparent conductive film 7, and an Al film with a thickness of, for example, 4000 Å is formed as the reflective film 8.

[0023] Then, a resist mask (not shown) is formed on the reflective film 8, and the reflective film 8 is patterned to an appropriate shape by etching, whereby a first grating 8a is formed as shown in Figure 4(b). Thereafter, as shown in Figure 4(c), an insulating layer 9 with a thickness of L_2 is formed so as to cover the grating 8a. In the

present embodiment, a SiO_2 layer with a thickness of $0.086\text{ }\mu\text{m}$ was formed as the insulating layer 9. The insulating layer 9 is used for preventing a short circuit between the first grating 8a and a second grating 8b described later.

[0024] Furthermore, a sacrifice layer 10 and a reflective film 8' are formed as shown in Figures 4(d) and 4(e). In the present embodiment, a polyimide layer with a thickness of $0.3\text{ }\mu\text{m}$ was formed as the sacrifice layer 10 and an Al film with a thickness of, for example, $4000\text{ }\text{\AA}$ was formed as the reflective film 8'. The sacrifice layer 10 functions as a spacer layer. Then, a resist mask (not shown) is formed on the reflective film 8', and the reflective film 8' is patterned to an appropriate shape by etching, whereby a second grating 8b which functions as a second electrode and an electrode 8c are formed as shown in Figure 4(f). The second grating 8b is formed as a plurality of beams with both ends thereof supported on the sacrifice layer (spacer layer) 10 and electrically connected to the electrode 8c. Finally, the sacrifice layer 10 is removed. This allows a space with a distance of L_3 to be formed between the second grating 8b and the insulating layer 9.

[0025] When a voltage is applied between the first electrode 7 and the second electrode 8b, the second grating 8b comes into contact with the SiO_2 layer 9 by electrostatic force. As a result, the distance between the first and second gratings 8a and 8b changes. This enables even the output efficiency of incident light from the substrate 1 side to be controlled.

[0026] A thickness L_2 of the SiO_2 layer 9 and a distance L_3 in the space between the second grating 8b and the SiO_2 layer 9 are set so as to satisfy $L_2 = \lambda/(4n\cos\theta)$, $L_3 = \lambda/(4\cos\theta_1)$, where the refractive index of the SiO_2 layer 9 is n (e.g., 1.5) and the wavelength of the incident light 4 is λ . (e.g., $0.5\text{ }\mu\text{m}$). Thus, under a state where a voltage is not applied as shown in Figure 2(a), the distance between the first grating 8a and the second grating 8b seen from the incident light 4 side becomes a $1/2$ wavelength, and the phases of light are matched in round travel. That is, the output efficiency control device 2 functions in the same way as in a mirror under no application of voltage, and only the reflected light 5 which is zero-th order diffracted light is generated. On the other hand, the distance between the first grating 8a and the second grating 8b becomes a $1/4$ wavelength under the application of a voltage as shown in Figure 2(b). Therefore, the phases become opposite in round travel, and reflected light beam disappears, whereby ± 1 st order diffracted light 11a and 11b are generated. That is, the intensity of the reflected light 5 or the intensities of ± 1 st order diffracted light 11a and 11b can be modulated; however, in the present embodiment, reflected light (zero-th order diffracted light) is paid attention to, and the reflected light is modulated.

[0027] The optical modulator focuses the incident light 4 onto the microlens 3a, directs the incident light 4 onto the output efficiency control device 2, collimates reflected light which is zero-th order diffracted light by the micro-

lens 3b, and outputs the collimated light as the outgoing light 5. This enables the efficiency of the outgoing light to be modulated by using the output efficiency control device 2 with an area much smaller than beam diameters of the incident light 4 and the outgoing light 5. In the output efficiency control device 2 with a size of $100\text{ }\mu\text{m} \times 100\text{ }\mu\text{m}$ produced as described above, the second grating 8b is not likely to adhere to the SiO_2 layer 9 during the step of floating the second grating 8b. Thus, an output efficiency control device 2 can be produced with a good yield.

[0028] Moreover, since the grating portion decreases in size, response speed can be improved.

[0029] Furthermore, in the optical modulator of the present embodiment, as described above, the microlenses 3a and 3b and the output efficiency control device 2 are monolithically integrated on the front and reverse surfaces of the transparent substrate 1. Thus, an optical modulator which is stable in terms of structure can be obtained.

[0030] In the case where incident light is focused onto the output efficiency control device 2 by using a microlens, it is required to dispose the output efficiency control device 2 exactly on the focal point of the microlens. However, in the optical modulator of the present embodiment, the distance between the microlens and the output efficiency control device 2 can be precisely set with ease only by prescribing the thickness of the transparent substrate 1 so as to correspond to the focal length of the microlens. Thus, assembly can be conducted with good precision.

[0031] An output efficiency control device and focusing means for focusing incident light onto the output efficiency control device may be provided on separate substrates and then combined. Furthermore, a conventional optical modulator and a microlens can be combined, although they cannot be integrated.

[0032] Furthermore, in place of the reflection-type output efficiency control device used in the present embodiment, a combination of an output efficiency control device which functions in the form of a transmission type and reflecting means such as a mirror, may be used with first and second focusing means such as microlenses.

[0033] A device with a grating structure utilizing diffraction is used as the output efficiency control device in the present embodiment. The output efficiency control device is not limited thereto. Any device which is capable of controlling an output efficiency of light can be used. For example, a movable mirror with a micro mirror structure capable of being controlled by electrostatic force may be used.

[0034] Figure 5 shows a structure in cross-section of an optical modulator using a movable mirror as an output efficiency control device. In this optical modulator, a substrate 20 with a movable mirror 24 provided on one surface and a transparent substrate 22 with microlenses 3a and 3b as first and second focusing means provided on one surface are disposed in such a manner that the mov-

able mirror **24** faces the microlenses **3a** and **3b**. Each movable mirror **24** is disposed right below a middle point between the adjacent microlenses **3a** and **3b** in the same way as in the above-mentioned output efficiency control device **2** with a grating structure, reflects light **4** which is incident through the microlens **3a**, and outputs the light **4** as reflected light **5** through the microlens **3b**. In the optical modulator with such a structure, light modulation is conducted utilizing only the reflection of light. Therefore, there is an advantage in that the output efficiency does not depend upon a wavelength of the incident light **4** and the device is easy to use.

(Embodiment 2)

[0035] Figure **6** is a perspective view seen from a lower surface, showing a basic structure of an optical modulator of Embodiment 2. In Figure **6**, the same components as those in Figure **1** are denoted by the same reference numerals as those therein, and the description thereof will be omitted.

[0036] The optical modulator of the present embodiment is different from that in the above-mentioned Embodiment 1 only in the structures of the first focusing means for focusing light onto an output efficiency control device **2** and second focusing means for outputting light from the output efficiency control device **2**. In Embodiment 1, the circular microlenses **3a** and **3b** are used as the first and second focusing means. However, in the present embodiment, elliptical microlenses **3'a** and **3'b** are provided in such a manner that their major axes are adjacent to each other.

[0037] Each of the elliptical microlenses **3'a** and **3'b** has a similar elliptical shape in which a cross-section in a thickness direction gradually becomes smaller. They are designed in such a manner that a size ratio of a major axis to a minor axis of an ellipsoid becomes $1/\cos\theta_1$, where θ_1 is an incident angle of incident light.

[0038] As described above, the microlenses **3'a** and **3'b** are designed so as to have elliptical shapes in accordance with the incident angle, thereby aberration caused with respect to light which is obliquely incident upon the microlens is reduced and optical modulation can be conducted satisfactorily.

[0039] In the present embodiment, the size ratio of a major axis to a minor axis of an ellipsoid was prescribed to be, for example, 1.22 at, for example, $\theta_1 = 35^\circ$. The device was able to function satisfactorily even at such a large incident angle. In particular, as the elliptical microlenses, diffraction-type elliptical microlenses with a binary/multi-level structure as shown in Figures **3(a)** and **(b)** are suitable in terms of production.

(Embodiment 3)

[0040] Still another embodiment of the output efficiency control device of the present invention will be described by describing an infrared sensor to which the

output efficiency control device is applied.

[0041] In Embodiments 1 and 2, the grating of the output efficiency control device is in the form of a rectangle. In Embodiment 3, a trapezoidal grating configuration is adopted. Hereinafter, Embodiment 3 will be described with reference to the drawings.

[0042] Figures **7** and **8** are a perspective view showing a basic structure of an infrared sensor using an output efficiency control device of Embodiment 3 according to the present invention and a cross-sectional view thereof. An infrared sensor **100** of the present embodiment has an output efficiency control device **101**, a pyro-electric element **103**, and a lens **105**. The output efficiency control device **101** and the pyro-electric element **103** are accommodated in a housing **111**, as shown in Figure **8**. The lens **105** is attached to an upper surface of the housing **111**. The lens **105** is, for example, a diffraction-type lens with a square aperture made of silicon having a cross-section as shown in Figure **8** and focuses light **107** which is incident upon the infrared sensor **100**. The output efficiency control device **101** is disposed in the optical path of the light **107** focused by the lens **105** so as to be tilted by an angle of θ_2 from a surface parallel to the surface to which the lens **105** is attached. The pyro-electric element **103** is disposed in such a manner that at least part of light output from the output efficiency control device **101** is incident upon the pyro-electric element **103**.

[0043] Figure **9** is a plan view of the lens **105** shown in Figures **7** and **8**. As shown in Figure **9**, in the infrared sensor **100** of the present embodiment, the lens **105** is a diffraction-type lens which has an aperture in the form of, for example, a square and has, for example, a four-stepped cross-section. As shown in Figure **9**, in the present embodiment, diffraction gratings are formed into four corners of the square, whereby an area of the aperture of the lens is increased and light utilization efficiency is improved.

[0044] As shown in Figure **7**, the pyro-electric element **103** generally has a rectangular shape because of its readiness of production and cost efficiency. However, when incident light is focused, for example, by an ordinary circular lens, a spot shape on the pyro-electric element also has a circular shape. Figure **10** shows an example of a spot shape on the pyro-electric element **103**. Figure **10(a)** shows the case where incident light is focused onto the pyro-electric element using a conventional circular lens. As is apparent from Figure **10(a)**, four corner portions of the pyro-electric element become a dead space where light is not incident, so that the entire pyro-electric element cannot be effectively utilized.

[0045] Figure **10(b)** shows a spot shape in the case where the lens **105** is in the form of a rectangle as in Embodiment 3. A spot formed on the pyro-electric element **103** becomes a rectangle whose size is smaller than that in the case of using a circular lens, as shown in Figure **10(b)**, and a pyro-electric element having a smaller area can be used, resulting in a decrease in cost. More specifically, the pyro-electric element can be de-

creased in area by 25% by using a rectangular lens as a lens for focusing light onto the pyro-electric element. Simultaneously, it becomes possible to allow light to be incident upon the entire pyro-electric element, whereby the level of an output signal from the infrared sensor can be increased by 25% or more than a conventional value.

[0046] When a lens having a rectangular aperture is used as in Embodiment 3, a spot shape of light which is incident upon the output efficiency control device **101** becomes a trapezoid as shown in Figure 7. In the present embodiment, for example, the size of the lens **105** is $\square 3$ mm, the focal length thereof is 6 mm, and the tilt angle θ_2 is 45° , and the output efficiency control device **101** is disposed, for example, at a position in the middle between the lens **105** and the pyro-electric element **103**. Thus, the spot shape is a trapezoid with a side (lower side) closer to the lens **105** of 2.0 mm, a side (upper side) farther from the lens **105** of 1.2 mm, and a height (z-direction) of 2.3 mm.

[0047] Figure 11(a) is a plan view of the output efficiency control device **101** of Embodiment 3, and Figure 11(b) is a cross-sectional view taken along a line B-B' in Figure 11(a).

[0048] A substrate **121** of the output efficiency control device **101** is obtained, for example, by thermally oxidizing a Si wafer to form a thermal oxide film with a thickness of $0.1\ \mu\text{m}$, and depositing a silicon nitride film to a thickness of $0.2\ \mu\text{m}$ by low-pressure chemical vapor deposition (hereinafter, referred to as LPCVD) to form an insulating layer. A spacer layer **123**, for example, made of a silicon oxide film doped with a large amount of phosphorus is formed on the substrate **121**. An elastic layer **125** is formed on the spacer layer **123**. In Embodiment 3, the elastic layer **125** was formed of a silicon nitride film with its residual stress reduced. Beams **126** are formed by patterning the elastic layer **125** as shown in Figure 11(b), and upper reflective films **127** are formed on the beams **126**. Lower reflective films **128** are formed on the substrate **121**. These reflective films **127** and **128** are composed of, for example, Au, having a thickness of $0.1\ \mu\text{m}$. When focused infrared light **115** is incident upon the output efficiency control device **101** with such a structure, a spot **129** of incident light in the form of a trapezoid is formed on the output efficiency control device **101** as shown in Figure 11(a).

[0049] As shown in Figure 11(a), in Embodiment 3, the output efficiency control device **101** has a trapezoidal shape. This corresponds to the use of a rectangular lens which forms the light spot **129** in the form of a trapezoid as shown in Figure 11(a) on the output efficiency control device **101**, as described above. In Embodiment 3, as described above, the shape of the spot **129** has an upper side of 1.2 mm and a lower side of 2.0 mm. Thus, the width in the y-direction varies. Therefore, with a grating composed of beams parallel to each other as in a conventional output efficiency control device, the number of the beams in a spot varies in the vicinity of the upper side and lower side of the spot. This results in nonuniformity

of the diffraction at upper and lower positions. As a result, a modulation efficiency decreases. In contrast, with the output efficiency control device **101** of the present embodiment, the number of the beams in the spot **129** is made constant by changing the period of the beams **126** forming a grating in accordance with the shape of the spot **129**, whereby a uniform diffraction phenomenon is allowed to occur, preventing the diffraction efficiency from decreasing.

[0050] Next, referring to Figure 12, an example of the steps of producing the output efficiency control device **101** will be described. In Figure 12, the same components as those in Figure 11 are denoted by the same reference numerals as those therein. The description thereof will be omitted.

[0051] First, a substrate **121** with an insulating film formed thereon is produced. As a substrate, for example, a silicon substrate or the like is used. In the present embodiment, a silicon substrate was used and was thermally oxidized to form an oxide film having a thickness of $0.1\ \mu\text{m}$, and thereafter a silicon nitride film having a thickness of $0.5\ \mu\text{m}$ was deposited by LPCVD.

[0052] Then, as shown in Figure 12(a), a spacer layer **123**, for example, made of a silicon oxide film doped with a large amount of phosphorus is formed on the substrate **121**, for example, by LPCVD. The thickness of the spacer layer **123** is given as $\lambda/(4\cos\theta_2)$, where λ is a wavelength of light which is incident upon an output efficiency control device. In the present embodiment, the wavelength λ of incident light is prescribed to be $10\ \mu\text{m}$. θ_2 denotes a tilt angle of the output efficiency control device **101** with respect to a surface parallel to a surface to which a lens is attached, i.e., an angle at which light is incident upon the output efficiency control device. In the present embodiment, $\theta_2 = 45^\circ$, as described above. Thus, in the present embodiment, a silicon oxide film doped with a large amount of phosphorus was deposited to a thickness of $3.5\ \mu\text{m}$ by LPCVD.

[0053] Next, as shown in Figure 12(b), an elastic layer **125** having a thickness of $\lambda/(4\cos\theta_2)$ is formed on the spacer layer **123**. In the present embodiment, a silicon nitride layer whose tensile stress remaining in the layer is reduced to, for example, 200 MPa or less by increasing the ratio of the content of silicon was formed to a thickness of $3.5\ \mu\text{m}$ by LPCVD.

[0054] Then, a resist is spin-coated onto the elastic layer **125**, and the resist is exposed to light and developed, whereby a resist mask **131** is formed as shown in Figure 12(c). Then, the elastic layer **125** is patterned by dry etching to form beams **126** and openings **132**. Thereafter, the resist **131** is removed, and the spacer layer **123** positioned in the openings **132** and under the beams **126** is removed by isotropic wet etching using buffered hydrofluoric acid. Thus, as shown in Figure 12(e), the beams **126** are floated. As a result, both ends of the beams **126** are supported on the spacer layer **123**.

[0055] Finally, a reflective film, for example, made of Au having a thickness of $0.1\ \mu\text{m}$ is vapor-deposited on

the resultant substrate, whereby upper reflective films **127** and lower reflective films **128** are formed as shown in Figure **12(f)**. A grating structure of the output efficiency control device is completed in the above-mentioned steps.

[0056] The operation of the output efficiency control device constructed as described above will be described with reference to Figure **13**. In Figure **13**, the same components as those in Figure **12** are denoted by the same reference numerals as those therein. The description thereof will be omitted.

[0057] The output efficiency control device **101** of Embodiment 3 is operated by turning on/off a voltage applied between the upper reflective films **127** and the substrate **121**. Figure **13(a)** shows a state where a voltage is not applied between the upper reflective films **127** and the substrate **121**, and the beams **126** are floated and an air layer **137** is formed between the beams **126** and the substrate **121**. At this time, the difference in step between the surfaces of the upper reflective films **127** and the surfaces of the lower reflective films **128** is set to be a value represented by $\lambda/(2\cos\theta_2)$, for example, assuming that an incident angle at which light **135** to be modulated is incident upon the output efficiency control device **101** is θ_2 (see Figure **13**) and a wavelength of the light **135** is λ .

[0058] For example, in Embodiment 3, $\theta_2 = 45^\circ$ and $\lambda = 10 \mu\text{m}$, so that the value is $7.0 \mu\text{m}$. At this time, the difference in phase between light reflected from the upper reflective films **127** and light reflected from the lower reflective films **128** becomes 2π in round travel, which corresponds to one wavelength, thereby the phases are matched. Thus, the output efficiency control device **101** functions as an ordinary mirror, and the incident light **135** becomes zero-th order diffracted light **136** and is reflected to an incident side.

[0059] Next, as shown in Figure **13(b)**, when a voltage is applied between the upper reflective films **127** and the substrate **121**, the upper reflective films **127** which are upper electrodes and the substrate **121** which is a lower electrode forms a capacitor interposing the air layer **137** and an insulating layer (not shown) formed on the surface of the substrate **121**. The upper reflective films **127** are, for example, positively charged and the substrate **121** is, for example, negatively charged. Electrostatic attracting force is affected between the charges, so that the beams **126** are attracted to the substrate **121** side until it comes into contact with the surface of the substrate **121**, as shown in Figure **13(b)**. At this time, the difference in step between the surfaces of the upper reflective films **127** and the surfaces of the lower reflective films **128** is set to be a value given by $\lambda/(4\cos\theta_2)$, e.g. ; $3.5 \mu\text{m}$ in Embodiment 3. Thus, the difference in phase between light reflected from the surfaces of the upper reflective films **127** and light reflected from the surfaces of the lower reflective films **128** becomes π in round travel which corresponds to a half of a wavelength. Therefore, these light beams disappear. As a result, zero-th order diffracted light is eliminated, and diffracted light other than zero-order

diffracted light is output. For example, as shown in Figure **13(b)**, when a voltage is applied between the upper reflective films **127** and the substrate **121**, ± 1 st order diffracted light **138a** and **138b** are generated at a diffraction efficiency of 41%, respectively.

[0060] Actually, in the vicinity of portions (C portion and D portion in Figure **11(a)**) at both ends of each beam **126** supported on the spacer layer **123**, the beams **126** are not completely attracted to the substrate **121**. Therefore, as shown in Figure **11(a)**, the beams **126** are made longer than the spot **129** of incident light in a longitudinal direction, thereby light is prevented from entering these incomplete operation portions so as to prevent the modulation ratio from decreasing.

[0061] According to the above-mentioned operation, in the output efficiency control device **101** of Embodiment 3, it is possible to modulate the intensity of zero-th order diffracted light by turning on/off an applied voltage.

[0062] Next, the configuration of a grating portion of the output efficiency control device **101** in Embodiment 3. In particular, the setting of a period of the grating will be described. In the infrared sensor **100** of Embodiment 3, focused light is incident upon the output efficiency control device **101**, in place of collimated light. Therefore, the inventors of the present invention found the following: almost 100% zero-th order diffraction efficiency is obtained at the center in the y-direction in the grating portion of the output efficiency control device **101** (when a voltage is not applied); however, an incident angle is tilted as shown by an angle β in Figure **11(b)** on the periphery in the y-direction, so that the diffraction efficiency gradually decreases. For the same reason, when a voltage is applied, the zero-th order diffraction efficiency increases from 0% on the periphery of the grating, and the modulation efficiency of the light amount decreases as a whole. However, the inventors of the present invention found the following: when a period Λ of the grating is 7 times or more the wavelength λ of the incident light ($\Lambda/\lambda \geq 7$), the decrease in diffraction efficiency is small even in the case where light is obliquely incident, and the incident light as focused light causes no problem in the infrared sensor **100**. Therefore, in Embodiment 3, the minimum period Λ in the C portion of Figure **11(a)** is set to be, for example, $70 \mu\text{m}$.

[0063] Furthermore, as described above, in Embodiment 3, the period Λ of the grating is changed in accordance with the shape of the spot of incident light. More specifically, assuming that the focal length of the lens **105** is f and the length of one side of the square lens **105** is L , the period Λ of the grating in the D portion in Figure **16(a)** is prescribed to be at least $(2f + L\tan\theta_2)/(2f - L\tan\theta_2)$ times the period Λ in the C portion. For example, in Embodiment 3, since $f = 6 \text{ mm}$, $L = 3 \text{ mm}$, and $\theta_2 = 45^\circ$, the period Λ of the grating in the D portion is prescribed to be $117 \mu\text{m}$ or more which is 1.67 times the period Λ in the C portion.

[0064] As described above, according to the structure of the output efficiency control device **101**, diffraction was

performed uniformly at any portion of the grating with respect to a light spot in the form of a trapezoid, and high modulation efficiency was able to be obtained.

[0065] In the conventional output efficiency control device shown in Figures 32 and 33, the difference in step between the surfaces of the upper reflective films and the surfaces of the lower reflective films is changed from 1/2 of a used wavelength to 1/4 thereof, and the incident angle is prescribed to be 0°, i.e., light is made to be vertically incident, whereby incident light is modulated. However, in such a structure, since light was made to be vertically incident upon the output efficiency control device, it was difficult to separate zero-th order diffracted light from the incident light, and therefore diffracted light other than zero-th order diffracted light was utilized as outgoing light. Thus, the light utilization efficiency was extremely low. In the above-mentioned conventional output efficiency control device, the inventors of the present invention found the following: when light is made to be obliquely incident upon the output efficiency control device by tilting the output efficiency control device in order to utilize zero-th order diffracted light, the difference in phase at a time of driving does not become an appropriate value, so that the modulation efficiency decreases.

[0066] In contrast, in the output efficiency control device of Embodiment 3, the difference in step between the upper reflective films 127 and the lower reflective films 128 is set to be $\lambda/(2\cos\theta_2)$ and $\lambda/(4\cos\theta_2)$, respectively, in accordance with the value of incident angle θ_2 . Because of this, zero-th order diffracted light becomes capable of being easily separated without decreasing the modulation efficiency.

[0067] As described above, in the output efficiency control device of the present embodiment, a uniform diffraction effect can be obtained in the grating portion, and modulation characteristics do not degrade partially. The configuration of the grating (the difference in step between the upper reflective films and the lower reflective films, the period of beams, etc.) is designed in accordance with the conditions under which light is incident upon the output efficiency control device, i.e., an incident angle, the shape of a spot which the incident light forms on the grating, and the like, whereby light is allowed to be incident upon the output efficiency control device obliquely, not vertically. As a result, zero-th order diffracted light can be easily obtained as outgoing light without decreasing the modulation efficiency. Thus, a miniaturized infrared sensor with high light utilization efficiency and high sensitivity can be provided by using the output efficiency control device.

[0068] In Embodiment 3, in particular, the case where a lens for focusing incident light onto the output efficiency control device has a rectangular aperture, and the configuration of the grating is designed to be a trapezoid in accordance with the shape of a spot of light to be focused is described. However, the shape of the lens and the configuration of the grating are not limited thereto. Even when a lens has an aperture having another shape in

which the number of beams in a spot of incident light on the output efficiency control device is different, no problem is caused by setting the configuration of the grating in accordance with the shape of the spot. Furthermore, the period of the grating is not particularly required to change in its longitudinal direction according to a linear function. A function representing an appropriate configuration in accordance with the shape of a spot of incident light on the output efficiency control device should be appropriately selected.

(Embodiment 4)

[0069] Referring to Figure 14, an infrared sensor of Embodiment 4 according to the present invention will be described.

[0070] The infrared sensor of Embodiment 4 is different from that of Embodiment 3 only in the structure of an output efficiency control device. Therefore, in the following description, the description of a schematic structure of the infrared sensor will be omitted and only the output efficiency control device will be described.

[0071] Figure 14 is a view showing a structure of an output efficiency control device of Embodiment 4: (a) is a plan view and (b) is a cross-sectional view taken along a line E-E' in (a).

[0072] As shown in Figure 14(b) an output efficiency control device 190 of Embodiment 4 has a substrate 192, and a reflection-type grating is formed thereon. The substrate 192 is produced, for example, by thermally oxidizing a Si substrate to form a thermal oxide film with a thickness of 0.1 μm , depositing a silicon nitride film to a thickness of 0.2 μm by LPCVD, and forming an insulating layer. A spacer layer 193, for example, made of a silicon oxide film doped with a large amount of phosphorus is formed on the substrate 192. An elastic layer 194 and beams 195 formed by patterning the elastic layer 194 to a predetermined shape are provided on the spacer layer 193. The elastic layer 194 is, for example, made of a silicon nitride film with its residual force reduced. Upper reflective films 196 are formed on the beams 195. Furthermore, lower reflective films 197 are formed on the substrate 192 through openings 199 which are simultaneously formed with the beams 195. The reflective films 196 and 197 are, for example, made of Au having a thickness of 0.1 μm .

[0073] In the output efficiency control device 190 with such a structure, incident focused infrared light 191 forms a spot 198 having a shape as shown in Figure 14(a).

[0074] As is understood from Figure 14(a), the output efficiency control device 190 of Embodiment 4 is different from the output efficiency control device of Embodiment 3 shown in Figure 11 in the plane configuration of a grating formed by the beams 195 and the openings 199. The output efficiency control device 190 of Embodiment 6 is characterized in that the period of the grating is made larger in the longitudinal direction of the beams and the lengths of all the beams 195 are made equal. Figure 22

shows the case where both ends of the beams **195** are positioned on circumferences centered on the identical point, as an example of the output efficiency control device **190**.

[0075] In the output efficiency control device of Embodiment 3, as is understood from Figure **11(a)**, the lengths of the beams are not equal. Therefore, the beams are attracted in decreasing order of length under the application of a voltage, and the beams return to an original position in increasing order of length when a voltage is turned off. As a result, the transition times, i.e., the rise and fall times of on/off of light become longer, so that the driving frequency cannot be made high. For example, in the case where a high precision measurement is conducted within a short period of time by using an infrared sensor having an output efficiency control device, it is required to drive the output efficiency control device at a high speed. However, in the output efficiency control device of Embodiment 3, the limit of a high-speed operation limits the precision of the infrared sensor.

[0076] In contrast, in the output efficiency control device **190** of Embodiment 4, the lengths of all the beams **195** are equal, so that the beams completely simultaneously operate when a voltage is turned on/off. This allows an operation of on/off of light to be performed within a very short period of time. As a result, the output efficiency control device can be driven at a high frequency, and the infrared sensor using the output efficiency control device **190** of Embodiment 4 makes it possible to conduct a detection at a high precision.

[0077] In Embodiment 4, for example, the case where both ends of the beams **195** of the output efficiency control device **190** are positioned on circumferences centered on the identical point. However, both ends may be on any curve as long as the lengths of the beams **195** are equal. For example, by disposing the center in the width direction of the respective beams **195** on either end on one straight line, the size of the output efficiency control device capable of modulating a light spot of the same size can be decreased.

[0078] In Embodiment 4, as an example of the infrared sensor, the output efficiency control device in which the lengths of all the beams forming the grating are the same has been described. However, the present invention is not limited thereto. It is appreciated that, for example, even in the case where the lengths of all the beams forming the grating are the same in the output efficiency control device of the optical modulator of the display apparatus, the same effect can be obtained.

(Embodiment 5)

[0079] An infrared sensor of Embodiment 5 of the present invention will be described with reference to Figures **15** through **17**. The infrared sensor of Embodiment 5 is different from that of Embodiment 3 only in the structure of an output efficiency control device. Therefore, the description of a schematic structure of the infrared sensor

will be omitted, and only the structure of the output efficiency control device will be described.

[0080] Figure **15(a)** is a view showing a structure of an output efficiency control device **200** of Embodiment 5: **(a)** is a plan view and **(b)** is a cross-sectional view taken along a line **F-F'** in **(a)**. As shown in Figure **15(b)**, the output efficiency control device **200** of Embodiment 5 has a substrate **221**, and a reflection-type grating is formed thereon. The substrate **221** is produced, for example, by thermally oxidizing a Si substrate to form a thermal oxide film with a thickness of 0.1 μm and depositing a silicon nitride film to a thickness of 0.2 μm by LPCVD, thereby forming an insulating layer. First posts **222** are provided on the substrate **221**. The first posts **222** are formed, for example, by depositing polycrystalline silicon by LPCVD and patterning it. A spacer layer **223**, for example, made of a silicon oxide film doped with a large amount of phosphorus is provided on the periphery of the substrate **221**.

[0081] Furthermore, the output efficiency control device **200** has an elastic layer **224**, and second posts **225** and beams **226** formed by patterning the elastic layer **224** to a predetermined shape. The second posts **225** are provided on the first posts **222**. In Embodiment 5, the elastic layer **224** is composed of a silicon nitride film with its residual force reduced. Reflective films **227** are formed on the second posts **225**, and reflective films **228** are formed on the beams **226**. These reflective films **227** and **228** are, for example, made of Au, having a thickness of 0.1 μm .

[0082] Next, referring to Figure **16**, an example of the steps of producing the output efficiency control device **200** of Embodiment 5 will be described. In Figure **16**, the same components as those in Figure **15** are denoted by the same reference numerals as those therein. The description thereof will be omitted. Hereinafter, referring to Figure **16**, the production steps will be described in an orderly fashion.

[0083] First, a silicon substrate is, for example, thermally oxidized to form an oxide film having a thickness of 0.1 μm , a silicon nitride film is deposited to a thickness of 0.5 μm , for example, by LPCVD to form an insulating layer, whereby a substrate **221** is produced. Then, for example, polycrystalline silicon is deposited, for example, by LPCVD, on the substrate **221** and patterned, for example, by dry etching, whereby first posts **222** are formed as shown in Figure **16(a)**.

[0084] For example, a silicon oxide film doped with a large amount of phosphorus is deposited on the resultant substrate **221**, for example, by LPCVD and a spacer layer **223** is formed as shown in Figure **16(b)**. Thereafter, the spacer layer **223** is etched over the entire surface of the substrate **221** by dry etching, whereby the surface is made flat as shown in Figure **16(c)**. The thickness of the first posts **222** and that of the spacer layer **223** are prescribed to be $\lambda/(4\cos\theta^2)$, e.g., 3.5 μm in Embodiment 5.

[0085] Then, a silicon nitride film in which tensile stress remaining in the film is reduced to, for example, 200 MPa or less by increasing the content ratio of silicon is formed,

for example, by LPCVD, whereby an elastic layer **224** is formed. Although the thickness of the elastic layer **224** is arbitrary, it is prescribed to be 2 μm in Embodiment 5. Furthermore, as shown in Figure **24(d)**, the elastic layer **224** is patterned to form second posts **225** and beams **226**.

[0086] Next, the spacer layer **223** is wet-etched from gaps between the second posts **225** and the beams **226**, for example, with buffered hydrofluoric acid, and the spacer layer **223** under the beams **226** is removed, whereby the beams supported at both ends are formed. Thereafter, a reflective film made of Au, having a thickness of 0.1 μm is formed by vapor deposition, whereby reflective films **227** and **228** are formed. An output efficiency control device **200** having a structure as shown in Figure 15 is completed in the above-mentioned steps.

[0087] The operation of the output efficiency control device **200** constructed as described above will be described with reference to Figure 17. In Figure 17, the same components as those in Figures 15 and 16 are denoted by the same reference numerals as those therein. The description thereof will be omitted.

[0088] The output efficiency control device **200** of Embodiment 5 is operated in accordance with the same principle as that of the output efficiency control device of Embodiment 3 by turning on/off a voltage applied between the reflective films **228** as upper electrodes and the substrate **221** as a lower electrode. Figure 17 (a) shows a state where a voltage is not applied. At this time, the beams **226** are floated, and the reflective films **227** and **228** are on the identical plane. Therefore, the output efficiency control device **200** functions as an ordinary mirror, and incident light **231** becomes reflected light **232** and is reflected to an incident side.

[0089] Next, when a voltage is applied between the upper electrodes **228** and the lower electrode **221**, the beams **226** are attracted to the surface of the substrate **221** by electrostatic attracting force until it comes into contact with the surface of the substrate **221**, as shown in Figure 17(b), in accordance with the principle described in Embodiment 3. At this time, the difference in step between the surfaces of the reflective films **227** and the surfaces of the reflective films **228** is set to be a value given by $\lambda/(4\cos\theta_2)$. In Embodiment 5, it is prescribed to be 3.5 μm . λ is a wavelength of the incident light **231**, and θ_2 is an incident angle of the incident light **231** incident upon the output efficiency control device **200**. At this time, the difference in phase between light reflected from the surfaces of the reflective films **227** and light reflected from the surfaces of the reflective films **228** becomes n in round travel which corresponds to a half of a wavelength. As a result, reflected light is eliminated, and diffracted light other than zero-th order diffracted light is output. For example, at this time, +1st order diffracted light **233a** and **233b** as shown in Figure 17(b) is generated at diffraction efficiency of 41%, respectively.

[0090] According to the above operation, in the output efficiency control device **200** of Embodiment 5, the inten-

sity of reflected light can be modulated by turning on/off an applied voltage.

[0091] In the output efficiency control device of the above-mentioned Embodiment 3, light is modulated by a diffraction phenomenon both under the application of a voltage and under no application of a voltage. Therefore, diffraction efficiency decreases, for example, in the case where a wavelength band of light to be modulated is large. However, in the output efficiency control device **200** of Embodiment 5, modulation is conducted by a diffraction phenomenon in the same way as in Embodiment 4 under the application of a voltage; however, almost 100% light reflected from a mirror surface is output under no application of a voltage. Therefore, the modulation ratio can be increased as a whole. Furthermore, according to the structure of Embodiment 5, the thickness of the elastic layer **224** can be arbitrarily selected, so that this thickness can be prescribed to be thin. As a result, the distance between the reflective films **228** which function as upper electrodes and the substrate **221** which functions as a lower electrode can be decreased, and energy required for deforming the beams **226** becomes smaller, so that a driving voltage can be decreased.

[0092] As described above, in the output efficiency control device of Embodiment 5, light is output as reflected light from a mirror surface, not zero-th order diffracted light under no application of a voltage, whereby a high modulation ratio can be obtained even for incident light having a large wavelength band. Furthermore, the thickness of the elastic layer can be made thin, so that the device can be driven at a low voltage.

[0093] Herein, the output efficiency control device of the present embodiment is described by exemplifying an infrared sensor. However, the output efficiency control device of the present embodiment is not limited to an infrared sensor. For example, the output efficiency control device of the present embodiment is applicable to an optical modulator of a display apparatus.

(Embodiment 6)

[0094] Referring to Figure 18, an infrared sensor of Embodiment 6 will be described. According to Embodiment 8, an infrared sensor is provided, in which an output efficiency control device can be decreased in size, a pyroelectric element is not influenced even when an electromagnetic noise generated from the output efficiency control device becomes substantially large, and which hardly varies even when the distance between the sensor and a light source (heat source) is relatively short and is capable of obtaining a high signal level in the case where a light source is relatively small.

[0095] Figure 18 is a view showing a structure of an infrared sensor **300** of Embodiment 6: (a) is a side view of the infrared sensor **300** and (b) is a view seen in a -x direction from a plane which is parallel to a y-z plane and includes a line G-G'.

[0096] As shown in Figures 18(a) and (b), the infrared

sensor **300** has an output efficiency control device **342**, a pyro-electric element **343**, a lens **344**, and a spacer **345** which are accommodated in a housing **346**. As shown in Figure **18(a)**, the spacer **345** determines an incident angle θ_2 when light from a point heat source (light source) **341** is incident upon the output efficiency control device **342**. The housing **346** has an entrance window **347** on its upper surface. The entrance window **347** is obtained, for example, by forming a band-pass wavelength filter on a silicon substrate.

[0097] The difference between the infrared sensor **300** of Embodiment 6 and that of Embodiment 3 lies in that the output efficiency control device **342** is disposed between the light source **341** and the lens **344**. In this arrangement, the lens **344** can be provided with an effect as an electromagnetic shield, for example, by forming the lens **344** of a conductive material. Therefore, particularly in the case where beams become shorter with the miniaturization of the output efficiency control device **342** and a driving voltage for deforming the beams becomes high, resulting in generation of an electromagnetic noise or the like, the pyro-electric element **343** can be prevented from being influenced by the electromagnetic noise. In this case, the lens **344** can be composed of Si, Ge, GaAs, InP, GaP, ZnSe, ZnS, or the like. Furthermore, the lens **344** may have a surface relief structure in accordance with the phase modulation amount of the lens.

[0098] The lens **344** is designed so that the light source **341** is positioned at a distance d from the entrance window **347**, as shown in Figure **18(a)**, not at an infinite distance therefrom. According to this design of the lens **344**, the ratio of light which is focused onto the pyro-electric element **343** among light radiated from the light source **341**, the light utilization efficiency, and the level of a signal output from the pyro-electric element **343** are increased. The pyro-electric element **343** is disposed at a position which is shifted in an x-axis direction by Δf from the position on which incident light is focused by the lens **344** as shown in Figure **18(a)**. Thus, light is made to be uniformly incident upon the pyro-electric element **343**, thereby preventing light from being excessively focused in order not to irradiate only a partial region of the pyro-electric element **343** with strong light energy density. Also, the output of a signal from the pyro-electric element **343** can be prevented from decreasing.

[0099] Furthermore, in Embodiment 6, the lens **344** has a rectangular shape so that light is incident upon the entire surface of the pyro-electric element **343** for the same reason as that of Embodiment 3. Therefore, the shape of a spot of light on the output efficiency control device **342** has a direction opposite to that of the spot shape formed on the output efficiency control device of Embodiment 3, i.e., the shape of a spot becomes a trapezoid which is narrow on a +z side. Therefore, the grating configuration of the output efficiency control device **342** has a trapezoidal shape which is narrow on a +z side as shown in Figure **18(b)** for the same reason as that of Embodiment 4. Thus, light irradiated onto the output ef-

ficiency control device **342** can be uniformly diffracted.

[0100] The infrared sensor **300** in which each component is arranged as described above is operated in almost the same way as in the infrared sensor of Embodiment 3. More specifically, the output efficiency control device **342** is driven by turning on/off a voltage applied to the upper and lower electrodes of the output efficiency control device **342**, whereby the incidence or non-incidence of light to the pyro-electric element **343** is switched. This allows chopping of light to be achieved, and a signal is output from the pyro-electric element **343**, thereby it becomes possible to know the presence of the light source **341**, the intensity of light therefrom, and the like.

[0101] In Embodiment 6, in the case where electromagnetic noise generated from the output efficiency control device **342** is substantially large and in the case where the position of the light source with respect to the infrared sensor **300** is relatively constant and in particular, the size of the light source is small, the light utilization efficiency is high. Therefore, an infrared sensor with a very high sensitivity can be provided.

(Embodiment 7)

[0102] Referring to Figures **19** through **21**, the case where the output efficiency control device of Embodiment 7 of the present invention is used as an infrared sensor will be exemplified. The output efficiency control device of Embodiment 7 becomes capable of two-dimensionally measuring the intensity of infrared light, for example, in the case where it is used as an infrared sensor. In the past, in order to two-dimensionally measure the intensity of infrared light, for example, pyro-electric bodies are arranged in a two-dimensional array, and a two-dimensional intensity distribution is obtained from the output information of the respective pyro-electric bodies. However, according to such a method, a number of pyro-electric bodies are required, greatly increasing the price.

[0103] Figure **19** is a view showing a structure of an infrared sensor **400** of Embodiment 7. As shown in Figure **19**, the infrared sensor **400** includes an output efficiency control device array **453**, a lens **452** for focusing incident light **451** onto the output efficiency control device array **453**, and a pyro-electric element **454** receiving light from the output efficiency control device array **453**, and a spacer **455** determining an angle θ_2 at which the incident light **451** is incident upon the output efficiency control device array **453**. The infrared sensor **400** of Embodiment 7 is different from that of Embodiment 3 only in that the output efficiency control device array **453** is used in place of one output efficiency control device. Therefore, only this point will be described.

[0104] Figure **20** is a view showing a structure of the output efficiency control device array **453**: (a) is a plan view, (b) is a cross-sectional view taken along a line H-H' in (a), and (c) is a cross-sectional view taken along a line I-I' in (a). As is understood from Figures **20(a)** through (c), the output efficiency control device array **453** of Em-

bodiment 7 basically has a structure in which the output efficiency control devices of Embodiment 3 are arranged in an array.

[0105] As shown in Figures 20(b) and (c), the output efficiency control device array 453 has a substrate 461 on which an array of gratings is provided. In Embodiment 7, a silicon substrate on which wiring (not shown) or the like for applying a voltage is formed is used as the substrate 461. A spacer layer 463, for example, made of a silicon oxide film doped with a large amount of phosphorus is formed on the periphery of the substrate 461. Furthermore, an elastic layer 464, for example, made of a silicon nitride film with its residual stress reduced to, for example, 200 MPa or less of tensile stress is provided on the spacer layer 463.

[0106] Upper reflective films 466 and lower reflective films 467 are formed, for example, by vapor-depositing Au to a thickness of 0.1 μm . Lower electrodes 468 are formed on the substrate 461, as shown in Figures 20(b) and (c). The lower electrodes 468 are obtained, for example, by depositing a polysilicon film, whose sheet resistance is reduced to, for example, 20 $\Omega\cdot\text{cm}$, by being doped with a large amount of phosphorus, to a thickness of 0.5 μm on the substrate 461 by LPCVD, followed by patterning. The lower electrodes 468 are connected to the above-mentioned wiring (not shown) for a voltage application on the substrate 461 so that a voltage is applied to the lower electrodes individually. The upper reflective films 466 which also function as upper electrodes are at a bias potential having a constant potential difference with respect to a voltage applied to these lower electrodes 468; for example, the upper reflective films 466 are grounded. In the output efficiency control device array 453 having a structure as described above, a varying voltage, e.g., 0 [V], +30 [V] is applied to the individual lower electrodes 468, whereby the individual output efficiency control devices can be driven.

[0107] Next, an example of means for measuring the two-dimensional intensity distribution of a light source (heat source) using the output efficiency control device array 453 will be described with reference to Figure 29. Here, as an example of the output efficiency control device array, an array 473 in which 4×4 output efficiency control devices are arranged is considered. For the purpose of clear description, as shown in Figure 21, a, b, c, and d columns from the left side and 1, 2, 3, and 4 rows from above are used. Hereinafter, the two-dimensional intensity distribution of the heat source 471 having a two-dimensional intensity distribution, for example, as in a human body will be successively described.

(1) Only the output efficiency control device in an a1 portion of the output efficiency control device array 473 is driven to conduct optical modulation, whereby the intensity of, for example, infrared light which is incident upon the a1 portion is detected by the pyro-electric element 474.

(2) Next, only the output efficiency control device in an a2 portion is similarly driven to conduct optical modulation, whereby the intensity of infrared light in the a2 portion is detected.

(3) Thereafter, the output efficiency control devices in a3 through d4 portions are successively driven in the same way.

[0108] According to the above procedure, the distribution of two-dimensional infrared light intensity can be detected as signal information in time sequence, not as instant information. For example, in Embodiment 9, the pyro-electric element 474 which takes 5 msec for detecting a signal was used. Therefore, for example, it was required to take about 1.3 seconds for obtaining a screenful of information in an array composed of a 16×16 device group.

[0109] In the output efficiency control device array of Embodiment 7, a rectangular lens is used so as to obtain a two-dimensional intensity distribution in a rectangular region. At this time, the shape of a spot of light which is incident upon the output efficiency control device array becomes a trapezoid for the same reason as that in Embodiment 4. Therefore, as shown in Figures 19 through 21, the plane configuration of the output efficiency control device array is also prescribed to be a trapezoid. In this manner, the energy amount of light which is incident upon the individual output efficiency control device can be made constant by matching the array shape with the spot shape. Therefore, an intensity distribution can be precisely measured.

[0110] As described above, the infrared sensor of Embodiment 7 is a two-dimensional infrared sensor which is less expensive and very useful. In the case where it is desirable to increase the number of output efficiency control devices so as to detect a large region or conduct detection with precision, or in the case where a long measurement time is shortened, it is considered that another plurality of infrared sensors described in Embodiment 9 are arranged and simultaneously driven.

(Embodiment 8)

[0111] Hereinafter, an infrared sensor of Embodiment 8 will be described with reference to Figure 22.

[0112] Figure 22 is a view showing a structure of an infrared sensor 500 of Embodiment 8: (a) is a cross-sectional view and (b) is a view seen in a -x direction from a plane which is parallel to a y-z plane and includes a line J-J'.

[0113] As shown in Figure 22, the infrared sensor 500 has an array 582 of a plurality of arranged output efficiency control devices, a pyro-electric element 583, a lens 584, and a spacer 585, which are accommodated in a housing 586 provided with an entrance window 587 on its upper surface. The spacer 585 determines an incident angle $\theta 2$ at which light from a light source 581 is

incident upon an output efficiency control device array **582**. The light source **581** has a two-dimensional intensity distribution with a relatively small area. In Embodiment 10, a diffraction-type lens formed on a square silicon substrate is used as the lens **584**. As the entrance window **587**, for example, a silicon substrate with a band-pass wavelength filter formed thereon can be used. As is understood from Figure **22**, the infrared sensor **500** of Embodiment 8 uses a plurality of output efficiency control devices arranged in an array in the same way as in Embodiment 7, in place of one output efficiency control device in the infrared sensor of Embodiment 6.

[0114] In the infrared sensor **500** of Embodiment 8, in the same way as in the infrared sensor of Embodiment 3, the lens **584** is disposed between the output efficiency control device array **582** and the pyro-electric element **583**, and the lens **584** is made of, for example, conductive silicon, thereby an electromagnetic noise generated from the output efficiency control device array **582** can be blocked. Furthermore, light utilization efficiency is high when a light intensity distribution in a relatively small region is measured, so that a two-dimensional intensity distribution can be measured at high sensitivity.

(Embodiment 9)

[0115] Hereinafter, referring to Figure **23**, a non-contact thermometer of Embodiment 9 will be described. Figure **23** is a view showing a structure in cross-section of a non-contact thermometer **600** of Embodiment 9. As shown in Figure **23**, the non-contact thermometer **600** has an output efficiency control device **641**, a pyro-electric element **643**, a lens **645**, and a contact-type temperature measuring means **649** such as a thermo-couple. These are accommodated in a housing **646**. As the output efficiency control device **641**, any of the output efficiency control devices described in the above-mentioned Embodiment 3, 4, and 5 may be used, or an array of a plurality of arranged output efficiency control devices as described in the above-mentioned Embodiment 7 may be used. Here, the non-contact thermometer **600** will be described, exemplifying the case where the output efficiency control device of the above-mentioned Embodiment 3 is used. In Embodiment 9, a diffraction-type lens having a square aperture made of silicon is used as the lens **645**. The non-contact thermometer **600** further has a shield **647**. The shield **647** is attached to a surface of the housing **646** to which the lens **645** is attached in a mechanically movable manner and blocks infrared light **650** which is incident upon the lens **645** from an object (not shown) whose temperature is to be measured.

[0116] Hereinafter, a measurement principle of the non-contact thermometer **600** will be described with reference to Figure **23**. Figure **23(a)** shows a state where the lens **645** is shielded with the shield **647** and the incident infrared light **650** does not enter the non-contact thermometer **600**. At this time, a signal generated in the pyro-electric element **643** by operating the output effi-

ciency control device **641** corresponds to the temperature of the shield **647**. In Embodiment 9, the contact-type temperature measuring means (thermo-couple) **649** is disposed, for example, on an inner wall of the housing **646** and measures the temperature of the housing **646** in a contact manner.

[0117] In terms of principle, the contact-type temperature measuring means **649** is desirably disposed on the shield **647**. However, as described later, in Embodiment 9, the shield **647** is mechanically moved; therefore, when the contact-type temperature measuring means **649** is disposed on the shield **647**, they become complicated in terms of mechanism and its durability is degraded. Therefore, in Embodiment 9, the temperature of the housing **646** is measured as the temperature of the shield **647**. According to the measurement by the inventors of the present invention, the difference in temperature between the shield **647** and the housing **646** is sufficiently smaller than 0.1°C which is a precision of the non-contact thermometer **600** of Embodiment 9. Thus, the difference in temperature has no practical problem.

[0118] Figure **23(b)** shows a state where the lens **645** is not shielded with the shield **647**. Such a state can be realized, for example, by manually sliding the shield **647**. At this time, the incident infrared light **650** enters the non-contact thermometer **600** through the lens **645**, and the intensity of the incident infrared light **650** can be detected as a signal from the pyro-electric element **643** by driving the output efficiency control device **641** in accordance with the principle described in Embodiment 3. In general, in the case where the radiation ratio of an object is constant, the intensity of infrared light output from the object is proportional to the fourth power of the object temperature. Therefore, the temperature of an object (not shown) whose temperature is to be measured can be calculated based on the measured signal intensity, the intensity of a signal output from the pyro-electric element **643** in the state shown in Figure **23(a)**, and the signal detected by the contact-type temperature measuring means **649**.

[0119] As described above, in the non-contact thermometer **600** of Embodiment 9, the incident infrared light **650** is modulated by the output efficiency control device **641**, whereby the non-contact thermometer **600** can be miniaturized and the power consumption can be decreased. Furthermore, in the output efficiency control device **641**, the output efficiency is modulated by a minute operation of the beams as described in Embodiments 3, so that noise is not caused at a time of driving. In recent years, an eardrum thermometer, which measures a body temperature by measuring the temperature of an eardrum of a human body in a non-contact manner, has been developed. The non-contact thermometer **600** of Embodiment 9 does not generate noise at a time of driving even when used for such a purpose. Therefore, the non-contact thermometer **600** has a great advantage that it does not involve any unpleasantness when in use.

[0120] In Embodiment 9, the case where the output

efficiency control device of the above-mentioned Embodiment 3 is used as the output efficiency control device has been described. However, it is appreciated that the output efficiency control device described in Embodiment 4 or 5 or the output efficiency control device array of Embodiment 7 may be used in accordance with the application. For example, the use of the output efficiency control device array described in Embodiment 7 enables the two-dimensional temperature distribution to be measured in a non-contact manner. It is also appreciated that the arrangement of the lens and the output efficiency control device is applicable in accordance with an object to be measured, as described in Embodiment 6 or 8.

INDUSTRIAL APPLICABILITY

[0121] As described above, in the optical modulator the output efficiency control device and the focusing means are used in combination, thereby a light irradiation area on the output efficiency control device is decreased and the output efficiency control device is miniaturized. Because of this, an optical modulator can be realized, which has a high response speed, is easily produced and capable of modulating incident light having a large beam diameter. When such an optical modulator is applied to a projection-type display apparatus, a projection-type display apparatus having large light utilization efficiency can be realized.

[0122] Furthermore, in the output efficiency control device, the plane configuration of a grating portion is designed in accordance with the shape of a spot of incident light formed on the output efficiency control device. For example, even when the spot shape of incident infrared light on the output efficiency control device becomes a trapezoid, the number of the beams included in the trapezoidal spot can be made constant in the upper and lower portions of the trapezoidal spot and a uniform diffraction effect can be obtained by prescribing the period of the beams forming the grating so as to vary according to a linear function in their longitudinal direction. Thus, the degradation of the modulation characteristics caused by non-uniform diffraction of light can be prevented.

[0123] Furthermore, in the output efficiency control device, the lengths of all the beams are prescribed to be equal. Because of this, all the beams can be completely, simultaneously operated when a voltage is applied or removed. Therefore, driving of on/off of light can be performed at a high speed, and driving at a high frequency becomes possible. Thus, in the case where such an output efficiency control device is applied to, for example, an infrared sensor, detection with high precision can be conducted within a short period of time.

[0124] The output efficiency control device having a grating whose plane configuration is designed as described above can also be applied to a display apparatus. For example, when a lens with a rectangular aperture is used as the focusing means, the plane configuration of the grating of the output efficiency control device in the

optical modulator is designed to be a trapezoid in which the interval between the beams varies according to a linear function in their longitudinal direction.

[0125] Furthermore, in the case where the output efficiency control device of the present invention is applied to an infrared sensor, for example, even when the spot shape on the output efficiency control device becomes a trapezoid, using a lens having a rectangular aperture, the modulation characteristics can be prevented from degrading by disposing the output efficiency control device between the lens and the pyro-electric element. In this case, a spot formed on the pyro-electric element has a rectangular shape with a size smaller than that in the case of using a lens having a circular aperture. Thus, light is enabled to be incident upon the entire pyro-electric element and a pyro-electric element with a small area will suffice, so that a cost can be reduced. Simultaneously, a signal level higher than the level conventionally obtained can be obtained. Therefore, an infrared sensor with an ultra-small size and high sensitivity can be realized as a whole.

[0126] Alternatively, in an infrared sensor using the output efficiency control device of the present invention, light output from the output efficiency control device is focused onto the pyro-electric element by using a lens, thereby outgoing light from a point light source at almost a constant distance from the sensor can be utilized at a high efficiency. Furthermore, by designing the lens so as to have a rectangular aperture and using an output efficiency control device having a grating with a plane configuration in accordance with a spot shape formed by the lens in such a structure, the area utilization efficiency of the lens is enhanced. Therefore, a miniaturized infrared sensor with high sensitivity for short distances can be realized.

[0127] Furthermore, in the case where the output efficiency control devices are arranged in a two-dimensional array, when the light intensity distribution is different in a spot, for example, due to the trapezoidal shape of the spot, the total amount of energy of light which is incident upon the individual output efficiency control device is made equal by prescribing the entire output efficiency control device array to be a trapezoid. In the case where a plurality of output efficiency control devices are arranged in a two-dimensional array and incorporated into an infrared sensor as described above, a two-dimensional infrared light intensity distribution can be detected as information in time sequence by successively operating the output efficiency control devices and successively detecting signals output from a pyro-electric element at that time, and a much less expensive two-dimensional infrared sensor can be provided.

[0128] Furthermore, the output efficiency control device can also be applied to a non-contact thermometer. In this case, first, the output efficiency control device is driven in a state where infrared light is prevented from entering a housing of the non-contact thermometer by using a shield and a signal generated from a pyro-electric

element is detected, while the temperature is measured by contact-type temperature measuring means provided in the housing. Thereafter, the output efficiency control device is driven and a signal generated from the pyro-electric element is detected, in a state where the shield is opened so as to allow infrared light to entering the housing of the non-contact thermometer. Based on the signals generated from the pyro-electric element in the above-mentioned two states and the temperature measured by the contact-type temperature measuring means, the temperature of an object to be measured can be measured with remarkable precision in a non-contact manner.

Claims

1. An infrared sensor comprising:

a lens (105) having a rectangular aperture, an output efficiency control device (2; 101) which modulates a light amount of incident light (4) and outputs the modulated light (5; 11a, 11b), comprising:

a plate (9) having a portion (7) which functions as a first electrode;
a spacer layer (10) formed on the plate (9);
and

a grating (8b) composed of a plurality of beams, wherein the beams having portions which function as second electrodes, both ends of the beams being supported on the spacer layer (10),

wherein a distance (L_3) between the grating (8b) and the plate (9) is varied by adjusting a voltage applied between the first electrode (7) and the second electrodes (8b), whereby an output efficiency of the light is controlled,
wherein the output efficiency control device (2; 101) is tilted by an angle (θ_2) from a surface parallel to the surface to which the lens (105) is attached, and wherein the period (A) of the grating is changed in accordance with the shape of the spot of incident light.

2. The infrared sensor according to claim 1, wherein a period of the grating gradually increases in a longitudinal direction of the grating.

3. The infrared sensor according to claim 2, wherein the period of the grating increases according to a linear function in a longitudinal direction of the grating.

4. The infrared sensor according to claim 2, wherein lengths of the plurality of beams are equal.

5. The infrared sensor according to claim 1, wherein the plurality of beams of the grating are aligned on an identical plane when a voltage is not applied between the first electrode (7) and the second electrodes (8b), and every other beam is attracted to the plate when a voltage is applied, thereby the output efficiency is controlled.

6. The infrared sensor according to claim 5, wherein the plurality of beams are densely aligned and function as a mirror when a voltage is not applied between the first electrode (7) and the second electrodes (8b).

7. The infrared sensor according to claim 1, wherein, assuming that a wavelength of the incident light (4) is λ , and an angle formed by a normal of a principal plane of the plate of the output efficiency control device (2) and an optical axis of the incident light (4) is θ , an operation distance of the grating is set to be $m\lambda/(4\cos\theta)$, where m is an integer.

8. The infrared sensor according to claim 1, wherein, assuming that a wavelength of the incident light (4) is λ , and an angle formed by a normal to a principal plane of the plate of the output efficiency control device (2) and an optical axis of the incident light (4) is θ , a thickness of the beams is set to be $m\lambda/(4\cos\theta)$, where m is an integer.

9. The infrared sensor according to claim 1, further comprising a reflective film (8') formed on a surface of the plate (9) and a surface of the grating.

10. The infrared sensor according to claim 1, further comprising an insulating film formed between the plate (9) and the grating.

11. The infrared sensor according to claim 10, further comprising a reflective film formed on a surface of the insulating layer and a surface of the grating.

12. The infrared sensor according to claim 1, wherein the infrared sensor further comprises:

a pyro-electric element (103); and wherein

the output efficiency control device (2; 101) receives the infrared light (115) focused by the lens (105) and outputs at least part of the infrared light (115) to the pyro-electric element (103).

13. The infrared sensor according to claim 12, wherein the pyro-electric element (103) has a rectangular surface.

14. The infrared sensor according to claim 13, wherein the lens (105) for focusing infrared light (115) has a

rectangular aperture.

15. The infrared sensor according to claim 12, wherein the output efficiency control device (2; 101) is obliquely disposed in such a manner that a normal to a principal plane of the plate (9) is disposed so as not to be parallel to an optical axis of the lens (105). 5
 16. The infrared sensor according to claim 12, wherein the output efficiency control device is disposed in such a manner that only zero-th order diffracted light of diffracted light diffracted by the grating of the output efficiency control device is incident upon the pyro-electric element (103) and diffracted light other than the zero-th order diffracted light is not incident upon the pyro-electric element (103). 10
 17. The infrared sensor according to claim 12, wherein a change in a distance between the grating and the plate of the output efficiency control device changes a light amount of the zero-th order diffracted light. 20
 18. The infrared sensor according to claim 12, wherein the infrared sensor (100) further includes a sealing member having an opening, and the sealing member contains the output efficiency control device and the pyro-electric element (103). 25
 19. The infrared sensor according to claim 18, wherein the lens (105) is provided in the opening of the sealing member. 30
 20. The infrared sensor according to claim 12, wherein the lens (105) is a diffraction-type lens. 35
 21. The infrared sensor according to claim 14, wherein a smallest period of the grating of the output efficiency control device is 7 times or more a wavelength of the infrared light (115). 40
 22. The infrared sensor according to claim 14, wherein, assuming that a length of one side of the lens (105) is L, a focal length of the lens (105) is f, and an angle formed by a normal to a principal plane of the plate of the output efficiency control device and an optical axis of the lens is θ , a largest period of the grating is $7(2f+L\tan\theta)/(2f-L\tan\theta)$ times or more a wavelength of the infrared light (115). 45
 23. The infrared sensor according to claim 12, wherein the output efficiency control device (2;101) is disposed in such a manner that a direction which is parallel to a principal plane of the plate and vertical to the grating is vertical to an optical axis of the lens. 50
 24. The infrared sensor according to claim 1, wherein the infrared sensor further comprises: 55
- a pyro-electric element (343); wherein the output efficiency control device (2; 101) outputs at least part of incident infrared light (115), and
- a lens (344), provided between the output efficiency control device (342) and the pyro-electric element (343), focuses the infrared light output from the output efficiency control device (342) onto the pyro-electric element (343).
25. The infrared sensor according to claim 24, wherein the pyro-electric element (343) has a rectangular surface.
 26. The infrared sensor according to claim 25, wherein the lens (344) has a rectangular aperture.
 27. The infrared sensor according to claim 24, wherein the output efficiency control device (342) is obliquely disposed in such a manner that a normal to a principal plane of the plate is not parallel to an optical axis of the lens (344).
 28. The infrared sensor according to claim 24, wherein the output efficiency control device (342) is disposed in such a manner that only zero-th order diffracted light of diffracted light diffracted by the grating of the output efficiency control device (342) is incident upon the pyro-electric element (343), and diffracted light other than the zero-th order diffracted light is not incident upon the pyro-electric element (343).
 29. The infrared sensor according to claim 24, wherein a change in a distance between the grating and the plate of the output efficiency control device (342) changes a light amount of the zero-th order diffracted light.
 30. The infrared sensor according to claim 24, wherein the infrared sensor (300) further includes a sealing member having an opening, and the sealing member contains the output efficiency control device (342) and the pyro-electric element (343).
 31. The infrared sensor according to claim 24, wherein the lens (344) has a surface relief structure in accordance with a modulated amount of a phase of the lens (344) and is composed of a material selected from a group consisting of Si, Ge, GaAs, InP, GaP, ZnSe, and ZnS.
 32. The infrared sensor according to claim 24, wherein the output efficiency control device (342) is disposed in such a manner that a direction which is parallel to a principal plane of the plate and vertical to the grating is vertical to an optical axis of the lens (344).
 33. An infrared sensor comprising:

a lens (452) having a rectangular aperture, and an output efficiency control device array which modulates a light amount of incident light and outputs the modulated light, having a plurality of output efficiency control devices arranged in a two-dimensional array (473), each of the plurality of output efficiency control devices comprising:

a plate (9) having a portion (7) which functions as a first electrode;
a spacer layer (463) formed on the plate (9); and
a grating composed of a plurality of beams, the beams having portions which function as second electrodes, both ends of the beams being supported on the spacer layer (463),

wherein a distance (L_3) between the grating and the plate is varied by adjusting a voltage applied between the first electrode and the second electrodes, whereby an output efficiency of the light is controlled, wherein the output efficiency control device is tilted by an angle (θ_2) from a surface parallel to the surface to which the lens (452) is attached, and wherein the period (Λ) of the grating is changed in accordance with the shape of the spot of incident light.

- 34.** An infrared sensor according to claim 33, further comprising a pyro-electric element (454), wherein

the lens (452) focuses infrared light and; the output efficiency control device array receives the infrared light focused by the lens (452), and outputs at least part of the infrared light to the pyro-electric element (454).

- 35.** An infrared sensor according to claim 33, further comprising a pyro-electric element (454), wherein

the output efficiency control device array outputs at least part of incident infrared light (451), and the lens, provided between the output efficiency control device and the pyro-electric element (454), focuses the infrared light output from the output efficiency control device onto the pyro-electric element (454).

- 36.** The infrared sensor of claim 34 or 35, comprising

means for successively operating the plurality of output efficiency control devices, and successively detecting output signals from the pyro-electric element thus obtained; and means for detecting a two-dimensional infrared light intensity distribution as information in time

sequence, based on the detected output signals from the pyro-electric element.

- 37.** A non-contact thermometer comprising:

the infrared sensor according to claim 1 ;
a housing (646) having an opening ;
a shield (647) which closes and opens the opening;
a pyro-electric element (643) provided in the housing (646); and
contact-type temperature measuring means (649) provided on a side wall of the housing (646);

wherein the lens (645) focuses infrared light (650) and the output efficiency control device (2; 101) is provided in the housing (646), receives the infrared light (650) focused by the lens (645), and outputs at least part of the infrared light (650).

- 38.** The non-contact thermometer according to claim 37, wherein the contact-type temperature measuring means (649) is a thermo-couple.

- 39.** The non-contact thermometer comprising:

the infrared sensor according to claim 1 ;
a housing (646) having an opening;
a shield (647) which closes and opens the opening;
a pyro-electric element (643) provided in the housing (646); and
contact-type temperature measuring means (649) provided on a side wall of the housing (646);

wherein the output efficiency control device is provided in the housing (646), receives infrared light (650) through the opening, and outputs at least part of the infrared light (650); and the lens outputs at least part of the infrared light output from the output efficiency control device (641) to the pyro-electric element (643).

- 40.** The non-contact thermometer according to claim 39, wherein the contact-type temperature measuring means is a thermo-couple.

- 41.** A non-contact thermometer comprising:

the infrared sensor according to claim 33;
a housing (646) having an opening;
a shield (647) which closes and opens the opening;
a pyro-electric element (643) provided in the housing (646); and
contact-type temperature measuring means

(649) provided on a side wall of the housing (646);

wherein the lens focuses infrared light (650) and the output efficiency control device array is provided in the housing (646), receives the infrared light (650) focused by the lens (645), and outputs at least part of the infrared light (650).

42. The non-contact thermometer according to claim 41, wherein the contact-type temperature measuring means (649) is a thermo-couple.

43. A non-contact thermometer comprising:

the infrared sensor according to claim 33;
a housing (646) having an opening;
a shield (647) which closes and opens the opening;
a pyro-electric element (643) provided in the housing (646); and
contact-type temperature measuring means (649) provided on a side wall of the housing (646);

wherein the output efficiency control device is provided in the housing (646), receives infrared light (650) incident through the opening, and outputs at least part of the infrared light (650); and
the lens outputs at least part of the infrared light output from the output efficiency control device (641) to the pyro-electric element (643).

44. The non-contact thermometer according to claim 43, wherein the contact-type temperature measuring means (649) is a thermo-couple.

Patentansprüche

1. Infrarotsensor, der umfasst:

eine Linse (105) mit einer rechtwinkligen Öffnung,
eine Ausgangsleistungs-Steuervorrichtung (2; 101), die eine Lichtmenge auftreffenden Lichts (4) moduliert, das modulierte Licht (5; 11a, 11b) ausgibt und umfasst:

eine Platte (9) mit einem Abschnitt (7), der als eine erste Elektrode dient;
eine Abstandshalterschicht (10), die auf der Platte (9) ausgebildet ist; und
ein Gitter (8b), das aus mehreren Balken aufgebaut ist, wobei die Balken Abschnitte besitzen, die als zweite Elektroden dienen, wobei beide Enden der Balken auf der Abstandshalterschicht (10) unterstützt sind,

wobei ein Abstand (L_3) zwischen dem Gitter (8b) und der Platte (9) durch Einstellen einer Spannung, die zwischen die erste Elektrode (7) und die zweiten Elektroden (8b) angelegt wird, eingestellt wird, wodurch die Ausgangsleistung für das Licht gesteuert wird,

wobei die Ausgangsleistungs-Steuervorrichtung (2; 101) in Bezug auf eine Oberfläche, die zu der Oberfläche parallel ist, an der die Linse (105) befestigt ist, um einen Winkel (θ) geneigt ist, und wobei die Periode (A) des Gitters in Übereinstimmung mit der Form des Lichtflecks auftreffenden Lichts geändert wird.

2. Infrarotsensor nach Anspruch 1, bei dem eine Periode des Gitters in einer Längsrichtung des Gitters allmählich zunimmt.

3. Infrarotsensor nach Anspruch 2, bei dem die Periode des Gitters gemäß einer linearen Funktion in einer Längsrichtung des Gitters zunimmt.

4. Infrarotsensor nach Anspruch 2, bei dem die Längen der mehreren Balken gleich sind.

5. Infrarotsensor nach Anspruch 1, bei dem die mehreren Balken des Gitters auf die gleiche Ebene ausgerichtet sind, wenn zwischen die erste Elektrode (7) und die zweiten Elektroden (8b) keine Spannung angelegt wird, und kein anderer Balken zu der Platte angezogen wird, wenn eine Spannung angelegt wird, wodurch die Ausgangsleistung gesteuert wird.

6. Infrarotsensor nach Anspruch 5, bei dem die mehreren Balken dicht angeordnet sind und als ein Spiegel dienen, wenn zwischen die erste Elektrode (7) und die zweiten Elektroden (8b) keine Spannung angelegt wird.

7. Infrarotsensor nach Anspruch 1, bei dem unter der Annahme, dass eine Wellenlänge des auftreffenden Lichts (4) durch λ gegeben ist und ein Winkel, der durch eine Normale einer Hauptebene der Platte der Ausgangsleistungs-Steuervorrichtung (2) und eine optische Achse des auftreffenden Lichts (4) gebildet wird, durch θ gegeben ist, ein Betriebsabstand des Gitters gleich $m\lambda/(4\cos\theta)$, wobei m eine ganze Zahl ist, gesetzt ist.

8. Infrarotsensor nach Anspruch 1, bei dem unter der Annahme, dass eine Wellenlänge des auftreffenden Lichts (4) durch λ gegeben ist und ein Winkel, der durch eine Normale zu einer Hauptebene der Platte der Ausgangsleistungs-Steuervorrichtung (2) und eine optische Achse des auftreffenden Lichts (4) gebildet wird, durch θ gegeben ist, eine Dicke der Balken gleich $m\lambda/(4\cos\theta)$, wobei m eine ganze Zahl ist, gesetzt ist.

9. Infrarotsensor nach Anspruch 1, der ferner eine reflektierende Schicht (8') aufweist, die auf einer Oberfläche der Platte (9) und auf einer Oberfläche des Gitters ausgebildet ist.
10. Infrarotsensor nach Anspruch 1, der ferner eine isolierende Schicht umfasst, die zwischen der Platte (9) und dem Gitter ausgebildet ist.
11. Infrarotsensor nach Anspruch 10, der ferner eine reflektierende Schicht umfasst, die auf einer Oberfläche der isolierenden Schicht und auf einer Oberfläche des Gitters ausgebildet ist.
12. Infrarotsensor nach Anspruch 1, wobei der Infrarotsensor ferner umfasst:
- ein pyroelektrisches Element (103); und wobei die Ausgangsleistungs-Steuervorrichtung (2; 101) das durch die Linse (105) fokussierte Infrarotlicht (115) empfängt und wenigstens einen Teil des Infrarotlichts (115) zu dem pyroelektrischen Element (103) ausgibt.
13. Infrarotsensor nach Anspruch 12, bei dem das pyroelektrische Element (103) eine rechtwinklige Oberfläche besitzt.
14. Infrarotsensor nach Anspruch 13, bei dem die Linse (105) zum Fokussieren von Infrarotlicht (115) eine rechtwinklige Öffnung besitzt.
15. Infrarotsensor nach Anspruch 12, bei dem die Ausgangsleistungs-Steuervorrichtung (2; 101) in der Weise schräg angeordnet ist, dass eine Normale zu einer Hauptebene der Platte (9) so angeordnet ist, dass sie zu einer optischen Achse der Linse (105) nicht parallel ist.
16. Infrarotsensor nach Anspruch 12, bei der die Ausgangsleistungs-Steuervorrichtung in der Weise angeordnet ist, dass nur Beugungslicht nullter Ordnung, das durch das Gitter der Ausgangsleistungs-Steuervorrichtung gebeugt wird, auf das pyroelektrische Element (103) auftrifft und gebeugtes Licht, das von gebeugtem Licht nullter Ordnung verschieden ist, nicht auf das pyroelektrische Element (103) auftrifft.
17. Infrarotsensor nach Anspruch 12, bei dem eine Änderung eines Abstandes zwischen dem Gitter und der Platte der Ausgangsleistungs-Steuervorrichtung eine Lichtmenge des gebeugten Lichts nullter Ordnung ändert.
18. Infrarotsensor nach Anspruch 12, wobei der Infrarotsensor (100) ferner ein Dichtungselement aufweist, das eine Öffnung besitzt, und das Dichtungselement die Ausgangsleistungs-Steuervorrichtung und das pyroelektrische Element (103) enthält.
19. Infrarotsensor nach Anspruch 18, bei dem die Linse (105) in der Öffnung des Dichtungselements vorgesehen ist.
20. Infrarotsensor nach Anspruch 12, bei dem die Linse (105) eine Linse des Beugungstyps ist.
21. Infrarotsensor nach Anspruch 14, bei dem eine kleinste Periode des Gitters der Ausgangsleistungs-Steuervorrichtung wenigstens gleich der siebenfachen Wellenlänge des Infrarotlichts (115) ist.
22. Infrarotsensor nach Anspruch 14, bei dem unter der Annahme, dass eine Länge einer Seite der Linse (105) durch L gegeben ist, eine Brennweite der Linse (105) durch f gegeben ist und ein Winkel, der durch eine Normale zu einer Hauptebene der Platte der Ausgangsleistungs-Steuervorrichtung und eine optische Achse der Linse gebildet wird, durch θ gegeben ist, eine größte Periode des Gitters wenigstens gleich der $7(2f + L \tan \theta) / (2f - L \tan \theta)$ -fachen Wellenlänge des Infrarotlichts (115) ist.
23. Infrarotsensor nach Anspruch 12, bei dem die Ausgangsleistungs-Steuervorrichtung (2; 101) in der Weise angeordnet ist, dass eine Richtung, die zu einer Hauptebene der Platte parallel und zu dem Gitter senkrecht ist, zu einer optischen Achse der Linse senkrecht ist.
24. Infrarotsensor nach Anspruch 1, wobei der Infrarotsensor ferner umfasst:
- ein pyroelektrisches Element (343); wobei die Ausgangsleistungs-Steuervorrichtung (2; 101) wenigstens einen Teil auftreffenden Infrarotlichts (115) ausgibt und eine Linse (344), die zwischen der Ausgangsleistungs-Steuervorrichtung (342) und dem pyroelektrischen Element (343) vorgesehen ist, das von der Ausgangsleistungs-Steuervorrichtung (342) ausgegebene Infrarotlicht auf das pyroelektrische Element (343) fokussiert.
25. Infrarotsensor nach Anspruch 24, bei dem das pyroelektrische Element (343) eine rechtwinklige Oberfläche besitzt.
26. Infrarotsensor nach Anspruch 25, bei dem die Linse (344) eine rechtwinklige Öffnung besitzt.
27. Infrarotsensor nach Anspruch 24, bei dem die Ausgangsleistungs-Steuervorrichtung (342) in der Weise schräg angeordnet ist, dass eine Normale zu einer Hauptebene der Platte zu einer optischen Achse

der Linse (344) nicht parallel ist.

- 28.** Infrarotsensor nach Anspruch 24, bei dem die Ausgangsleistungs-Steuervorrichtung (342) in der Weise angeordnet ist, dass nur Beugungslicht nullter Ordnung von durch das Gitter der Ausgangsleistungs-Steuervorrichtung (342) gebeugtem Licht auf das pyroelektrische Element (343) auftrifft und Beugungslicht, das von Beugungslicht nullter Ordnung verschieden ist, nicht auf das pyroelektrische Element (343) auftrifft.
- 29.** Infrarotsensor nach Anspruch 24, bei dem eine Änderung eines Abstandes zwischen dem Gitter und der Platte der Ausgangsleistungs-Steuervorrichtung (342) eine Lichtmenge des Beugungslichts nullter Ordnung ändert.
- 30.** Infrarotsensor nach Anspruch 24, wobei der Infrarotsensor (300) ferner ein Dichtungselement aufweist, das eine Öffnung besitzt, und das Dichtungselement die Ausgangsleistungs-Steuervorrichtung (342) und das pyroelektrische Element (343) enthält.
- 31.** Infrarotsensor nach Anspruch 24, bei dem die Linse (344) eine Oberflächenreliefstruktur in Übereinstimmung mit einem modulierten Betrag einer Phase der Linse (344) besitzt und aus einem Material gebildet ist, das aus einer Gruppe gewählt ist, die aus Si, Ge, GaAs, InP, GaP, ZnSe und ZnS besteht.
- 32.** Infrarotsensor nach Anspruch 24, bei dem die Ausgangsleistungs-Steuervorrichtung (342) in der Weise angeordnet ist, dass eine Richtung, die zu der Hauptebene der Platte parallel und zu dem Gitter senkrecht ist, zu einer optischen Achse der Linse (344) senkrecht ist.
- 33.** Infrarotsensor, der umfasst:
- eine Linse (452) mit einer rechtwinkligen Öffnung und
- eine Ausgangsleistungs-Steuervorrichtungsanordnung, die eine Lichtmenge auftreffenden Lichts moduliert und das modulierte Licht ausgibt und mehrere Ausgangsleistungs-Steuervorrichtungen besitzt, die in einer zweidimensionalen Anordnung (473) angeordnet sind, wobei jede der mehreren Ausgangsleistungs-Steuervorrichtungen umfasst:
- eine Platte (9) mit einem Abschnitt (7), der als eine erste Elektrode dient;
- eine Abstandshalterschicht (463), die auf der Platte (9) ausgebildet ist; und
- ein Gitter, das aus mehreren Balken aufgebaut ist, wobei die Balken Abschnitte besitzen, die als zweite Elektroden dienen, wo-

bei beide Enden der Balken auf der Abstandshalterschicht (463) unterstützt sind,

wobei ein Abstand (L_3) zwischen dem Gitter und der Platte durch Einstellen einer Spannung, die zwischen die erste Elektrode und die zweiten Elektroden angelegt wird, verändert wird, wodurch eine Ausgangsleistung für das Licht gesteuert wird, wobei die Ausgangsleistungs-Steuervorrichtung in Bezug auf eine Oberfläche, die zu der Oberfläche, an der die Linse (242) befestigt ist, parallel ist, um einen Winkel (θ_2) geneigt ist und wobei die Periode (Λ) des Gitters in Übereinstimmung mit der Form des Lichtflecks auftreffenden Lichts geändert wird.

- 34.** Infrarotsensor nach Anspruch 33, der ferner ein pyroelektrisches Element (454) umfasst, wobei

die Linse (452) Infrarotlicht fokussiert und die Ausgangsleistungs-Steuervorrichtungsanordnung das durch die Linse (452) fokussierte Infrarotlicht empfängt und wenigstens einen Teil des Infrarotlichts zu dem pyroelektrischen Element (454) ausgibt.

- 35.** Infrarotsensor nach Anspruch 33, der ferner ein pyroelektrisches Element (454) umfasst, wobei

die Ausgangsleistungs-Steuervorrichtungsanordnung wenigstens einen Teil auftreffenden Infrarotlichts (451) ausgibt und die Linse, die zwischen der Ausgangsleistungs-Steuervorrichtung und dem pyroelektrischen Element (454) vorgesehen ist, das von der Ausgangsleistungs-Steuervorrichtung ausgegebene Infrarotlicht auf das pyroelektrische Element (454) fokussiert.

- 36.** Infrarotsensor nach Anspruch 34 oder 35, der umfasst:

Mittel zum sukzessiven Betreiben der mehreren Ausgangsleistungs-Steuervorrichtungen und zum sukzessiven Detektieren von Ausgangssignalen von dem pyroelektrischen Element, die auf diese Weise erhalten werden; und Mittel, um eine zweidimensionale Infrarotlicht-Intensitätsverteilung als Informationen in einer zeitlichen Abfolge anhand der detektierten Ausgangssignale von dem pyroelektrischen Element zu detektieren.

- 37.** Kontaktloses Thermometer, das umfasst:

den Infrarotsensor nach Anspruch 1;

ein Gehäuse (646) mit einer Öffnung;

eine Abschirmung (647), die die Öffnung ver-

schließt und öffnet;
ein pyroelektrisches Element (643), das im Gehäuse (646) vorgesehen ist; und
Temperaturmessmittel (649) des Kontakttyps, die an einer Seitenwand des Gehäuses (646) vorgesehen sind;

wobei die Linse (645) Infrarotlicht (650) fokussiert und die Ausgangsleistungs-Steuervorrichtung (2; 101) in dem Gehäuse (646) vorgesehen ist, das durch die Linse (645) fokussierte Infrarotlicht (650) empfängt und wenigstens einen Teil des Infrarotlichts (650) ausgibt.

38. Kontaktloses Thermometer nach Anspruch 37, bei dem die Temperaturmessmittel (649) des Kontakttyps ein Thermoelement sind.

39. Kontaktloses Thermometer, das umfasst:

den Infrarotsensor nach Anspruch 1;
ein Gehäuse (646) mit einer Öffnung;
eine Abschirmung (647), die die Öffnung verschließt und öffnet;
ein pyroelektrisches Element (643), das in dem Gehäuse (646) vorgesehen ist; und
Temperaturmessmittel (649) des Kontakttyps, die an einer Seitenwand des Gehäuses (646) vorgesehen sind;

wobei die Ausgangsleistungs-Steuervorrichtung in dem Gehäuse (646) vorgesehen ist, Infrarotlicht (650) durch die Öffnung empfängt und wenigstens einen Teil des Infrarotlichts (650) ausgibt; und
die Linse wenigstens einen Teil des Infrarotlichts, das von der Ausgangsleistungs-Steuervorrichtung (641) ausgegeben wird, zu dem pyroelektrischen Element (643) ausgibt.

40. Kontaktloses Thermometer nach Anspruch 39, bei dem die Temperaturmessmittel des Kontakttyps ein Thermoelement sind.

41. Kontaktloses Thermometer, das umfasst:

den Infrarotsensor nach Anspruch 33;
ein Gehäuse (646) mit einer Öffnung;
eine Abschirmung (647), die die Öffnung verschließt und öffnet;
ein pyroelektrisches Element (643), das in dem Gehäuse (646) vorgesehen ist; und
Temperaturmessmittel (649) des Kontakttyps, die an eine Seitenwand des Gehäuses (646) vorgesehen sind;

wobei die Linse Infrarotlicht (650) fokussiert und die Ausgangsleistungs-Steuervorrichtungsanordnung im Gehäuse (646) vorgesehen ist, das durch die Lin-

se (645) fokussierte Infrarotlicht (650) empfängt und wenigstens einen Teil des Infrarotlichts (650) ausgibt.

42. Kontaktloses Thermometer nach Anspruch 41, bei dem die Temperaturmessmittel (649) des Kontakttyps ein Thermoelement sind.

43. Kontaktloses Thermometer, das umfasst:

den Infrarotsensor nach Anspruch 33;
ein Gehäuse (646) mit einer Öffnung;
eine Abschirmung (647), die die Öffnung verschließt und öffnet;
ein pyroelektrisches Element (643), das in dem Gehäuse (646) vorgesehen ist; und
Temperaturmessmittel (649) des Kontakttyps, die an einer Seitenwand des Gehäuses (646) vorgesehen sind;

wobei die Ausgangsleistungs-Steuervorrichtung in dem Gehäuse (646) vorgesehen ist, Infrarotlicht (650), das durch die Öffnung auftritt, empfängt und wenigstens einen Teil des Infrarotlichts (650) ausgibt; und
die Linse wenigstens einen Teil des Infrarotlichts, das von der Ausgangsleistungs-Steuervorrichtung (641) ausgegeben wird, zu dem pyroelektrischen Element (643) ausgibt.

44. Kontaktloses Thermometer nach Anspruch 43, bei dem die Temperaturmessmittel (649) des Kontakttyps ein Thermoelement sind.

Revendications

1. Détecteur à infra-rouge comprenant :

une lentille (105) ayant une ouverture rectangulaire,
un dispositif de commande d'efficacité de sortie (2; 101) qui module une quantité de lumière d'une lumière incidente (4) et délivre en sortie la lumière modulée (5; 11a, 11b), comprenant :

une plaque (9) ayant une partie (7) qui fonctionne comme une première électrode ; une couche intercalaire (10) formée sur la plaque (9); et
une grille (8b) composée d'une pluralité de rayons, dans laquelle les rayons ayant des parties qui fonctionnent comme des secondes électrodes, les deux extrémités des rayons étant supportées par la couche intercalaire (10),

dans lequel une distance (L_3) entre la grille (8b) et

- la plaque (9) est modifiée en ajustant une tension appliquée entre la première électrode (7) et les secondes électrodes (8b), en fonction de laquelle une efficacité de sortie de la lumière est commandée, dans lequel le dispositif de commande d'efficacité de sortie (2; 101) est basculé d'un angle (02) depuis une surface parallèle à la surface sur laquelle la lentille (105) est fixée, et dans lequel la période (Λ) de la grille est modifiée conformément à la forme du point de lumière incidente.
2. Détecteur à infrarouge selon la revendication 1, dans lequel une période de la grille augmente progressivement dans une direction longitudinale de la grille.
 3. Détecteur à infrarouge selon la revendication 2, dans lequel une période de la grille augmente selon une fonction linéaire dans une direction longitudinale de la grille.
 4. Détecteur à infrarouge selon la revendication 2, dans lequel des longueurs de la pluralité du rayon sont égales.
 5. Détecteur à infrarouge selon la revendication 1, dans lequel la pluralité de rayons de la grille est alignée sur un plan identique lorsqu'une tension n'est pas appliquée entre la première électrode (7) et les secondes électrodes (8b), et un rayon sur deux est attiré vers la grille lorsqu'une tension est appliquée, permettant ainsi de commander l'efficacité de sortie.
 6. Détecteur à infrarouge selon la revendication 5, dans lequel la pluralité de rayons est alignée de façon dense et fonctionne comme un miroir lorsqu'une tension n'est pas appliquée entre la première électrode (7) et les secondes électrodes (8b).
 7. Détecteur à infrarouge selon la revendication 1, dans lequel, en supposant qu'une longueur d'onde de la lumière incidente (4) est λ , et un angle formé par une normale du plan principal de la plaque du dispositif de commande d'efficacité de sortie (2) et un axe optique de la lumière incidente (4) est θ , une épaisseur des rayons est établie à $m\lambda/(4\cos\theta)$, où m est un nombre entier.
 8. Détecteur à infrarouge selon la revendication 1, dans lequel, en supposant qu'une longueur d'onde de la lumière incidente (4) est λ , et un angle formé par une normale du plan principal de la plaque du dispositif de commande d'efficacité de sortie (2) et un axe optique de la lumière incidente (4) est θ , une épaisseur des rayons est établie à $m\lambda/(4\cos\theta)$, où m est un nombre entier.
 9. Détecteur à infrarouge selon la revendication 1, com-
- prenant en outre un film réfléchissant (8') formé sur une surface de la plaque (9) et une surface de la grille.
10. Détecteur à infrarouge selon la revendication 1, comprenant en outre un film isolant formé entre la plaque (9) et la grille.
 11. Détecteur à infrarouge selon la revendication 10, comprenant en outre un film réfléchissant formé sur une surface de la couche intercalaire et une surface de la grille.
 12. Détecteur à infrarouge selon la revendication 1, dans lequel le détecteur à infrarouge comprend en outre :
 - un élément piézoélectrique (103) ; et dans lequel le dispositif de commande d'efficacité de sortie (2; 101) reçoit la lumière infrarouge (115) focalisée par la lentille (105) et délivre en sortie au moins une partie de la lumière infrarouge (115) à l'élément piézoélectrique (103).
 13. Détecteur à infrarouge selon la revendication 12, dans lequel l'élément piézoélectrique (103) a une surface rectangulaire.
 14. Détecteur à infrarouge selon la revendication 13, dans lequel la lentille (105) destinée à focaliser une lumière infrarouge (115) a une ouverture rectangulaire.
 15. Détecteur à infrarouge selon la revendication 12, dans lequel le dispositif de commande d'efficacité de sortie (2; 101) est disposé de façon oblique de telle manière qu'une normale par rapport à un plan principal de la plaque (9) est disposée de façon à ne pas être parallèle à un axe optique de la lentille (105).
 16. Détecteur à infrarouge selon la revendication 12, dans lequel le dispositif de commande d'efficacité de sortie est disposé d'une telle manière que seule une lumière diffractée d'ordre zéro-ème d'une lumière diffractée diffractée par la grille du dispositif de commande d'efficacité de sortie est incidente sur l'élément piézoélectrique (103) et une lumière diffractée autre que la lumière diffractée d'ordre zéro-ème n'est pas incidente sur l'élément piézoélectrique (103).
 17. Détecteur à infrarouge selon la revendication 12, dans lequel une modification d'une distance entre la grille et la plaque du dispositif de commande d'efficacité de sortie modifie une quantité de lumière de la lumière diffractée d'ordre zéro-ème.
 18. Détecteur à infrarouge selon la revendication 12,

- dans lequel le détecteur à infrarouge (100) comprend en outre un élément d'étanchéité ayant une ouverture, et l'élément d'étanchéité contient le dispositif de commande d'efficacité de sortie et l'élément piézoélectrique (103).
19. Détecteur à infrarouge selon la revendication 18, dans lequel la lentille (105) est prévue dans l'ouverture de l'élément d'étanchéité.
20. Détecteur à infrarouge selon la revendication 12, dans lequel la lentille (105) est une lentille du type à diffraction.
21. Détecteur à infrarouge selon la revendication 14, dans lequel une période la plus petite de la grille du dispositif de commande d'efficacité de sortie est 7 fois ou plus une longueur d'onde de la lumière infrarouge (115).
22. Détecteur à infrarouge selon la revendication 14, dans lequel, en supposant qu'une longueur d'un côté de la lentille (105) est L, une longueur focale de la lentille (105) est f, et un angle formé par une normale par rapport à un plan principal de la plaque du dispositif de commande d'efficacité de sortie et un axe optique de la lentille est θ , une période la plus grande de la grille est $7(2f+L\tan \theta)/(2f-L\tan \theta)$ fois ou plus une longueur d'onde de la lumière infrarouge (115).
23. Détecteur à infrarouge selon la revendication 12, dans lequel le dispositif de commande d'efficacité de sortie (2; 101) est disposé de telle manière qu'une direction qui est parallèle par rapport à un plan principal de la plaque et verticale par rapport à la grille est verticale par rapport à un axe optique de la lentille.
24. Détecteur à infrarouge selon la revendication 1, dans lequel le détecteur à infrarouge comprend en outre :
- un élément piézoélectrique (343) ; dans lequel le dispositif de commande d'efficacité de sortie (2; 101) délivre au moins une partie de la lumière infrarouge incidente (115), et une lentille (344), prévue entre le dispositif de commande d'efficacité de sortie (342) et l'élément piézo-électrique (343), focalise la lumière infrarouge délivrée en sortie par le dispositif de commande d'efficacité de sortie (342) sur l'élément piézoélectrique (343).
25. Détecteur à infrarouge selon la revendication 24, dans lequel l'élément piézoélectrique (343) a une surface rectangulaire.
26. Détecteur à infrarouge selon la revendication 25, dans lequel la lentille (344) a une ouverture rectan-
- gulaire.
27. Détecteur à infrarouge selon la revendication 24, dans lequel le dispositif de commande d'efficacité de sortie (342; 101) est disposé de façon oblique d'une telle manière qu'une normale par rapport à un plan principal de la plaque (9) n'est pas parallèle à un axe optique de la lentille (344).
28. Détecteur à infrarouge selon la revendication 24, dans lequel le dispositif de commande d'efficacité de sortie (342) est disposé d'une telle manière que seule une lumière diffractée d'ordre zéro-ème d'une lumière diffractée diffractée par la grille du dispositif de commande d'efficacité de sortie (342) est incidente sur l'élément piézoélectrique (343) et une lumière diffractée autre que la lumière diffractée d'ordre zéro-ème n'est pas incidente sur l'élément piézoélectrique (343).
29. Détecteur à infrarouge selon la revendication 24, dans lequel une modification d'une distance entre la grille et la plaque du dispositif de commande d'efficacité de sortie (342) modifie une quantité de lumière de la lumière diffractée d'ordre zéro-ème.
30. Détecteur à infrarouge selon la revendication 24, dans lequel le détecteur à infrarouge (300) comprend en outre un élément d'étanchéité ayant une ouverture, et l'élément d'étanchéité contient le dispositif de commande d'efficacité de sortie (342) et l'élément piézoélectrique (343).
31. Détecteur à infrarouge selon la revendication 24, dans lequel la lentille (344) a une structure en relief en surface conformément à une quantité modulée d'une phase de la lentille (344) et se compose d'un matériau sélectionné à partir d'un groupe composé de Si, Ge, GaAs, InP, GaP, ZnSe, et ZnS.
32. Détecteur à infrarouge selon la revendication 24, dans lequel le dispositif de commande d'efficacité de sortie (342; 101) est disposé de telle manière qu'une direction qui est parallèle par rapport à un plan principal de la plaque et verticale par rapport à la grille est verticale par rapport à un axe optique de la lentille (344).
33. Détecteur à infra-rouge comprenant :
- une lentille (452) ayant une ouverture rectangulaire, et un réseau de dispositifs de commande d'efficacité de sortie qui module une quantité de lumière de lumière incidente et délivre en sortie la lumière modulée, ayant une pluralité de dispositifs de commande d'efficacité de sortie disposée dans un réseau bidimensionnel (473), chacun d'une

pluralité de dispositifs de commande d'efficacité de sortie comprenant :

une plaque (9) ayant une partie (7) qui fonctionne comme une première électrode; une couche intercalaire (463) formée sur la plaque (9); et
une grille composée d'une pluralité de rayons, les rayons ayant des parties qui fonctionnent comme des secondes électrodes, les deux extrémités des rayons étant supportées par la couche intercalaire (463),

dans lequel une distance (L_3) entre la grille et la plaque est modifiée en ajustant une tension appliquée entre la première électrode et les secondes électrodes, en fonction de laquelle une efficacité de sortie de la lumière est commandée,
dans lequel le dispositif de commande d'efficacité de sortie est basculé d'un angle (θ_2) depuis une surface parallèle à la surface sur laquelle la lentille (452) est fixée, et
dans lequel la période (Λ) de la grille est modifiée conformément à la forme du point de lumière incidente.

- 34.** Détecteur à infrarouge selon la revendication 33, comprenant en outre un élément piézoélectrique (454), dans lequel

la lentille (452) focalise une lumière infrarouge et ;
le dispositif de commande d'efficacité de sortie reçoit la lumière infrarouge focalisée par la lentille (452), et délivre en sortie au moins une partie de la lumière infrarouge à l'élément piézoélectrique (454).

- 35.** Détecteur à infrarouge selon la revendication 33, comprenant en outre un élément piézoélectrique (454), dans lequel

le dispositif de commande d'efficacité de sortie délivre en sortie au moins une partie de la lumière infrarouge incidente (451), et
la lentille, prévue entre le dispositif de commande d'efficacité de sortie et l'élément piézo-électrique (454), focalise la lumière infrarouge délivrée en sortie par le dispositif de commande d'efficacité de sortie sur l'élément piézoélectrique (454).

- 36.** Détecteur à infrarouge de la revendication 34 ou 35, comprenant

un moyen pour faire fonctionner successivement la pluralité de dispositif de commande d'efficacité de sortie, et successivement détecter

des signaux de sortie par l'élément piézoélectrique ainsi obtenu ; et

un moyen pour détecter une distribution d'intensité de la lumière infrarouge bidimensionnelle comme une information en séquence temporelle, basé sur des signaux de sortie détectés par l'élément en piézoélectrique.

- 37.** Un thermomètre sans contact comprenant:

le détecteur à infrarouge selon la revendication 1;
un logement (646) comportant une ouverture (30);
un écran (647) qui ferme et ouvre l'ouverture;
un élément piézoélectrique (643) disposé dans le logement (646) ; et un moyen de mesure de la température du type à contact (649) disposé sur une paroi latérale du logement (646) ;

dans lequel la lentille (645) focalise une lumière infrarouge (650) et le dispositif de commande d'efficacité de sortie (2; 101) est disposé dans le logement (646), reçoit la lumière infrarouge (650) focalisée par la lentille (645), et délivre en sortie au moins une partie de la lumière infrarouge (650).

- 38.** Thermomètre sans contact selon la revendication 37, dans lequel le moyen de mesure de la température du type à contact (649) est un thermocouple.

- 39.** Thermomètre sans contact comprenant :

le détecteur à infrarouge selon la revendication 1 ;
un logement (646) comportant une ouverture ;
un écran (647) qui ferme et ouvre l'ouverture ;
un élément piézoélectrique (643) disposé dans le logement (646) ; et un moyen de mesure de la température du type à contact (649) disposé sur une paroi latérale du logement (646) ;

dans lequel le dispositif de commande d'efficacité de sortie est placé dans le logement (646), reçoit une lumière infrarouge (650) à travers l'ouverture, et délivre en sortie au moins une partie de la lumière infrarouge (650); et
la lentille délivre en sortie au moins une partie de la lumière infrarouge délivrée en sortie par le dispositif de commande d'efficacité de sortie (641) à l'élément piézoélectrique (643).

- 40.** Thermomètre sans contact selon la revendication 39, dans lequel le moyen de mesure de la température du type à contact est un thermocouple.

- 41.** Thermomètre sans contact comprenant :

le détecteur à infrarouge selon la revendication 33 ;
 un logement (646) comportant une ouverture ;
 un écran (647) qui ferme et ouvre l'ouverture ;
 un élément piézoélectrique (643) disposé dans le logement (646) ; et un moyen de mesure de la température du type à contact (649) disposé sur une paroi latérale du logement (646) ;

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dans lequel la lentille focalise une lumière infrarouge (650) et le faisceau de dispositifs de commande d'efficacité de sortie est disposé dans le logement (646), reçoit la lumière infrarouge (650) focalisée par la lentille (645), et délivre en sortie au moins une partie de la lumière infrarouge (650).

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- 42.** Thermomètre sans contact selon la revendication 41, dans lequel le moyen de mesure de la température du type à contact (649) est un thermocouple.

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- 43.** Thermomètre sans contact comprenant:

le détecteur à infrarouge selon la revendication 33 ;
 un logement (646) comportant une ouverture ;
 un écran (647) qui ferme et ouvre l'ouverture ;
 un élément piézoélectrique (643) disposé dans le logement (646) ; et un moyen de mesure de la température du type à contact (649) disposé sur une paroi latérale du logement (646) ;

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dans lequel le dispositif de commande d'efficacité de sortie est placé dans le logement (646), reçoit une lumière infrarouge (650) incidentes à travers l'ouverture, et délivre en sortie au moins une partie de la lumière infrarouge (650); et
 la lentille délivre en sortie au moins une partie de la lumière infrarouge délivrée en sortie par le dispositif de commande d'efficacité de sortie (641) à l'élément piézoélectrique (643).

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- 44.** Thermomètre sans contact selon la revendication 43, dans lequel le moyen de mesure de la température du type à contact (649) est un thermocouple.

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FIG. 1

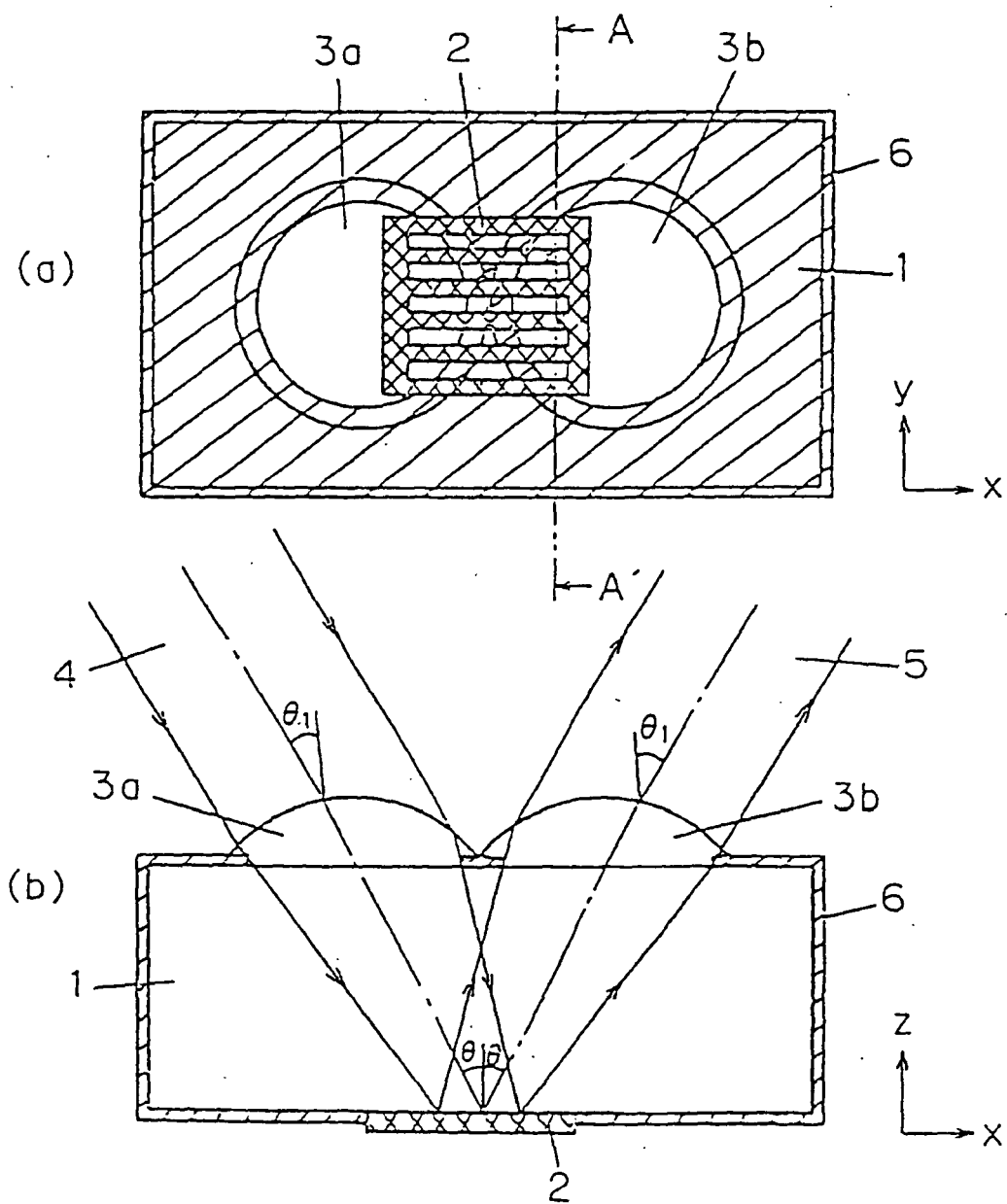


FIG. 2

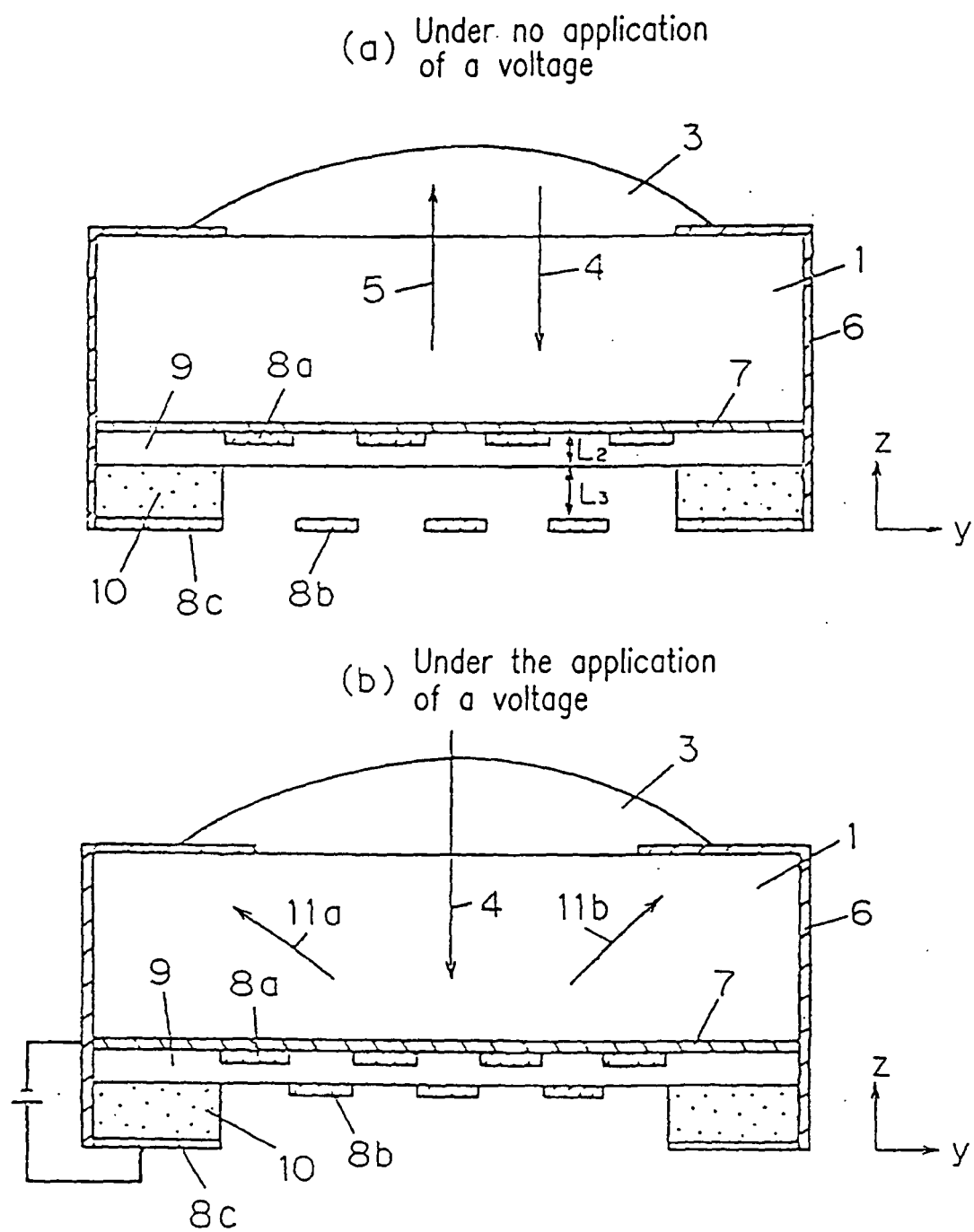


FIG. 3

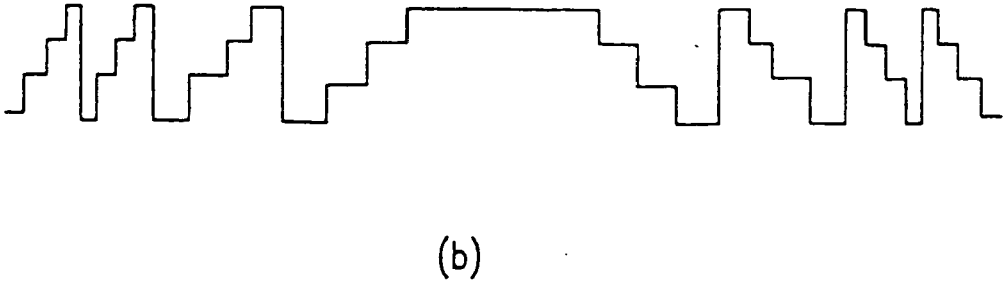
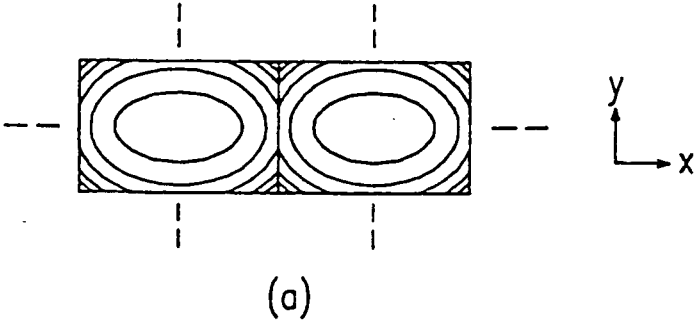


FIG. 4

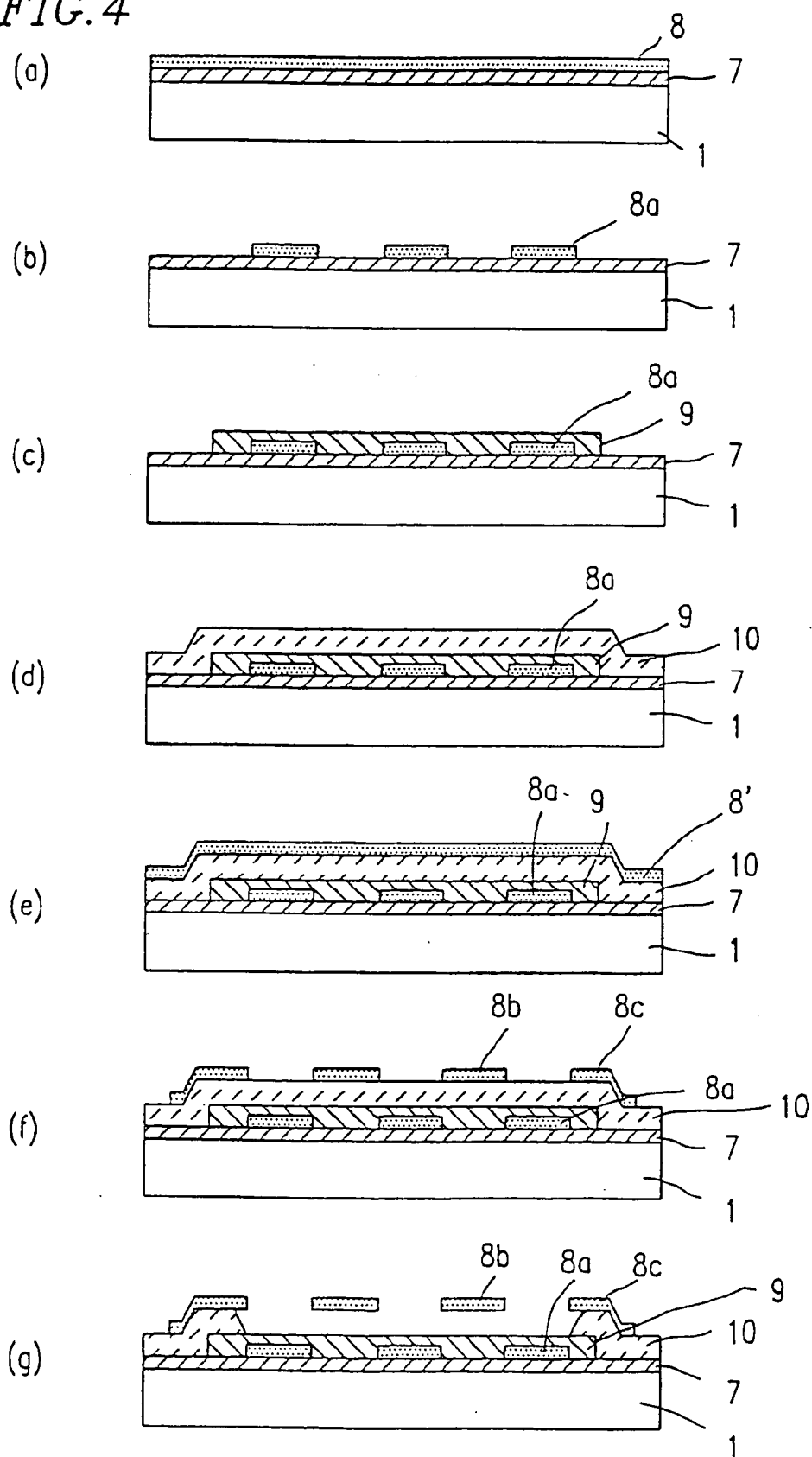


FIG. 5

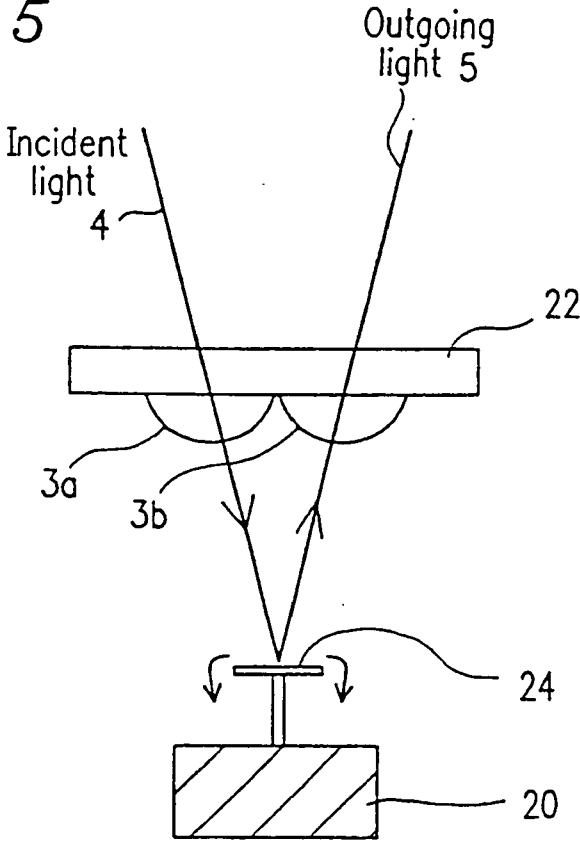


FIG. 6

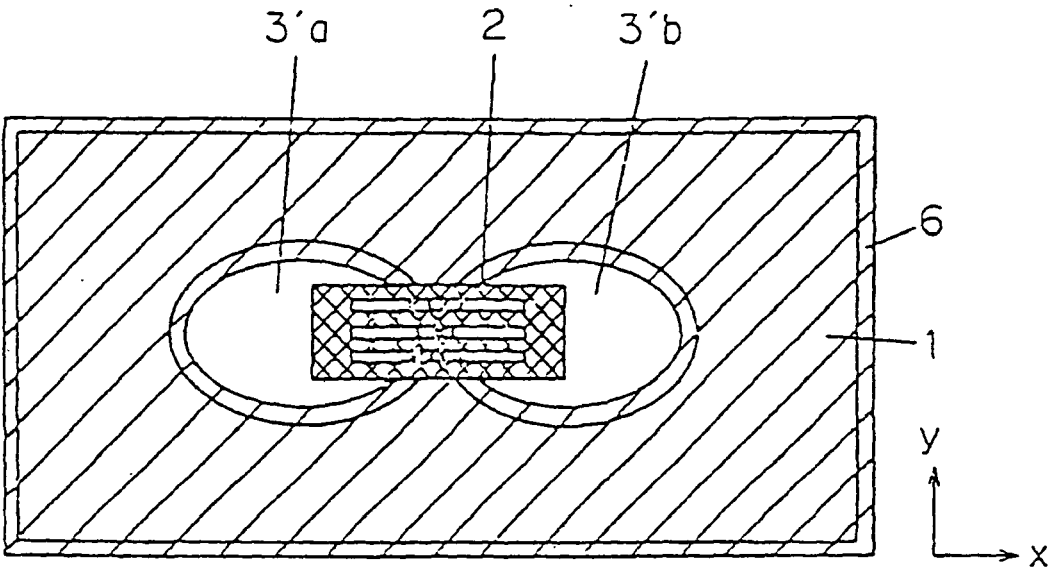


FIG. 7

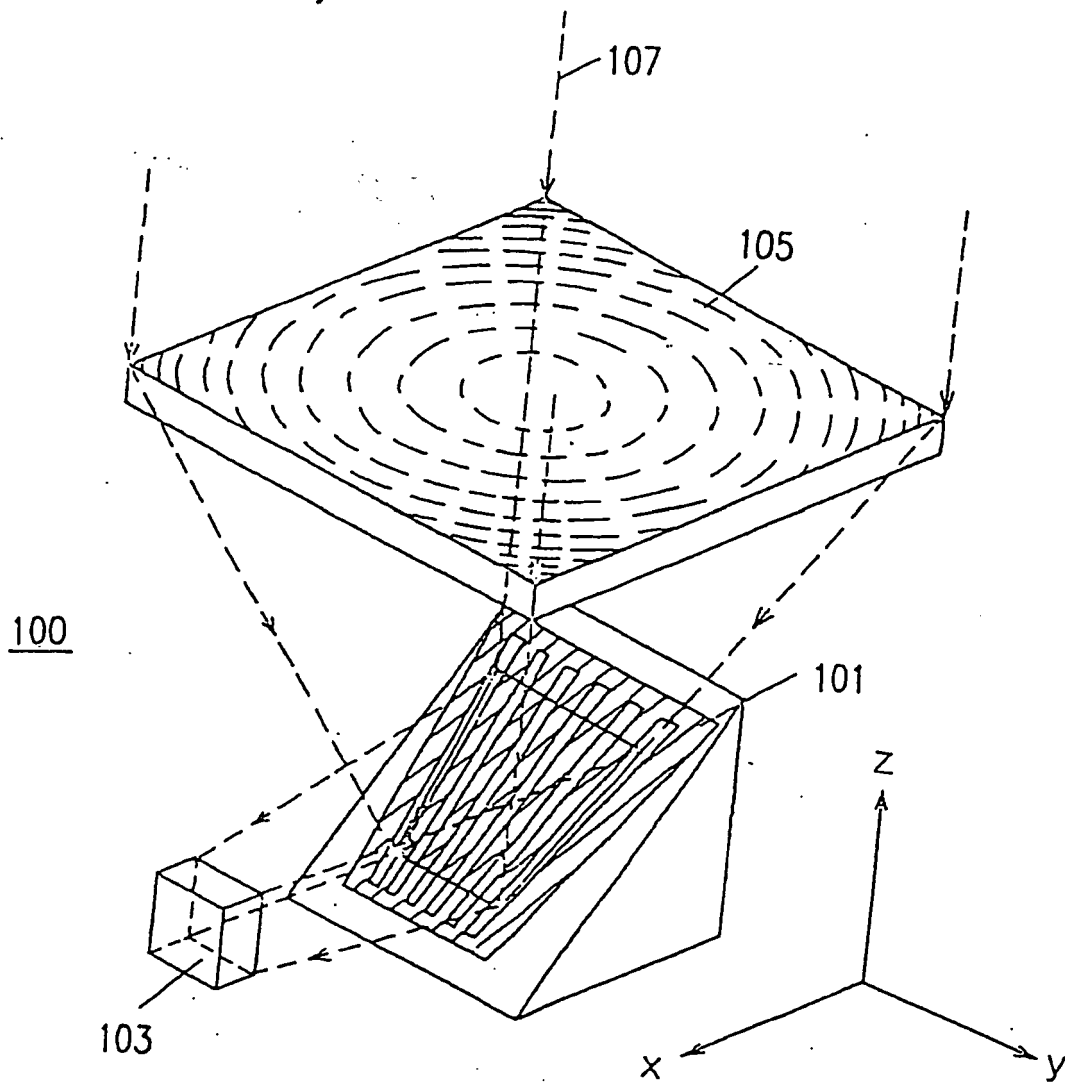


FIG. 8

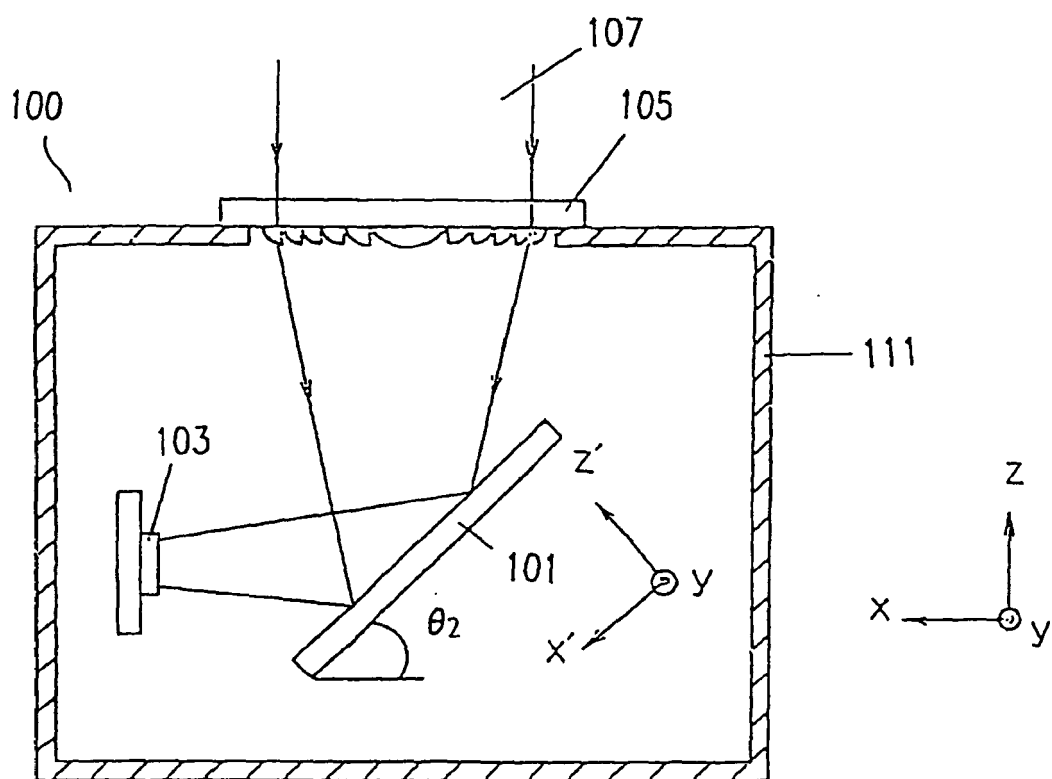


FIG. 9

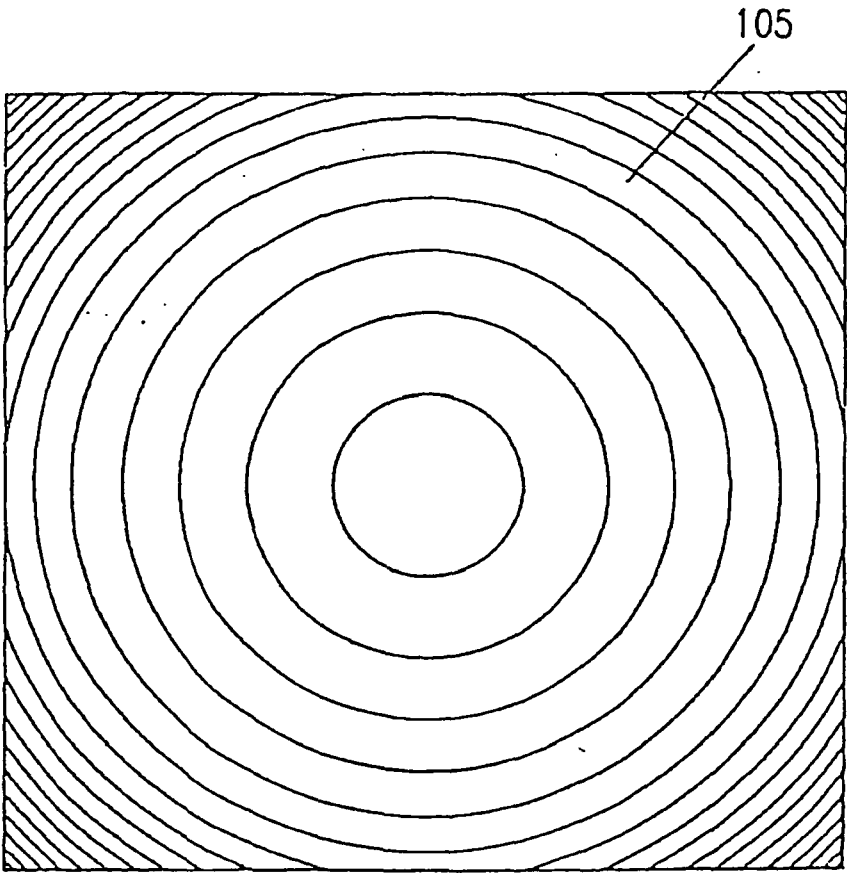
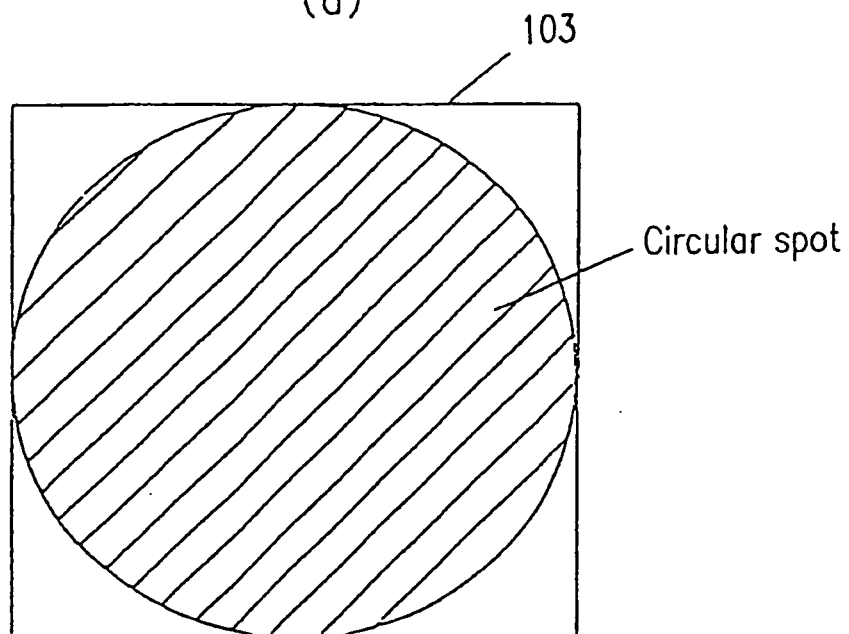


FIG.

10

(a)



(b)

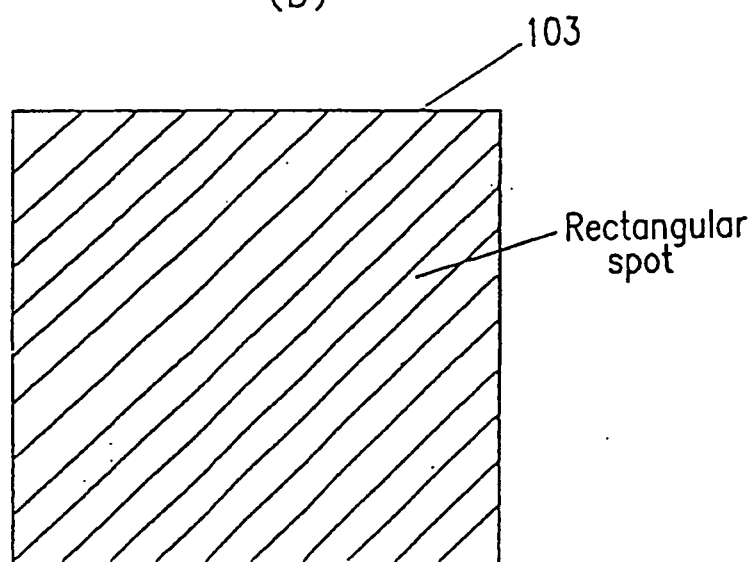


FIG. 11

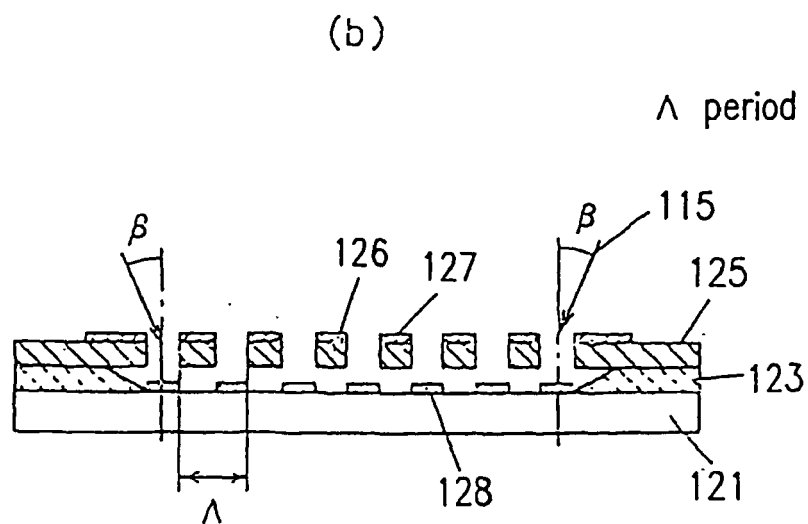
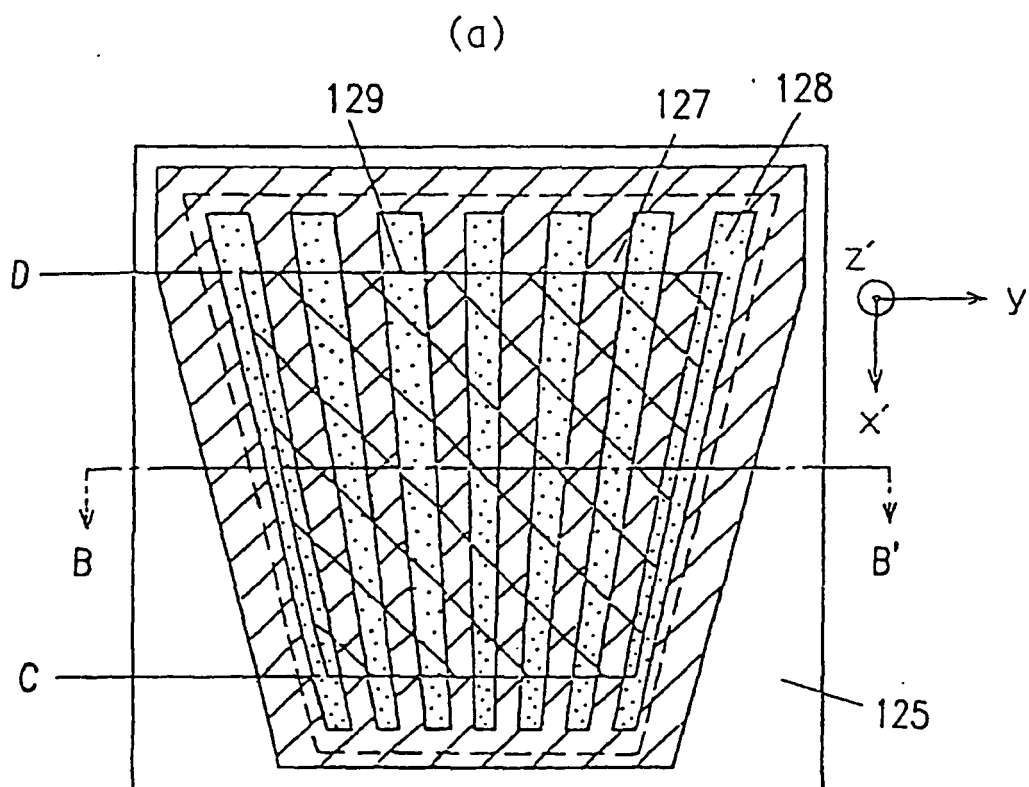


FIG. 12

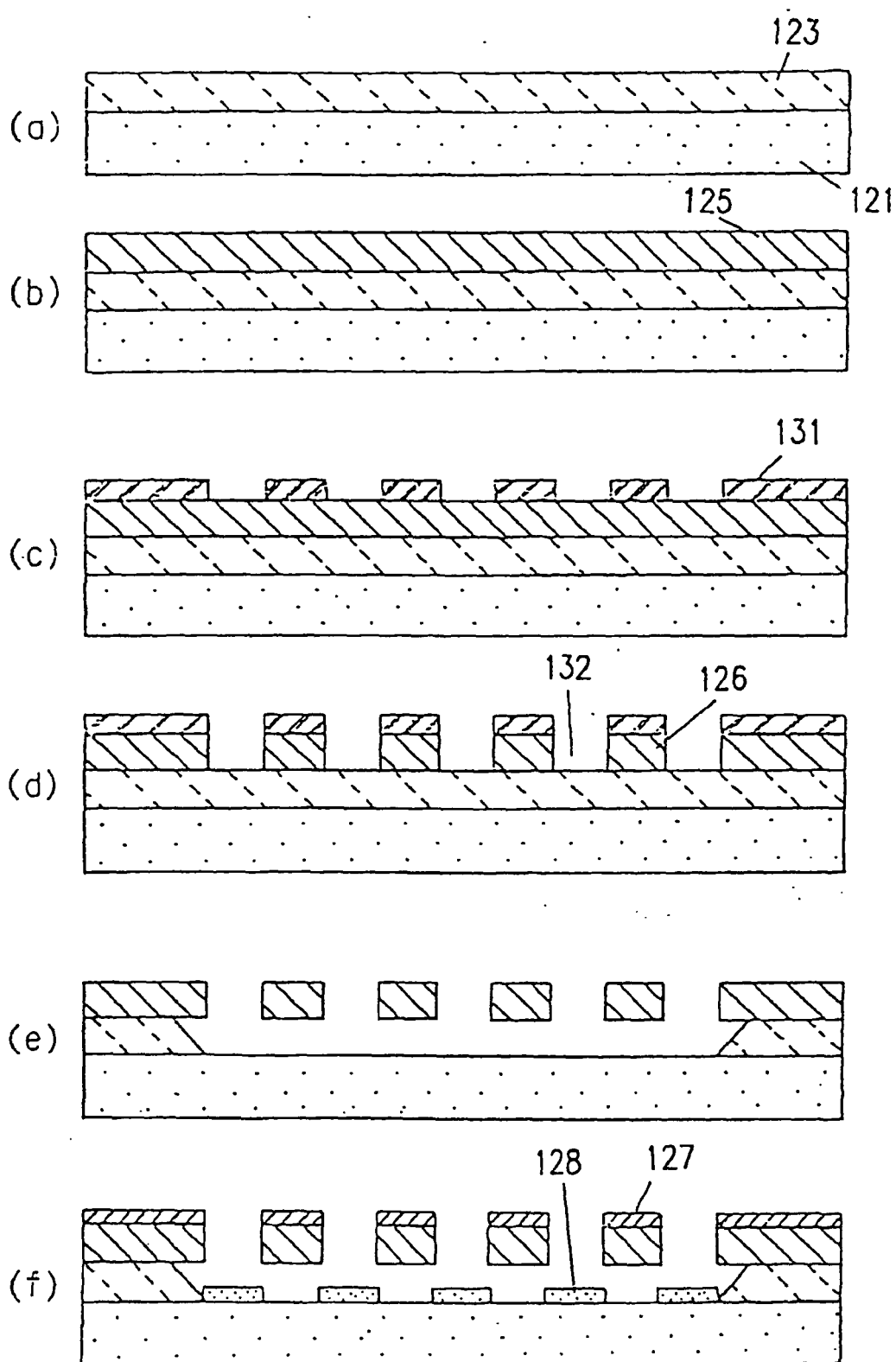
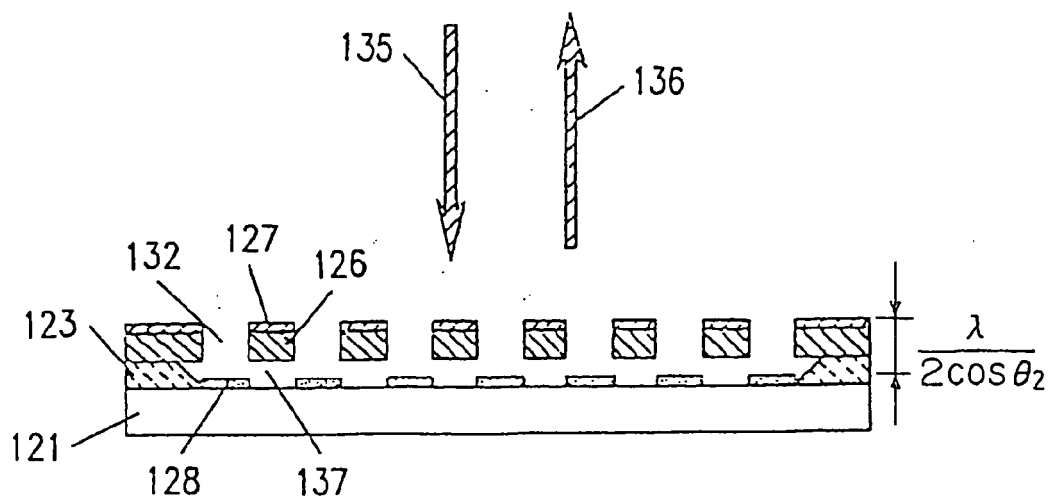


FIG. 13 (a)



(b)

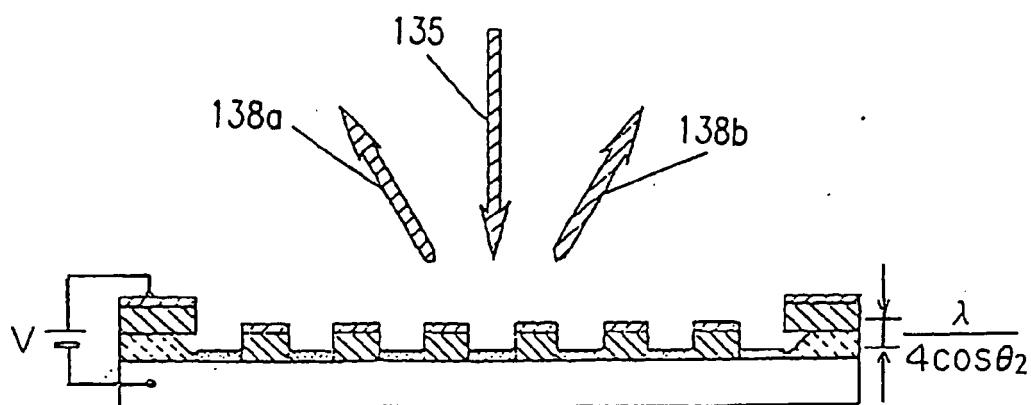
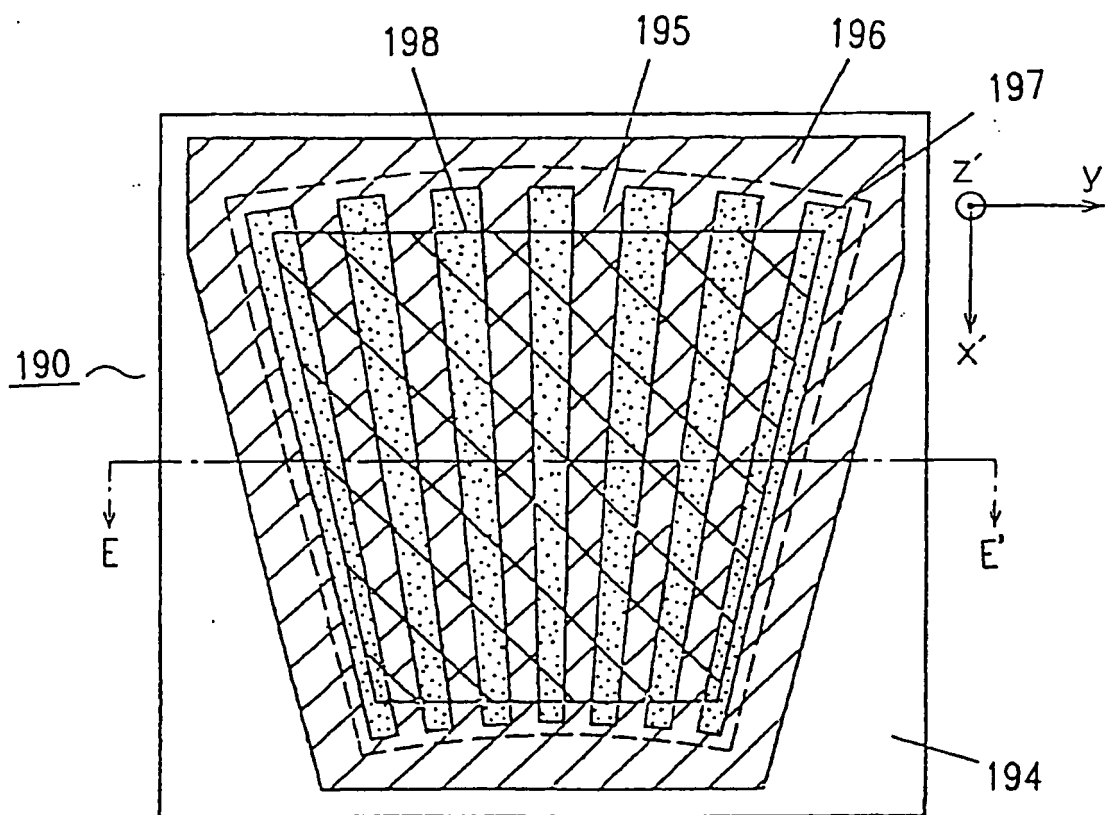


FIG. 14 (a)



(b)

Λ period

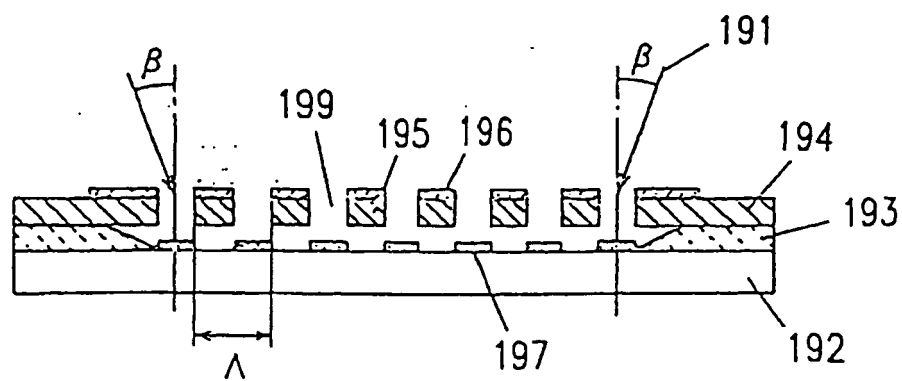


FIG. 15

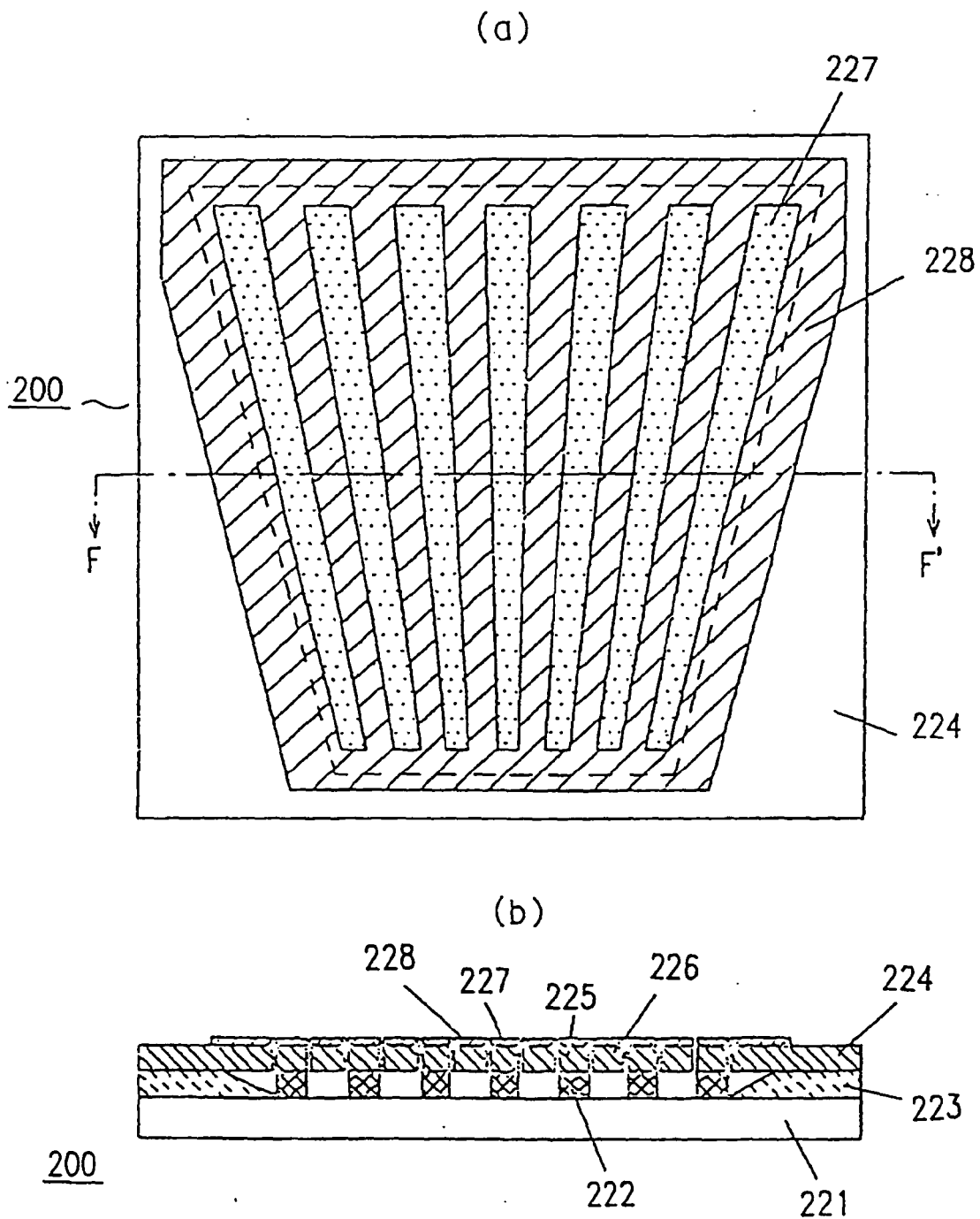


FIG. 16

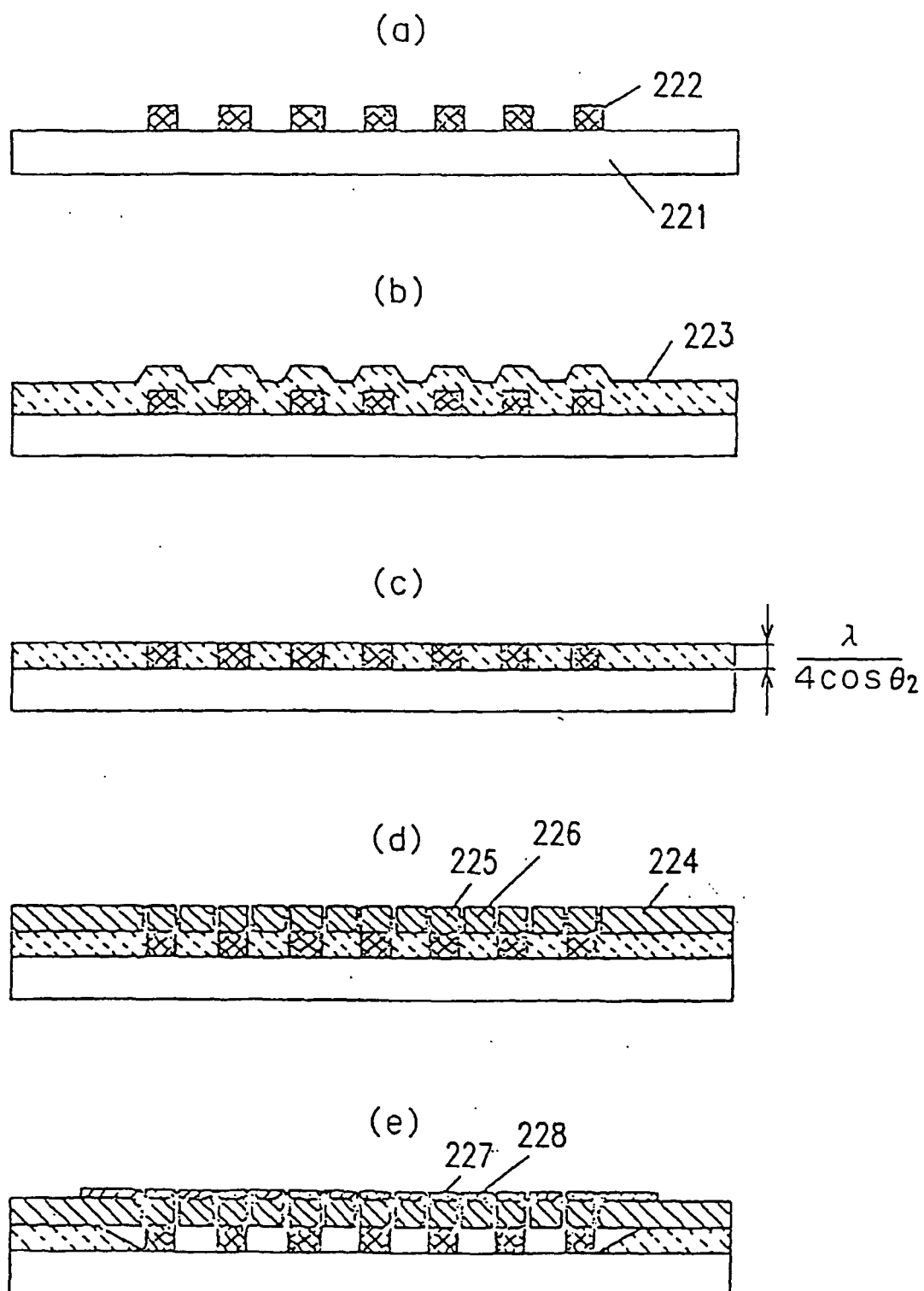
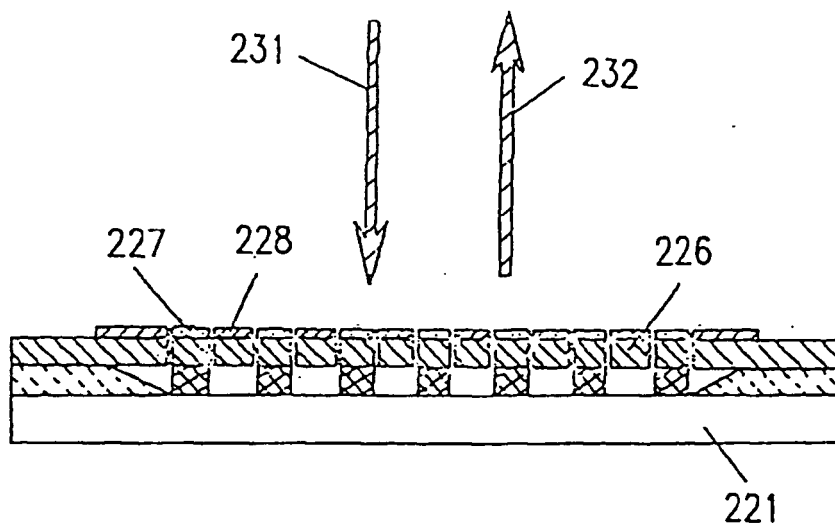


FIG. 17

(a)



(b)

λ Wavelength of incident light
 θ Incident angle

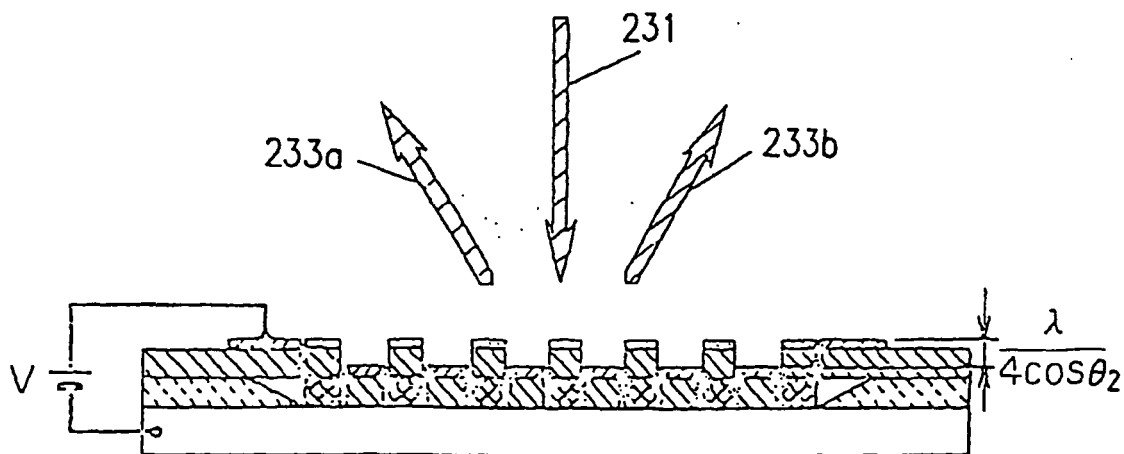


FIG. 18

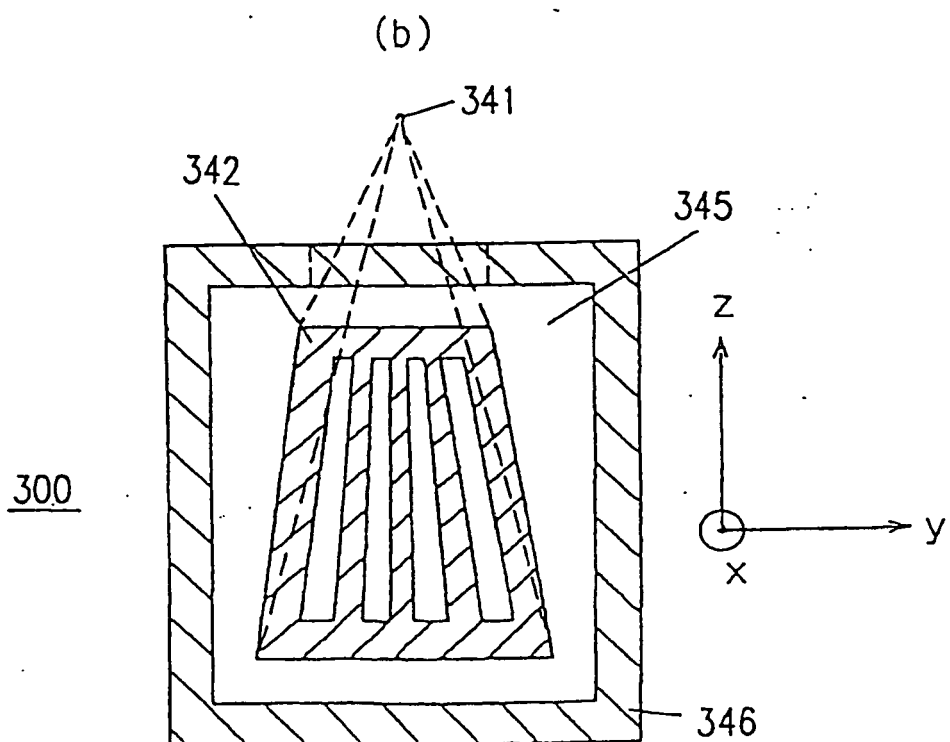
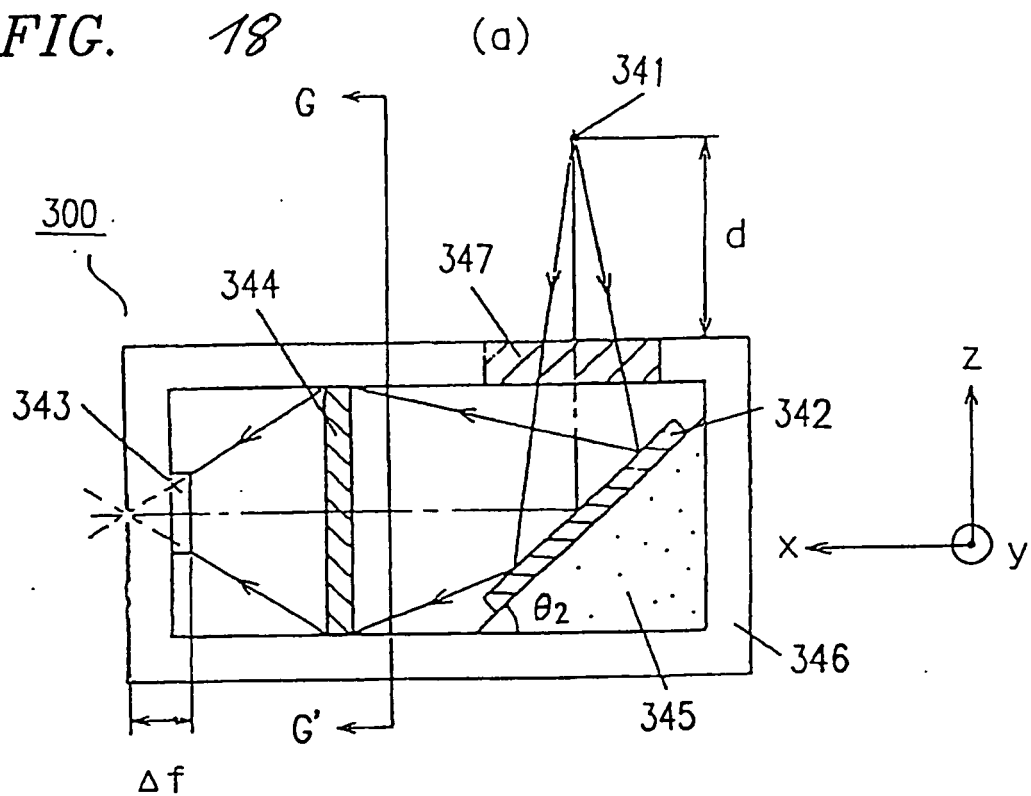


FIG. 19

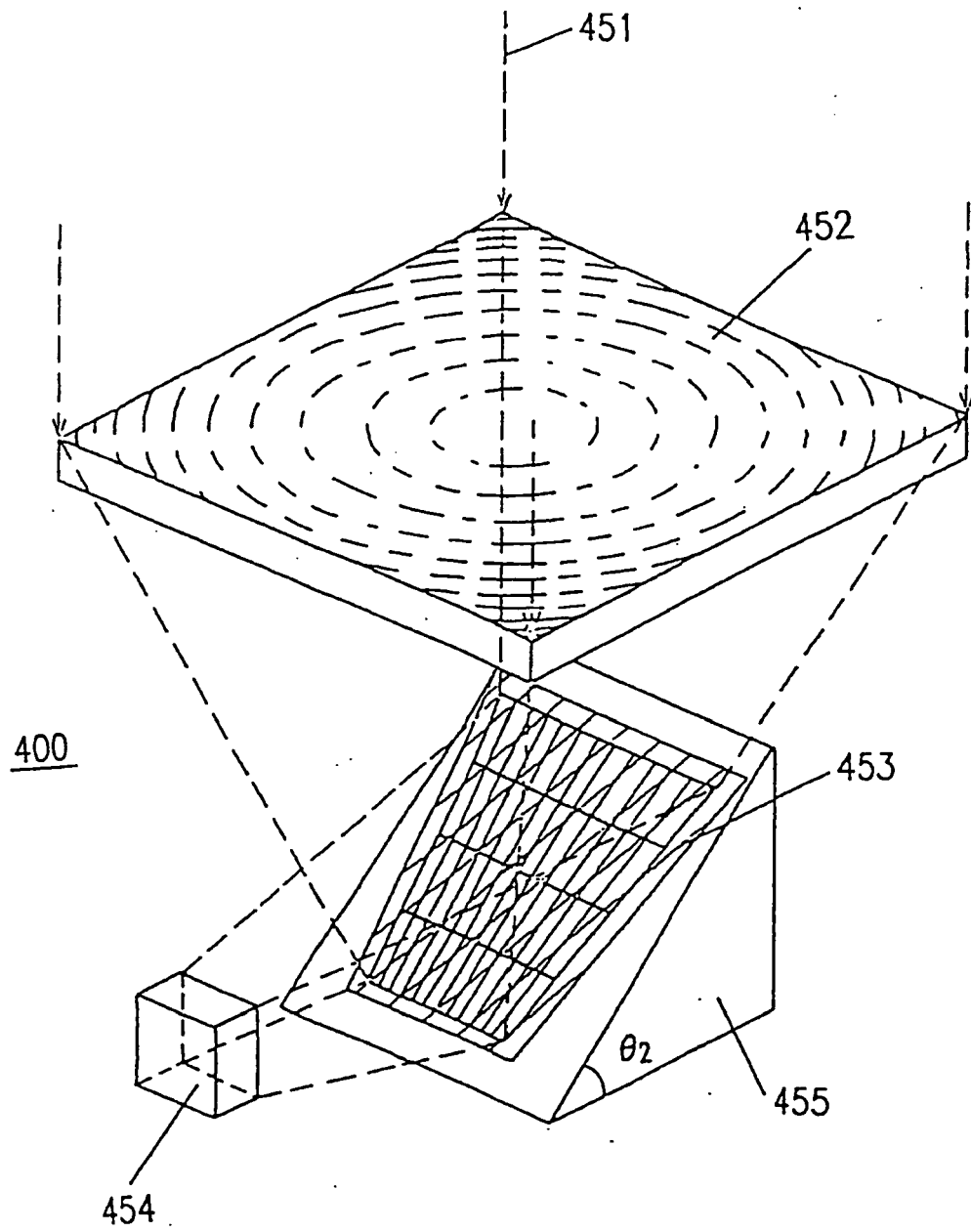


FIG. 20

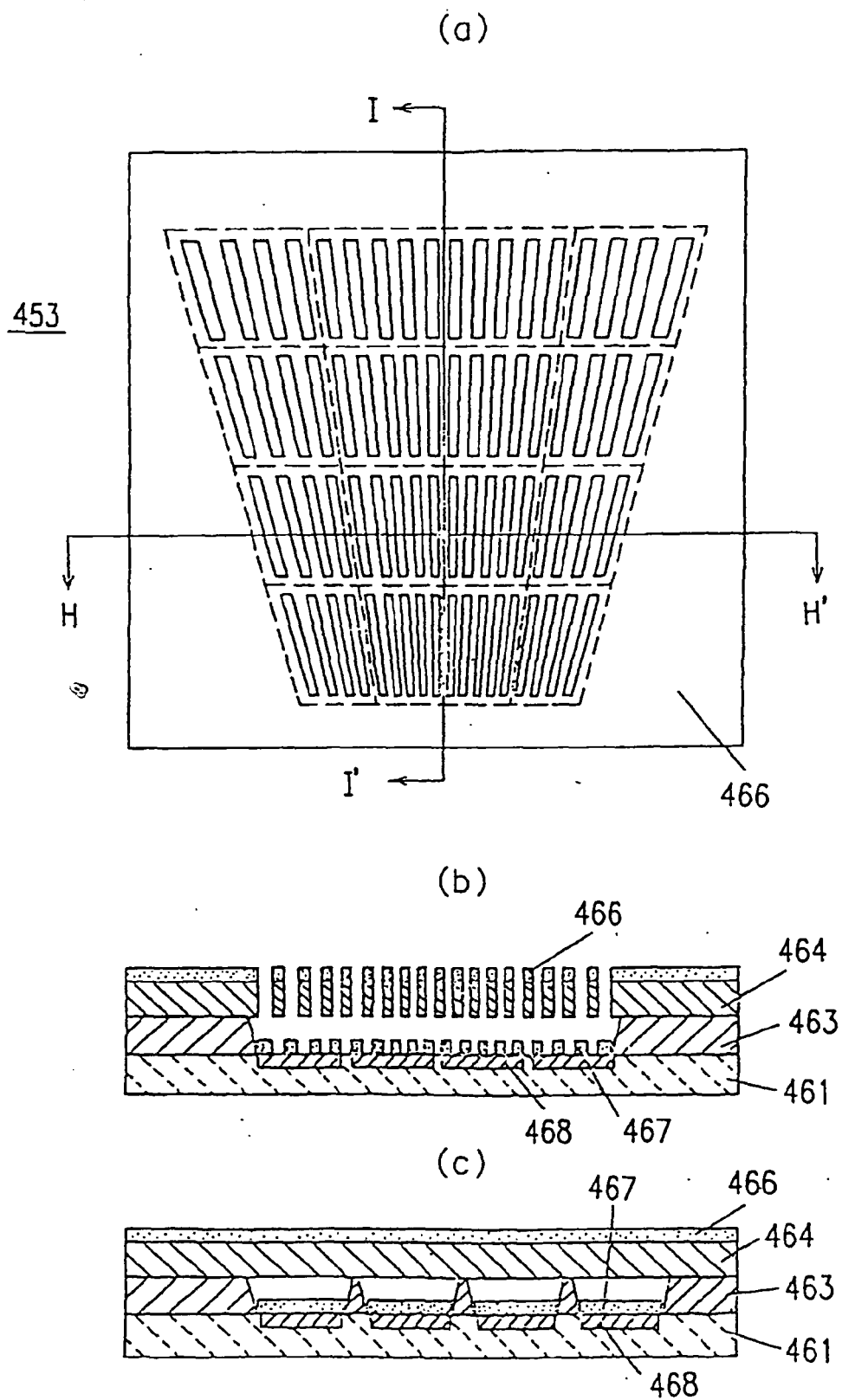


FIG. 21

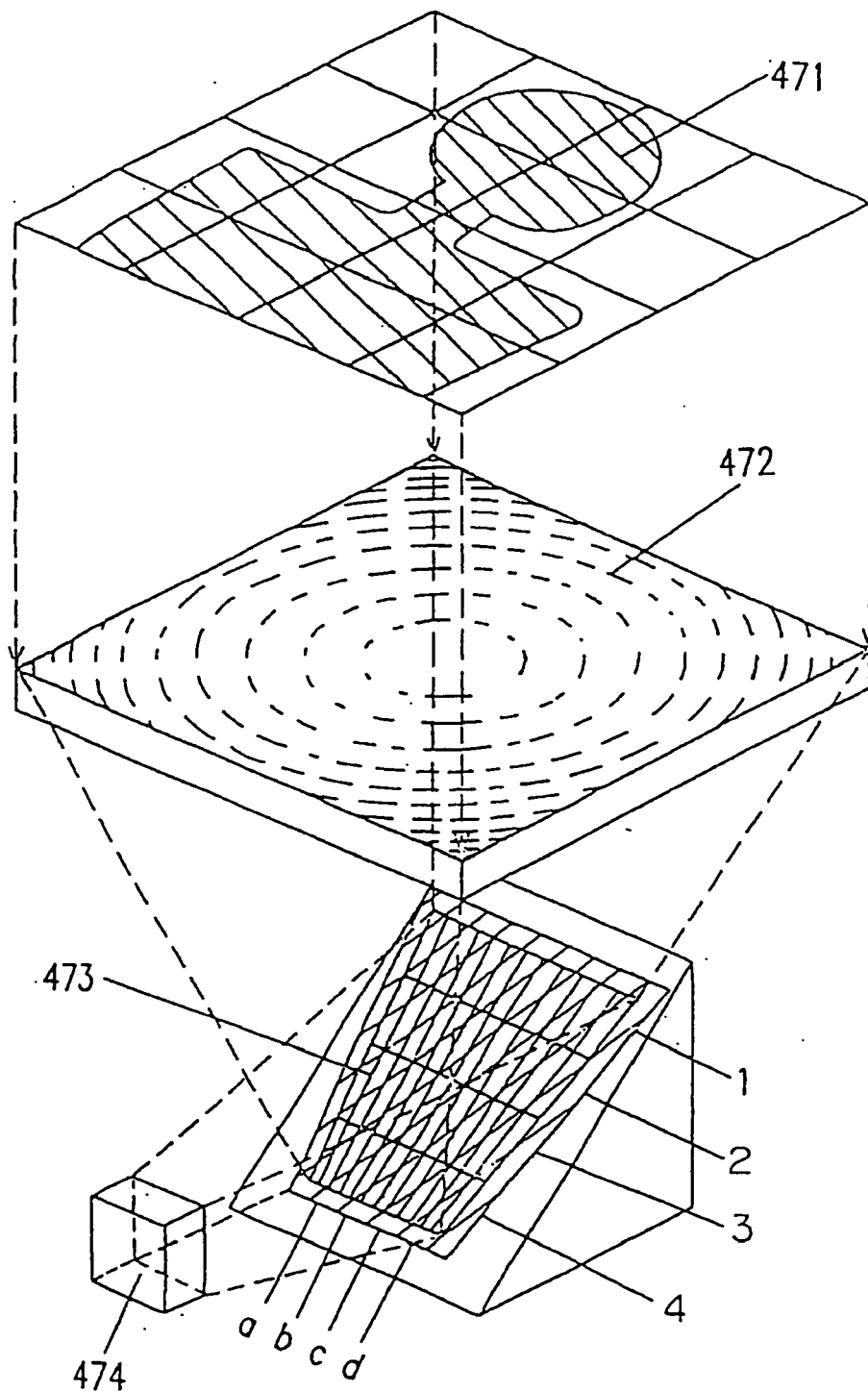
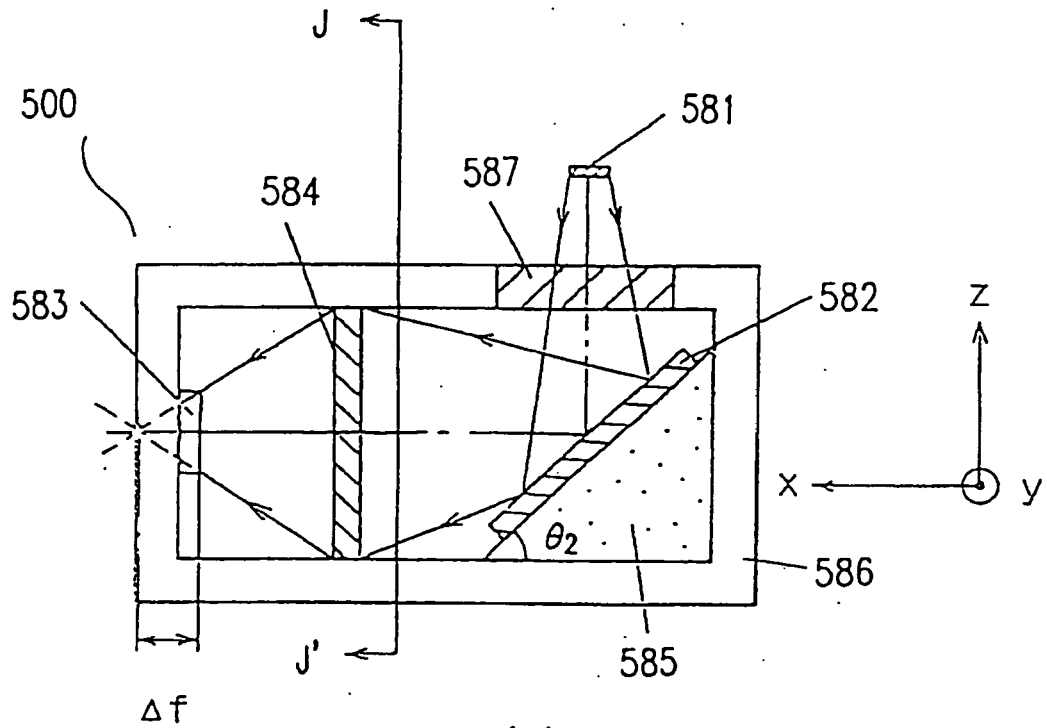


FIG. 22

(a)



(b)

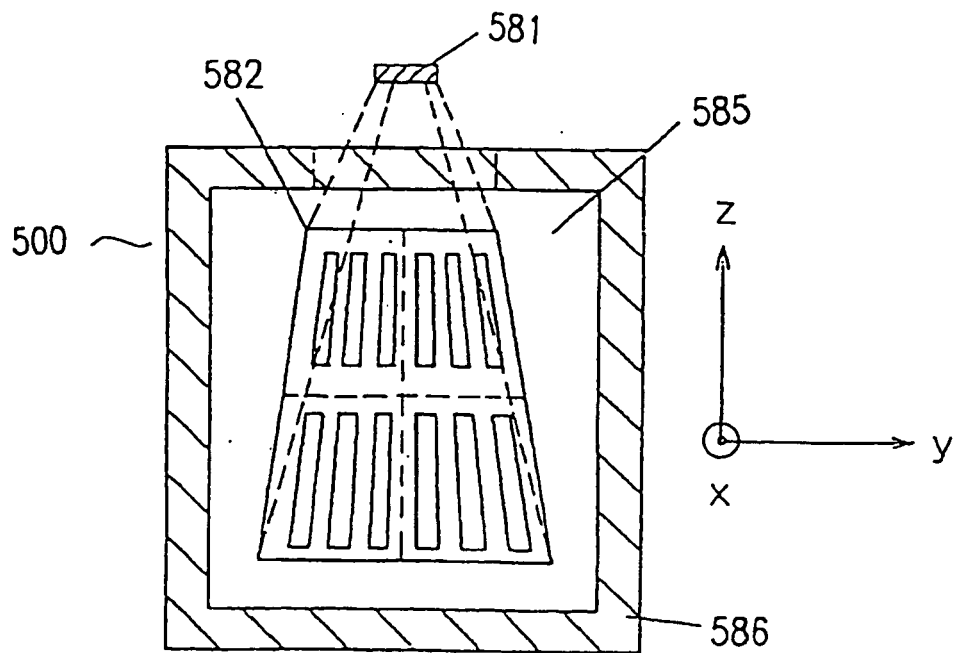


FIG. 23

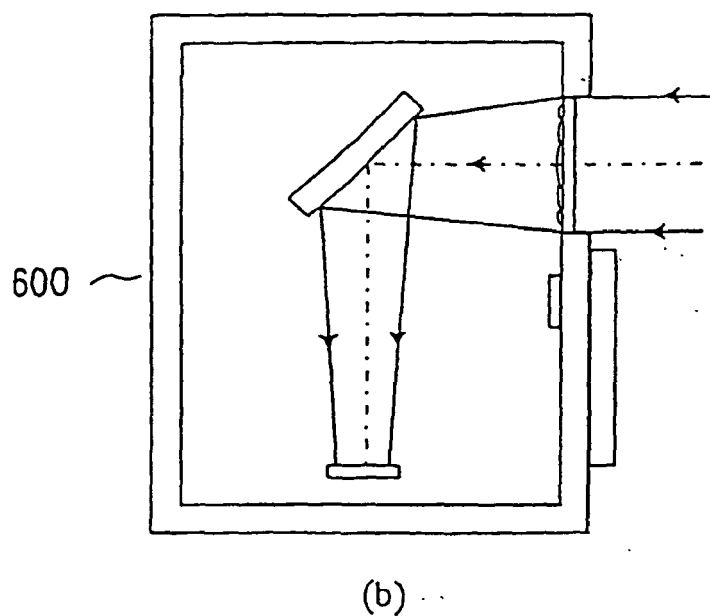
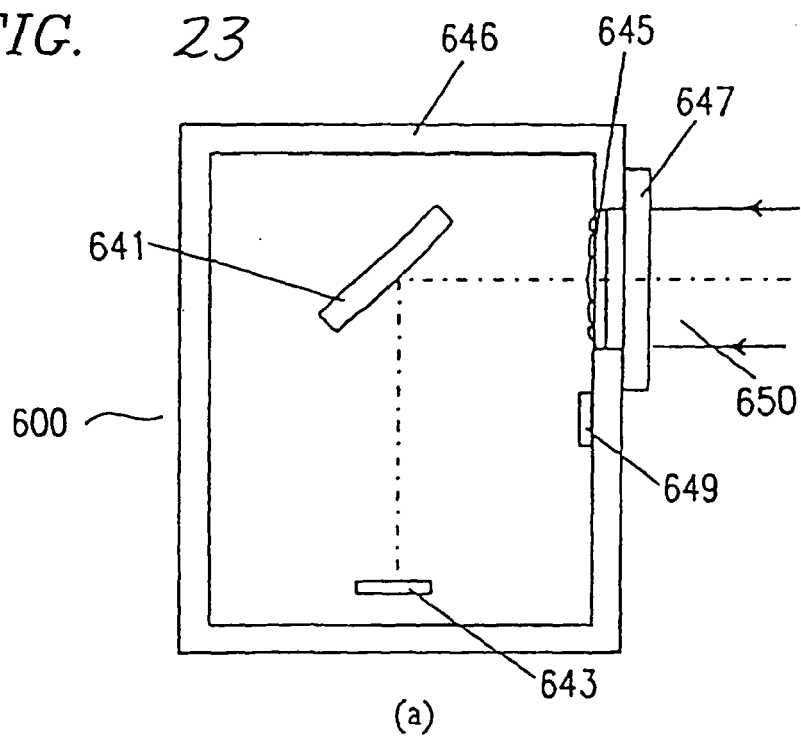
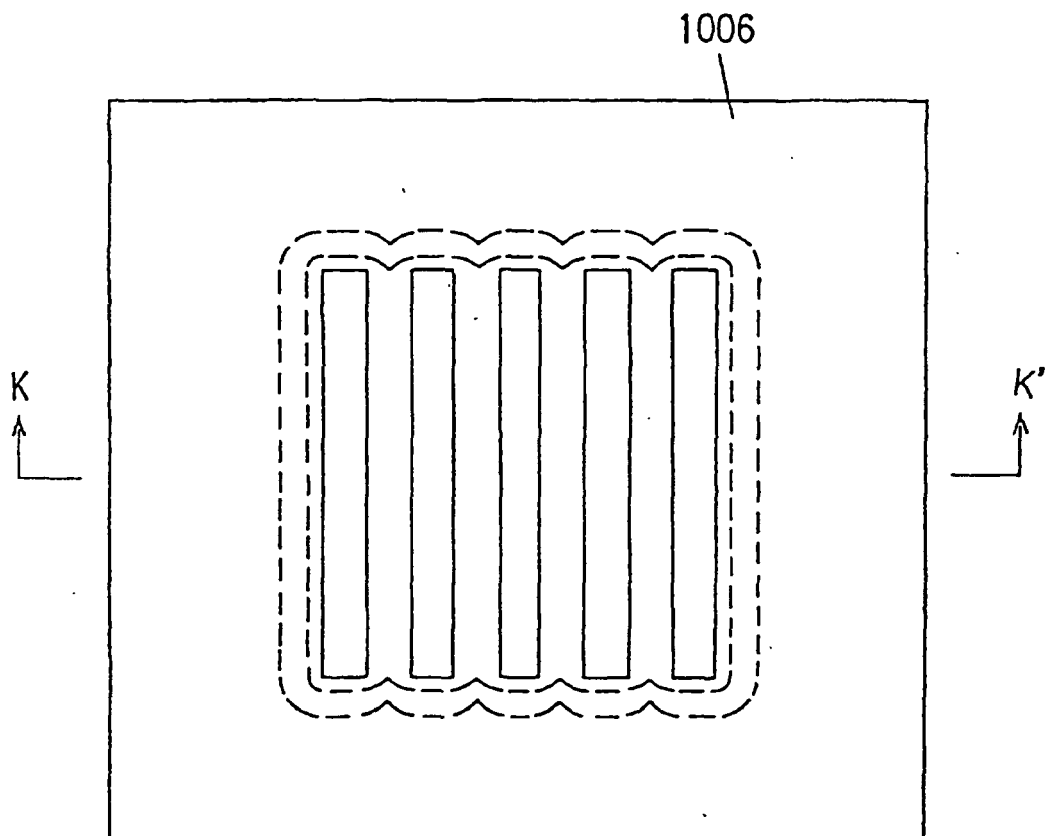


FIG. 24 (a)



(b)

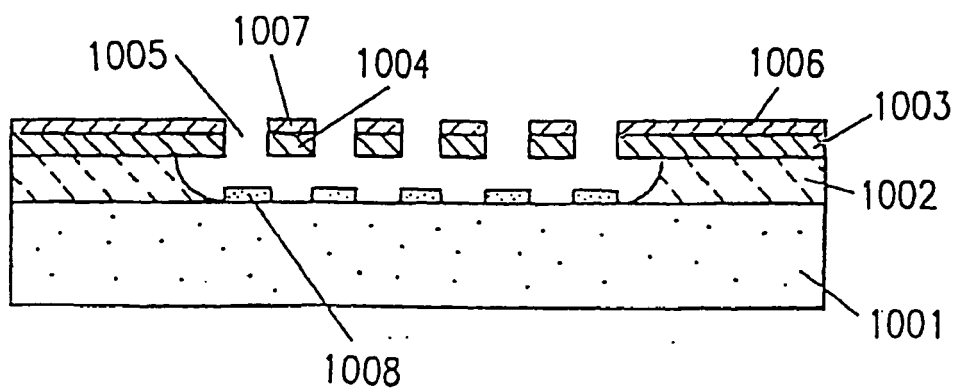
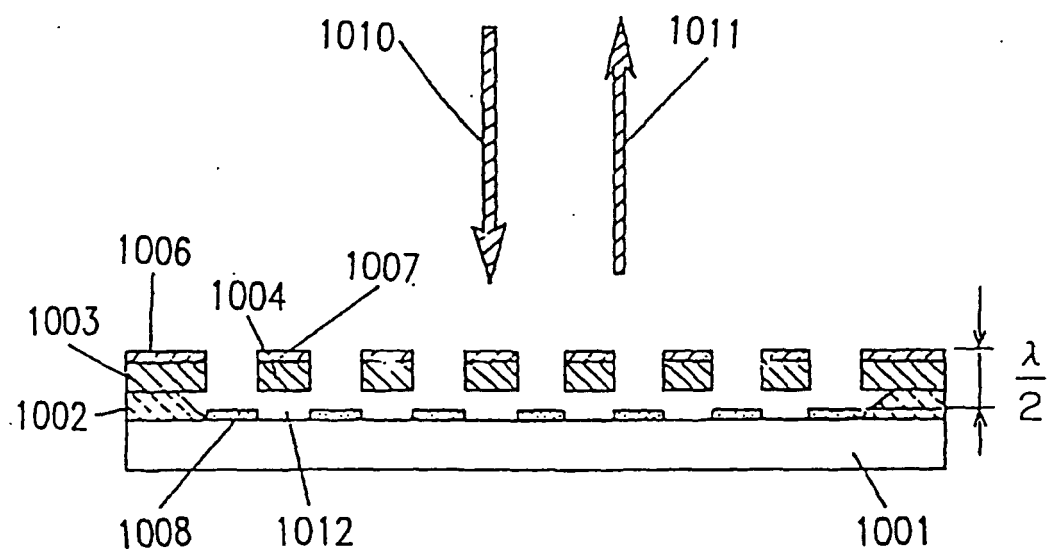


FIG. 25

(a)



(b)

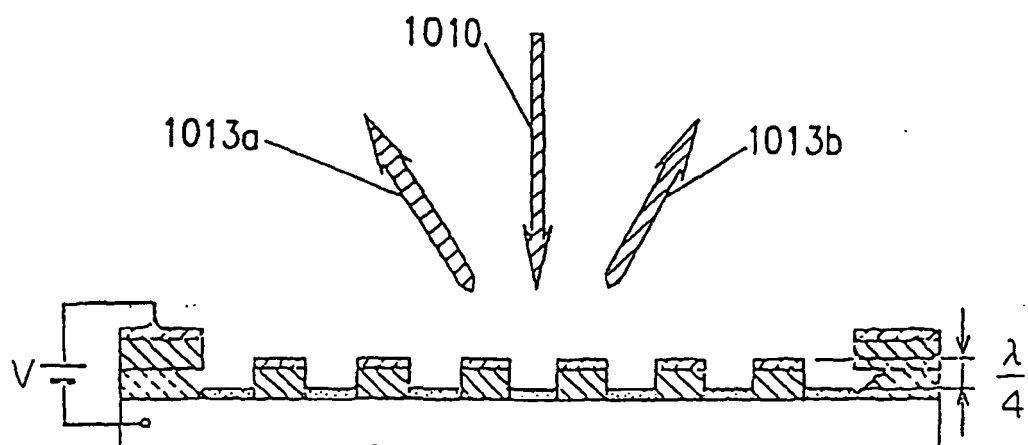


FIG. 26

