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(54) Infra-red detection apparatus.

(57) Apparatus for the detection of infra-red radiation comprises a passive infra-red sensor (16), a focusing reflector (20) constructed and arranged to focus infra-red radiation received by the apparatus from a first range of distances from the apparatus, on the sensor (16) , and a focusing refractor (14) constructed and arranged to focus infra-red radiation received by the apparatus from a second range of distances from the apparatus, on the sensor (16), the second distance range encompassing distances shorter than the first distance range. The refractor may be a Fresnel lens (14) or an array of Fresnel lenses (32, 33, 34) formed in a polyethylene window (12) through which the radiation is transmitted. The reflector (20) may be a concave reflector and a second plane reflector (22) may be included to produce a more compact construction.

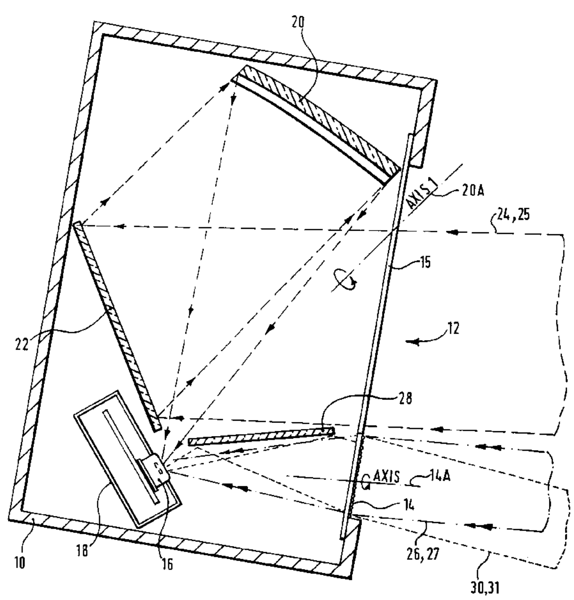

FIG.1.

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This invention relates to apparatus for the detection of infra-red radiation having a passive infra-red sensor and optical elements for focusing infra-red radiation received from a surveyed scene onto the sensor. The primary use of the invention is as an intruder detector responsive to heat radiation radiated by the body of an intruder.

Detection of intruders by monitoring infra-red energy from body heat radiation is now a well-established practice. British Patent Specification No. 1335410 describes detection apparatus using an array of spherical mirror segments sharing a common focal point at which is located a thermoelectric sensor. The axis of each mirror segment is arranged to produce radially projecting fields of view spaced apart so that an intruder crossing the area and entering and leaving the fields of view causes fluctuations in the level of infra-red energy incident on the sensor. A device using a mirror array generally requires a protective housing with a window on that side of the housing facing the scene to be surveyed to allow infra-red energy to pass to the array without significant absorption and to protect the array from air currents and dust. It is known to use silicon or germanium windows, but polyethylene film typically having a thickness in the region of 0.4mm is more commonly used.

More recently, the combination of a mirror array and a polyethylene window has been replaced by a polyethylene window in the form of a Fresnel lens, or an array of Fresnel lenses arranged to produce discrete fields of view. Such lenses are generally less expensive to manufacture than a focusing array of mirror segments.

Whilst Fresnel lenses are adequate for intruder detection over a distance range up to about 25 metres, they are less suitable for longer range detection since it is difficult to produce an inexpensive polyethylene lens with a sufficiently accurately defined field of view and without excessive aberration, which at the same time passes the longer infrared wavelengths (typically 7 to 11 microns) without significant absorption.

It is an object of the invention to provide apparatus capable of producing a well-defined image from infra-red radiation emitted by a body at a range in excess of 25 metres, and preferably in excess of 50 metres.

According to this invention, apparatus for the detection of infra-red radiation comprises a passive infra-red sensor, a focusing reflector constructed and arranged to focus infrared radiation received by the apparatus from a first range of distances from the apparatus, on the sensor, and a focusing refractor constructed and arranged to focus infrared radiation received by the apparatus from a second range of distances from the apparatus, on the sensor, the second distance range encompassing distances shorter than the first distance range. The focusing refractor may be a Fresnel lens or an array of Fresnel lenses formed in a sheet of polyethylene material, the lens or array of lenses causing radiation received from an object within the second distance range to converge on the sensor, which is preferably positioned at or near the focal plane of the lens or array of lenses. Preferably, the sensor and the reflector are contained within a housing one wall of which is formed as a window facing the scene to be surveyed. Advantageously, the window is a polyethylene film, part of which, preferably a lower part, is formed as an array of Fresnel lenses, and another part of which is parallel-sided so as to pass infrared radiation largely without refraction.

The focusing reflector may be a concave mirror arranged to receive radiation through the plane portion of the window from objects in the first distance range to cause such radiation to converge on the sensor. A particularly, compact arrangement can be achieved by including a second reflector, preferably a plane reflector, as an intermediate reflector in the optical path between the window and the above-mentioned focusing refractor. For instance, if the sensor is located in a lower part of the housing at or near the effective focal plane of the Fresnel lens or lenses, the concave reflector is best positioned in the top part of housing with its reflective surface facing downwards and away from the window, and the plane reflector is best mounted generally at the same level as the parallel-sided part of the window rearwardly with respect to the concave reflector oriented so that radiation from a distant object is reflected upwardly to the concave reflector which then reflects the radiation downwardly to converge on the sensor. It will be appreciated that the sensor should be located at or near the focal plane of the concave reflector, i.e. at or near the intersection of the focal planes of the concave reflector and the Fresnel lens or lenses. It will also be appreciated that a similarly compact arrangement may be achieved with the sensor in an upper part of the housing and with the concave reflector in a lower part.

Other arrangements are possible. That described above results in a housing of relatively small depth. In some situations, however, it may be important to restrict instead the height of the housing, in which case the concave reflector can be positioned towards the rear of the housing so as to reflect incoming radiation forwardly in the housing towards a forwardly mounted sensor.

In practice, when the apparatus is mounted some distance above the ground, for example at a height of two metres or greater, the positioning of the sensor and the optical components described above determines the effective ranges within which radiation sources may be detected according to the inclination of the paths of the incoming radiation with respect of the horizontal. Thus, radiation emanating from a body less than 25 metres from the apparatus will be incident upon the window at a greater angle with respect of the horizontal than radiation emanating from a body at, for example, 50 metres. Accordingly, the positioning of the concave and plane reflectors with respect to the sensor and the parallel-sided part of the window is arranged such that radiation from objects at a distance of 50 metres or greater is directed onto the sensor, while the position of the sensor with respect to the lower part of the window, containing the Fresnel lens or lenses is such that the sensor receives radiation only from objects at a distance of 25 metres or less. A typical commercially available infrared sensor has two heat sensitive elements about 1mm wide by 2mm high spaced apart by 1mm. It will be appreciated, then, that if for example, the positioning of the sensor is such that radiation from objects at a distance of approximately 25 metres reaches the sensor, then objects much closer may not be detected. This difficulty can be overcome by including a second plane reflector in the region between the Fresnel lens or lenses and the sensor and alongside the radiation path therebetween in order to reflect radiation instant upon the Fresnel lens at a steeper angle of inclination (i.e. emanating from objects much nearer than 25 metres) onto the sensor. When the sensor is located in a lower part of the housing, it is advantageous that this second plane mirror has a downwardly facing surface and is positioned generally above the path of radiation travelling directly between the Fresnel lens and the sensor so that the reflector can act as a shield protecting the sensor from direct sunlight.

The invention will now be described by way of example with reference to the drawings in which:-

Figure 1 is a sectional side view of apparatus in accordance with the invention;

Figure 2 is a front elevation of the apparatus of Figure 1;

Figure 3 is a diagrammatic side view illustrating the fields of view of the apparatus of Figure 1, shown in a vertical plane;

Figure 4 is a diagrammatic plan view showing the same fields of view as shown in Figure 3;

Figure 5 is a front view of an alternative window for the apparatus of Figure 1;

Figure 6 is a diagrammatic side view showing the fields of view in a vertical plane obtained with the window shown in Figure 5; and

Figure 7 is a plan view of the fields of view produced by the window of Figure 5.

Referring to Figure 1, infra-red detection apparatus in accordance with the invention has an outer housing 10 with a front aperture covered by a polyethylene film window 12 which is sufficiently thin to pass infra-red radiation having a wavelength typically in the region of 7 to 11 microns without significant absorption. As will be seen from both Figures 1 and 2, the window 12 has a lower part which is ribbed on one surface to form a Fresnel lens 14 having a lens axis 14A. The remainder of the window, i.e. the upper part 15, is generally parallel-sided and is smooth on both sides so as to pass radiation substantially without refraction. The housing, together with its window provides environmental protection and electrical screening. It will also be noted that the housing 10 is taller than it is deep.

Situated inside the lower part of the housing 10 is a pyro-electric sensor 16 containing one or more heat sensing elements and mounted in a metallic casing 18 which also contains electronic circuitry for amplifying and filtering the electrical signal produced by the sensor, as well as generating an alarm signal or other response. The sensor 16 includes an integral long-pass optical filter allowing transmission of long infra-red wavelength radiation (i.e. longer than, for example, 7 microns), and is directed towards the window and towards the opposite (upper) part of the housing so as to be sensitive to radiation incident directly from the window 12 and from the upper part of the housing. In order that radiation emanating from objects 25 metres or less from the apparatus is incident upon the sensor 16, the latter is positioned at least approximately in the focal plane of the Fresnel lens 14 at a level corresponding to the position of the image produced by a radiating object at the expected declination with respect to the window 12 for an object within that distance range, taking into account the intended mounting orientation of the housing 10 with respect to the horizontal and its height above ground. Fresnel lens 14 is, of course, a positive, converging lens formed on the inner or outer surface of the window 12.

The sensor 16 has two heat sensitive elements typically 1mm wide by 2mm high spaced apart by 1mm. Thus, when located on the focal plane of a collecting lens or mirror it will have a field of view with a similar width-to-height ratio and a divergence dependent upon focal length. Typically, a focal length of 50mm results in a field of view approximately 300mm at 15 metres distance. The sensitivity of the sensor is such that an aperture of not less than f3 is needed for reliable detection of an intruder at 15 to 20 metres with a focal length of 50mm. It will, therefore, be appreciated that, in order to detect an intruder reliably at, say, 60 metres range, the optical system requires a focal length of at least 100mm and an aperture greater than f2. If a lens were to be used, its diameter would be in the region of 50mm. Such performance cannot be achieved reliably by means of a Fresnel lens made of an inexpensive infra-red transparent material such as polyethylene. A polyethylene lens suitable for passing the longer infra-red wavelengths without significant absorption must be comparatively thin, and since the material is soft and flexible, a lens formed from it displays a considerable lack of flatness resulting in optical aberration and a poorly defined field of view. For this reason, the present apparatus combines a Fresnel lens short range optical system with a mirror-based long range optical system, both using the sensor 16. In the preferred embodiment, as shown in Figure 1, a concave mirror 20 (preferably having a parabolic or other comic section) is located oppositely with respect to the sensor 16 in the housing 10, here in the upper part of the housing 10 with its reflecting concave surface facing downwardly and to the rear at a level corresponding to or slightly above the upper edge of the window 12. The upper part 15 of the window 12, above the Fresnel lens 14 is parallel-sided for passing infra-red radiation substantially without refraction. A second mirror 22, which is a plane mirror, is located to the rear of the housing 10 opposite the plane portion 15 of the window 12 with its reflecting surface directed forwardly and upwardly so as to direct incoming radiation emanating from objects at a distance of 25 metres or greater upwardly towards the focusing mirror 20. The latter then focuses such radiation on the sensor 16 which is located at the focal plane. The precise positioning of the mirrors 20, 22 with respect to each other and with respect to the sensor 16 is such that radiation entering the window 12 at the angle of declination corresponding to a radiation source at a distance of 25 metres to, say, 100 metres is focused on the sensor 16. It will be noted that the plane mirror 22 is positioned so as not to obstruct radiation reflected from the focusing mirror 20 onto the sensor 16, i.e. it is generally further from the window 12 than the sensor 16. The optical axis of the focusing mirror 20 is inclined some 45° with respect to the horizontal, although other angles may be used. The plane mirror 22 has dimensions somewhat greater than the field of view of the focusing mirror and is positioned to direct radiation entering the window 12 at an inclination of some 2° upwardly at a new inclination of some 45°. Thus, the housing 7 can be relatively small in depth and the window can be relative close to the mounting surface. The focal length of the focusing mirror 20 is approximately 100mm the focal point being on an offset axis 20A of the mirror located some 10mm below the front edge of the mirror and parallel to the field of view of the sensor 16. The latter has two heat sensing elements 1mm wide by 2mm wide located horizontally on either side of the mirror axis 20A in its focal plane, i.e. the sensor 16 lies on the axis 20A at the focal point. As a result two long range fields of view are provided having a cross-sectional ratio of 2:1 with a divergence in the ratio 100:1 horizontally and 50:1 vertically, as shown by the reference numerals 24 and 25 in Figures 3 and 4.

When an intruder crosses the fields of view 24, 25, infrared energy due to body heat enters window 12, and is reflected by plane mirror 22 onto focusing mirror 20 which then focuses the energy firstly onto one and then secondly on to the other of the heat-sensing elements of sensor 16. The connection of the heat-sensing elements is such that one element produces a positive-going electrical signal whilst the other element produces a negative-going signal so that changes in ambient background temperatures produce opposing signals which cancel out, whereas an intruder crossing first one, and then the other field of view will produce a signal of one polarity followed by a signal of the other polarity. The electronic circuitry coupled to the sensor 16 is arranged to detect such signal sequences in order to generate an alarm signal. It will be understood that additional heat-sensing elements may be used to provide differently directed fields of view within the scope of the invention.

Referring again to Figures 3 and 4, the positioning of the sensor 6 and the axis 14A of the Fresnel lens 14 results in fields of view centred on a declination of approximately 5 degrees below the centre declination of the long range fields of view 24, 25. These shorter range fields of view are shown by reference numerals 26 and 27 in figures 3 and 4. As a result, movement of an intruder at a range of 25 metres and somewhat less produces the same electrical signals as described above with respect to the long range fields of view produced by focusing mirror 20.

To extend the range of operation of the apparatus still nearer, a second plane mirror 28 is positioned within the housing behind the Fresnel lens portion 14 of window 12 just above the radiation envelope corresponding to the field of view provided by direct optical transmission between lens 14 and sensor 16, with its reflecting surface facing downwardly and slightly towards window 12. So positioned, this second plane mirror 28 reflects radiation emanating from an intruder much closer to the apparatus, the radiation passing through the Fresnel lens 14 and, as before, being focused in the region of the sensor 16. The positioning of the mirror 22 also shades the sensor from sunlight entering through the upper part 15 of window 12. The fields of view provided by mirror 28 in combination with lens 14 and sensor 16 are indicated by reference numerals 29 and 30 in Figures 3 and 4.

The approximate angle of inclination of radiation entering from the three field of view pairs so far described are shown in Figure 1 by dotted lines and by the same reference numerals as used in Figures 3 and 4.

Referring now to Figures 5, 6, and 7, additional fields of view may be provided by dividing the lower portion of window 12 into more than one Fresnel lens. In this second embodiment three Fresnel lenses 32, 33, and 34 are formed beneath the plain part of window 12, central lens 33 having an axis which passes through the window at approximately the same position as that of lens 14 shown in Figure 2, while lenses 32 and 34 have axes 32A and 34A below the level of axis 33A of the central lens 33, as shown in Figure 5.

This arrangement results in fields of view due to lenses 32 and 34 at generally steeper angles of inclination than those due to lens 33. These fields of view are shown in Figures 6 and 7. As before, the fields of view due to focusing mirror 20 are indicated by numerals 24 and 25, and those due to the Fresnel lens 33 with direct transmission between the lens and the sensor 16 are shown by reference numerals 26 and 27. Again, as before, the fields of view due to central lens 33 and mirror 28 are indicated by reference numerals 30 and 31. The additional fields of view produced by lenses 32 and 34 are indicated by the numerals 36, 37 and 38, 39 respectively for direct transmission to the sensor 16, and by the numerals 40, 41 and 42, 43 respectively for transmission via mirror 28. It will be noted from Figure 7 that these additional fields of view are directed to either side of the fields of view 26, 27, 30, 31 produced by the central lens 33 due to the positioning of the axes 32A, 34A, of the lens 32 and 34 to either side of the central lens axis 33A.

While in the embodiments described above the positions of the plane mirror 22 and 28 are fixed, it is possible to provide for fine adjustment of their position to allow adjustment of the positions of the fields of view. The same may be said of focusing mirror 22.

Clearly, combinations of lenses other than those shown in Figures 2 and 5 may be used in order to provide alternative layouts of fields of view depending on the scene to be surveyed. Additional focusing reflectors may be used in combination with the Fresnel lens or lens array to produce additional long range fields of view.

The apparatus described above may be summarised as an infrared intrusion detector system having a pyro-electric sensor with long pass infra-red filter means, a focusing mirror, a polyethylene film window having a smooth area and a focusing Fresnel lens or lens array. A plane reflector is located within the field of view of the focusing mirror between that mirror and the polyethylene window. A secondary plane reflector is located between the sensor and the Fresnel lens or lens array, the sensor being located substantially at the common focal point of the focal mirror and the Fresnel lens or lens array to produce discrete spaced-apart fields of view. The focusing mirror has a focal length substantially longer than the focal length of the Fresnel lens or lens array to produce a relatively narrow long range field of view in comparison to the fields of view obtained with the Fresnel lens.

Several focusing reflectors may be provided each having a focal length longer than the focal length of the Fresnel lens or lens array to provide additional long range fields of view. Also, additional fields of view may be provided by including a sensor arrangement with more than two sensing elements at predetermined positions.

In yet a further embodiment, the Fresnel lens or lens array may be separately located from the smooth window portion. It is also possible to use materials other than polyethylene which transmit infrared radiation, for example germanium or silicon. This applies both to the Fresnel lens or lens array and to the smooth part of the window.

Uses of the apparatus in addition to intruder detection may include the control of internal or external lighting, and the control of observation cameras, for example.

Claims

1. Apparatus for the detection of infra-red radiation comprising a passive infra-red sensor (16), a focusing reflector (10) constructed and arranged to focus infrared radiation received by the apparatus from a first range of distances from the apparatus, on the sensor (16), and a focusing refractor (14) constructed and arranged to focus infra-red radiation received by the apparatus from a second range of distances from the apparatus, on the sensor (16), the second distance range encompassing distances shorter than the first distance range.

2. Apparatus according to claim 1, constructed and arranged to receive radiation from the first distance range which is incident on the apparatus at an inclination less than that of the second distance range.

3. Apparatus according to claim 1 or claim 2, wherein the sensor is mounted substantially at an intersection of the focal planes of the focusing reflector (10) and the focusing refractor (14) .

4. Apparatus according to any preceding claim, wherein the focusing refractor comprises at least one Fresnel lens (14; 32, 33, 34).

5. Apparatus according to any preceding claim, wherein the sensor and reflector are contained within a housing, (10), one wall of which comprises a window (12) for transmitting infra-red radiation.

6. Apparatus according to claim 5, wherein the window (12) comprises a first portion (15) having substantially parallel sides for the transmission of infra-red radiation largely without refraction and a second portion (14) which forms the focusing refractor.

7. Apparatus according to claim 6, wherein the window (12) is formed from a polyethylene material.

8. Apparatus according to claim 6 or claim 7, wherein in use, the first portion (15) is above the second portion (14).

9. Apparatus according to any preceding claim, wherein the focusing reflector (20) is a concave mirror arranged to receive radiation through the first portion (15) of the window from an object in the first distance range and to cause such radiation to converge on the sensor (16).

10. Apparatus according to any preceding claim, comprising a second reflector (22) mounted in the optical path between the window (12) and the focusing reflector (20) such that radiation from the first distance range is incident on the second reflector (22) and is thereby reflected to the focusing reflector (20).

11. Apparatus according to claim 10, wherein the second reflector (22) is a plane reflector.

12. Apparatus according to any preceding claim, comprising an additional reflector (28) mounted between the sensor (16) and the focusing refractor (14), and constructed and arranged to reflect radiation incident on the focusing refractor (14) from a third range of distances from the apparatus, on the sensor (16), the third distance range encompassing distances shorter than the second distance range.

13. Apparatus according to claim 12, wherein the additional reflector (28) is a plane reflector.

14. Apparatus according to claim 12 or claim 13, constructed and arranged to receive radiation from the third distance range which is incident on the apparatus at an inclination greater than that of the second distance range.

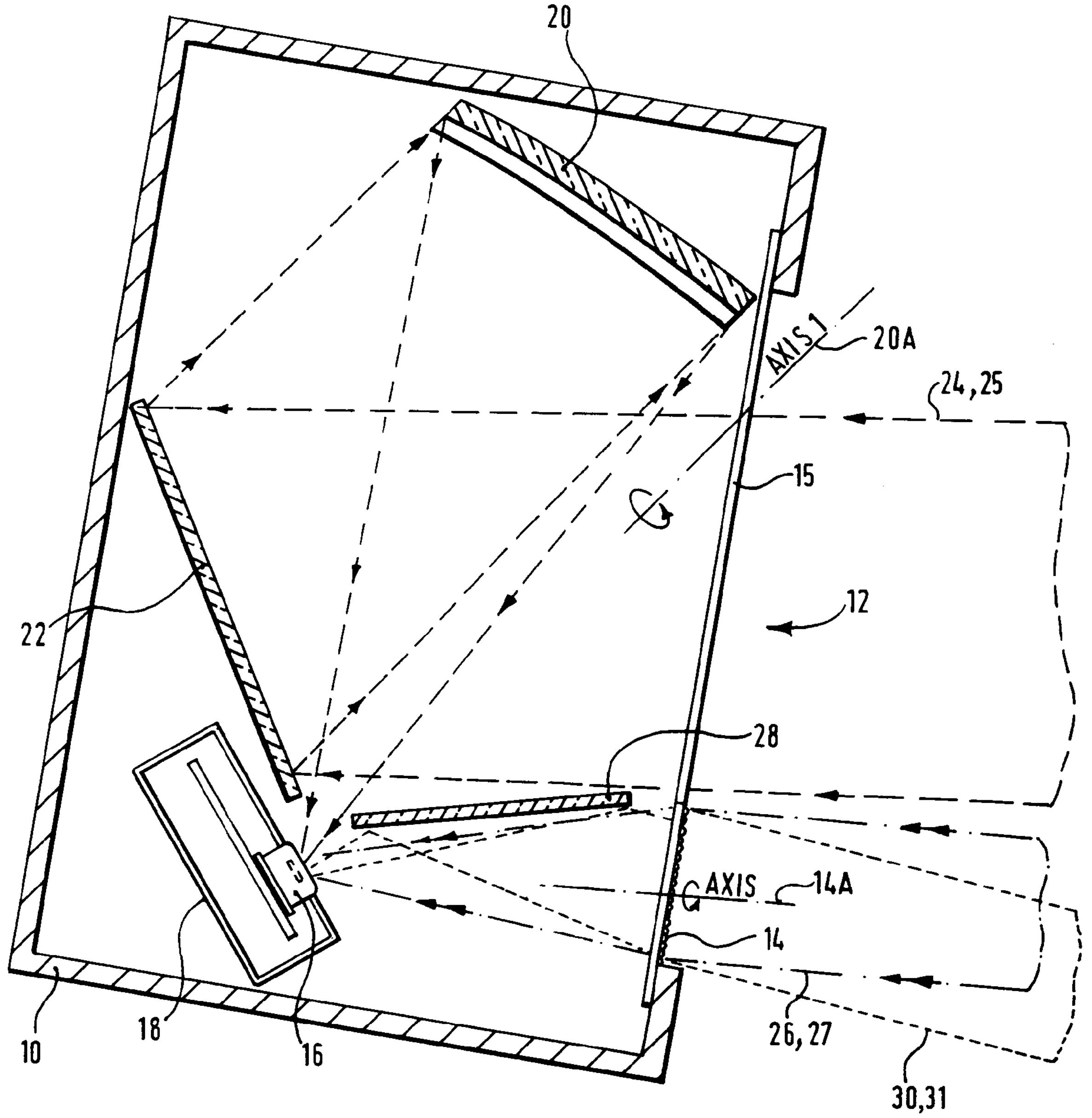

FIG.1.

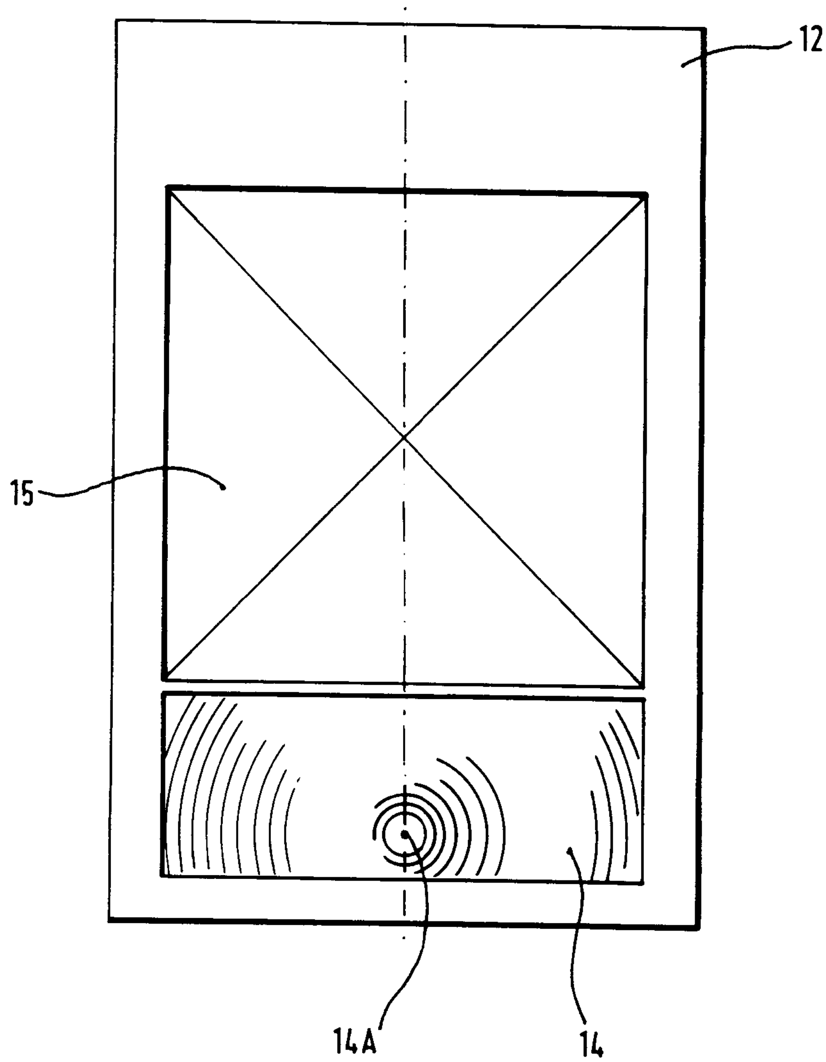

FIG. 2.

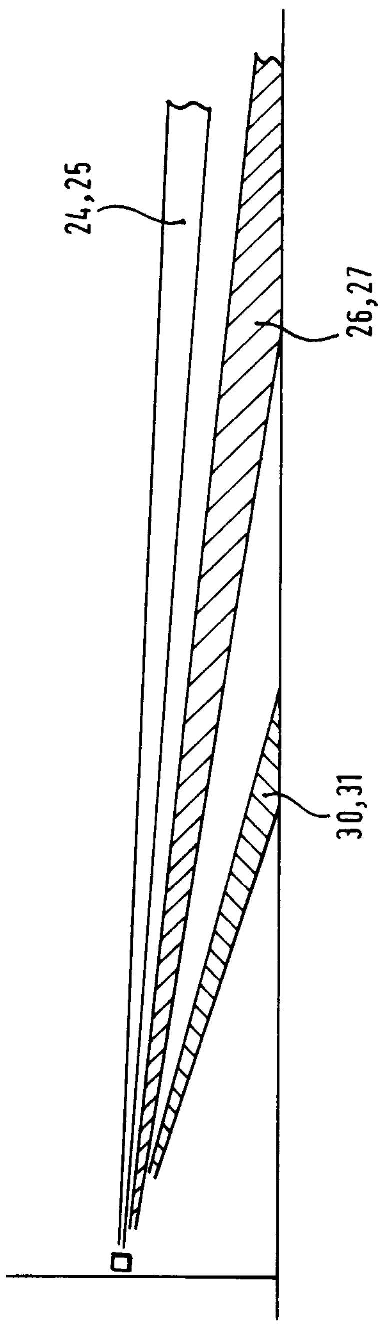

FIG. 3.

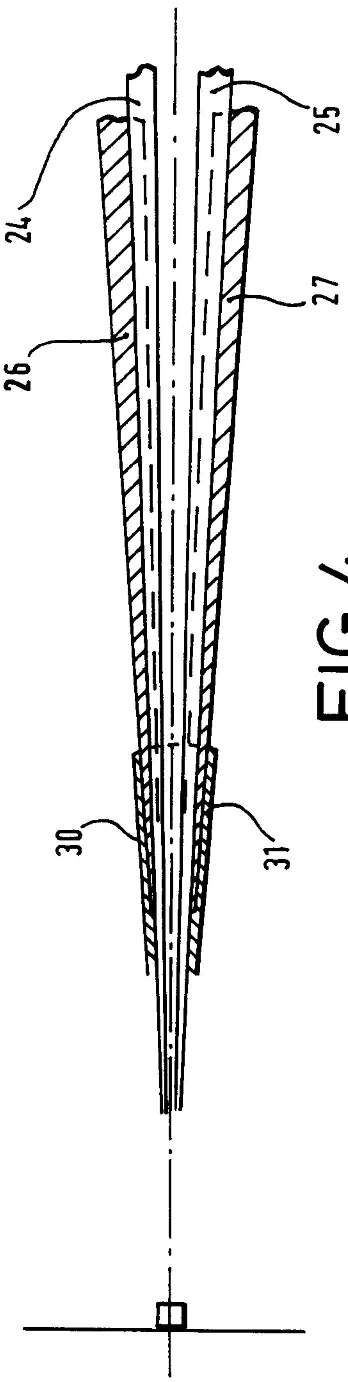

FIG. 4.

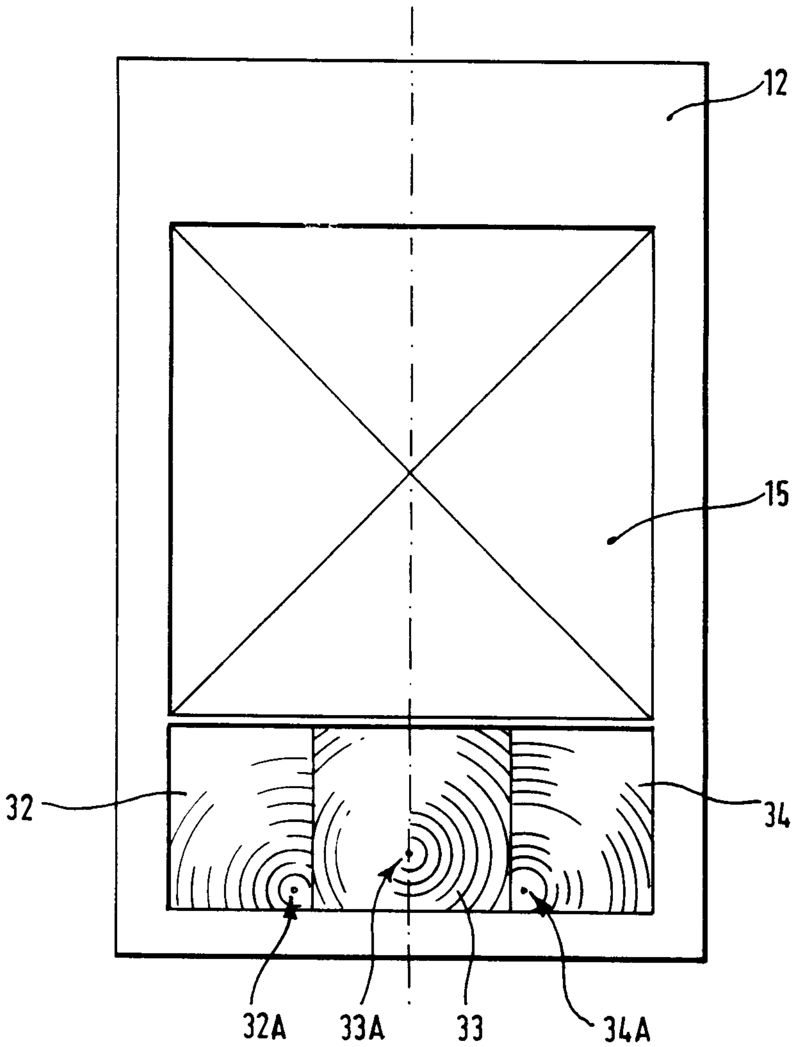

FIG.5.

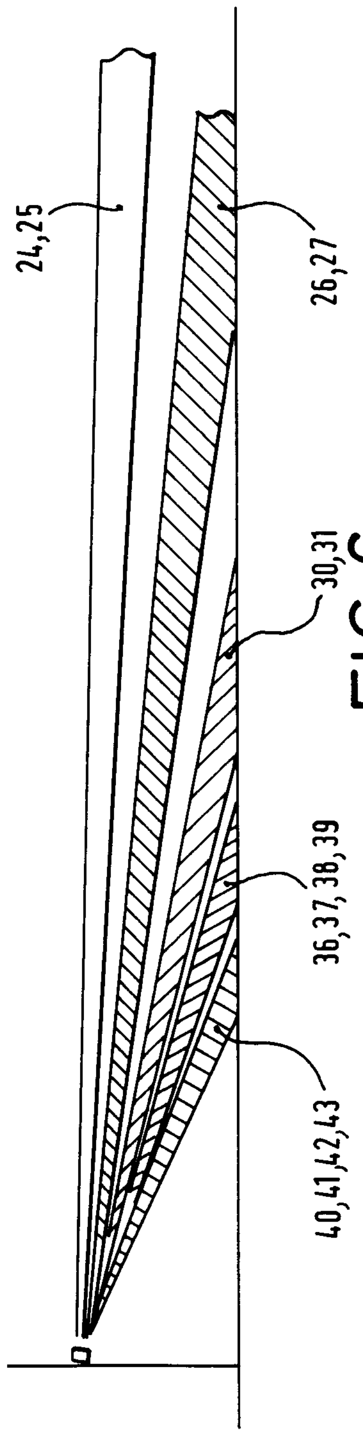
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FIG. 6.

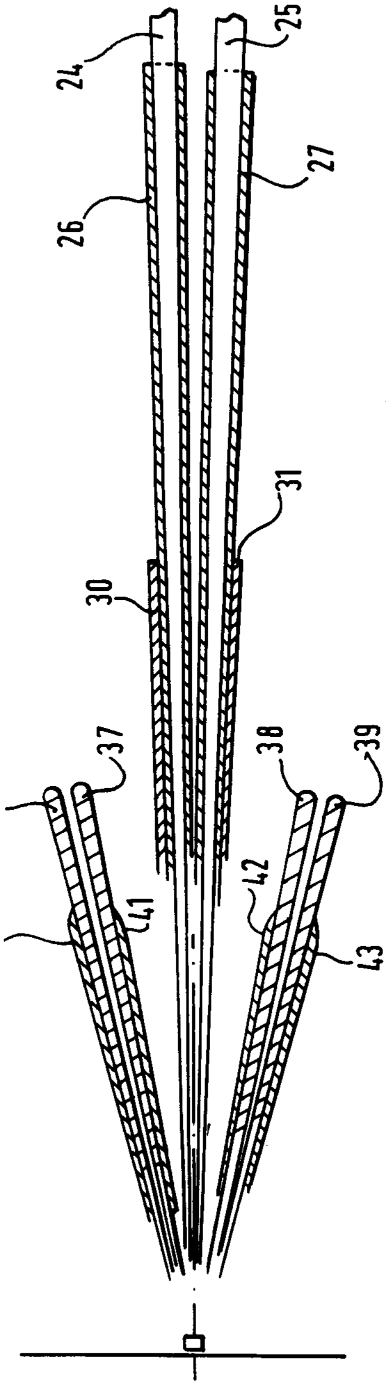
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FIG. 7.

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EUROPEAN SEARCH REPORT

Application Number
EP 92 30 9235

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	DE-A-3 812 969 (GEBRÜDER MERTEN) * the whole document * ---	1-11	G08B13/193
A	EP-A-0 219 954 (MAXIMAL ELECTRICAL ENGINEERS) * page 3, line 6 - page 7, line 9; figures 2-4 * ---	1-14	
A	US-A-4 841 284 (J. BIERSDORFF) * the whole document * -----	1-11	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

G08B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	17 DECEMBER 1992	SGURA S.

CATEGORY OF CITED DOCUMENTS

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