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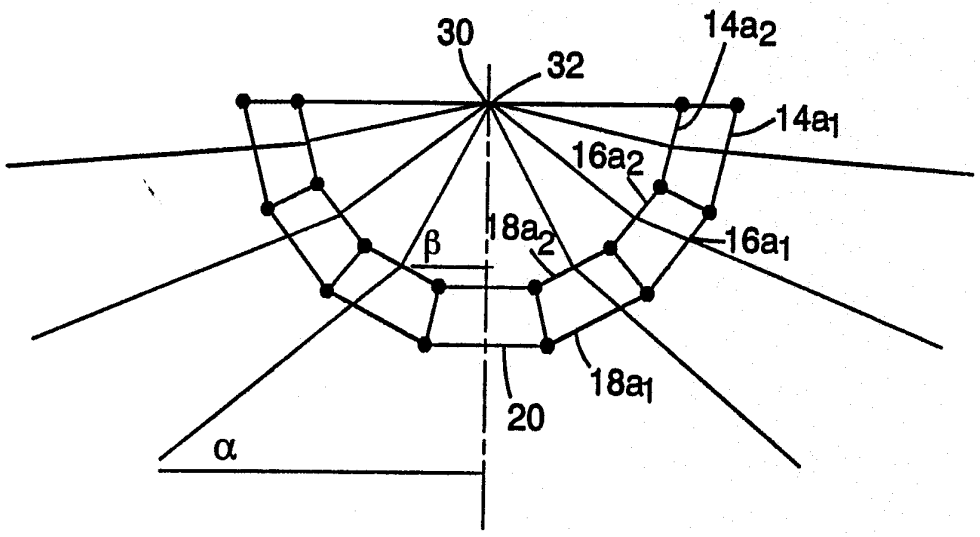
(54) Title: AN IMPROVED 360 DEGREE FIELD OF VIEW OPTICAL SENSING DEVICE



(57) Abstract

A 360° pattern field of view optical system for passive infrared detection device (10) is disclosed. The optical system uses a combination of a fresnel lens ($18a_1$) and a fresnel prism ($18a_2$) to gather infrared radiation, focus the radiation, and refract radiation onto a focal point (30). Each of the combination of fresnel lens ($18a_1$), and prism ($18a_2$) is positioned substantially circumferentially about a central location (30) to gather the infrared radiation from a 360° field of view and for focusing radiation gathered onto the central location (30). At the central location (30) a sensor (32) is located. The sensor converts the focused infrared radiation into an electrical signal.

* See back of page

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AN IMPROVED 360 DEGREE FIELD OF VIEW OPTICAL SENSING DEVICE

Technical Field

The present invention relates to an improved three hundred sixty degree (360°) field of view optical sensing device, and more particularly to such a device where a fresnel lens and a fresnel prism are used in combination to increase the field of detection.

Background of the Invention

Optical systems for the gathering of infrared radiation for passive infrared intrusion detection devices are well known in the art. In particular, infrared intrusion detection devices which are mounted on ceilings and can detect intruders within a 360° degree field of view are well known in the art.

However, heretofore, a 360° field of view optical system for passive infrared intrusion detection has used either a combination of two mirrors and a fresnel lens or two mirrors to receive the infrared radiation. The use of mirrors requires that the mirrors have superior surface finish and excellent reflection coating properties. Such mirrors with excellent coated qualities necessarily mean that they are expensive.

Another prior art ceiling mounted device for the collection of infrared radiation from a 360° field of view uses a plurality of fresnel lenses. In such a device, the plurality of fresnel lenses collect infrared radiation and focus them at a focal point where a single sensor is located. The problem with the use of fresnel lenses alone is that there is no long range detection capability. In addition,

this prior art device has a "dead" zone wherein the device is unable to detect intruders in that zone or is able to detect intruders only when they are very close to the detector. This has limited the use of such a device.

Summary Of The Invention

A 360° field of view passive infrared intrusion detection device for gathering radiation at a distance spaced apart from a ground plane is disclosed. The device comprises a plurality of infrared radiation gathering and focusing means which are positioned substantially circumferentially about a central location and which gather infrared radiation from a 360° field of view and focus the radiation gathered onto the central location. Each of the plurality of radiation gathering and focusing means further comprises a fresnel lens for gathering the radiation at a first angle with respect to the ground plane and for focusing the radiation gathered to the central location and a fresnel prism for gathering radiation from the fresnel lens at the first angle and for refracting the gathered radiation onto the central location at a second angle. The second angle is greater than the first angle with respect to the ground plane. A sensor is located at the central location for converting the infrared radiation into an electrical signal.

Brief Description Of The Drawings

Figure 1 is a perspective view of the passive infrared optical gathering device of the present invention shown positioned at a level spaced apart from a ground plane.

Figure 2 is a schematic cross sectional view of the device shown in Figure 1 taken along the lines 2-2.

Figure 3 is a plan view of the pattern of detection of the device of the present invention.

Figure 4 is a partial schematic view of one combination of fresnel lens and fresnel prism showing the gathering of the radiation, the focusing thereof by the fresnel lens, and the refraction thereof by the fresnel prism onto the focal point.

Detailed Description of the Drawings

Referring to Figure 1 there is shown a perspective view of a 360° field of view passive infrared intrusion detection device 10 of the present invention. The device 10 is typically mounted on a ceiling 8 at a distance spaced apart from a ground plane 12. The device 10 comprises a plurality of infrared radiation gathering and focusing means 14 (a...h...) which are positioned substantially circumferentially about a central location 30. Further, a plurality of rows of the infrared radiation gathering and focusing means 14, 16 and 18 are positioned substantially circumferentially about the central location 30. Each of the rows 14, 16 or 18 of the infrared radiation gathering and focusing means gather infrared radiation from a 360° field of view and focuses the radiation gathered onto the central location 30. A single radiation gathering and focusing means 20 gathers radiation substantially perpendicular to the ground plane 12.

Referring to Figure 2, there is shown schematically three of the infrared radiation gathering and focusing means (14a, 16a and 18a). Each of the infrared radiation gathering and

focusing means (14a, 16a and 18a) comprises two parts: a fresnel lens (designated with subscript 1 such as $14a_1$) and a fresnel prism (designated with the subscript 2 such as $14a_2$). For the purpose of illustrating the function of each of the infrared radiation gathering and focusing means, the description will now relate to the infrared radiation gathering and focusing means 18a. However, it should be apparent to those of ordinary skill in the art that the description is equally applicable to all the other infrared radiation gathering focusing means (14a...; 16a...; and 18b...).

In the operation of the infrared radiation gathering and focusing means 18a, the fresnel lens $18a_1$ gathers infrared radiation at a first angle α with respect to the ground plane 12. The light is gathered by the fresnel lens $18a_1$, passes therethrough and is focused through the fresnel prism $18a_2$ at the central location 30. The fresnel prism $18a_2$ gathers the radiation from the fresnel lens $18a_1$ also at the first angle α and refracts the gathered radiation onto the central location 30 at a second angle ß with respect to the ground plane 12. The second angle ß is greater than the first angle α. Each of the infrared radiation gathering and focusing means, comprising of a fresnel lens and a fresnel prism, function in the same manner. The plurality of gathered and focused and refracted radiation from each of the infrared radiation gathering focusing means is brought to a focus at the central point 30.

Located at the central point 30 is a sensor 32, which converts the detected infrared radiation into an electrical signal. Such a sensor 32, such as pyroelectric, is well known in the art.

Referring to Figure 3, there is shown a graphical illustration of the 360° field of view provided by the plurality of infrared radiation gathering and focusing means. There is one zone associated with each of the infrared radiation gathering and focusing means.

Referring to Figure 4 there is shown in greater detail an infrared radiation gathering and focusing means comprising of a fresnel lens $14a_1$ and its associated fresnel prism $14a_2$. The fresnel lens $14a_1$ is of conventional design with the grooved facet and slope of each groove in the fresnel lens located on the side adapted to received the infrared radiation. Such a fresnel lens is well known in the art and can be constructed in accordance with the following spherical or aspheric equation:

$$Z = \frac{CY^2}{1+\sqrt{1-(K+1)C^2Y^2}}$$

The C & K values refer to the grooved surface.

$$\text{Slope} = \frac{dz}{dy} = \frac{2YC}{1+\sqrt{1-(K+1)C^2Y^2}} + \frac{(K+1)C^3Y^3}{\sqrt{1-(K+1)C^2Y^2}\left\{1+\sqrt{1-(K+1)C^2Y^2}\right\}^2}$$

OR an equation used to calculate the groove angle a to correct for spherical aberration.

$$\tan a = \frac{\sin\alpha+\sin\beta}{\sqrt{N^2-\sin^2\alpha}-\cos\beta}$$

a = groove angle

α = ray angle with respect to optical axis plano surface

β = ray angle with respect to optical axis grooved surface

After finding the slope for optimum refraction, there are three ways to design the grooves.

1. Maintain the same depth on all grooves and vary the width;

2. Maintain the same width and vary the depth;

3. Vary both the depth and the width.

As for the refraction by the fresnel prism $14a_2$, the angle of deviation β_1 can be determined from the following equation:

$$N(\sin\tfrac{1}{2}A) = \sin\tfrac{1}{2}(A + \beta_1)$$

N = refraction index

A = apex angle of the prism (see Fig. 4)

Both the fresnel lens and the fresnel prism can be manufactured by compression or injection molding. The quality of compression molding of a fresnel lens is superior to that produced by injection molding. As for the design for the master fresnel lens and prism, a diamond tool is typically used to cut into a die material forming the entire surface of the fresnel lens and prism. This process is repeated as many times as there are grooves required for the lens and prism design.

There are many advantages of the apparatus of the present invention. First, because only refractive material is used, i.e., no mirror is used, less costly materials can be used. Further, by using a fresnel lens in conjunction with a fresnel prism to refract the light, the fresnel lens can be used to gather light from further distances than heretofore achievable. Once the radiation from

the long range is gathered, it is refracted by the fresnel prism onto the focal point. Thus, the device 10 of the present invention has long range capabilities in addition to intermediate and short range. Of course, it should be understood that the diameter of the circle of the zones depends upon the device 10's mounting height. Each zone can be divided into one or more elements depending on the number of sensing elements used in each of the sensors 32 and 34, thereby varying the number of zones of protection.

WHAT IS CLAIMED IS:

1. A three hundred sixty degree (360°) passive infrared radiation intrusion detector for gathering radiation at a distance spaced apart from a ground plane comprising:

a plurality of infrared radiation gathering and focusing means positioned substantially circumferentially about a central location for gathering infrared radiation from a 360° field of view and for focusing said radiation gathered onto said central location;

each of said plurality of infrared radiation gathering and focusing means further comprising:

a fresnel lens for gathering radiation at a first angle with respect to said ground plane and for focusing said radiation onto said central location;

a fresnel prism for gathering radiation from said fresnel lens at said first angle and for refracting said gathered radiation onto said central location at a second angle, greater than said first angle, with respect to said ground plane; and

a sensor at said central location for receiving radiation from said plurality of infrared radiation gathering and focusing means and for converting same into an electrical signal.

2. The detector of Claim 1 further comprising:

a lens for gathering radiation from said ground plane substantially

perpendicular thereto and for focusing said gathered radiation onto said sensor.

AMENDED CLAIMS

[received by the International Bureau on 8 March 1991 (08.03.91); original claims 1 and 2 replaced by amended claims 1-3 (2 pages)]

1. A three hundred sixty degree (360°) passive infrared radiation intrusion detector for gathering radiation at a distance spaced apart from a ground plane comprising:

a plurality of infrared radiation gathering and focusing means positioned substantially circumferentially about a central location for gathering infrared radiation from a 360° field of view and for focusing said radiation gathered onto said central location;

each of said plurality of infrared radiation gathering and focusing means comprises a combination fresnel lens and fresnel prism for directing said infrared radiation onto said central location; and

a sensor at said central location for receiving radiation from said plurality of infrared radiation gathering and focusing means and for converting same into an electrical signal.

2. The detector of Claim 1 further comprising:

a lens for gathering radiation from said ground plane substantially perpendicular thereto and for focusing said gathered radiation onto said sensor.

3. The detector of Claim 1 wherein each of said combination fresnel lens and fresnel prism further comprising:

a fresnel lens for gathering radiation at a first angle with respect to said ground plane and for focusing said radiation onto said central location; and

a fresnel prism for gathering radiation from said fresnel lens at said first angle and for refracting said gathered radiation onto said central location at a second angle, greater than said first angle, with respect to said ground plane.

STATEMENT UNDER ARTICLE 19

The PCT search report alleges that Baldwin et al. is relevant to the invention because Baldwin et al. allegedly teaches a ceiling mounted 360° passive infrared intrusion detector using an arrangement of fresnel lenses. Further, it is alleged that Baldwin et al. discloses a central aperture which is perpendicular to the floor. Thus, the search report deems it relevant to the addition of a fresnel prism to the claimed invention to help focus the radiation onto the sensor.

As stated in the application, one of the advantages obtained by using the present invention of a combination of fresnel lens and fresnel prism is that the apparatus of the present invention can be used to gather light from further distances than heretofore achievable. Thus, the device of the present invention has long range capabilities in addition to intermediate and short range.

In contrast, Baldwin et al. does not disclose long range capabilities. In fact, even with his device, Baldwin et al. discloses the potential failure of his detector in the lens configuration to indicate the presence of an intruder. To alleviate this potential failure of his detector to detect an intruder, Baldwin et al. teaches changing the sensing element of his sensor (see Col. 4, lines 35 - Col. 5, line 2). Thus, even with Baldwin et al.'s device without long range capabilities, Baldwin et al. has a potential problem of unable to detect the presence of an intruder. To solve this problem, Baldwin et al. teaches changing the distance of separation between the sensing elements. Thus, the logical extension of the teaching of Baldwin et al., if any, to accommodate long range capability, is to further separate his sensing elements in order to detect the presence of intruders at long ranges. This is a teaching that is directly away from Applicant's invention.

In Applicant's invention, as claimed, there is no necessity whatsoever of changing the distance of separation between the sensing elements. By using the combination of fresnel lens and fresnel prism, Applicant is able to detect intruders both near and far without changing the distance of separation between the sensing elements. The sensing element that Applicant uses is commercially available and therefore is not amenable to be changed readily. Applicant's teaching of using the fresnel prism to solve the problem of detection of intruders near as well as far, is a teaching which is away from Baldwin et al. and therefore would not be obvious to one of ordinary skilled in the art. Thus, Applicant respectfully submits that Baldwin et al. is not applicable.

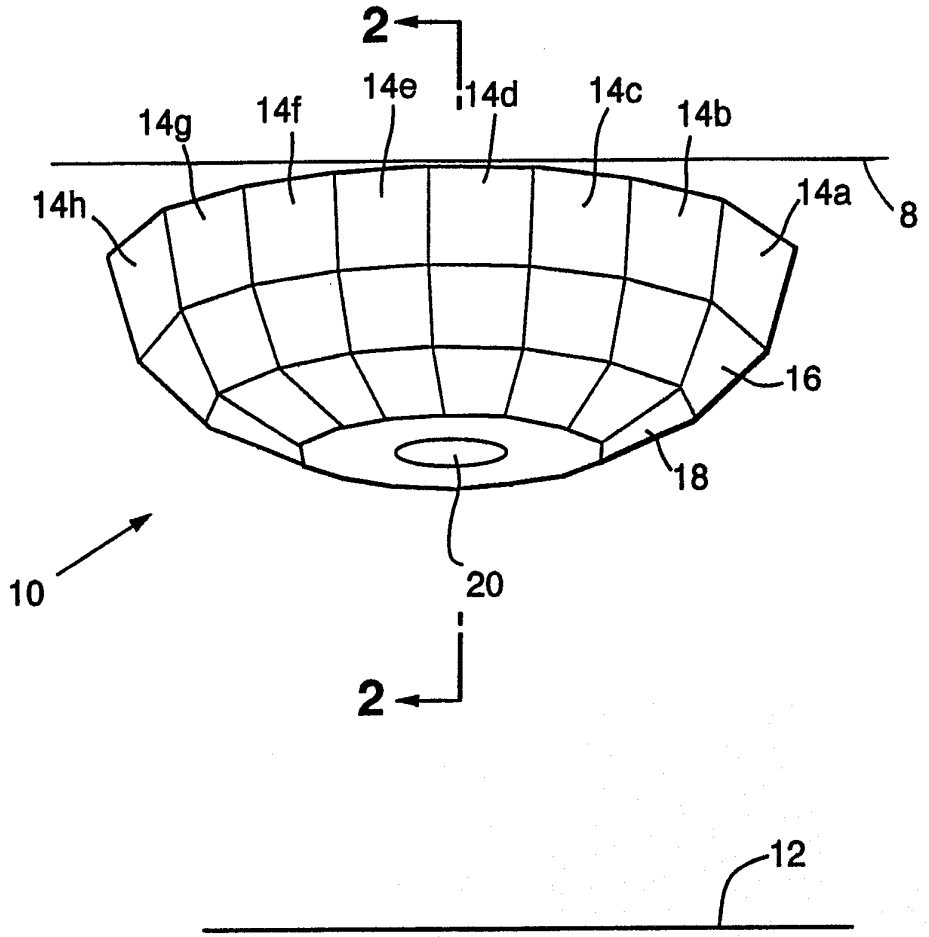
2
14g
14f
14e
14d
14c
14b
14h
14a
8
16
18
10
20
2
12

FIG. 1

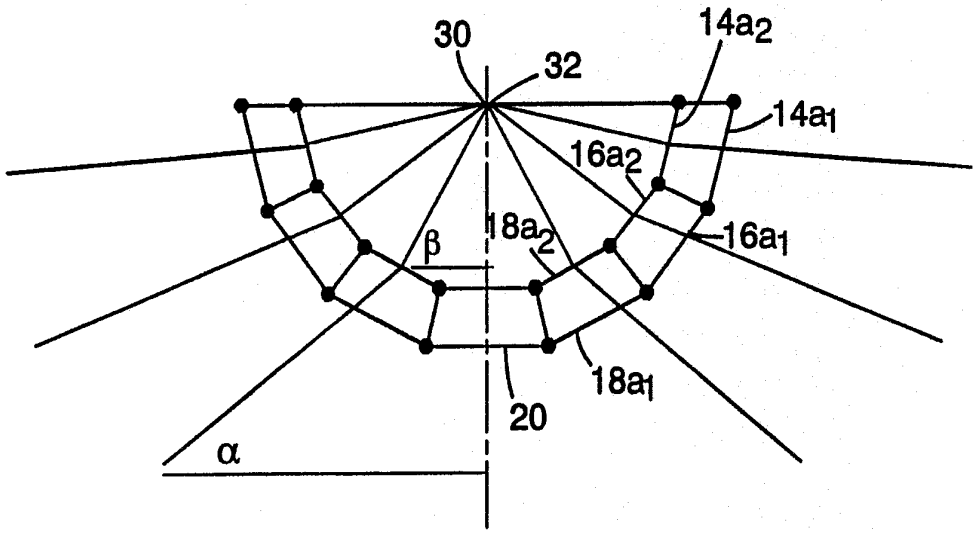
30
32
14a2
14a1
16a2
16a1
β
18a2
18a1
20
α

FIG. 2

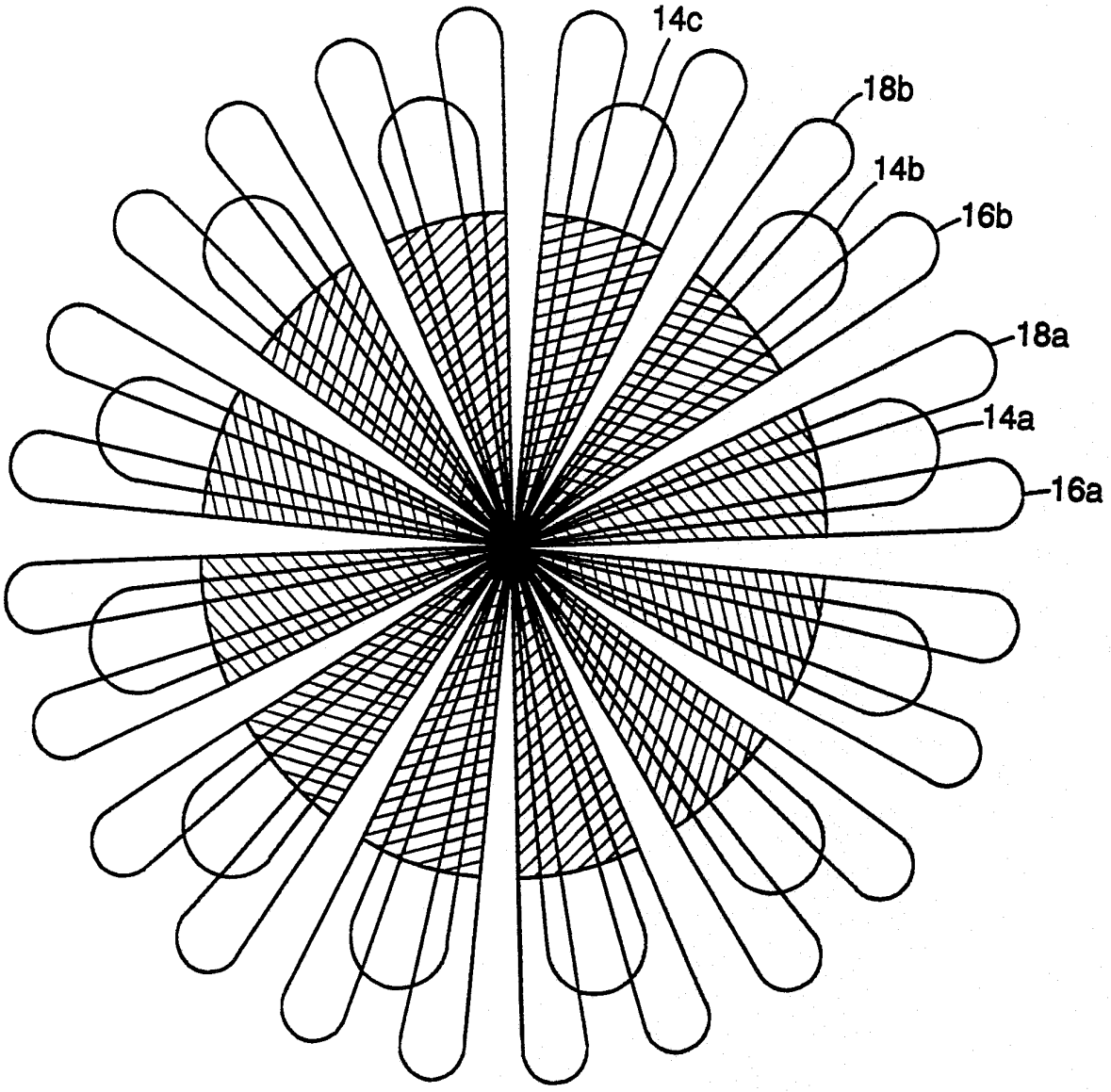

FIG. 3

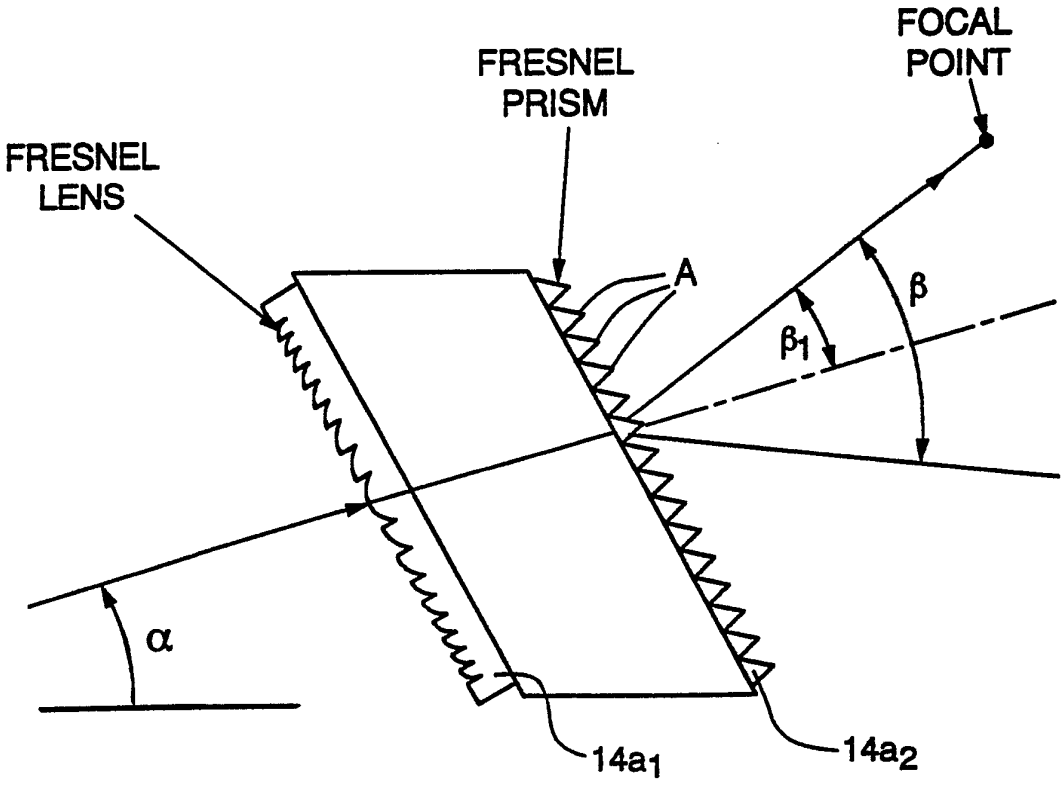

FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No PCT/US90/03916

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5): G01J 5/08; G08B 13/18

U.S.Cl.: 250/342,353

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System [5]	Classification Symbols
U.S.Cl.	250/342.353

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [6]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
Y	US, A, 4,757,204 (BALDWIN et al.) 12 July 1988 (Note col. 1 line 47 - col. 2 line 10, col. 3 lines 9-15)	1-2

* Special categories of cited documents: [15]

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

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
13 September 1990	17 JAN 1991
International Searching Authority [1]	**Signature of Authorized Officer** [20]
ISA/US	For Drew A. Dunn — NGUYEN NGOC-HO, INTERNATIONAL DIVISION

Form PCT/ISA/210 (second sheet) (May 1986)