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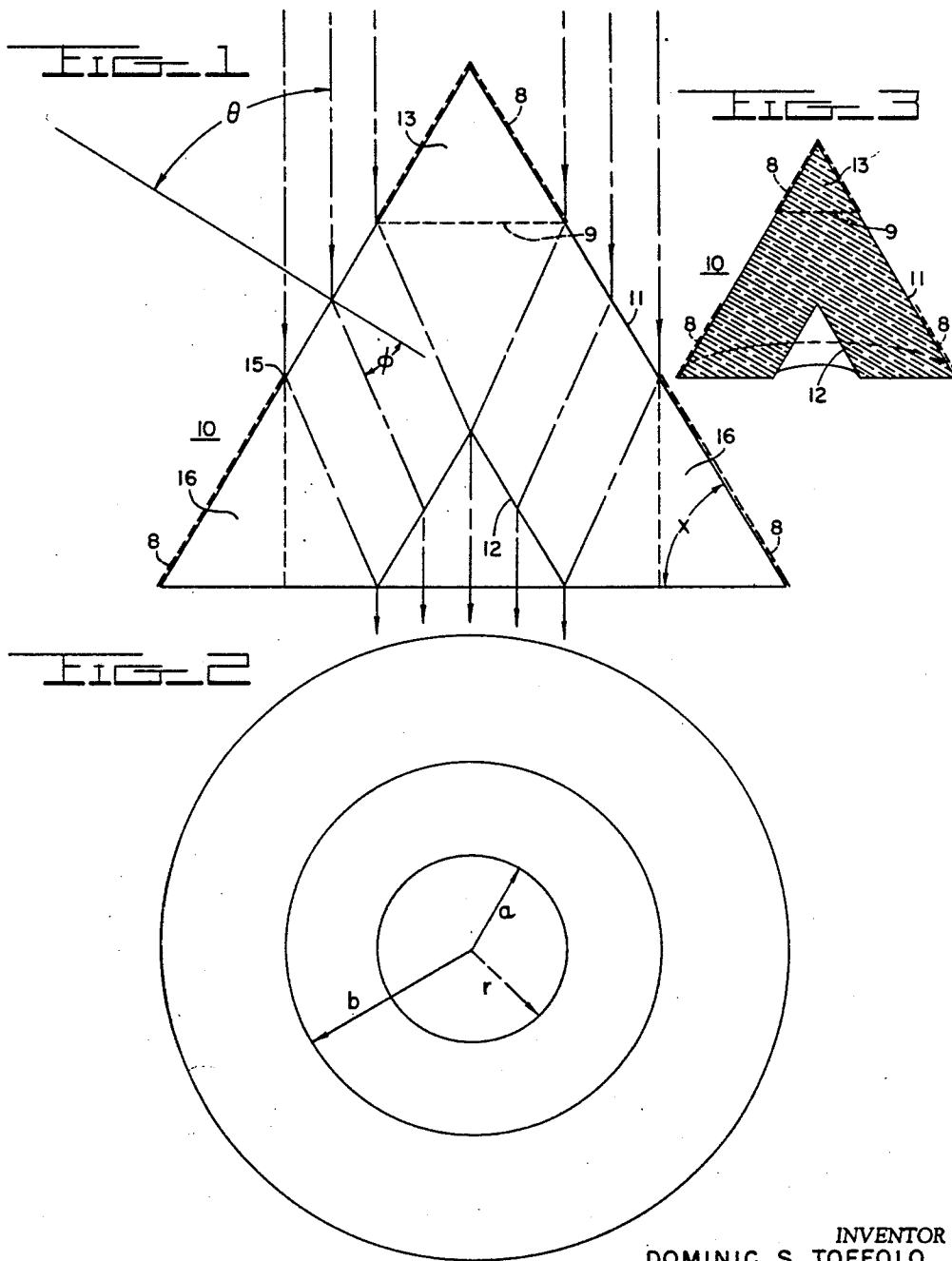
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CONICAL REFRACTOR

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CONICAL REFRACTOR

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1 Claim. (Cl. 88—1)

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The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to refractors and more particularly to a refractor which passes plane parallel incident radiation of a given intensity to plane parallel radiation of greater intensity than the incident radiation.

The refractor comprises a radiation transparent medium presenting to the incident flux an annular conical surface and having a second conical surface coaxial therewith through which the emergent flux passes. The element may be formed as a cone with a conical surface axially formed in the base of the cone with elements parallel with the outer cone surfaces. In this case, the entrance cone surface may be centrally masked to leave at its lower portion an annular conical incident surface. Peripheral incident flux is refracted to concentrate centrally of the exit pupil at greatly increased intensity.

The refractor of this invention therefore affords means of increasing the intensity of an incident radiation source and further provides many advantages in optical and astronomical work. It may replace multi-element lenses of a telescope wherein the same telescopic effect can be obtained without the use of multiple lenses. The refractor may be installed in front of a light signalling device to increase the intensity of the signal, and by use of different materials in making the refractor, increases in intensity of radio frequency radiation can be obtained where the application of optical techniques is desired, such as antennas.

An object of the present invention is to increase the intensity of incident radiation that passes through a refractor.

A further object of the present invention is to produce an element which will afford a desired emergent intensity related to the intensity of plane parallel radiation incident on the element.

A still further object of the present invention is to provide a refractor which will effectively replace the use of multiple number of expensive optical lenses now used in optical equipment.

A final object of the present invention is to provide a refractor which can be made inexpensively as by molding or other means.

Other and more specific objects of this invention will become apparent upon a careful consideration of the following detailed description when taken together with the accompanying drawings, in which:

Fig. 1 is a side elevational view of the refractor diagrammatically illustrating the incident and emergent light rays.

Fig. 2 is a line projection from Fig. 1 illustrating the relationship of the areas covered by the incident plane parallel radiation and the emergent intensity.

Fig. 3 is a sectional view taken through the axis of the element to illustrate the cut-out portion of the cone shaped element.

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Referring now to the drawings there is illustrated in Fig. 1 one typical embodiment of a refractor 10 comprising this invention. The refractor 10 comprises preferably a single block of radiation refracting material 5 having similar cone shaped parallel outer and inner surfaces arranged to form a radiation entrance surface 11 and a radiation emergent surface 12. The single block element may be formed in a solid cone shape and then a similar cone shape cut axially from the solid block to form the emergent parallel surface or the refractor may 10 be formed with a mold wherein the axially cone shaped inner surface may be formed by the mold. The vertex end 13 of the cone shaped element may be cut away along dotted line 9 and the flat end surface coated or masked with radiation absorbing material which tends 15 to prevent incidence through that portion, or the vertex may be left uncut and coated or masked with an absorbing material 8. The radius of the cone at the vertex end to be coated with absorbing material will be explained in detail later.

In many applications where precision requirements do not arise, such as systems for illuminating photocells or photosensitive crystals, the utilization device may present a sensitive area limited to the intensified exit pupil area and in such situations an uncoated or unmasked element may be used. The emergent rays away from the exit pupil presents increasingly lower intensities which may be negligible in many applications. Only that radiation which strikes the inner surface emerges as parallel 25 rays and those are the emergent rays that are confined to an area having a greater intensity than the incident intensity.

It is obvious from Snell's law

$$N = \frac{\sin \theta}{\sin \phi}$$

where the refractor is in air, N = the index of refraction of the material forming the refractor, $\sin \theta$ is the angle of incidence, and $\sin \phi$ is the angle of refraction, if the incident radiation is plane parallel radiation and the incident and emergent surfaces are parallel then the incident radiation will pass through the element and emerge as parallel radiation. It has been determined that a cone shaped element with any base angle and made according to this invention will have an emergent intensity which is greater than the incident intensity due to the incident radiation being confined to a smaller area by refraction caused by the material of the element. There is a critical base angle which determines the surfaces of the element which will be formed by the least amount of material and yet pass incident radiation which will have the desired intensity on emerging from the element. This angle "X" (Fig. 1) is determined by the formula $\cos (\theta - \phi) = N(1 - \cot^2 \theta)$ where N is the index of refraction of the material forming the element, θ is the incident angle, and ϕ is the refracted angle for said incident radiation. It is to be noted that the incident angle θ is numerically equal to the base angle "X" of the element which is equal to the angle formed by the interception of a line perpendicular to the outer surface 11 and a line perpendicular to the base as shown in Fig. 1.

Since the cut-out cone portion has its surface 12 parallel to the outer surface 11 of the element, the base angle of the cut-out portion will be the same as the base angle "X" of the element. The incident radiation passes through the element and emerges from surface 12 with a radiation intensity which is greater than the incident intensity. It does this by two refractions which are self correcting at any wave-length, thus making it achromatic. If b is the radius of the circle at 15 formed by the outer extremities of the incident radiation which will be

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refracted as parallel rays by the surface of the cutaway cone portion, r is the radius of the inner cutaway cone at the base, and a is the radius of the top portion of the element which is coated with a light absorbing material, then the usable incident light is contained within the conical surface bounded by b and a (Fig. 1) and it can be shown that $b=a+r$. The incident intensity has a direct relationship to the emergent intensity and is related according to the formula

$$\frac{\text{emergent intensity}}{\text{incident intensity}} = \frac{2b}{r} - 1$$

for intensity amplification. The radius a is made such that the plane parallel incident radiation striking the refractor at the beginning of the uncoated surface at the top portion of the element will enter the element and be refracted to the top point of the cutaway cone portion, to be refracted again as parallel radiation. All incident radiation striking the refractor away from the radiation absorbing material will be refracted inwardly toward the cutaway cone and will again be refracted on emerging therefrom but will be confined to a smaller area than the incident light whereby the intensity will be greater.

Fig. 1 illustrates a bundle of plane parallel light rays entering the surface 11 and refracted toward the surface 12 wherein the rays are again refracted as parallel emergent rays. The emerging rays will be parallel with the incident rays and confined to a smaller bundle which is confined within the circle having a radius of r , Fig. 2, the usable light area after passing through the optical element.

In making a refractor of the present invention, the element may be made of glass, or a more readily moldable material of which there are many suitable clear plastics on the market which can be used, also, in case of use with X-rays the element can be made of wax, such as paraffin. The refractor of this invention may be used for many purposes in increasing the intensity of incident radiation and is bound by the index of refraction of the specific material which is used for the specific radiation to get the proper angle of refraction for the greatest emergent intensity, that is, for optical elements which are formed from the minimum amount of material. For refractors having base angles not determined by the above formula, the base angles will be equal to the angle of incidence but the amount of material forming the refractor will be greater than the material used when the refractor is made according to the above formula.

The values for forming the refractor can be determined by choosing the ratio of emergent intensity and incident light and the desired radius b formed by the extremity of the bundle of rays desired to be used. From the formula

$$\frac{\text{emergent intensity}}{\text{incident intensity}} = \frac{2b}{r} - 1$$

the correct value of r can be determined. These values b and r determine the radius a for the portion of the vertex end that should be coated with radiation absorption material. From the values of a , b and r the refractor can be formed but in order to form the optical element with the minimum amount of material, the element must be formed with a specific base angle which may be determined by the formula

$$\cos(\theta - \phi) = N(1 - \cot^2 \theta)$$

as given above, where the base angle is equal to θ . This formula is used only to determine the base angle for an element in which the minimum amount of material is to be used. For elements in which the amount of material is of no concern, the desired intensity ratio can be obtained as illustrated above for any chosen radius of incident radiation and the desired intensity ratio.

For illustrative purposes an element having an index

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of refraction of 1.5 and formed in accordance with the present invention for an emergent intensity three times the incident intensity that has a radius b of 3 cm. for the incident radiation is shown in Fig. 1. From the formula

$$\frac{\text{emergent intensity}}{\text{incident intensity}} = \frac{2b}{r} - 1$$

it is determined that the emergent pupil r will be 1.5 cm., thus the radius a of the circle at the vertex end that is coated with radiation absorption material is 1.5 cm. This determines the dimensions of the various functional parts of the element. Now, for the angle in which the least amount of material will be used, the formula $\cos(\theta - \phi) = N(1 - \cot^2 \theta)$ is used, and it is determined for an index of refraction of 1.5 the angle x (Fig. 1) is $58^\circ 3'$. For a different index of refraction, the angle x will be different. An element made in accordance with the above disclosure will make a good telescope and could be used for other purposes where incident radiation is to be increased and confined to a specific area.

The vertex end 13 and the surface portion 16 of the element below 15 Fig. 1 may be coated with a light absorbing material 8 or either cut away and then coated to prevent interference by light which normally would enter those portions of the element. The surface below 15 (Fig. 1) if cut should be cut perpendicular to the base of the element to prevent the possibility of interference with the usable light passing through the lens. A refractor made in accordance with this invention may be used to replace multiple lens devices now used in the optical field. Such an element makes a good telescope, it can be used to increase the intensity of X-rays, increase light intensity for photo-detectors, increase the intensity of light signalling devices and many other applications which will be obvious to those skilled in the art.

Obviously many modifications and variations of the present invention are possible in the light of the above teaching. It is therefore to be understood, that within the scope of the appended claim, the invention may be practiced otherwise than as specifically described.

What is claimed is:

A single achromatic refractor comprising a solid cone shaped body of radiation transparent material having similar cone shaped parallel outer and inner surfaces having a common base and arranged to form a radiation entrance surface and a radiation emergent surface, said inner surface being formed by cutting a cone shaped surface extending axially and inwardly from the base of said radiation transparent material, said cone shaped body having a base angle equal to an angle formed by the interception of a line perpendicular to said outer surface and a line perpendicular to the base whereby the latter angle is equal to an angle of incidence of plane parallel incident radiation along the line perpendicular to the base, said base angle being formed by the formula

$$\cos(\theta - \phi) = N(1 - \cot^2 \theta)$$

where θ is the angle of incidence of plane parallel radiation, ϕ is the angle of refraction, and N is the index of refraction of the radiation transparent material, said outer surface having a central portion thereof coated with a radiation absorbing material and adapted to permit passage of only peripheral incident plane parallel radiation which will be refracted toward the axis and emerge from said inner parallel surface formed by the axially cut-out cone shaped surface whereby only radiation incident on the uncoated surface will emerge from the inner parallel surface as a central circular beam of plane parallel radiation of circular form and with a greater intensity than said incident radiation.

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