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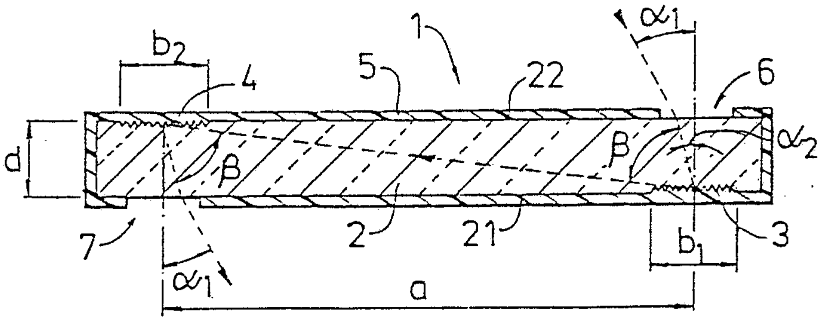

(57) Abstract

A dispersive optical device for use such as a polarizer, spectroscope, monochromator or the like for utilization as a basic component for a monochromator, polarizer, spectroscope, spectrophotometer or the like, includes a dispersive optical member comprising a first and a second grating (3, 4) planar parallel applied on a substrate, preferably reflection gratings with the same grating frequency, said gratings (3, 4) being applied with parallel grating rulings, whereby light diffracted by the first grating is arranged to strike the second grating (4). The first grating (3) defines the element's input and the second grating (4) defines the element's output.

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DISPERSIVE OPTICAL DEVICE

TECHNICAL FIELD

The invention relates to a dispersive optical device for use such as a spectroscope, polarizer, monochromator or the like, of for use as a basic component for a monochromator, spectograph, spectophotometer, polarizer or the like.

BACKGROUND

Conventional dispersive optical devices, such as those utilizable as spectroscopes or monochromators, have relatively large physical dimensions, are fragile, and contain slits and focussing elements which result in high production costs.

OBJECT

One object of the invention is to propose a dispersive device which can have small physical dimensions, is robust, can be produced at a relatively low cost, and has relatively high light strength and high resolution. Another object of the invention is to propose a dispersive device which furthermore allows through-sighting with transmission of an image which is in scale. Further objects and advantages of the invention will be apparent from the following.

SUMMARY OF THE INVENTION

The inventive dispersive optical device includes a dispersive optical member comprising a first and a second grating applied to planar parallel substrate surfaces, preferably reflection gratings which have the same grating frequency and have parallel grating scores or rulings, the second grating being adapted for being struck by a portion of the light defracted by the first grating, so that light which is defracted by the second grating is parallel with light incident on the first grating.

Since a greater defraction angle gives a greater angular dispersion, the angle between a normal to a grating and a line between the gratings should attain at least 60^o and preferably at least 70^o. The upper limit of the angle is 90^o, for natural reasons, but attains in practice to about 88^o. The angle is selected to advantage within the interval $80\text{-}85^o$.

By selecting, for example, a relatively large distance between the gratings and a relatively narrow width for them, the angular variation will be small for rays between the gratings. This signifies that only a correspondingly small spectrum portion of parallel light incident on the first grating will strike the second grating. Since the gratings are mutually the same, light defracted by the second grating will be parallel to the light incident on the first grating. By measuring the angle of the member (i.e. the grating) to incident light, an indication can be obtained of the wavelength of the light observed at the member output. In a corresponding mode, when the member is utilized as a monochromator, for example, it can be arranged for light of a predetermined wavelength range to leave the output of the member by setting a given angle between incident light and the member. When the member is used as a monochromator, a focussing lens can be arranged behind the member output with a slit after the lens, suitably at its focal point, so that aligning errors are eliminated, as well as extraneous light wavelengths, only the whole of the pertinent pencil of rays being looked after.

It should further be clear that the dispersive member can be provided with a wavelength scale which is readable at the output from the second grating, so that the wavelength of the light observed at the output of the second grating can be read off by eye directly.

In one embodiment of the invention, the member is built up on a transparent substrate with planar parallel surfaces, e.g. a plate of so-called float glass, a grating being arranged on each chief surface of the substrate at opposed ends thereof. The gratings are preferably protected by some kind of covering on their surfaces facing away from the substrate. It is further suitable for the whole member to be enclosed by a light-absorbing coating, e.g. a black paint, the refractive index of which is close to that of the substrate, except at the surfaces of the substrate used as input, output and total reflection surfaces.

According to another embodiment of the invention, the gratings can be arranged opposite, and adjacent each other between a first and a second planar parallel substrate, the substrates being arranged mutually parallel and adjacent. In such a case, a third planar parallel substrate is preferably arranged perpendicular to said first and second substrate at one end thereof. A mirror means can hereby be arranged at the free surface of the third substrate. Light which is defracted by the first grating can thus be arranged for total reflection at the free surface of the first substrate, for subsequently striking the first mirror means, whereat it is directed towards the free surface of the second substrate for being totally reflected there. The light can subsequently be arranged for directing towards the second grating, where it is defracted and departs from the member. The departing light will, however, be mirror-inverted in relation to the light incident on the first grating, although the member can be made such that light which is totally reflected at the free surface of the second substrate strikes a second mirror means at the free end of the second substrate, for direction towards the second grating with an angle of incidence corresponding to the defraction angle at the first grating.

In the embodiments where both gratings of the member are adapted mutually adjacent and opposite, the source of the light incident on the first grating can be observed with full sharpness and substantially without parallax. Said first and second gratings can possibly constitute opposing sides of a single grating element. In an embodiment of the dispersive member in which said first and said second grating are also mutually opposing, a light--absorbent coating should be arranged to surround the member excepting the substrate surfaces which form the input and output of the member and the substrate surfaces at which said total reflections are arranged to occur. By suitable selection of grating line density, width of grating and distance between the gratings in the ray path, it can be ensured that only light wavelengths within an interval determined by said factors strike the second grating. Due to the second grating having the same grating frequency as the first grating, light which is defracted in the second grating will have the same direction as light incident on the first grating. Said light wavelength range can be varied by varying the angle between the first grating and incident light.

The invention is defined in the appended claims.

In the following, the invention will be described in detail in the form of an example while referring to the appended drawing.

DRAWING

Fig. 1 schematically illustrates a first embodiment of a dispersive member incorporated in the device in accordance with the invention. Fig. 2 illustrates an alternative embodiment of the device in accordance with the invention. Fig. 3 illustrates an embodiment of the device according to Fig. 1. Fig. 4 illustrates a device in accordance with the invention, utilizable as a monochromator and including the member according to Fig. 1. Fig. 5 is a section taken along the line V-V in Fig. 4. Figs 6 and 7 illustrate members according to Fig. 1, incorporated in a spectrograph and a spectrophotometer, respectively. Fig. 8 illustrates a member in accordance with the invention, provided with an angle scale. Fig. 9 illustrates a monochromator in accordance with the invention containing two members according to Fig. 1.

EMBODIMENT EXAMPLES

A dispersive member 1 is illustrated in Fig. 1, and includes a transparent substrate 2, e.g. of float glass, with planar parallel chief surfaces 21,22. At one end zone of the member 1 there is a first refletion grating 3 arranged on the surface 22. At the other end zone of said member 1 there is a second reflection grating 4 arranged on the surface 21. The substrate 2 and gratings 3,4 are outwardly covered by a light-absorbent medium 5, e.g. a black paint, with a refractive index as near to that of the substrate as possible, excepting at the substrate surfaces 6,7 opposite the respective grating 3,4. The surface 6 can be the input of the member, in which case the surface 7 constitutes its output.

The gratings 3,4 have the same grating frequency, and mutually parallel scores or rulings, extending normal to the plan of the Fig. 1. The function of the member is as follows. Assume that white light strikes the substrate surface 6 at an angle of incidence of α_1. The light is refracted there so that the angle of incidence will be α_2 to the grating 3. α_2 is defined by the expression arcsin $((\sin \alpha_1)/n_2)$, n_2 being the substrate refractive index. At the grating 3, the light will be defracted according to the grating formula

$$\sin \alpha_2 + \sin \beta_2 = \lambda \cdot \nu / n_2$$

where β_2 = defraction angle, λ = wavelength of the light, and ν = grating frequency (lines/mm).

Only the portion of the light which is defracted within an angle between β_{max} and β_{min} will strike the grating 4. The following is applicable here:

$$\beta_{max} = \arctan (a+(b_2+b_1)/2)/d \text{ and}$$
$$\beta_{min} = \arctan (a-(b_2+b_1)/2)/d;$$

where b_1 = width of grating 3, b_2 = width of grating 4, a = distance between centres of gratings 3, 4 and d = substrate thickness.

In this mode the grating 4 will only be struck by light with a wavelength between λ_{max} and λ_{min}. (λ_{max} and λ_{min} are obtained by insertion of β_{max} and β_{min} in the grating formula above.)

A portion of the light incident on the grating 4 will be defracted. If grating 4 has the same frequency as grating 3, the defraction angle will be equal to the angle of incidence on the grating 3. i.e. α_2. The light leaving the grating 4 will thus be parallel to the light incident on the grating 3.

Accordingly, it will be seen that the dispersive member according to Fig. 1 is utilizable as a spectroscope and is directly readable by the human eye.

By varying the angle of the member 1 to the light source which is to be studied, a portion of the spectrum of the light incident on the surface 6 can be scanned at the output 7.

It should be similarly clear that by measuring the angle between the member 1 and the incident or departing light, and observing the surface 7 during a corresponding angle, a direct indication of the wavelength of the light observed at the output 7 can be obtained from the measured angle. It should also be clear that by setting said angle at a certain value in such a device, light departing from the output 7 can be obtained with a given wavelength, i.e. the device constitutes a so-called monochromator. Fig. 4 illustrates a member 1 according to Fig. 1, which is pivotably mounted about a shaft substantially in the plane of the grating parallel to the grating lines, and at half the width of the grating 3. The member 1 is enclosed in a housing 30 having an opening 31 opposite the grating 3.

Fig. 3 illustrates a modified embodiment of a dispersive member in accordance with the invention. The function of the member according to Fig. 3 is the same as for the element according to Fig. 1. In the embodiment according to Fig. 3, the gratings are, however, arranged mutually opposite and adjacent, so that a direct through-sighting is enabled from the output 7 through the gratings and through the input 6, or in the opposite direction.

In the embodiment according to Fig. 2, transmission gratings 3',4' are utilized, which are applied to the substrate 2. Otherwise, the same conditions apply as for Fig. 1.

The member according to Fig. 3 includes two planar parallel substrates 102,103, on which the gratings 3,4 are applied directly opposite each other. The substrates 102, 103 are placed one against the other. At the left-hand end of the substrates 102,103 in Fig 2, a third substrate 104 is abutted tightly against the ends of the substrates 102, 103. Both ends of the substrate 104 are provided with a reflecting coating 107,108 to form mirrors at right angles to the plane of the gratings 3,4. A light-absorbing coating 5 is applied to the member, excepting at its input 6 and output 7, and possibly the positions 105 and 106. At the positions 105 and 106 the free surfaces of the substrares 102,103 may be coated to allow total reflection of light defracted by the grating 3, as is illustrated by the dashed ray path. Alternatively, a medium with a lower refractive index than that of the substrate can be applied at the positions 105,106, whereat the coating 5 can be applied to the medium in the positions 105,106.

Incident light is defracted at the grating 3, mirrored at the position 105 at the mirror 107, and at the position 106 at the mirror 108 to strike the grating 4 at an angle of incidence corresponding to the defraction angle at the grating 3.

It should be clear that the position 106 can be directly contiguous to the output 7. In the device according to Fig. 3, light which departs from the output 7 will have the same direction as light incident on the input 6. A comparison between Figs. 1 and 3 demonstrates that the member according to Fig. 3 allows direct through-sighting, and therefor avoids so-called parallax effects which can occur with the element according to Fig. 1.

Figs. 4 and 5 illustrate a device in accordance with the invention, which includes a member according to Fig. 1 and is adapted for utilization as a monochromator and/or spectrograph or the like.

The monochromator according to Fig. 4 comprises a housing 30 with an opening 31 for incident light. At the opening 31 a wide slit can be arranged to afford a relatively large wavelength resolution. Furthermore, a focussing element can be arranged in connection with the opening to provide focussing towards the measuring point.

It is generally desirable to have the incident light parallel, focussing means being adapted for the purpose. A mirror 32 is arranged to deflect incident light by 90°.

A mirror 33, parallel to the mirror 32, deflects the light to the incident direction. The mirror 33 is arranged parallel displaceable at right-angles to the incident light. The mirror 33 is arranged to direct incident light to the input 6 of the element 1. The member 1 is pivotably mounted on a shaft 34, which is mounted in the plane of the grating 4 at half the width thereof. The shaft 34 extends in the normal plane to Fig. 4. The focussing lens 35 is arranged opposite the output 7 of the member 1 to focus departing light towards a slit 36 in the housing 30. The slit 36 is in a position defined by a line through the shaft 34 parallel to the incident light. A screw 37 is connected to the member 1 in a position at a distance from the shaft 34. The screw 37 is adapted to provide pivoting of the member 1 about the shaft 34 when the screw is turned. Furthermore, the screw

37 or the member 1 is connected to the mirror 33 to provide parallel displacement of the mirror 33, so that light deflected by the mirror 33 strikes the input 6 of the member 1 irrespective of the pivotal position of the member. The screw 37 has a wheel 39 and is connected to a revolution counter indicating the angle of the member 1, and thus the light wavelength passing through the slit 36.

Fig. 5 illustrates a mirror 41, pivotably mounted on a shaft 40 with an operating wheel 43. An eyepiece 42 is mounted in the upper part of the housing 30. When the mirror 40 is swung upwards, the ray path is deflected towards the eyepiece 42. The lens 35 focusses in front of the eyepiece 42, and a graduation scale 49 is arranged at the focus of the lens 35. The scale 49 extends normal to the plane of the Fig. 5. The mirror 40 and eyepiece 42 thus allow visual scanning of the light, and the scale provides an indication of the wavelength in question.

Fig. 6 illustrates an apparatus housing 50 with an opening 51, in the housing 50 there is a member 1 according to Fig. 1, mounted with the input 6 opposite the opening 51,so that light coming through the opening strikes the input 6 substantially normal to the grating 3. A focussing lens 55 is arranged at the output 7 of the member 1, and a diode array 59 is arranged after the lens 55. This diode array can then sense the focussing position, and thereby register the detected wavelength. The apparatus according to Fig. 6 thus constitutes a spectograph. Fig. 7 illustrates a spectrophotometer in accordance with the invention, the rigidly mounted lens 55 and diode array 59 in Fig. 5 being replaced by a detector means 156, which is pivotable about a shaft through the centre of the grating 4. The means 156 contains a focussing lens 155 and a detector 159. For the detection of light against the detector 159, the angle of the means 156 to the grating 4 is red so that a purposeful registration of the scanned spectrum can be obtained.

Figs. 6,7 illustrate only two examples of a plurality of possible applications, wherein the member in accordance with the invention can be utilized.

Fig. 8 schematically illustrates a member according to Fig. 1 with an angle scale 81 and a focussing member 82 depicting the scale at infinity in front of the input 6. The scale 81 is suitably arranged visible in a marginal area of the image field.

The angle scale 81 and member 82 can of course be arranged in the apparatuses according to Figs. 2 and 3 also.

The monochromator according to Fig. 9 can be said to contain two series-connected members according to Fig. 1. By utilizing two series-connected members 1, the departing light is caused to be coaxial with the incident light, and the wavelength of departing light can easily be adjusted by the angular setting of both members 1, whereby the member on the input side is pivotable about a shaft 71 at the centre of the grating 3 and the other member 1 is pivotable about a shaft 72 at the centre of the other grating 4. Pivoting both members is arranged to be done simultaneously and to the same extent, so that the angle to incident light of the first member is always the same as the angle of the second member to departing light. No focussing member is required in the apparatus according to Fig. 9. A focussing lens 75 with large focal length, which is arranged between the output of the first member and the input of the second member, has been found to almost double the light intensity of the monochromator, simultaneously as resolution is more or less doubled. To advantage, the lens 75 is arranged at an angle of about 55^{o} to the ray path.

By the arrangement shown in Fig. 9 of the two members 1, with the input of the first member substantially in line with the output of the second member, there is obained very great resolution.

The large defraction angle at the first grating and the correspondingly large angle of incidence to the second grating in a member result in that departing light will be polarized, to a very grat extent. Apparatuses in accordance with the invention are therefore very well utilizable as polarizors, especially the apparatus according to Fig. 9.

CLAIMS

1. A dispersive optical device for use as a polarizer, spectroscope, monochromator or the like, for use as a basic element for a monochromator, polarizer, spectroscope, spectrophotometer or the like, characterized by a dispersive optical member including a first and a second grating (3,4) applied planar parallel on a substrate, preferably reflection gratings with the same grating frequency, said gratings (3,4) being applied mutually oriented with parallel grating scores or rulings, whereby light defracted by the first grating is arranged to strike the second grating (4).

2. Device as claimed in claim 1, characterized in that the first grating (3') is arranged adjacent and opposite the second grating (4') and that mirror means (105-108) are adapted to direct light defracted by the first grating (3) towards the second grating (4).

3. Device as claimed in claim 1, characterized in that the gratings (3,4) are applied on either side of the transparent substrate (2) with planar parallel surfaces, and in that the gratings are arranged mutually displaced in their planes.

4. A device as claimed in any of claims 1-3, characterized in that the angle between a normal to the first grating and a line between the centres of the gratings attains 60-90°, preferably 70-88°, in that the substrate preferably comprises glass, e.g. float glass, and in that a light-absorbent coating, preferably a black coating, the refractive index of which is close to that of the substrate, is preferably applied to the member, excepting at the surface portions of the substrate facing away from the gratings.

5. A device as claimed in any of claims 1-4, characterized by means (37-39) for measuring the angle member (1) to the direction of the departing light during observation of a certain spectrum portion, e.g. a spectrum

line at the output of member (1) in said direction, the measured angle constituting an indication of the wavelength of the observed spectrum line.

6. A device as claimed in any of claims 1-4, characterized by means (37-39) for setting the angle of the member to incident light, whereby light, departing from the member output parallel and to incident light, is of a predetermined wavelength.

7. A device as claimed in any of claims 1-4, characterized in that the member (1) is provided with a wavelength scale (49,81) readable at the output from the other grating (4).

8. A device as claimed in any of claims 1, 3, 4, 6, characterized in that two members (1) are coupled in series and adapted with the input of the first member in line with the output of the second member.

9. A device as claimed in claim 8, characterized by means (71,72) for setting the angle included between both members (1).

10. A Device as claimed in claim 9, characterized by a focussing element (75) of large focal length, between the output of the first member and the input of the second member.

Fig. 1

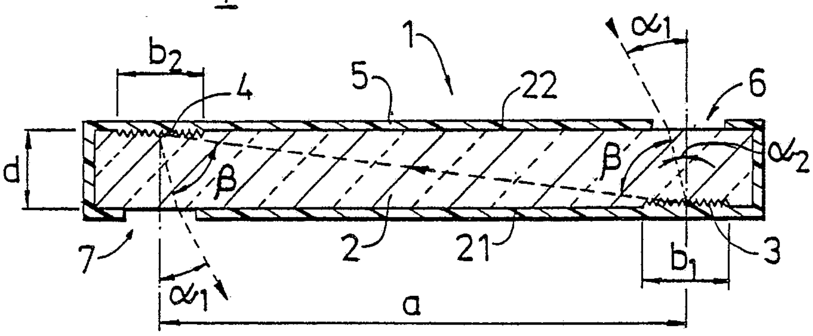


Fig. 2

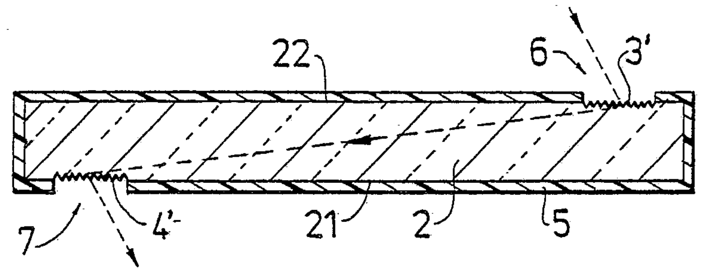


Fig. 3

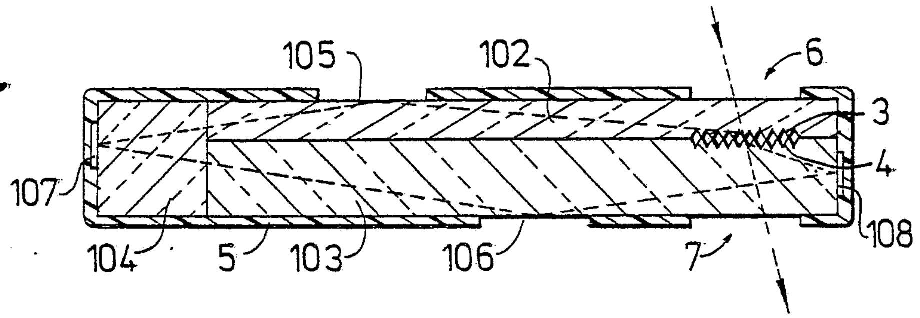


Fig. 4

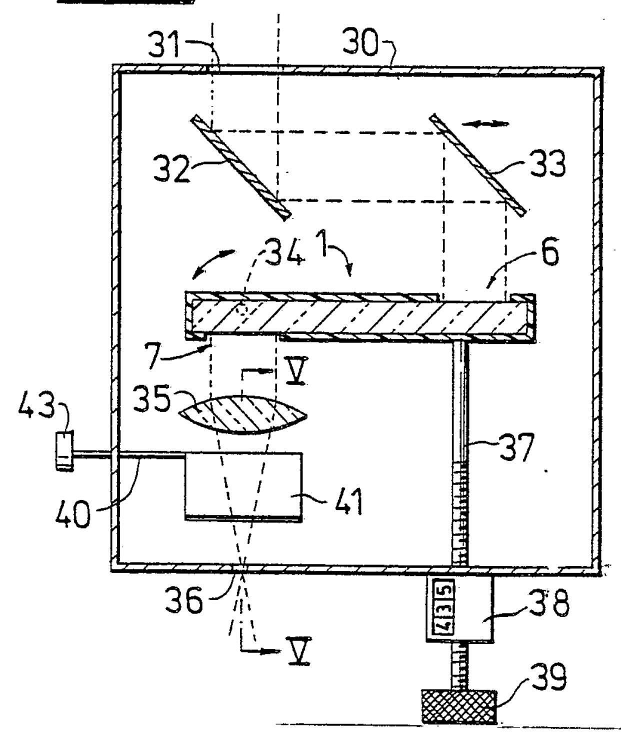
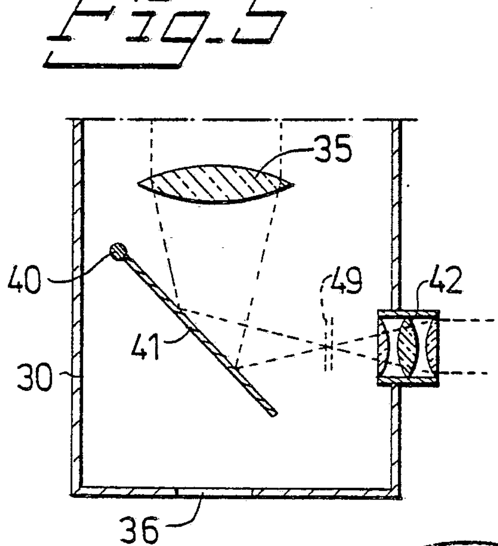


Fig. 5



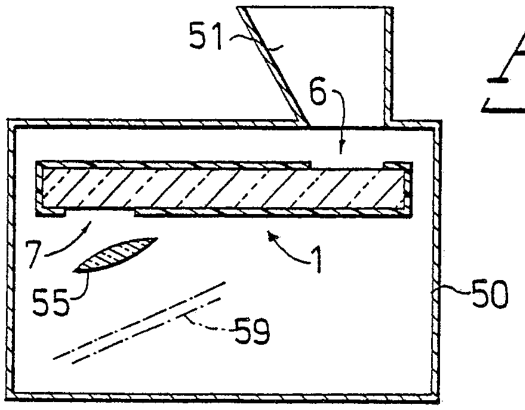


Fig. 6

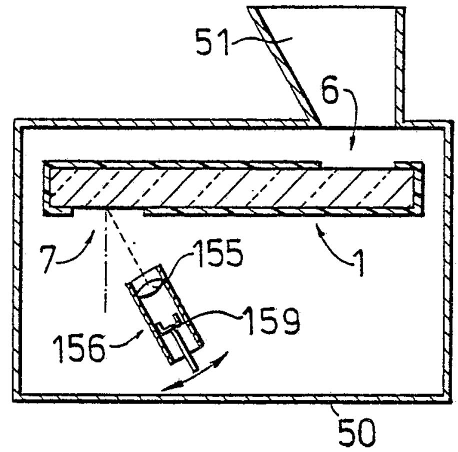


Fig. 7

Fig. 8

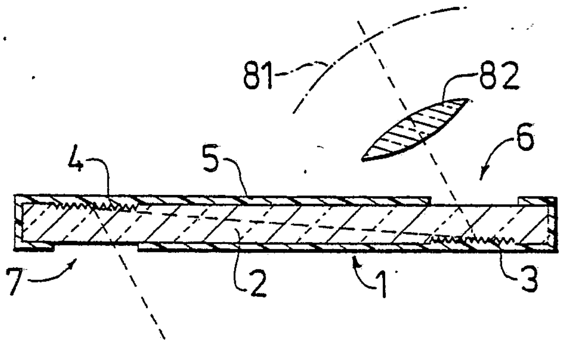
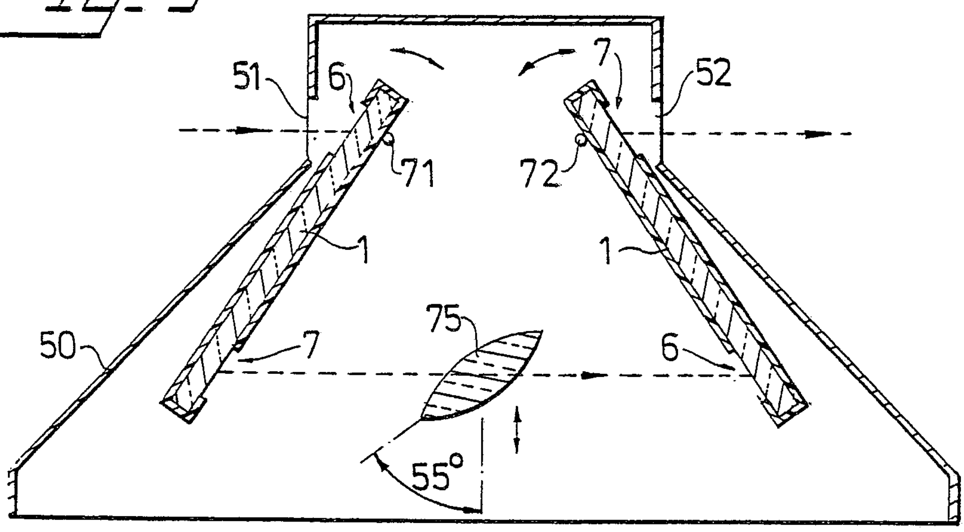


Fig. 9



INTERNATIONAL SEARCH REPORT

International Application No PCT/SE81/00101

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 3

G 02 B 27/38, G 02 F 1/29

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
IPC 3	G 02 B 5/18, 5/30, 17/00, 27/10, 27/14, 27/38, G 01 J 3/18, 3/24, G 02 F 1/29
US Cl	350:152,162,168; 356:79,94,100,300,305,324,328,334

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

SE, NO, DK, FI classes as above

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]
X	GB, A, 1 319 097 published 1973, May 31, Thomson C S F	1, 3, 5
X	GB, A, 1 470 810 published 1977, April 21, Perkin-Elmer Corp	1, 5, 8
A	DE, A1, 2 555 559 published 1977, June 16, Danielsson N A, Lindblom K-P C	
A	DE, A1, 2 831 813 published 1979, February 8, Quantel S A	
A	DE, A1, 2 427 236 published 1975, December 18, Ernst Leitz GmbH	
A	DE, A1, 2 225 870 published 1973, December 6, Hoffmann K	
A	FR, A, 2 364 436 published 1978, April 7, International Business Machines Corp	
A	FR, A, 2 394 789 published 1979, January 12, Agence Nationale de Valorisation de la Recherche (Anvar)	
A	US, A, 3 603 668 published 1971, September 7, Dominick John DeBitetto	
A	US, E, (3 254 556) 26 617 published 1969, June 24, J J J Staunton	

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"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
1981-06-12	1981-06-15
International Searching Authority [1]	Signature of Authorized Officer [10]