United States Patent

Girard et al.

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[54] SPECTROMETRIC INSTRUMENT WITH TRANSPOSITION OF RAY PATHS

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **356/97**, 250/226, 356/100

[51] **Int. Cl.** **G01j 3/42**, G01j 3/12

[58] **Field of Search** 356/74–101; 250/226

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Assistant Examiner—V. P. McGraw
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[57] **ABSTRACT**

Spectrometer for the analysis of a polychromatic radiation flux which comprises, in a plane, a single radiation-conveying window having two multiplicities of alternating zones with different conveying characters for the radiation flux to be analyzed and such that the pattern of the zone boundaries has an axis of symmetry in that plane and a center of symmetry, the spectrometer also comprising an image-forming apparatus made up of a dispersive system having a spectrum-scanning movement and a collimating system, a receiver for the radiation flux, and means to modulate the radiation flux.

The pattern of the zone boundaries and the image-forming apparatus are such that this apparatus casts, in the plane of the single window, a plurality of monochromatic enantiomorphous images of the window provided respectively by the monochromatic radiations constituting the flux to be analyzed, the center of one of these images being, for each position of the dispersive system, coincident with the center of the window.

10 Claims, 10 Drawing Figures

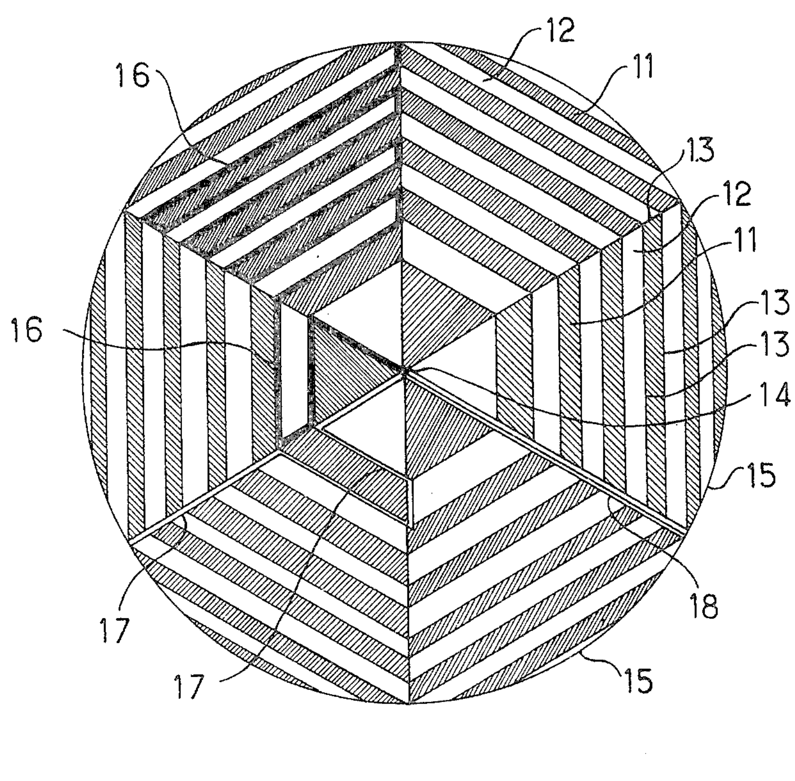

FIG. 1

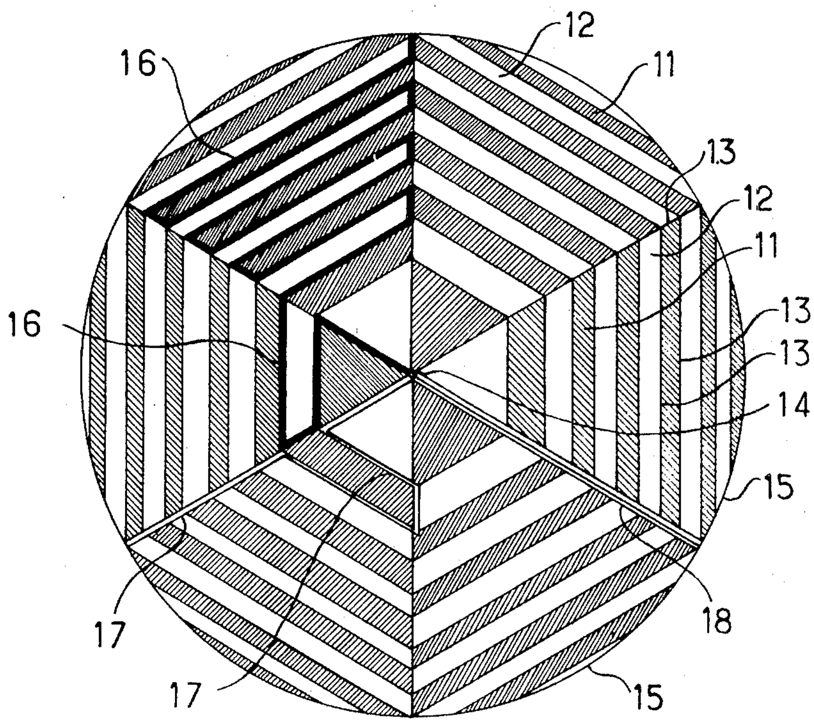

FIG. 1A

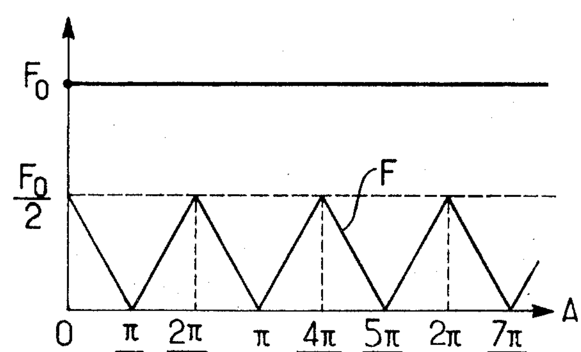

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FIG. 2

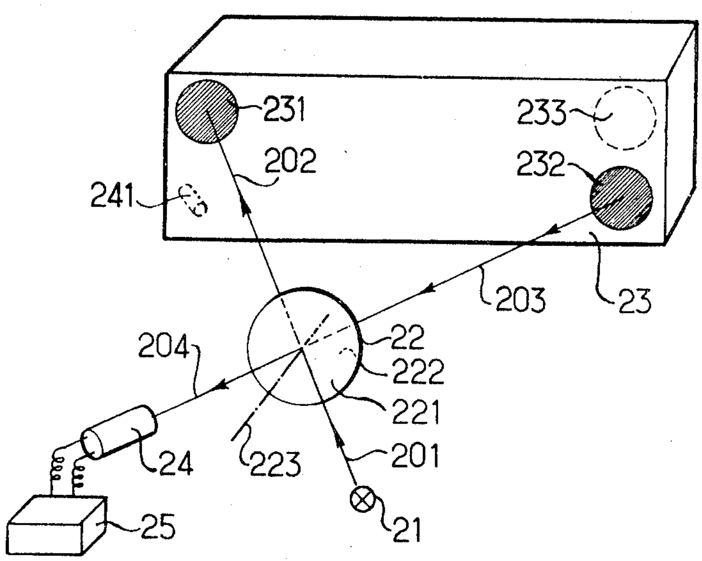

FIG. 3

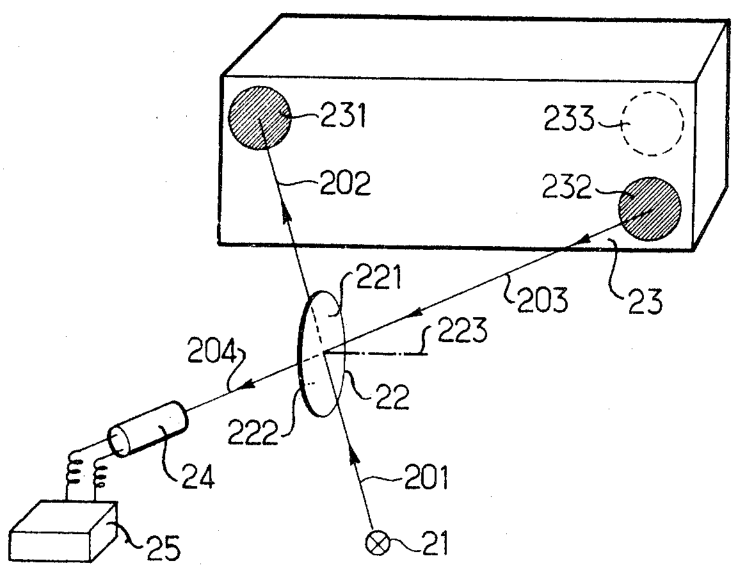

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FIG. 4

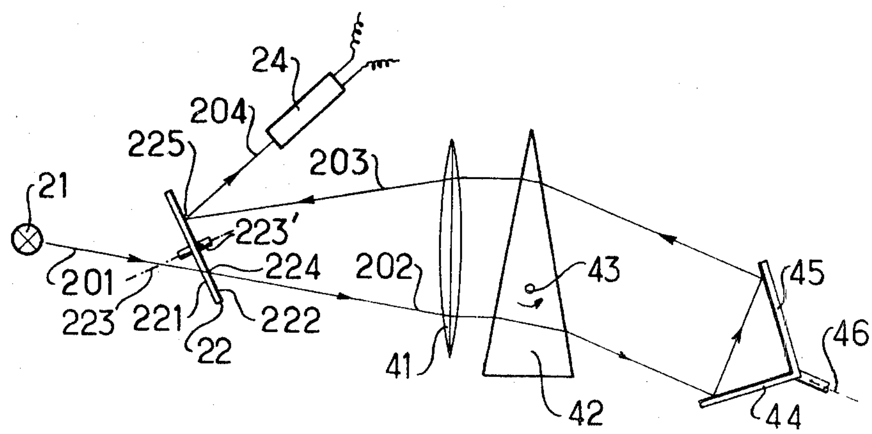

FIG. 5

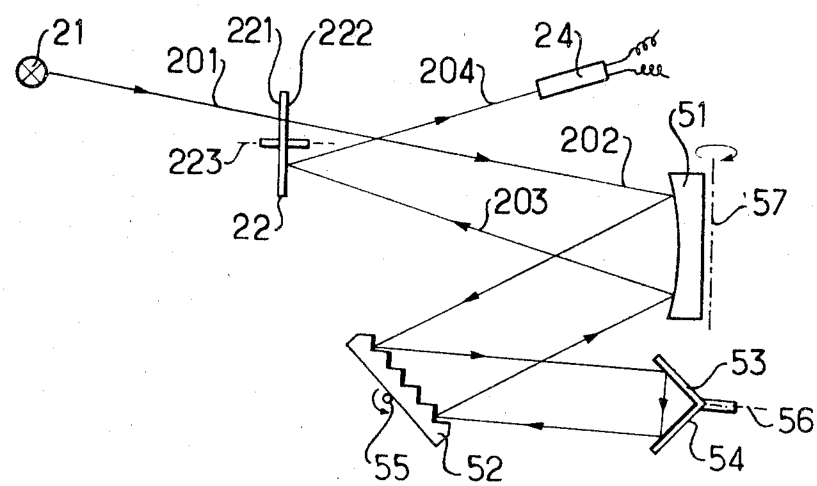

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FIG. 6

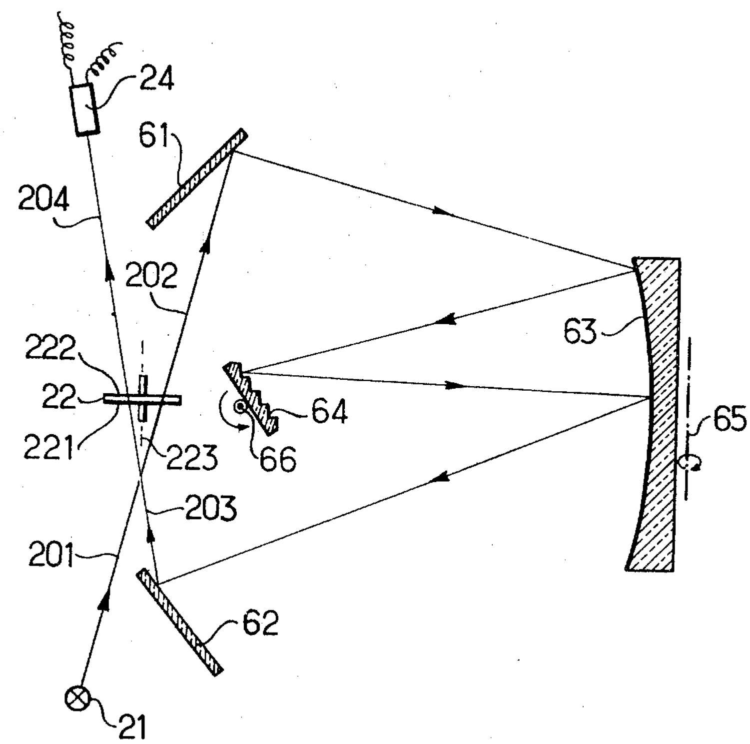

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FIG. 7

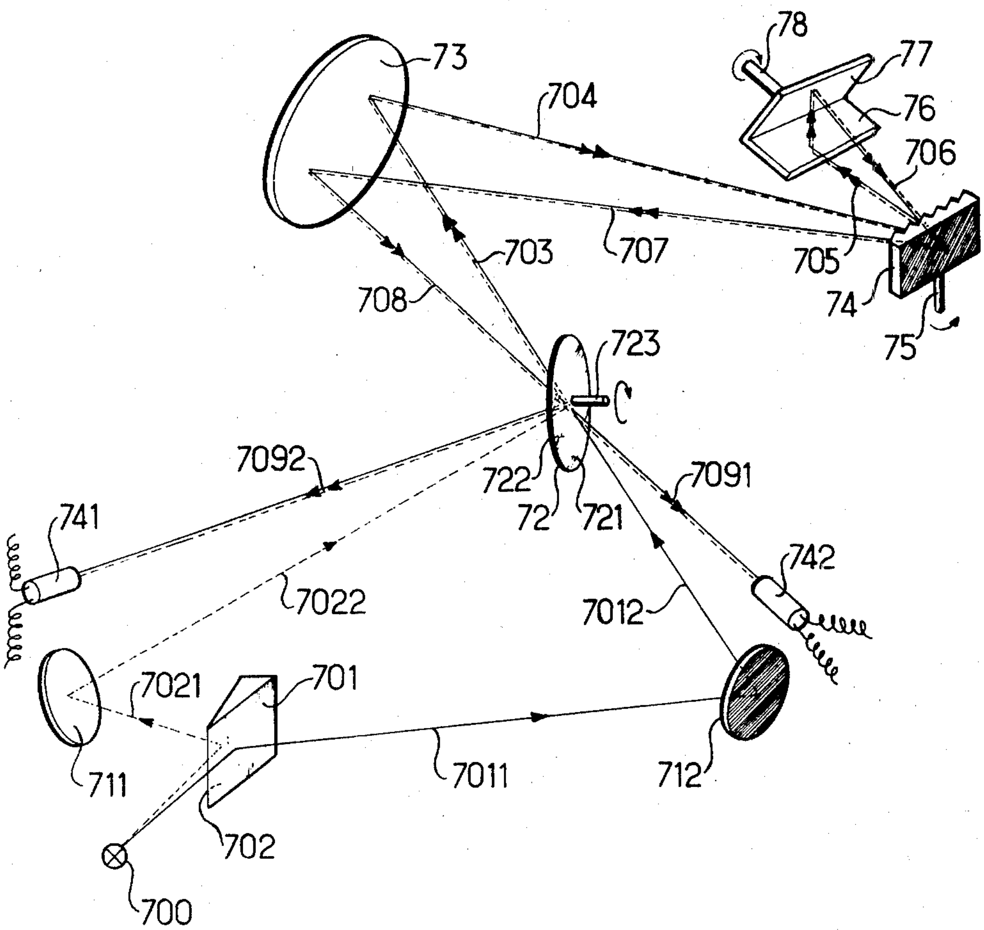

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FIG. 8

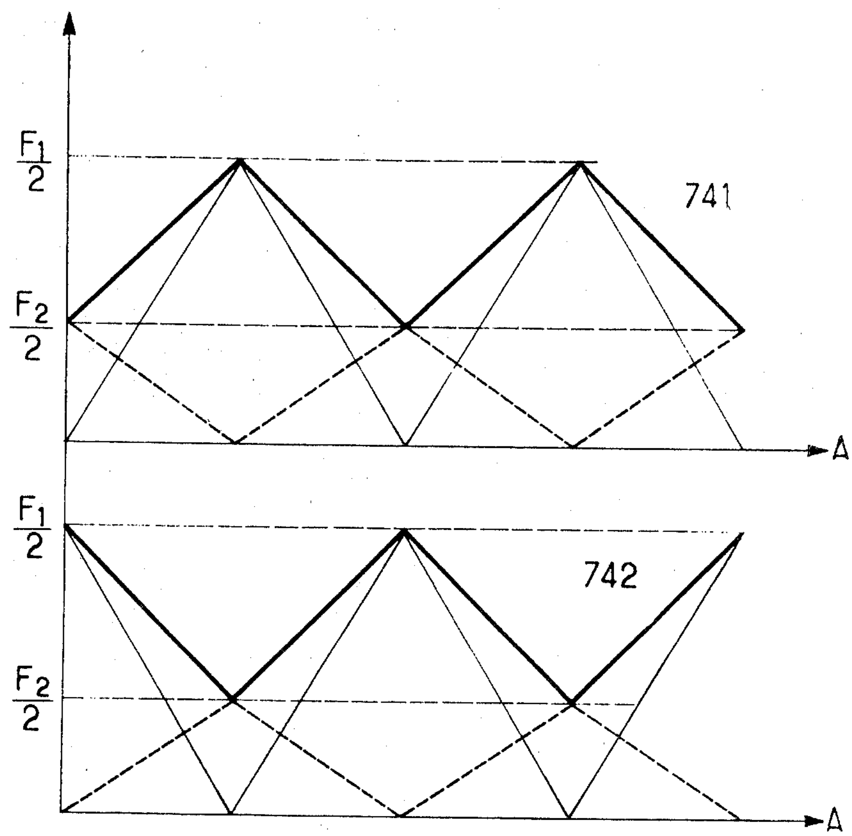

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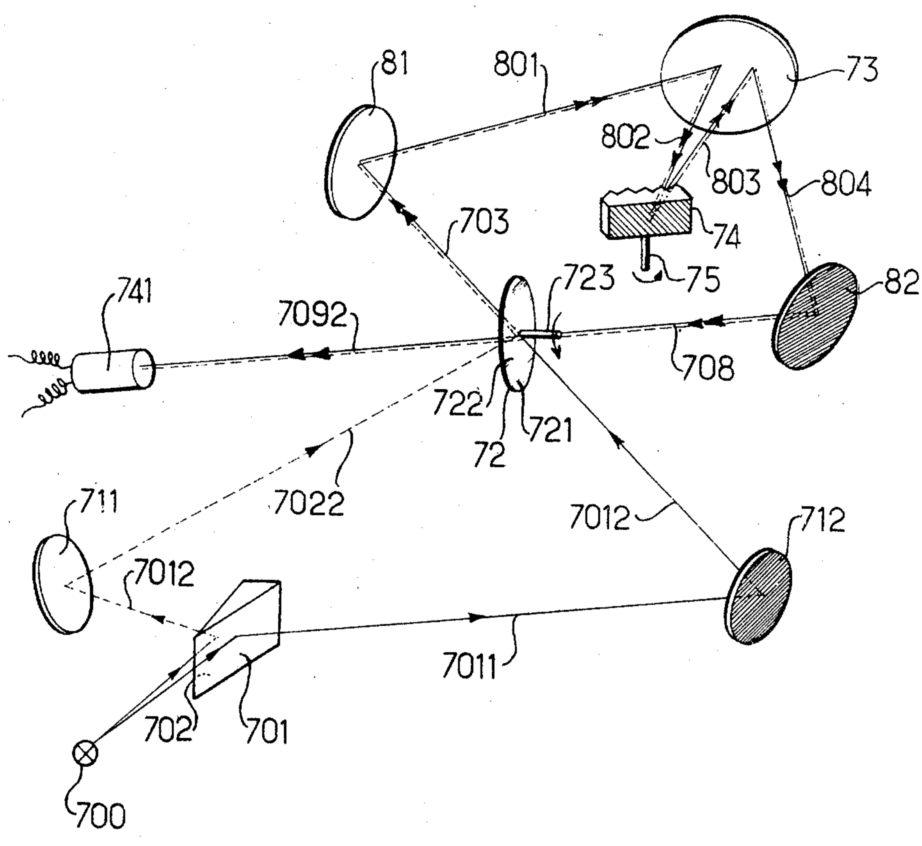
FIG. 9



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SPECTROMETRIC INSTRUMENT WITH TRANSPOSITION OF RAY PATHS

The invention relates to spectrometric instruments made up of a dispersive system (prism or grating), of entrance and exit windows or grids, and of a receiver supplying a signal proportional to the outgoing radiation flux impinging upon it.

The windows or grids of such an instrument are optical elements, plane as a rule, made up of two multiplicities of adjacent alternating zones with respectively different conveying characteristics for the radiation to be analyzed by the spectrometer, for example respectively transparent and opaque, or transparent and reflecting; the pattern of the boundaries of these zones is such that if one window of a couple of superposed windows with identical zone-boundary patterns is translated or rotated with respect to the other window, the optical system thus made up conveys, by reflection or by transparency, an extreme (maximum or minimum) portion of the incoming radiation flux in the position of coincidence of the patterns of the zone boundaries of the two windows, and an average proportion of that flux in any other relative position of the zone-boundary patterns.

When a polychromatic radiation goes through such a spectrometer including, between the windows, not only the dispersive system, but also a collimating apparatus, the latter costs, in the plane of the exit window, a plurality of monochromatic images of the entrance window, of the same size as the exit window, distinct from one another owing to the intervention of the dispersive system; the latter is usually subject to a motion of rotation in the dispersion plane, named scanning motion, in such a way that the aforesaid monochromatic images successively coincide zone for zone with the exit window.

When an image of the entrance window carried by a monochromatic radiation coincides with the exit window in a particular instantaneous position of the dispersive system the wavelength of that radiation being then called "adjustment wavelength," the exit window conveys, either by transparency or by reflection, a maximum (generally the whole) or minimum (generally zero) proportion of the flux corresponding to that radiation as conveyed by the entrance window, while for noncoincident images the exit window conveys an average proportion (generally half) of the corresponding fluxes conveyed by the entrance window.

In order to measure or to record the energies corresponding to the adjustment wavelengths, without the intervention of the energies on the other wavelengths, one may impart to the images of the entrance window a periodical motion with respect to the exit window, by means of a periodical back-and-forth motion imparted to one of the windows or to any other element taking part in the transmission of the flux from the entrance window to the exit window, for instance a collimating element. During the scanning, only the fluxes corresponding to the adjusting wavelengths and impinging on the receiver or transducer are modulated, so that if the transducer is followed by an AC amplifier tuned to the modulating frequency, the signals issuing from the amplifier are distinctive of the fluxes present on the adjustment wavelengths, and thus may operate measuring and recording instruments.

Spectrometers of this type are known which are modulated by vibration and include a single window acting both as entrance window and as exit window, the collimating apparatus being such as to cast the images of this window, supplied by the dispersive system, in the plane of this same window. Such single-window spectrometers modulated by vibration offer particular advantages over the two-window spectrometers modulated by vibration, such as, for instance, smaller dimensions, a higher luminosity, and a better correction of the aberrations.

Spectrometers with two windows are also known in which the particular pattern of the zone boundaries of the windows allows to modulate the fluxes corresponding to the adjustment wavelengths by a continuous relative rotation of the images of the entrance window with respect to the exit window, instead of by vibration. Such spectrometers modulated by rotation offer particular advantages over the spectrometers modulated by vibration, such as, for instance, a larger depth of modulation (difference between the maximum and the minimum value of the various modulated fluxes successively impinging upon the transducer during the scanning), and also a simplification in the mechanical apparatus operating the motion of the moving window or modulator. However, such spectrometers cannot be fitted with a single window, because the images cast by the dispersive system upon this rotating window would be subject to a rotating motion in the same direction and with the same speed as that of the window, and the fluxes to be measured would not be modulated.

It is an object of the invention to provide a single-window spectrometer modulated by a continuous rotation, offering the advantages of both the single-window spectrometers and the spectrometers modulated by rotation.

A spectrometer according to the invention, for the analysis of a polychromatic radiation flux issuing from a source, comprises, in a plane, a single radiation-conveying window with two multiplicities of alternating zones having different conveying characters for the radiation flux to be analyzed, and such that the pattern of the zone boundaries has an axis of symmetry in that plane, an image-forming apparatus including a dispersive system subject to a scanning movement and a collimating system, a receiver for the radiation flux, and means to modulate the radiation flux between the source and the receiver, the pattern of the zone boundaries and the image-forming apparatus being such that this apparatus casts, in the plane of the window, a plurality of monochromatic enantiomorphous images of the window provided respectively by the monochromatic radiations constituting said flux, the center of one of these images being, in each position of the dispersive system, coincident with the center to the window.

It is recalled that by enantiomorphous image of an object one means an image symmetrical of that object with respect to a plane.

The spectrometer according to the invention may be designed for operation by a so-called single-beam mode, to carry out spectrometric measurements on a radiation flux; it may also be designed for use according to a two-beam working mode, to carry out differential spectrometric measurements on two radiation fluxes.

Moreover, the single-window spectrometer according to the invention may be subjected to modulation by vibration.

The following description, given by way of example, refers to the appended diagrammatic drawing, in which:

FIG. 1 shows an embodiment of a window, and FIG. 1A shows the diagram of the modulation of the flux which may be obtained with same;

FIG. 2 shows very diagrammatically the general structure of a spectrometer according to the invention;

FIG. 3 is a view similar to FIG. 2, for another embodiment;

FIG. 4 is a more detailed view of a spectrometer according to the invention, for a single-beam embodiment;

FIG. 5 is a view similar to FIG. 4, for a modification;

FIG. 6 is a view similar to FIGS. 4 and 5, for another modification;

FIG. 7 shows an embodiment of a two-beam-type spectrometer according to the invention;

FIG. 8 shows diagrams of the modulation of the flux obtained with the spectrometer shown in FIG. 7 and;

FIG. 9 shows a modification of the embodiment of FIG. 7.

Reference is first made to FIG. 1 which shows very diagrammatically, as an example, a window made of a plane optical element, divided into two multiplicities of zones, such as **11** and **12**, having respectively different conveying characters for the radiation flux to be analyzed, being respectively opaque and transparent, for instance, or transparent and reflecting, or else opaque and reflecting.

The zone boundaries form a pattern which is nonrepetitive in at least one reference direction.

The totals of the areas of the two multiplicities of zones are equal.

A window fulfilling the above-mentioned conditions is designed for a spectrometer modulated by vibration.

Furthermore, in the window shown diagrammatically, the pattern made up by lines **13**, which are zone boundaries, as well as the pattern of the contour **15** of the optical element show a rotational symmetry of even order, that is of order 2N, N being an integer ($N=3$ in the present case), about a center **14**, and the maximum number of independent paths which may be drawn out along the zone boundaries, joining the center **14** to the contour **15**, is an odd multiple of 2N; by independent paths one means paths without any common points, or else with common singular points such as tangential points, cusps, points of intersection, but without any common segments.

For example, such a path **16** is shown by a thick line, and another such path **17** is shown by a double line.

A window such as just defined is adapted to constitute an entrance window and an exit window of a spectrometer modulated by a continuous rotation. If two such windows with identical patterns of zone boundaries are superimposed, and subject to a relative motion of rotation about an axis perpendicular to their plane of contact and passing through their common center, the flux which they transmit varies periodically, its value reaching an extreme equal to half of the incident flux in a certain relative position of the two windows, and vanishing upon a relative rotation of π/N radians (π/3 in the present case) with respect to that position.

With a couple of windows such as shown in FIG. **1**, the shape of the variation of the transmitted flux is substantially illustrated by the diagram of FIG. 1A, where F^o stands for the value of the incident flux, assumed to be constant. The value F of the flux transmitted by the couple of windows varies between 0 and $F^o/2$, depending on the angle A of relative rotation of the two windows.

The pattern of the zone boundaries of a window according to FIG. **1** is characterized by the fact that 2N independent paths, such as path **18** shown by a triple line, may be drawn out along the zone-boundary lines, from the center **14** to the contour **15**, which taken together show a rotational symmetry of order 2N; in other words, on this pattern and in its plane, 2N axes of symmetry passing through the center **14** may be drawn.

If the window is subject to a rotation of π radians about an axis of symmetry such as **18**, the same pattern of zone boundaries is recovered, i.e., the pattern of the zone boundaries of this flipped window is enantiomorphous to the original.

On the other hand, the configuration of the zones is not enantiomorphous to itself, zones such as **11** taking the place of zones such as **12** and vice versa after such flipping. The same configuration of the zones may be recovered only through a rotation of π/N radians in the plane of the window (π/3 in the case of FIG. **1**) of the enantiomorphous image.

In the following general description of a spectrometer according to the invention, and of the various embodiments or variants thereof, we have used these terms:

"plane of the window": the plane of the pattern of the zone boundaries;

"emitting side" of the window: the side from which the radiation flux is conveyed towards the forming apparatus;

"receiving side" of the window: the side receiving the monochromatic flux sent back by the forming apparatus;

"forming apparatus": the optical apparatus made up of the dispersive system (prism or grating) subject to a scanning motion, and of the collimating apparatus; this apparatus casts in the window plane monochromatic images of the window corresponding to the various radiations making up the spectrum to be analyzed.

Reference is now made to FIG. **2** which shows very diagrammatically the general layout of a spectrometer embodying our invention.

The flux of radiation to be analyzed, issuing from the source **21**, is diagrammatically represented by its axis **201**, and impinges upon a window **22** through its side **221**. The window **22** is made up of two multiplicities of zones respectively opaque and transparent. The side **222** may be considered as emitting that part of the flux **201** which goes through the window **22**, the other part of the flux being lost for the analysis. After going through the window, the flux **202** enters the forming apparatus, symbolized here by a box **23**, at a location symbolized here by an opening **231**.

The flux going through the forming apparatus is on the one hand dispersed into monochromatic fluxes and, on the other hand guided to leave that apparatus along a direction **203** and to project in the plane of the window **22** a multiplicity of monochromatic enantiomorphous images of that window, the contour of the image of the window which corresponds to the adjustment wavelength being coincident with the contour of the window.

The invention provides means to impart a rotation to the flux directed along line **203**, either by a rotation of the window **22** in its plane, the enantiomorphous images then rotating in a direction opposite to that of the window, or by a rotation of an element of the forming apparatus, the window **22** then being fixed.

The part of the flux **203** going through the window **22**, which constitutes a flux **204** issuing from the side **221**, may be thought of as made up of two fluxes:

A selected component which is actually modulated, is constituted by the energy whose wavelength is the adjustment wavelength, that is the wavelength of the radiation giving the monochromatic image whose contour coincides with that of the window; this flux is transformed into an electric signal by a transducer **24**, on which impinges the flux **204**; this modulated signal, after being amplified by an AC amplifier **25** tuned to the modulation frequency, operates measuring or recording instruments not shown in the figure;

A residual component made up of the energies with wavelengths different from the adjustment wavelength, which corresponds to images not coincident with the window and is not modulated by the rotation, according to a well-known property of spectrometric windows; the corresponding signal supplied by the transducer **24** is not modulated and is not transmitted by the AC amplifier **25**.

In the embodiment shown in FIG. **2**, the source **21**, the sensor or transducer **24** and the elements of the forming apparatus **23** are set up in such a way that the axes **201** et **202** of the entering flux and the axes **203** and **204** of the exiting monochromatic flux (corresponding to the adjustment wavelengths of the fluxes **201**, **203** incident on the window) make the same angle with the axis **223** of the window, which is normal to its plane and passes through its center of symmetry. In other words, the source **21** and the sensor **24** are set along the generatrices of a cone of revolution which has as its axis **223** the axis of the window and vertex the center of the window, the places **231** and **232** where the flux goes in and out of the forming apparatus **23** being also set along these generatrices. If this condition were not fulfilled, the images cast by the forming apparatus **23** in the plane of the window **22**, and, in particular, the image corresponding to the adjustment wavelength, would be subject to anamorphasis and the modulation would be inaccurate. This arrangement renders unnecessary to include, in the forming apparatus, anamorphasis-correcting devices difficult to realize and to adjust. It also allows an automatic compensation of most of the aberrations which might occur in the forming apparatus.

Likewise, according to the invention, in this embodiment where the same side of the window, in this case side **222**, acts both as emitting side and as receiving side, the forming apparatus subjects the fluxes to an even number of reflections, which makes it possible to obtain projections which are enantiomorphous images of the window.

Moreover, the evenness of the number of reflections does not necessarily entail the evenness of the number of reflecting elements of the forming apparatus.

Reference is now made to FIG. **3**, which relates to another embodiment, and which differs from the preceding one only by the arrangement of the window plane with respect to the axes of the fluxes. While in the embodiment according to FIG. **2** the fluxes **201** and **203** impinge upon opposite sides **221** and

222 of the window 22, they impinge upon the same side 221 in the embodiment according to FIG. 3. The conditions fulfilled by the embodiment according to FIG. 3 are identical with those fulfilled by the embodiment according to FIG. 2, except that in FIG. 3 the emitting side and the receiving side of window 22, that is side 222 and side 221 respectively, are opposite, so that the number of reflections imposed upon the flux by the forming apparatus is odd as more fully described below.

In both embodiments the window may include multiplicities of respectively transparent and reflecting rather than opaque transmitting zones. In this modification, the embodiment according to FIG. 2, for example, includes a forming device in which the exit point of the fluxes is located at 233, as shown by a dotted line. The transducer is then located as shown at 241.

Reference is now made to FIG. 4, which shows an embodiment of a spectrometer according to the invention, arranged according to a setup similar to the Littrow setup of slit spectrometers, and using a prism as its dispersive system.

The zones of the two multiplicities of the window 22 are respectively transparent and reflecting.

The collimating lens 41 is located so that its axis traverses the center of symmetry 223′ of the window 22. There is shown in FIG. 4 the path of the axis 201 of an elementary flux crossing the window 22 at a point 224 spaced from the center 223′. The flux first goes through the lens 41 and the prism 42 (which is subject to a motion of rotation about an axis 43 in order to scan the spectrum), undergoes a double reflection on a right dihedral made up of plane mirrors 44 and 45, and again goes through the prism 42 and the collimating lens 41. The elementary monochromatic flux corresponding to the adjustment wavelength is reflected at a point 225 of the side 222, symmetrical to point 224 with respect to a plane perpendicular to the plane of the figure and passing through the axis 223, and impinges upon the transducer 24.

In the embodiment shown in FIG. 5, the dispersive system is a grating 52 rotating about the axis 55 in order to scan the spectrum. Here the forming apparatus includes a collimating mirror 51. It also includes a reflecting dihedral made up of mirrors 53 and 54.

In both embodiments, the same side 222 of the window 22 acts as emitting side and as receiving side; the number of reflections in the forming apparatus is even. The axes of the fluxes 201, 202, 203, 204, make equal angles with the axis 223 of the window 22.

The modulation may be obtained by a rotation of the window 22 about the axis 223, in which case the enantiomorphous images rotate with the same frequency as the window, but in the opposite direction. It may also be obtained by a rotation of the dihedral 44–45 or of the dihedral 53–54 about an axis 46 or 56 respectively bisecting the dihedral, in which case the window 22 is fixed and the enantiomorphous images are subject to a motion of rotation with a frequency which is double of that of the dihedron.

In the embodiment of FIG. 5, the modulation of the flux may also be obtained by oscillation of the collimating mirror 51 about an axis 57 located in the plane of the figure.

Reference is now made to FIG. 6, which shows an embodiment of a spectrometer according to the invention relaying upon the Ebert-Fastie setup known for slit spectrometers.

The forming apparatus is made up of two plane mirrors 61 and 62, a collimating mirror 63, and a grating 64 subject to rotation about an axis 66 for scanning the spectrum. The axes 201, 202, 203, 204 of an elementary flux of radiant energy, with a wavelength which is the adjustment wavelength, make equal angles with the axis 223 of the window 22. The window 22 is made up of zones of two multiplicities, respectively transparent and opaque.

The emitting side and the receiving side are the opposite sides 222 and 221 of the window; the number of reflections in the forming apparatus is odd.

The modulation of the flux is obtained by a rotation of the window 22 about its axis 223.

The modulation could also be obtained by oscillation of the collimator 63 about an axis 65 located in the plane of the figure.

The invention contemplates not only single-beam spectrometers but also two-beam spectrometers, usually called "-double beam" spectrometers, with which it is possible to carry out differential measurements on two radiation beams, one of which is regarded as a reference flux. Such spectrometers are intended, for instance, to obtain the absorption spectrum of a material and are then called spectrophotometers.

FIG. 7 shows an embodiment of a double-beam spectrometer the elements of which are arranged according to the Littrow setup, so that each radiation flux undergoes two dispersive reflections on the grating.

In order to facilitate the comprehension of the figure, the beams to be analyzed have been shown by their main axes passing through the center of the optical elements making up the spectrometer.

The radiation flux issuing from the source 700 is split into two beams 7011 and 7021 (respectively shown in full lines and in dotted lines) by the reflecting sides 701 and 702 of a dihedral called "separator." These two beams are reflected by mirrors 711 and 712, along lines 7012 and 7022 respectively.

In the path of one of these beams may be for instance, interposed the sample of material to be examined not shown in the figure, and in the path of the other beam, there may be interposed, as known, an optical wedge controlled by a servo device, the motion of which shows the intensity of the absorption rays of the sample.

Compensating elements, now shown, may also be set along the two beams so as to equalize the intensities of the fluxes carried by the two beams before the sample is interposed.

The window 72 includes two multiplicities of zones, alternately transparent and reflecting for the fluxes, and is rotated about an axis 723 passing through its center and perpendicular to its plane.

A fraction of the flux of beam 7012 is reflected by the side 721 of the window and is not treated by the apparatus. The other fraction goes through the window along the axis 703.

A fraction of the flux of beam 7022 is reflected by the side 722 of the window along the axis 703. The other fraction, which goes through the window, is not subjected to treatment by the apparatus.

Thence the fractions of the fluxes conveyed by the window 72 proceed along the same axes, the radiant energy carried by these two fractions of fluxes being referred to hereinafter as "the compound flux."

The compound flux, reflected by a collimating mirror 73 along the line 704, impinges upon the grating 74, subject to rotation about an axis 75 for the scanning of the spectrum, which disperses it in the direction 705; this compound flux then impinges upon a dihedral called "reverser" made up of two mutually perpendicular plane mirrors 76 and 77, then impinges again on the grating 74 along the line 706. The compound flux again reaches the collimator 73 along a line 707, and is sent back to the window 72 in the direction 708.

A fraction of this compound flux is conveyed, by reflection on the side 722 of the window 72, towards a transducer or sensor 741, and the complementary fraction is conveyed, by going through the transparent zones of window 72, towards another transducer or sensor 742.

In this setup, the same side 722 of window 72 acts both as emitting side and as receiving side, and the forming apparatus, made up of the collimator 73, the grating 74 and the dihedral 76–77; is designed so that the compound flux undergoes an even number of reflections.

The various axes of the fluxes impinging upon the window 72 or conveyed by it make equal angles with the axis 723; they constitute the generatrices of the same cone of revolution which has as its axis the axis 723 of the window 72 and as its vertex the center of symmetry of the window, i.e., the point at which the axis 723 crosses the window. Actually, as far as the dispersive fluxes are concerned, this condition is strictly fulfilled only by the axes of the constituent fractions of the flux carrying the radiant energy with a wavelength which is the adjustment wavelength of the dispersive system. The contour of the enantiomorphous images of the window 72 supplied by the forming apparatus is then superimposable on that of said window.

Means are provided to rotate, in the plane of the window 72, the images of that window supplied by the forming apparatus, these means either rotating the window 72 about the axis 723 or rotating the reversing dihedral 76–77 about an axis 78 perpendicular to the line of intersection of the two mirrors and located in their bisecting plane. After passing through the forming apparatus, the radiations of the flux assembly with a wavelength different from the adjustment wavelength give, in the plane of the window 72, enantiomorphous images thereof whose contours do not coincide with that of this window. According to the well-known property of spectrometer windows, one-half of these radiations is conveyed towards the transducer 741 and the other half is conveyed towards the transducer 742, irrespective of the relative angular position of these images and that window. Consequently the corresponding fluxes are not modulated.

The part of the flux assembly corresponding to the adjustment wavelength, or the adjustment flux, gives, after being treated by the forming apparatus, an image of the window 72 enantiomorphous to said window; during the relative rotation, this image is periodically in a position of coincidence when, with the images of the zone boundaries superimposed on the zone boundaries of the window, the images of the transparent zones and the images of the reflecting zones register respectively with the transparent zones and on the reflecting zones of the window; it is periodically in "anticoincidence" when, with the zone boundaries superimposed, the images of the transparent zones register with the reflecting zones and vice versa.

If the adjustment flux incident upon the window 72 along the axis 7012 has the value F_1, and if the adjustment flux incident along the axis 7022 has the value F_2, the window 72 transmits towards the forming system, along the axis 703, a combined adjustment flux of value

$$F_1 12 + F_2 12$$

in which the first term stands for the part of the adjustment flux along the axis 7012 transmitted by going through the window, and the second term stands for the part of the adjustment flux 7022 transmitted by reflection on the side 722 of the window.

When the image given by the forming apparatus is in coincidence with the window, the transducer 741 does not receive any energy corresponding to the flux 7011, the fraction of the combined flux 708 relating to the flux 7011 being entirely transmitted by going through the window, consequently without reflection on the side 722.

On the other hand, under the same condition, that is when the image of the window given by the forming system is in coincidence with the window, the transducer 741 receives the whole of that fraction of the combined flux 708 which corresponds to the flux 7021 first reflected along the axis 703, and then, after being treated in the forming system, reflected (after passing along the axis 708) along the axis 7092. The transducer 741 thus receives a flux of value $F_2/2$.

Conversely, the transducer 742 receives, through transmission by going through the window 72, the flux of value $F_1/2$ corresponding to the fraction of the flux 7012 transmitted by going through the window 72 along the axis 703 towards the forming system; the transducer 742 does not receive any flux corresponding to the adjusting flux carried by the beam 7022.

In a similar way, when the image of the window is in anticoincidence with the window, the transducer 741 receives only the energy $F_1/2$ corresponding to the fraction of the flux 7012 transmitted by going through the window 72 towards the forming system, wherein it is treated before being reflected by the window along the axis 7012, while the transducer 742 receives only the energy $F_2 12$ corresponding to the fraction of the flux 7022 transmitted by reflection on the side 722 of the window 72 towards the forming system, wherein it is treated before traversing the window 72. (One disregards the of radiant energy inside the forming system, which, moreover, affect in the same way the fluxes 7012 and 7092).

When the image and the window are in intermediate angular positions between coincidence and anticoincidence, the respective proportions of the fluxes 7012 and 7022 received by the transducers vary linearly in terms of the angle characterizing these positions.

This process is summarized by the diagrams of FIG. 8. The upper diagram relates to the energy received by the transducer 741, and the lower diagram relates to the energy received by the transducer 742.

In each diagram, the graph in thin lines gives the values of the energy corresponding to the flux 7012, the graph in dotted lines gives the values of the energy corresponding to the flux 7022, and the graph in thick lines gives the values of the sum of these energies. Note that each transducer receives a radiant energy the value of which periodically varies between $F_1 12$ $F_2 12$.

Thus each transducer supplies a modulated exit signal, the amplitude of the modulation being proportional to the difference between the intensities of the fluxes 7012 and 7022.

The instrument is thus used according to a two-beam setup, for instance to obtain, from the signal supplied by either transducer, the absorption spectral curve of a sample interposed in one of the two fluxes.

In accordance with this invention we may also connect the exits of the two transducers 741 and 742 to the same AC amplifier tuned to the modulation frequency. As the signals supplied by these transducers are in phase opposition (FIG. 8) it is possible, by interposing one or several compensating devices in one or both of the fluxes 7012 and 7022, to attain a position for which the energies carried by these two fluxes are equal. The spectrometer may thus be used to obtain differential spectral response curves of the two transducers, one of which may be chosen as a standard.

In a modification, one of the amplifiers associated with a transducer may be provided with a dephasing device giving a phase shift equal to the modulation half-period. The electric signals thus obtained are added to those supplied by the other amplifier, which enhances to the sensitivity of the spectrometer.

We may further apply to single-beam spectrometers the combination of a window with two multiplicities of respectively transparent and reflecting zones, and of two transducers receiving modulated fluxes in phase opposition.

Reference is now made to FIG. 9, which relates to a modification of a double-beam spectrometer according to the invention, built along the Ebert-Fastie setup.

This modification includes, as does the embodiment according to FIG. 7, a source 700, a separating dihedral 701–702, mirrors 711 and 712, a window 72 rotating about an axis 723, a collimating mirror 73, and a dispersive grating 74 rotating about an axis 75 to carry out the scanning of the spectrum.

In this modification, the forming system includes two plane mirrors 81 and 82, and the flux assembly undergoes only one dispersive reflection on the grating 74. Starting from the window 72, the flux assembly follows in the forming system the paths along the axes 703, 801, 802, 803, 804 and 708.

In this modification, the emitting side 722 and the receiving side 721 are the opposite sides of the window 72; the flux assembly undergoes an odd number of reflections in the forming system.

In this modification, only one transducer 741 is shown.

The instrument may also be equipped with a second transducer, located as the transducer 742 of the embodiment according to FIG. 7.

The modulation diagrams obtained with the instrument according to FIG. 9 are identical with those obtained with the embodiment according to FIG. 7, and may be used in the same way.

The instruments shown in FIGS. 7 and 9 are also adapted for modulation by vibration, which may for instance be obtained by imparting to the collimating mirror 73 periodical oscillations in a direction parallel to the rotation axis 75 of the dispersive grating 74.

It will thus be seen that our spectrometric instrument utilizes a centrally symmetrical pattern (FIG. 1) whose zones form a plurality of periodically recurring sectors, the enantiomorphous images being produced by a transposition of the rays of the original beam (more specifically, of a component thereof transmitted by the window 22 or 72) within the radiation-guiding apparatus 23. Owing to this transposition, each ray of the selected component returns to the window at an angle of coincidence which is inverted with reference to the original angle, as described above in connection with FIGS. 2 and 3; for the adjustment wavelength the returning ray impinges upon the window at a point diametrically opposite its point of incidence in the original beam (see FIGS. 4–6).

We claim:

1. A spectrometric instrument for the analysis of a flux of polychromatic radiation issuing from a source, comprising:
- a planar window with a centrally symmetrical pattern of alternating zones forming two multiplicities of different transmission characteristics for the flux to be analyzed, said zones forming a plurality of periodically recurrent sectors, said window being disposed in the path of an original beam of said radiation emitted by said source;
- a projection system for directing a component of said original beam, transmitted by one of said multiplicities of zones, back to said window over a guide path transposing the rays of said component whereby each ray returns to said window at an angle of incidence inverted with reference to its angle of incidence in said original beam;
- a dispersive system in said guide path for making the relationship of said angles of incidence dependent on wavelength whereby a ray of a selected adjustment wavelength impinges upon said window at diametrically opposite points in said original beam and in the returning component;
- modulating means for periodically varying the position of said pattern with reference to said guide path; and
- detector means positioned to receive a portion of the returning component of said beam as retransmitted by one of said multiplicities.

2. A spectrometric instrument as defined in claim 1 wherein said modulating means comprises drive means for rotating said window about its central axis.

3. A spectrometric instrument as defined in claim 1 wherein said modulating means comprises drive means for oscillating an element of said projection system.

4. A spectrometric instrument as defined in claim 1 wherein said modulating means comprises drive means for oscillating an element of said dispersive system.

5. A spectrometric instrument as defined in claim 1 wherein said projection system comprises a plurality of reflectors.

6. A spectrometric instrument as defined in claim 5 wherein the number of reflections of said component on said guide path is even, said original beam and said returning component entering said window from opposite sides.

7. A spectrometric instrument as defined in claim 5 wherein the number of reflections of said component on said guide path is odd, said original beam and said returning component entering said window from the same side.

8. A spectrometric instrument as defined in claim 5 wherein said reflectors include a dihedral.

9. A spectrometric instrument as defined in claim 1, further comprising separating means for splitting said original beam into two branches impinging upon said window from opposite sides.

10. A spectrometric instrument as defined in claim 9 wherein said detector means comprises separate detectors for retransmitted portions of said branches.

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