July 28, 1970 H. S. NEWCOMER 3,521,960

MONOCHROMATOR

Filed Jan. 20, 1964 3 Sheets-Sheet 1

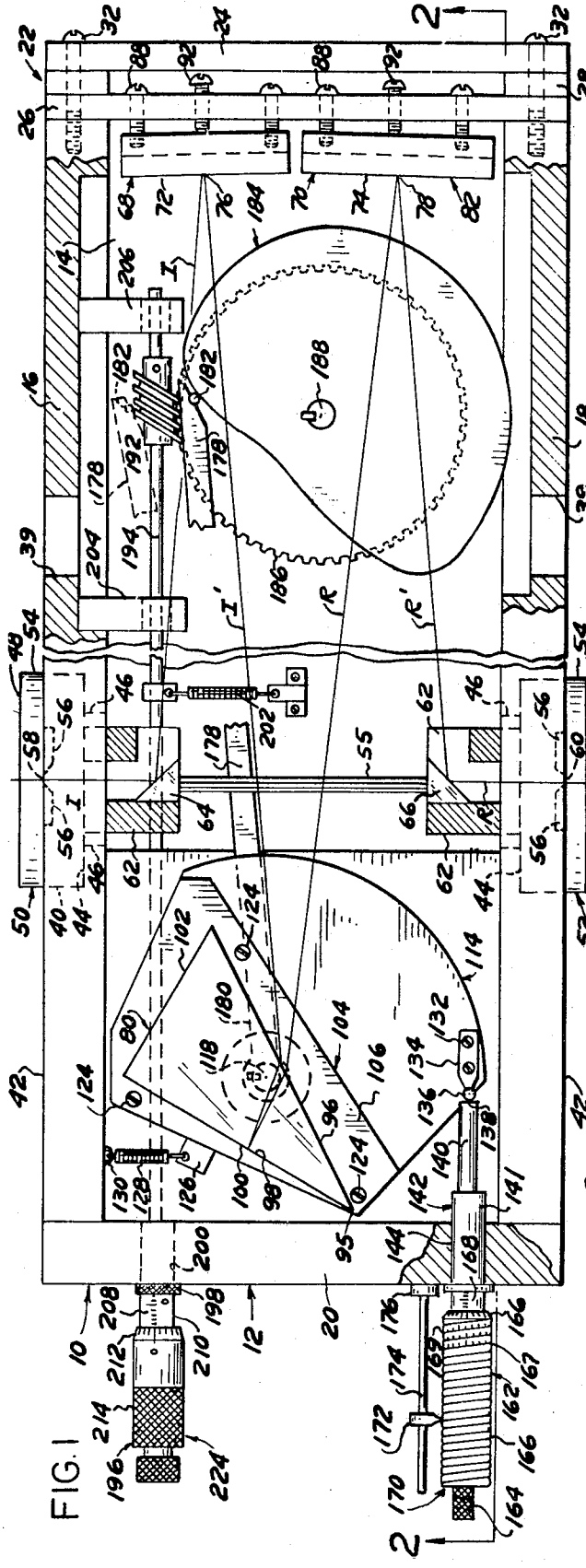

FIG. 1

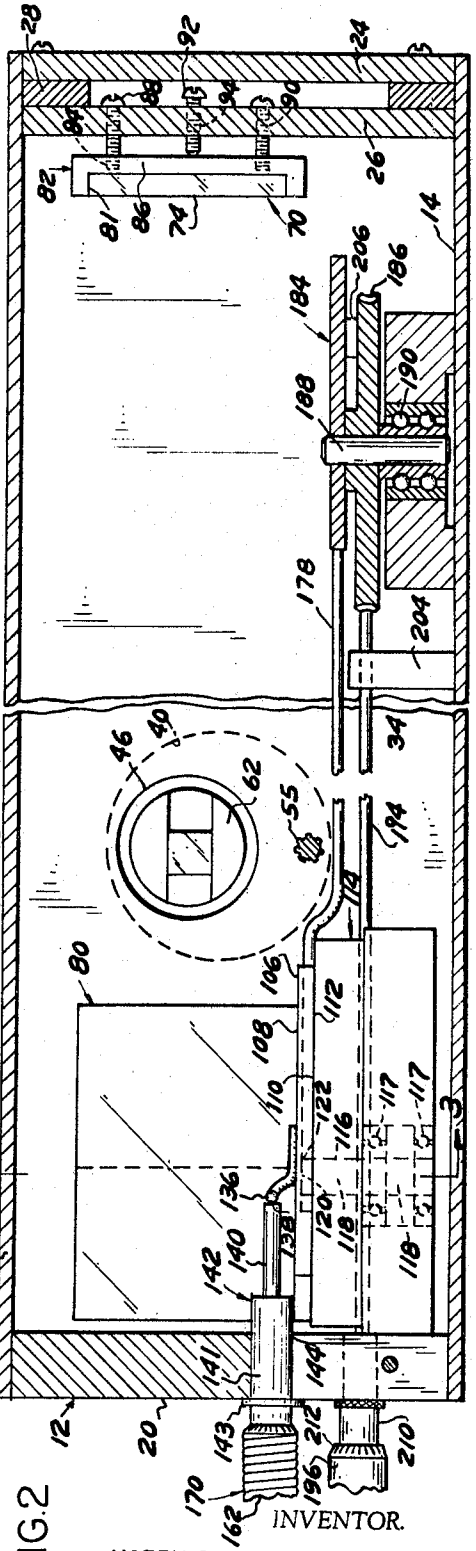

FIG. 2

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MONOCHROMATOR

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FIG. 4

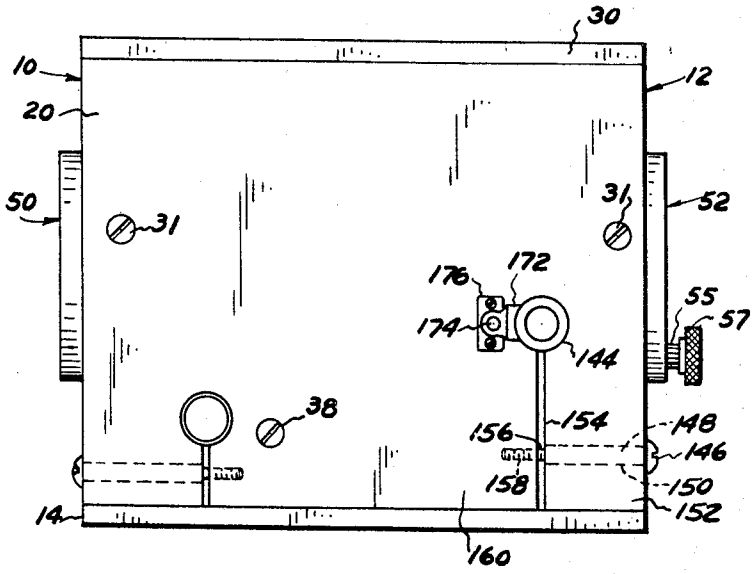


FIG. 3

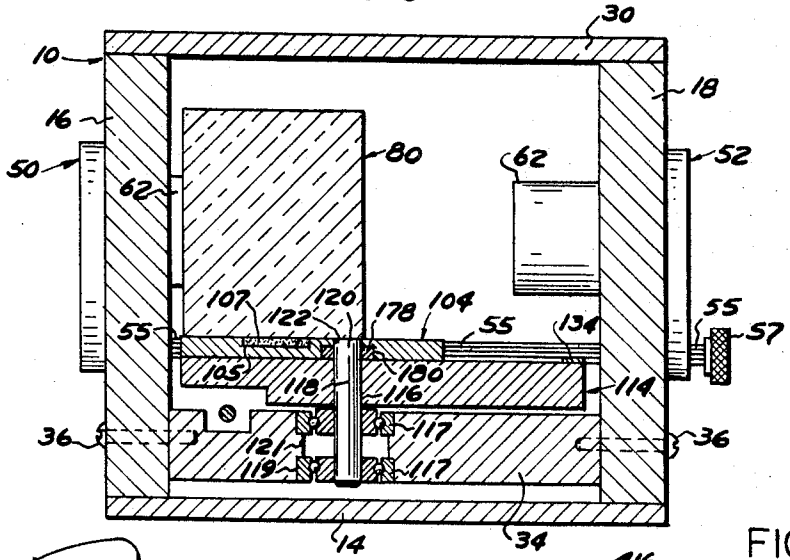


FIG. 7

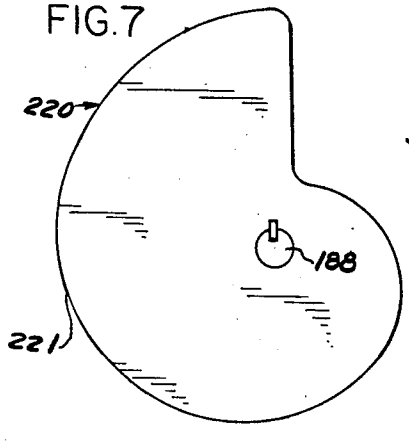
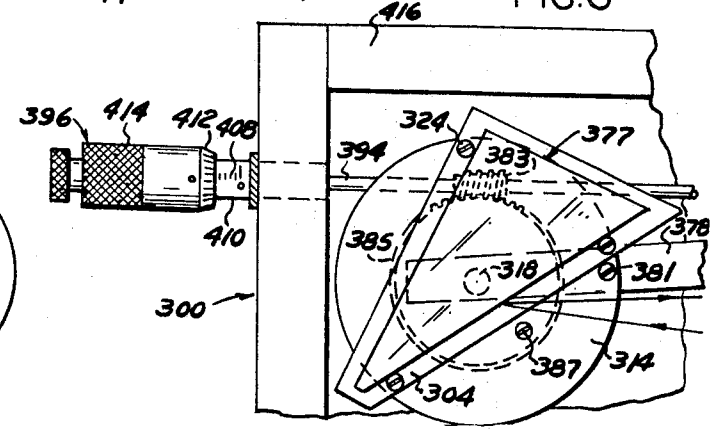


FIG. 6



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MONOCHROMATOR

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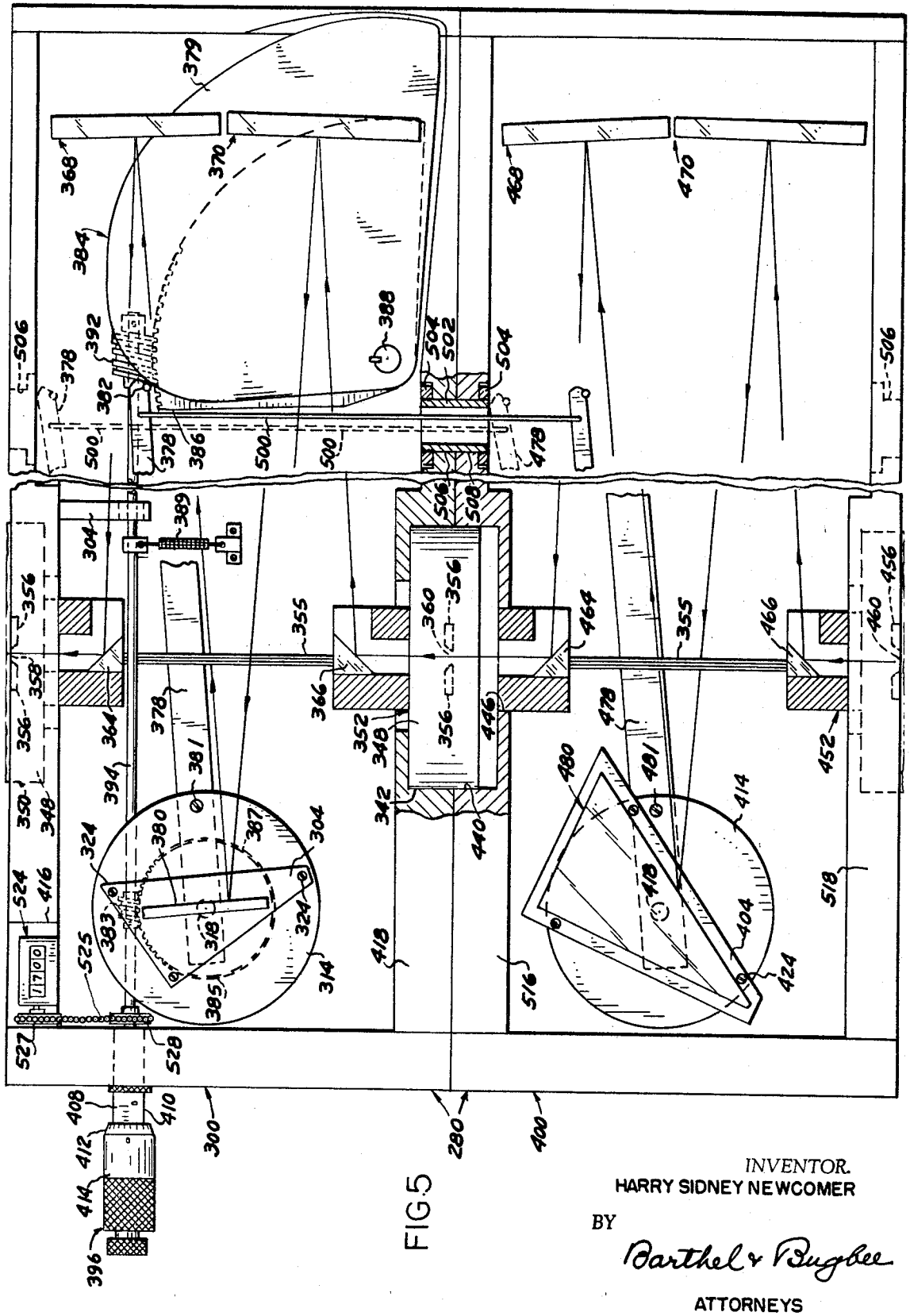

FIG. 5

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3,521,960

MONOCHROMATOR

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Filed Jan. 20, 1964, Ser. No. 338,761
Int. Cl. G01j 3/14, 3/18
U.S. Cl. 356—101 5 Claims

ABSTRACT OF THE DISCLOSURE

This monochromator has a housing or "box" with the entrance and exit slit units disposed in lateral alignment with one another with their slit openings disposed substantially in the planes of the outer surfaces of their respective opposite side walls of the housing so that two such monochromators may be placed side by side in juxtaposition and coupled to form a double monochromator after one of the slit units in the abutting side walls has been temporarily removed.

These entrance and exit slit units are contained within casings of substantially the same size and configuration removably mounted in and having coupling portions projecting slightly outward from aligned recesses in their respective housing side walls so that removal of one of the slit units from its recess in one of the two side walls to be abutted enables the remaining adjacent projecting slit unit casing to be seated as a pilot portion in the recess thus vacated, thereby positively and precisely securing the two housings to one another in exactly aligned condition by thus, in effect, keying the one to the other, to form a double monochromator, the slit unit which has not been removed then constituting the intermediate slit of said double monochromator.

The slit adjusting mechanisms of both slit units are simultaneously adjusted by an elongated adjusting member extending from one to the other across the intervening space within the housing at a location spaced vertically away from the paths of the light rays within the housing so as to avoid interference therewith, and wherein said adjusting member can be long enough to project through two such juxtaposed monochromators to simultaneously adjust three slits.

The slit adjusting mechanism includes gearing having aligned input gears, and the elongated adjusting member consists of a rotary shaft or pinion having an operative connection with the input gears of the slit adjusting mechanism in the two slit units, so that rotation of the shaft simultaneously rotates the gearing in these two slit units and simultaneously adjusts the widths of the two slit openings thereof.

The prism turntable is smoothly and precisely rotated to vary the wave length of the rays emerging from the exit slit by a contact member mounted near the periphery of the turntable and carrying a contact element, such as a ball, engageable with the end of a micrometer screw shaft such as a conventional micrometer head mounted approximately tangentially of the turntable and carrying a spirally-grooved drum bearing the calibrated wave length scale corresponding to the wave length of the rays emerging from the exit slit.

The barrel or nut of the micrometer screw shaft is clamped in the end wall of the monochromator housing and held in an immovable position precisely aligned and positioned with respect to the contact element on the prism turntable.

Where two such monochromators abut one another to form the above-mentioned double monochromator, the arm of the second monochromator is linked by a rigid

member with the arm of the first monochromator, so that no cam is needed in the second monochromator because said rigid member passes from one monochromator box to the other through an aperture and tubular coupling in the juxtaposed walls, thereby receiving rotation of the two dispersing units in unison.

In the accompanying drawings:

FIG. 1 is a top plan view, with the top wall or cover plate removed, of a monochromator according to one form of the invention, with the central portion broken away to enable illustartion, with the central portion broken away to enable illustration upon a larger scale, and with the left-hand end wall broken away to disclose the underlying micrometer adjusting screw or micrometer head locating and retaining construction;

FIG. 2 is a vertical section taken along the broken line 2—2 of FIG. 1, immediately inside the housing side wall containing the exit slit unit;

FIG. 3 is a vertical cross-section taken along the line 3—3 in FIG. 2, showing details of the prism mounting and turntable construction;

FIG. 4 is a left-hand end elevation of the monochromator shown in FIG. 1, illustrating the means for mounting the wave length micrometer adjusting screw;

FIG. 5 is a top plan view of two monochromators as shown in FIG. 1, placed side by side and coupled to form a double monochromator with a single linear wave length drive and slit width operating pinion;

FIG. 6 is a fragmentary top plan view of the upper left-hand corner portion of FIG. 5, as modified to employ a dispersing prism rather than a diffraction grating; and

FIG. 7 is a top plan view giving the outline of a cam having a contour such as give a linear readout of wave number position for a prism of the monochromator.

Referring to the drawings in detail, FIGS. 1, 2 and 3 show a monochromator, generally designated **10**, according to one form of the invention as including a box-like housing structure, generally designated **12**, consisting of a bottom wall **14** from which rise opposite side walls **16** and **18**, a single end wall **20** and a double end wall **22** consisting of outer and inner end walls **24** and **26** respectively separated from one another by spacers **28**. Closing the housing structure **12** is a top wall or cover **30** (FIG. 2). The various side and end walls **16**, **18** and **20** are bolted or otherwise secured to one another in any suitable way, as by the screws **31** (FIG. 4), the outer and inner end walls **24** and **26** being secured to the side walls **16** and **18** by screws **32** passing through spacers **28** into the ends of the side walls **16** and **18** (FIG. 1). A cross member or platform **34** extends between the opposite side walls **16** and **18** near the end of the housing structure **10** opposite the double end wall **22** at a level slightly above the bottom wall **14** (FIG. 3) and is secured to the opposite side walls **16** and **18** by screws **36** and to the end wall **20** by one or more screws **38** (FIG. 4). Alternatively, the box-like housing structure may be of unitary construction, such as a die casting.

The opposite side walls **16** and **18** are provided with small-diameter coupling bores **39** for a purpose to be described later, and with large diameter bores **40** of the same diameters extending inward from the external surface **42** and terminating in bottom surfaces **44** from which an eccentrically-located bore **46** extends inwardly through the remainder of the side walls **16** and **18**, the center of the smaller bore **46** being located above the center of the larger bore **40** (FIG. 2). Snugly mounted in the bores **40** in the opposite side walls **16** and **18** are the correspondingly-shaped casings **48** of adjustable entrance and exit slit units, generally designated **50** and **52**, respectively, having projecting coupling portions **54** snugly fitting the

bores 40. The details of these slit units are beyond the scope of the present invention and are described and claimed in my copending application Ser. No. 338,906 filed Jan. 20, 1964, now U.S. Pat. No. 3,365,262, issued Jan. 23, 1968 for Adjustable Slit Device for Spectrum-Producing Instruments. Here it is believed sufficient to state that each casing 48 contains a pair of sharp-edged slit jaws 56 movable toward and away from one another to widen or narrow the entrance slit 58 or exit slit 60, both of which are disposed in the planes of the outer surfaces 42 of their respective side walls 16 and 18 (FIG. 1), whichever the case may be. The slit jaws 56 are mounted in rectilinear guideways (not shown) and movable toward and away from one another by an externally-threaded screw, internally conical cam ring and driving gear arrangement (not shown) disclosed in my above-mentioned copending application and operated by a pinion rod 55 and knob 57. Means are provided, as set forth below, for precisely orienting and locating the slit unit with the jaws or slit opening 58, 60 perpendicular to the axial plane I, R', that is parallel to the prism apex 95.

Mounted in hollow cylindrical blocks 62 secured to the slit mechanism casings 48 in line with the entrance and exit slits 58 and 60 are plane front-aluminized entrance and exit slit mirrors 64 and 66 respectively which because of their form are herein termed prism mirrors. These prism mirrors reflect the incident light rays I and I' from the entrance slit 58 to a concave front-aluminized incident beam collimating mirror 68 and the refracted and dispersed rays R and R' from a concave front-aluminized refracted beam collimating mirror 70 to the exit slit 60. The mirror 70 is somewhat wider than the mirror 68. The radii of curvatures of the reflecting front surfaces 72 and 74 of the collimating mirrors 68 and 70 are twice the optical lengths of path from their respective slits 58 and 60 by way of their respective mirrors 64 and 66 to their respective centers 76 and 78 in order that collimation of the incident rays shall occur in the collimating mirrro 68 and that the refracted and dispersed rays from the dispersing prism 80 shall be focussed by the collimating mirror 70 upon the exit slit 60.

Each of the collimating mirrors 68 and 70 is of rectangular outline and is mounted in a recess 81 in a channel-shaped cell or mount 82 (FIG. 2) having threaded holes 84 in the back wall 86 receiving adjusting screws 88 passing through holes 90 in the inner end wall 26 so as to urge the rear wall 86 against the ends of an abutment screw 92 threaded through holes 94 in the inner end wall 26. As a consequence, by adjusting the adjusting screws 88 and abutment screw 92 (FIGS. 1 and 2), the collimating mirrors 68 and 70 may be tilted to their proper inclinations, and brought to a distance from the slit mirrors such that they focus in the slits. Such adjustment is made by first removing the outer end wall 24 by removing the screws 32 and then replacing the end wall 24 after the adjustments have been made, in order to prevent tampering with their adjustments, or other antitampering means, such as sealing, may be provided.

The dispersing prism 80 is of the so-called Littrow type and is of right-angled configuration with an angle at the apex 95 of 30° or thereabouts, having a slant face 96 which performs the refraction, a reflecting altitude face 98 provided with an aluminized or other suitable internal reflecting coating 100, and a base or blind face 102 disposed at right angles to the reflecting face 98. The prism 80, for purposes of simplicity of showing, is illustrated as a single solid prism. It will be understood, however, that an array of multiple prisms may likewise be used, if desired, as disclosed and claimed in my copending application Ser. No. 338,744 filed Jan. 20, 1964, for Multiple-Prism Monochromator, now U.S. Pat. No. 3,428,391, issued Feb. 18, 1969. It will likewise be understood that a plane diffraction grating may be used as an alternative dispersing unit, with its ruled surface in the plane of the surface 96.

The dispersing prism or grating 80 is mounted upon a plane parallel mounting plate or support 104 (FIGS. 1 and 2). The upper surface 106 of the plate 104 is machined to be precisely flat in order to receive the flat ground lower face 108 of the refracting and dispersing prism 80 (FIG. 2). The face 108 is surfaced to give a prism angle at its apex 95 free from pyramidal error. The upper surface of the plate 104 is recessed in the area 105 beneath the prism to receive bonding material 107 (FIG. 3). The lower surface 110 of the plate 104 is also machined precisely flat to rest upon the similarly precisely-machined flat upper surface 112 of a prism turntable 114 having a vertical bore 116 perpendicular to the top surface 112. The bore 116 (FIG. 3) snugly receives a pivot shaft 118, the upper portion 120 of which snugly fits a correspondingly-shaped bore 122 in the prism support or mount 104. The pivot shaft 118 of the turntable 114 is precisely and rotatably mounted in a pair of ball bearing units 117 mounted in annular recesses or counterbores 119 in a vertical bore 121 in the platform 34. This arrangement partially locates and fixes the position of the prism mount or support 104 upon the turntable 114 and its orientation is fixed by screws 124 passing through the plate 104 (FIG. 1) into threaded holes (not shown) in the turntable 114. This arrangement enables the prism 80, which is bonded at 105, 107 to its mounting plate 104, to be removed from the turntable 114 and replaced by another prism of different material or by a multiple prism array or by other dispersing means, depending upon the task to be performed by the monochromator 10 and the region of the spectrum to be investigated. It will be understood that the prism 80 or prism array may be of any suitable material, such as quartz or glass, according to its suitability for the particular region of the spectrum under study. It will likewise be understood that a plane diffraction grating may be used as an alternative dispersing unit with its ruled face in the plane of the surface 96.

Projecting from the rearward edge of the turntable 114 is an arm 126 (FIG. 1) drilled to receive the hooked inner end of a tension spring 128, the hooked outer end of which is secured to an anchor fastener 130. Mounted on the periphery of the turntable 114 and secured thereto by screws 132 is a contact element 134 having a hardened ball contact tip 136 which may be of hard steel, tungsten carbide or the like to resist wear. Engaging the ball contact tip 136 is the flat inner end 138 of a micrometer screw shaft 140 of a micrometer 142 rotatably mounted in a stationary barrel 141 which is fixedly secured against rotation in a bore 144 in the end wall 20 of the housing structure 12. The micrometer barrel 141 has a flange or seat 143 which precisely locates the end position of the end 138 for any position of the micrometer drum 162.

Clamping of the barrel 141 in the bore 144 is accomplished by means of a clamping screw 146 (FIG. 4) having a smooth shank portion 148 passing through a smooth hole 150 in a corner portion 152 of the end wall 20 separated from the remainder thereof by a radial slot 154 extending downwardly from the bore 144 to the bottom of the end wall 20. The reduced diameter inner threaded end portion 156 of the clamping screw 146 crosses the slot 154 and enters a threaded hole 158 in the adjacent main portion 160 of the end wall 20. As a consequence, when the clamping screw 146 is tightened by rotating it in a clockwise direction, the end wall portion 152 is pulled toward the main portion 160 of the end wall 20, narrowing the gap or slot 154 and constricting the bore 144 so as to tightly clamp the barrel 141 therein.

Mounted on the outer end of the micrometer screw shaft 140 is a graduated thimble or drum 162 (FIGS. 1 and 2) of the conventional micrometer head 142 rotated by a kneurled integral knob 164 and carrying a graduated circumferential scale 166 registering with an index line and graduated linear scale 168 engraved as is customary

on the micrometer barrel or sleeve **141**. The graduated scale **166** may suffice as a wavelength indication by reference to a conversion table or graph to be provided for the dispersion unit in use. The micrometer thimble or drum **162** preferably bears, in addition, a helical groove **167** carrying a wavelength scale **169**. The micrometer **142** including the screw shaft **140**, barrel **141**, thimble or drum **162** and index line and wavelength scale **169** collectively constitute a micrometric adjusting screw device, generally designated **170**. A sharp-edged groove follower **172** slidably mounted on a shaft **174** anchored at **176** to the box end **20** serves to index the scale **169**.

When there is incorporated with the micrometer head device **170** the grooved drum extension **167** bearing the wavelength scale **169**, which for a conventional one-inch micrometer head may involve employing as much as $\frac{4}{10}$ or $\frac{5}{10}$ inch movement, or 16 to 20 turns of the drum, there will be a corresponding number of spiral turns on the drum **167**, which if it has a 3-inch circumference, will then constitute a wavelength scale **169** as much as 60 inches long.

By my invention for rotating the dispersing unit and indicating its wavelength position, I have provided a cam-actuated mechanism (FIGS. 1 and 2) direct linear wavelength readout. This includes a flat cam follower arm **178** (FIGS. 2 and 3) rigidly fastened in a groove or channel **180** on the under surface of the plate **104** and centered on the shaft **118** at such a level as to pass forward under the pinion shaft **55** to the right-hand rearward corner of the box **12** a ball contact **182** on the arm **178** bears on a cam **184** there located, so that when the cam is at the position for maximum thrust throw of the arm **178**, the dispersing prism or grating **80** is at its maximum wavelength setting. The cam **184** is mounted on a worm gear **186**, itself on a shaft **188** journalled in ball bearings **190** and driven by a worm **192** on a shaft **194** which is an extension of a driving micrometer head **196** located and secured by its nut **198** in a bore **200** in the box end **20** just as is the micrometric adjusting screw device **170** at the other corner of the end **20**.

The prism driving arm **178** is held against the cam **184** by a spring **202** and is held in plane by a slotted block **204**. Prism dispersive units of any material can be used, the correctly-shaped cams **184** and properly oriented arms **178** being supplied therewith. In this possible embodiment, the shaft **194** can be recessed into the end of a micrometer head screw and be small enough and flexible enough to be held by the spring **202**, forcing it and the worm **192** into close mesh with the gear **186**, thus reducing backlash. Vertical alignment, groove alignment in the gear, can be secured by passing the shaft **194** through another slotted block **206**.

If, by way of example, the driving micrometer **196** is a conventional 1" micrometer graduated zero to one inch, then in FIG. 1 the cam **184** is so drawn as to be suitable for use in conjunction with the flint prism **80** composed of Schott glass SF12 shown positioned at .410 micron wave length orientation, and the worm gear **186** is a 100-tooth 48 pitch diameter gear driven by a double left-hand thread worm **192**. In the design of the cam, allowance has been made for the advance of the micrometer, and the design is such that the micrometer graduation in thousandths of an inch indicate a direct linear readout of the prism wavelength position in fractional microns, the range being from 1.0 micron to 0.4 micron, with the drawing showing a setting equal to .41 micron, the micrometer being at .410 inch, indicated on the linear graduated scale **208** of the barrel **210** and the circumferential graduated scale **212** on the micrometer thimble or drum **214**.

As is well known, the wave number settings for a prism approach linearity and consequently the difficulty of constructing a cam for wavelength determination where the dispersion of the prism is increasing rapidly and the attack angle is steep can be avoided if recourse is had to a readout in terms of wave number determination. FIG. 7 shows the outline **221** of a cam **220** with center **188** such as could be substituted for the cam **184** in FIG. 1 to give a correct orientation of a prism **80** of fused silica, the cam being positioned by a micrometer **196** as shown in FIG. 1, a shaft **194**, a worm **192** and worm gear **186** which in this case is a quadruple thread right-hand **48** pitch **100** tooth gear, the wave numbers being read directly on the micrometer for a range of 1650 angstrom units to 25,000 angstrom units, that is, from a setting of .606" to .040" on the readout device **224**, wave numbers 60.6 to $4.\times 10^3$ cm.$^{-1}$.

The arm **178**, the cam **184** and the worm and gear **192** and **186** and the driving micrometer **196** generally constitute a direct linear wave length readout device, designated **224**. It is apparent that when using the direct linear wave length readout device **224**, the turntable contact readout device **170** would be withdrawn or otherwise retracted out of the way, and vice versa. Micrometer barrel positions on either side are obviously available to make either one of the other readout device inoperable.

In the operation of the monochromator **10** of the present invention, let it be assumed that the refracting and dispersing prism or prism array **80** or other dispersing unit has been mounted on its mounting plate **104**, a cam arm **178** correctly oriented and attached thereto, the bore **122** of the plate **104** superimposed upon the projecting top portion **120** of the turntable pivot shaft **118** and that the screws **124** have properly oriented and secured the mounting plate **104** to the turntable **114** in the manner described above. Let it also be assumed that the collimating mirrors **68** and **70** have been tilted to their proper positions by adjusting the adjusting screws **88** and abutment screws **92** as described above, and that the slit jaws **56** have been adjusted to provide the proper and desired widths of the entrance and exit slits **58** and **60**.

A suitable conventional light source and optical condensing system (not shown) is arranged to project light upon the entrance slit **58** of the entrance slit device **50** (FIG. 1). Rays passing through the entrance slit **58** are reflected at the entrance slit prism mirror **64** and pass in the general direction of their principal incident ray I to the incident collimating mirror **68**, whence they are reflected at the reflecting surface **72** in the direction of the incident collimated principal ray I' to the refracting face **96** of the prism **80**. There the rays are refracted, dispersed, reflected and refracted and dispersed again. The dispersed rays travel along the path of the principal refracted ray R, are reflected at the reflecting surface **74** of the refracted ray collimating mirror **70** and thence proceed along the refracted principal ray path R' to reflection at the exit slit prism mirror **66** and focussing at the exit slit **60**, whence they pass into the subsequent apparatus served by the monochromator **10**.

By rotating the drum **162** of the micrometric screw device **170**, the optrator consequently rotates the micrometric screw shaft **140** so as to move its inner end **138** inward or outward so as to push against and move the ball contact tip **136** tangentially of and with the turntable **114**. This action rotates the turntable **114** around its pivot shaft **118**, thereby turning the refracting and dispersing prism **80** or other such unit so as to bring rays of different wave lengths to and through the exit slit **60**. If the graduated scale **169** is graduated in terms of wavelengths, the operator can set the desired wavelength for the emergent light from the exit slit **60** on the scale **169** in registry with the index follower **172**, whereupon the light of the desired wavelength will pass through the exit slit **60** if the foregoing adjustments have been properly made.

Simultaneously, the slit widths **58** and **60** can be moved or changed in unison by means of the pinion shaft **55**, at least one end of which projects through and beyond the face of the slit units **50** or **52** to make it accessible at the knob **57**. The mechanism by which this slit jaw movement is secured through rotation of the pinion is described in my copending application, Ser. No. 338,906,

now U.S. Pat. No. 3,365,262, issued Jan. 23, 1968, mentioned above.

If, instead of the micrometer screw device **170**, use is made of the linear wavelength readout device **224**, then the prism or other dispersive unit **80** on the turntable **114** is turned by virtue of the cam profile **184** to translate wavelength orientation to direct readout on the linearly spaced divisions **208**, **212** of the driving micrometer **196**. Moreover, each dispersive unit **80** alternatively supplied for the instrument can be provided with a prepositioned arm **178** and cam **184** with profile such that such direct readout always occurs. Also, it is now possible to assemble two monochromators **10**, as above described, side by side, with one intermediate slit mechanism **50** or **52** removed and the projecting coupling portion **54** of the other piloting in the opposite bore **40** in the adjacent side wall **16** or **18** at such assembly. The readout device **224**, except for the arm **178**, can be omitted from the second unit and instead one can couple the two cam arms **178** by a rigid bar as described below.

In particular, the modified double monochromator, generally designated **280** shown in FIG. 5 includes a first monochromator **300** similar in principle to the monochromator **10** of FIG. 1 and coupled in the above manner to a second monochromator **400** mounted beside it. To avoid needless repetition, parts of the double monochromator **280** similar or corresponding to those of the monochromator **10** employ the same last two digits in their reference numerals. Thus, **352** is the exit slit device of the unit **300** pilotly engaging the bore **440** of the second monochloromator unit **400**. **380** is a dispersing unit, by way of example a diffraction grating for which may be substituted a quartz prism **377** (FIG. 6). The grating **380** is mounted on a plate **304** which itself is secured by locating screws **324** to a turntable **314**. The turntable **314** is loosely and rotatably mounted upon a vertical shaft **318** supported in bearings similar to those supporting the shaft **118** in FIG. 1. Keyed or otherwise drivingly secured to the shaft **318** is a worm wheel **385** which in turn meshes with a worm **383** drivingly secured to a shaft **394** operatively connected to a micrometer head **396** including a stationary barrel **410** carrying linear graduations **408** and a thimble **414** carrying circumferential graduations **412**. The turntable **314** and worm wheel **385** are drilled and threaded peripherally to receive a coupling screw **387** by which the two may be coupled in driving relationship with one another or, when the screw **387** is unscrewed, released from such driving relationship to permit the turntable **314** to pivot freely upon the shaft **318**.

Also loosely and rotatably mounted upon the shaft **318** below the turntable **314** and above the worm wheel **385** is a cam follower arm or driving arm **378**. The turntable **314** and arm **378** are also drilled and threaded to receive a coupling screw **381** by which the two may be drivingly interconnected or, when the screw **381** is unscrewed, made movable independently of one another. The outer or free end of the cam follower arm **378** carries a contact ball **382** which engages the peripheral edge **379** of a cam **384**. The cam **384** is keyed or otherwise drivingly secured to a vertical shaft **388** which is also journaled in antifriction bearings (not shown) similar to the antifriction bearings **117** of FIG. 1.

Also keyed or other wise drivingly secured to the shaft **388** is a quadrant worm wheel **386** which meshes with a worm **392** also keyed or otherwise drivingly secured to the shaft **394**. The worms **383** and **392** are maintained in constant mesh with their respective worm wheels **385** and **386** by a tension spring **389** in a manner similar to the spring **202** of FIG. 1 and similarly guided and supported by a slotted block **304** secured to the side wall **416**. In this manner, the wavelength setting of the grating **380**, which may be one of 30,000 lines to the inch, is linearly controlled by the micrometer head **396** through the driving connection of the shaft **394**, worm **383**, worm wheel **385** and coupling screws **387**, the arm **378** being disconnected from the turntable **314** at this time by unscrewing the coupling screw **381**.

If, on the other hand, the grating **380** is replaced by a dispersing prism **377** as shown in FIG. 6, the coupling screw **387** is unscrewed to release the turntable **314** from the worm wheel **385** and the coupling screw **381** is engaged with the arm **378** to cause turning of the turntable **314** by the cam **384** and arm **378**, as described below. This is also linearly controlled by the micrometer head **396** through its driving connection by way of the shaft **394**, worm **392** and quadrant worm wheel **386**. If the prism **377**, for example, is a fused silica prism, then the cam **384** will drive it through the wavelength range of 170 to 500 millimicrons. Instead of the solid prism **377** of FIG. 6, a prism array of fused silica prisms may be usefully employed in this same wavelength range, such a prism array being disclosed and claimed in my copending application Ser. No. 338,744, filed Jan. 20, 1964, now U.S. Pat. No. 3,428,291, issued Feb. 18, 1969.

In FIG. 5, a similar prism or prism array **480** is similarly positioned upon a supporting plate **404** which in turn is secured by locating screws **424** to a turntable **414** similarly loosely and pivotally mounted on a vertically-journaled shaft **418** in a second monochromator **400**. A driving arm **478** is also pivotally mounted on the shaft **418** and coupled to the turntable **414** by a coupling screw **481**. Alternatively, the turntable **414** and driving arm **478** may be keyed or otherwise drivingly secured to the vertical shaft **418** where the turntable **414** is not to be driven by a worm and worm wheel, as in the case of the turntable **314** of the monochromator **300**. The outer or free ends of the driving arms **378** and **478** are pivotally interconnected by a rigid connecting rod **500** so that the driving arm **478** is, in effect, a slave arm operated by the master arm **378** in accordance with the motion transmitted to the master arm **378** by the periphery **379** of the cam **384**. In this manner, the two monochromators **300** and **400** are operable in unison by the micrometer head **396** and no other drive is needed in the monochromator **400**. In FIG. 5, the positions of the grating **380** and prism **480** correspond to their 170-millimicron wavelength positions, which are also those of the solid line positions of the arms **378** and **478** and connecting rod **500**. The dotted line positions thereof correspond to the 500 millimicron wavelength setting of this double monochromator. In this example of the wave length drive for the double monochromator, the gear **386** is a 48 pitch quadrauple left-hand thread worm wheel of 200 teeth whereas the gear **385** is a left-hand double-thread worm wheel of 300 teeth.

With the diffraction grating **380** in the monochromator **300**, the direction of light path has been so chosen and indicated by arrows as to make the entrance slit the slit **460** in the outer side wall **518** of the second monochromator **400** (FIG. 5) and the exit slit at **358** in the outer side wall **416** of the first monochromator **300**, the light exiting there after final dispersion by the diffraction grating **380**. This simple conjuctive arrangement of the two monochromators **300** and **400** provides a double monochromator **280** with several possible choices of pairs of dispersive units chosen from diffraction gratings, solid prisms or prism arrays will be obvious to those skilled in this art, as imparting a flexibility to the instrument.

Where the two monochromators **300** and **400** are joined to one another to constitute a double monochromator **280** as described above, the slit mechanisms **350**, **352** and **452** are operated simultaneously and in unison by a single elongated pinion shaft **355** which spans the interiors of both monochromators **300** and **400**, and which is substituted for the shorter individual pinion shaft **55** shown in FIG. 1. Alternatively, for some pur-

poses, a narrow fixed slit **360** can be substituted for the adjustable intermediate slit device **352**.

In the double monochromator **280**, accurate alignment of the first and second monochromators **300** and **400** is accomplished by an end-threaded coupling sleeve **502** extending through and snugly fitting aligned counterbored holes **506** and **508** (FIG. 5) with nuts **504** threaded onto the opposite ends of the sleeve **502**. The sleeve **502** and holes **506** and **508** are so located as to provide a free passageway for the connecting rod **500**, the nuts **504** being contained in the counterbores of the holes **506** and **508**. In addition, as previously stated, the two monochromators **300** and **400** are precisely aligned by the engagement of the housing **348** of the intermediate adjustable slit device **352** in the bore **440** of the inner side wall **516** of the second monochromator **400**, the threaded sleeve **502** and nut **504** locking this assembly together in piloted aligned relationship.

In the operation of the double monochromator **280**, light entering the entrance slit opening **460** of the slit device **452** is reflected off the front-aluminized prism mirror **466** to the collimating mirror **470** where it is reflected to the dispersing prism **480**. There it is dispersed and emerges in a light path leading to the collimating mirror **468**, whence it is reflected off the front-aluminized mirror prism **464** through the intermediate slit opening **360** off the front-aluminized prism mirror **366** to the collimating mirror **370**. There it is reflected in a path leading to the diffraction grating **380** (or prism **377** of FIG. 6 or prism array, if used) and after dispersion proceeds to the collimating mirror **368** where it is reflected to a light path leading to the front-aluminized prism mirror **364** and thence out to the exit slit opening **358** of the exit slit device **350**. The operation of the micrometer head **396** as a linear readout device for either the diffraction grating **380** of FIG. 5 or the solid prism **377** of FIG. 6 is believed self-evident from the description of their construction above, and hence requires no repetition.

Where, in the double monochromator **280** there is an advantage in employing a diffraction grating **380** in the first monochromator **300** to accomplish the final dispersion, then the slit opening **358** of the slit device **350** is the final or exit slit, and the illustrative example of FIG. 5 has been so contrived. Where, on the other hand, the prism **377** is substituted for the diffraction grating **380**, as described above, the light may proceed in either direction, so that the slit opening **358** may be either the entrance or exit slit while the slit **460** at the same time is the exit or entrance slit respectively. This latter statement is subject to the reservation that the aperture is greater in the reverse direction, as indicated by the arrows.

In FIG. 7, there is shown a cam **220** which may be substituted for the cam **184** on the shaft **188** in the monochromator **10** of FIG. 1 and of which the peripheral edge **221** is configured to cause readout for a fused silica prism to be in terms of wave numbers 60.6 to 4.0×10^3 cm.$^{-1}$ which are the reciprocals of wave lengths 1650 to 25,000 angstrom units.

The double monochromator **280** with two quartz prisms **377** and **480** may also be provided with a like wide-range number readout. In fact, such a readout or any of the readouts abovedescribed may advantageously be digital in character as in FIG. 5, where there is shown a four-digit counter **524** connected by a bead chain **525** with a sprocket **527** to a drive sprocket **528** on the shaft **394** and so sprocket-ratioed, as is well known in the art, as to give a correct digital translation of the micromether head setting, in this instance 1700 angstrom units, as described above.

Further, according to my invention, where two stock monochromators **10** of FIG. 1 of identical construction are to be assembled into a double monochromator **280** of FIG. 5, the individual readouts **170** for this purpose may be sprocketed and coupled directly by bead chains to thus accomplish in a simple manner the synchronization of the dispersive units **380** and **480**, or **377** and **480**. If the readout spindle **140** is a fine pitch, such as 200 threads per inch, the accuracy of this coupling can be assured and correspondingly an accurate digital readout coupling facilitated, if desired. Naturally electronic means of digital readout coupling can be used, as are known to those skilled in the electronic computer art.

It will be evident to those skilled in the art that the single monochromator **10** of FIG. 1 or the double monochromator **280** of FIG. 5 as abovedescribed can also serve as a spectrometer or spectrophotometer. For the latter purpose, in place of the exit slit device **52** or **350**, there is substituted an aperture plate (not shown) carrying either photographic film or preferably a camera housing including a lens for imaging the aperture plate on the surface of the film of the photographic camera.

It will also be evident that the foregoing mechanisms including the wavelength indicating and slit adjusting devices may obviously be readily automated and programmed for complete automation of either the single or double monochromator **10** or **280** as the case may be.

What is claimed is:

1. A monochromator construction comprising a first monochromator having

a box-shaped housing structure having a bottom wall and opposite side and end walls secured thereto,

said opposite side walls being disposed parallel to one another and having recesses therein aligned with one another on an axis transverse to said side walls,

a turntable rotatably mounted in said housing structure for rotation upon a substantially vertical axis of rotation,

a light-dispersing unit mounted upon said turntable,

entrance and exit slit units removably and interchangeably mounted one in each of said recesses and having coupling portions projecting outwardly from their respective recesses beyond the outer surfaces of their respective walls,

the projecting coupling portion of each slit unit snugly and interchangeably fitting each of said recesses,

said entrance and exit slit units having slit openings disposed substantially in the planes of the outer surfaces of their respective side walls and aligned with one another on an axis transverse to said outer surfaces,

and an optical system for directing and collimating light rays from the slit of said entrance slit unit to said dispersing unit and thence to the slit of said exit slit unit,

whereby to enable precise juxtaposition and coupling of two such monochromators to form a double monochromator.

2. A monochromator construction, according to claim **1**, wherein a second monochromator of like construction to said first monochromator is placed adjacent a side wall of said first monochromator, wherein one of said monochromators is without a slit unit in its adjacent wall, and wherein the coupling portion of the slit unit of the adjacent wall of the other monochromator projects into the recesses vacated by the removal slit unit in snugly interfitting aligned coupling engagement therewith.

3. A monochromator construction, according to claim **1**, wherein said slit units have paired slit jaws adjustably movable toward and away from one another for varying the slit openings therebetween and also have mechanism for so moving said slit jaws, and wherein an elongated slit jaw-adjusting member is movably mounted in said housing structure and extends across the intervening space within said housing structure at a location spaced vertically away from the paths of the light rays within said housing structure into operative engagement with the jaw-

moving mechanism of each of said slit units for simultaneous adjustment of the jaws thereof.

4. A monochromator, according to claim 3, wherein said slit jaw adjusting member is a rotatable member rotatably engaging said slit jaw-moving mechanisms.

5. A monochromator construction comprising a first monochromator having

a box-shaped housing structure having a bottom wall and opposite side and end walls secured thereto,

said opposite side walls being disposed parallel to one another and having recesses therein aligned with one another on an axis transverse to said side walls,

a turntable rotatably mounted in said housing structure for rotation upon a substantially vertical axis of rotation,

a light-dispersing unit mounted upon said turntable,

entrance and exit slit units removably mounted in said recesses in said opposite side walls and having coupling portions projecting outwardly from their respective recesses beyond the outer surfaces of their respective walls,

the projecting coupling portion of each slit unit snugly and interchangeably fitting each of said recesses,

a cam pivotally mounted in said housing structure and having a cam edge,

a micrometric wavelength readout device rotatably mounted in one of said structure walls and carrying direct linear wavelength graduations,

said readout device being drivingly and rotatably connected to said cam,

a first operating arm engaging said cam edge and operatively connected to said turntable for rotating said turntable,

said cam edge being configured to swing said arm and light dispersing unit to project radiation of a wavelength corresponding to the indicated wavelength reading of said graduations in response to the rotation of said micrometric direct linear wavelength readout device to said corresponding direct linear wavelength indication on the graduations of said readout device,

an optical system for directing and collimating light rays from the slit of said entrance slit unit to said dispersing unit and thence to the slit of said exit slit unit;

a second monochromator of like construction to said first monochromator placed adjacent said first monochromator with the outer side walls of said monochromators placed in juxtaposed contact but with the slit unit of the adjacent side wall of one of said monochromators removed and with the slit unit of the adjacent side wall of the other monochromator projecting snugly into the recess vacated by the removed slit unit in interfitting aligning coupling engagement therewith,

said second monochromator having a light dispersing unit turntable with a second operating arm operatively connected thereto, and a link pivotally interconnecting said first and second operating arms,

the adjacent side walls of the first and second monochromator housing structures having aligned communicating apertures therethrough and said link passing through said apertures,

said slit units having slit openings all of which are aligned with one another on an axis transverse to said juxtaposed outer walls, whereby the second turntable swings correspondingly to the first turntable in response to rotation of the readout device of the first monochromator.

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