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[45] **Aug. 5, 1975**

[54] **X-RAY MONOCHROMATIC AND FOCUSING SYSTEM**

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[52] **U.S. Cl.** **250/280;** 250/272; 250/505

[51] **Int. Cl.** **G01m 23/00**

[58] **Field of Search** 250/272, 276, 280, 505, 250/511

[56] **References Cited**

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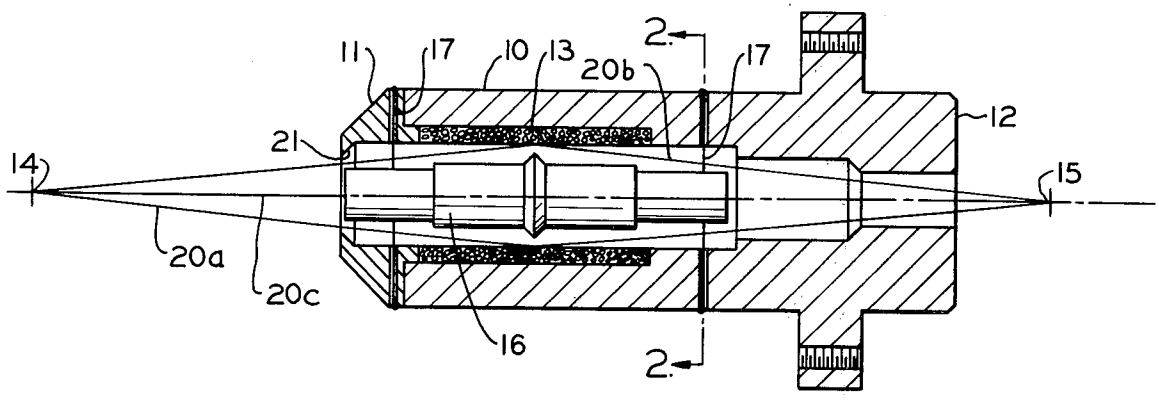
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Primary Examiner—James W. Lawrence
Assistant Examiner—B. C. Anderson

[57] **ABSTRACT**

There is disclosed herein a system and apparatus for monochromatic X-rays from crystals by diffraction according to Bragg's law, the system providing a high relative aperture and interception of the primary axial X-ray beam whereby improved characteristics and focus of emergent diffracted X-ray beams may be achieved.

13 Claims, 8 Drawing Figures



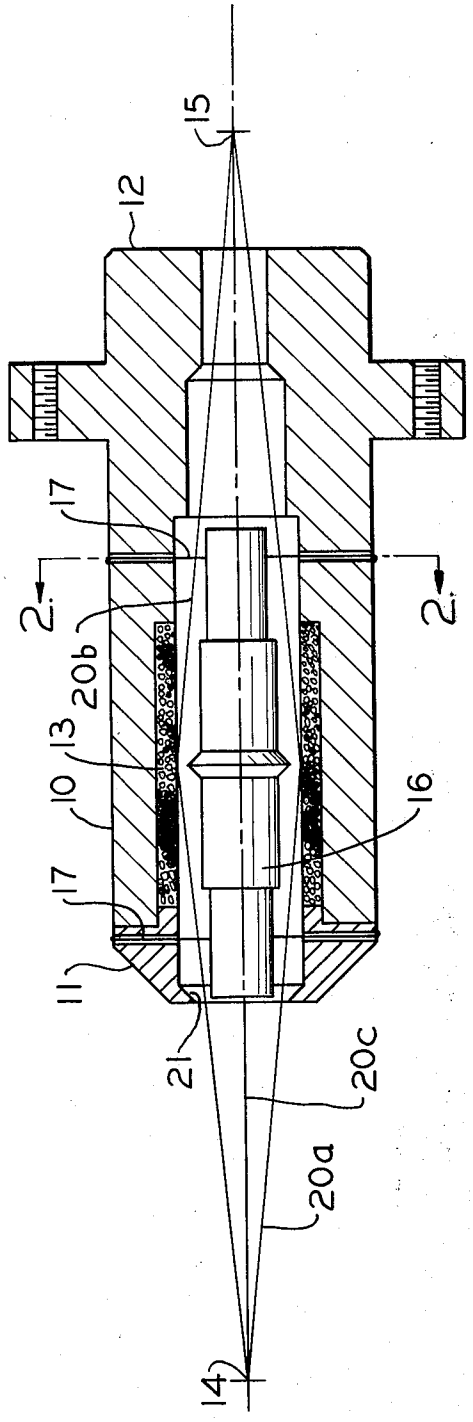


FIG. 1.

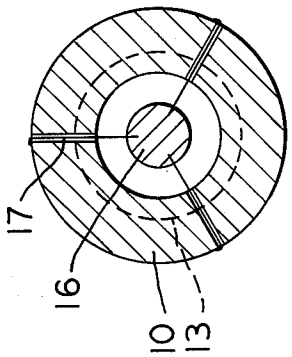


FIG. 2.

FIG. 3.

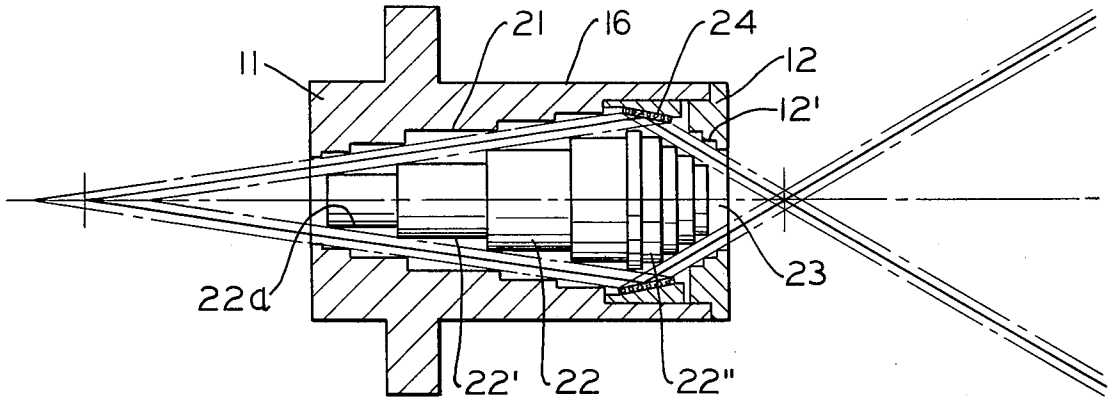


FIG. 4.

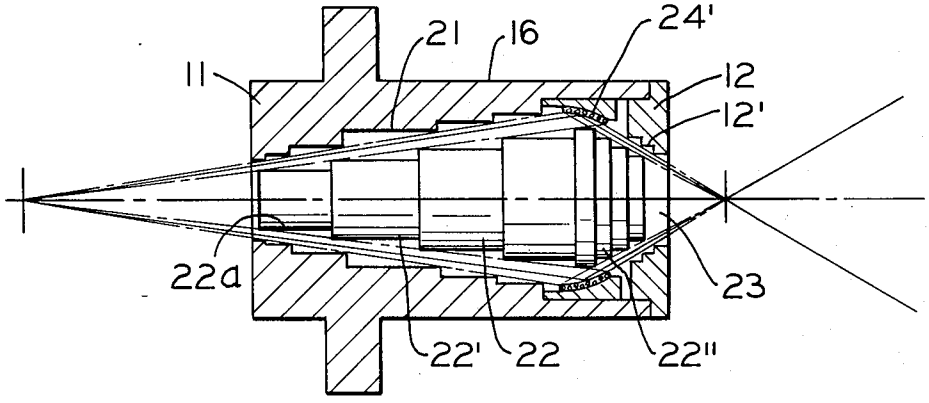


FIG. 5.

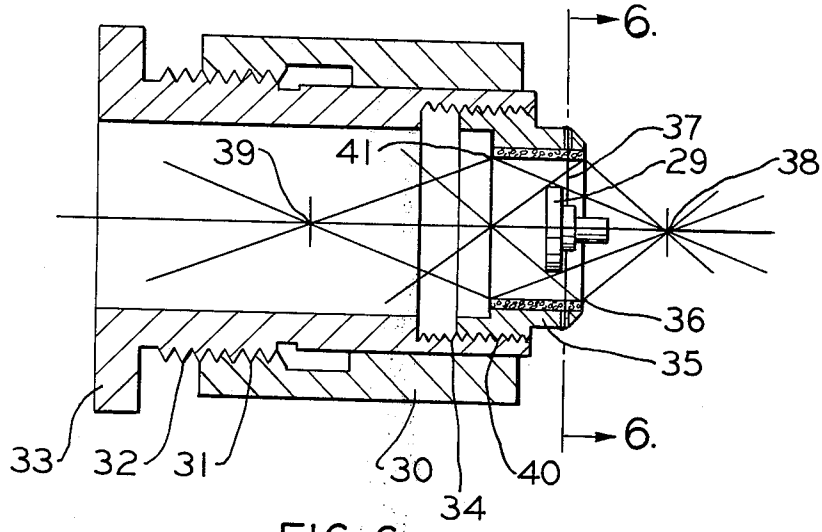
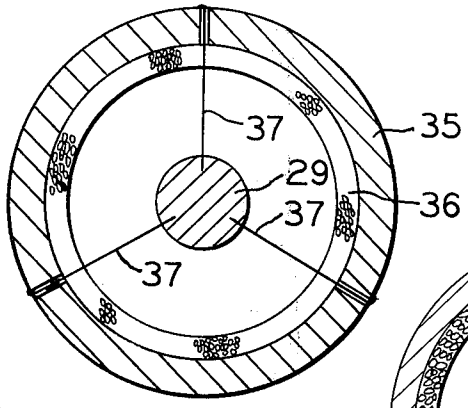


FIG. 6.



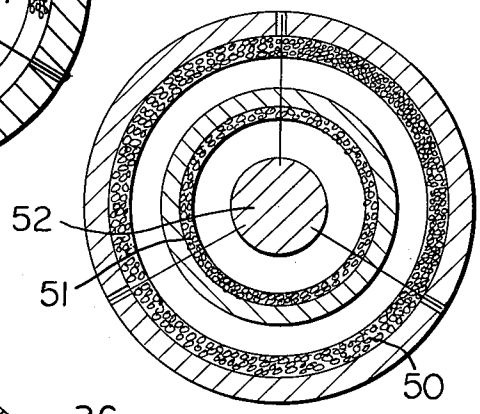


FIG. 7.

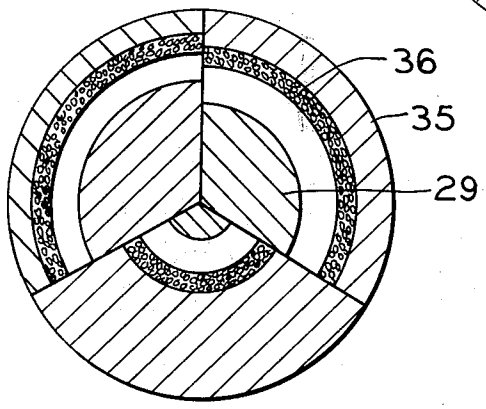


FIG. 8

X-RAY MONOCHROMATIC AND FOCUSING SYSTEM

My invention relates to an improved system and apparatus for attaining monochromatic X-rays and focusing the X-ray beams in a manner to provide either an excitation source or a selective band pass for X-ray analysis.

Recently, energy-dispersive devices have been developed which can simultaneously analyse for almost every element in the periodic table. However, such devices have had distinct limitations, i.e. in gross count rates and lack of suitable prediscrimination to reduce undesired count rates. To overcome the same, filters have been employed to filter the incident X-ray beam or secondary (fluorescence) targets combined with filters have been used to excite the specimen with as nearly monochromatic X-rays as possible. These systems have been extremely inefficient in their use of power. The power of the X-ray tube has been driven to its economic limit and the attenuation achieved by a filter is gradual over the extended spectral region of greatest interest. Only a small fraction of the original X-ray energy excites the specimen and the scattered exciting spectrum overloads the detector.

In contrast thereto, my invention achieves efficient utilization of the output of an X-ray tube, excites a specimen more intensely than heretofore with a sharply defined band of X-radiation with negligible background beyond the wave-length or energy band and facilitates the detection or radiation emitted from a sample under efficient power conditions. Signal-to-noise ratios obtainable are also significantly improved over the filtration method and better chemical analyses can be obtained at similar power levels than with prior art devices and the sensitivity of the system is improved thereover.

It is thus a principal object of this invention to provide an improved type of monochromator which is capable of realizing a low or high degree of resolution with high optical efficiency.

It is further an object of the invention to provide a high numerical aperture in high performance monochomators.

Another object of the invention is to achieve high flux in desired wave lengths or energy with a minimum of background or interference from undesired wave lengths.

A further object of the invention is to provide an improved system of the type referred to which will be particularly useful in relatively longer wave lengths.

Another object of the invention is to provide a monochromator of high efficiency for a specific band pass.

Still another object of the invention is to provide parfocal monochromators of different wave lengths or band passes.

Another object is to provide a high efficiency for collection of selected bands of fluorescence X-radiation emitted by a specimen for measurement by a suitable detector without interference from the exciting radiation or even from undesired matrix radiation in certain cases.

Other objects of the invention and the invention itself will become more readily apparent from a purview of the following description, in which reference will be made to the appended drawings, in which drawings:

FIG. **1** is a sectional view of a monochromator of one form of my invention with a diagrammatic showing of the X-ray beams;

FIG. **2** is a view taken from the line **2—2** of FIG. **1**;

FIG. **3** is a sectional view similar to that of FIG. **1** showing a second form of my invention;

FIG. **4** is a sectional view similar to that of FIG. **3** showing a third form of my invention;

FIG. **5** is a sectional view similar to that of FIG. **1** of a form of my invention wherein a disc type beam stop is employed;

FIG. **6** is a sectional view taken from the line **6—6** of FIG. **5**;

FIG. **7** is a sectional view similar to FIG. **6** showing an assembly of toroidal segments of parfocal monochromators of the form shown in FIG. **5**;

FIG. **8** is a sectional view similar to FIG. **6** showing a co-axial arrangement of two toroidal monochromators designed for different spectral regions.

Referring now to the drawings in all of which like parts are designated by like reference characters, in FIGS. **1** and **2**, I show a first form of the improved monochromator of my invention. At **10** a tubular support or cylindrical housing is provided having an inlet **11** and outlet **12**, the inlet **11** being adapted to be associated with or secured to a source of X-ray radiation for entry of X-ray beams as indicated, the outlet **12** providing passage of emergent X-ray beams as further indicated for excitation of specimens or passage to a detector (not shown). In the monochromator of FIG. **1** the tubular support is lined on its inner periphery with bent crystal or mosaic **13** such as mica, graphite, lithuim floride, or the like which acts as an interceptor of beams from an X-ray source, indicated at **14**, and diffracts the same according to Bragg's law. The bent crystals or mosaics are preferably arranged in a toroid or in toroidal segment and the resulting diffracted beam may be used to excite a specimen located substantially at the foci of the beams or may be directed through an aperture into a detector. The reference character **15** is used to designate the area of focus.

A beam stop shown at **16** is used to shield the specimen or detector from the undiffracted beam, i.e., the axial or primary X-ray beam, and to limit or define the extent of the spectral range. The beam stop is, as shown in FIG. **1**, a stepped rod **16** suspended co-axially and centrally of the tubular support or housing **10** by wires or other means **17**, which beam stop acts, according to the size, dimensions and steps of the rod, to limit the spectral range.

The incident X-ray beams from X-ray source **14** are indicated at **20***a* and pass through the aperture **21**. They are then directed upon the crystal **13** lining the tubular support to form diffracted X-rays **20***b* which tend to focus at the point **15**. The emergent rays may be used to excite a speciment located substantially at the focus area **15**. A large angle of X-rays may thus be intersected and focused on the sample to be excited. Because of the interception of axial or primary X-ray beam **20***c* no undesired wave lengths which would interfere with the analysis are allowed to strike the specimen. Thus high sensitivity and accuracy in measurement can be achieved in energy dispersive spectography or wave length dispersive analysis requiring low background.

In the form of my invention shown in FIGS. **3** and **4**, the inner periphery of the tubular support or housing

is of asymmetrical form, said inner periphery comprising a series of steps **21** of various depth, length, and spacing. A beam stop **22** is centrally suspended within the said inwardly stepped tubular support or housing and is provided with a series of externally disposed stepped portion **22'**, the said stop being provided with relatively greater diameter and shorter steps **22''** at its outlet end, certain of said more outwardly disposed steps **22''** being positioned relative to inwardly projecting stepped portion **12'** in the outlet portion of the housing **16** forming a narrowed passage for the diffracted beams through the outlet aperture **23.** At the entrance end of the housing, steps **21** surround the incident X-ray beam entrance passage and a relatively lesser diameter step **22*a*** of the beam stop.

It will be noted that the greater diameter portion of the beam stop **22** is adjacent the center of the crystal monochromator in this form of the invention and in FIG. **3** the crystal or mosaic toroid **24** is frusto-conical and surrounds the outer annuli **22''** thereof. In FIG. **4** the crystal **24'** is bent in the plane of the figure and arranged in the form of a toroid about the axis of the figure and achieves a more precise focus of the emergent diffracted beams.

FIG. **5** shows another form of my invention adapted for use over a large spectral range. In this form, the monochromator comprises a tubular support or frame **30** having an internally threaded portion **31** which is threaded upon an externally threaded portion **32** of an adapter **33** internally threaded as shown at **34** at an opposite end thereof and adapted to be threaded as at **40** onto a tubular housing **35** lined with a monochromator crystal **36.** The disc type beam stop **29** is suspended within the housing **35** by means of wires **37** carried by the said housing and connected thereto. Through the use of a disc type beam stop and a non-stepped housing, the maximum spectral range may be attained.

The object of the threaded portions at either end of the assembly is to provide axial adjustment in a 2:1 ratio, the threaded portions **31, 32** having an axial pitch twice that of the threaded portions **34, 40** so that rotation of the adapter **33,** while restraining the frame **30** and the tubular housing **35** from rotation, causes the desired 2:1 relative motion of the detector (not shown) contained in the adapter and of the monochromator crystal **36** which lines the tubular housing **35.** The distance from the selected focus **38** to a point on the crystal such as **41** equals the distance from said point **41** on the crystal to the diffracted focus **39** of the wave length, which satisfies Bragg's law at that point **41.** It will be understood other means for achieving such relative adjustment could be employed.

The detector (not shown) in this form of the invention is positioned to intercept at any desired location diffracted beams according to the spectral range desired. The 2:1 adjustment allows continued alignment of the crystal and detector for use in other spectral regions.

FIG. **7** shows a means of extending the spectral range beyond that which can be achieved in one setting of FIGS. **5** and **6.** It is accomplished by taking segments of a particular housing, crystal and beam stop combination and positioning it adjacent similar segments designed for a different spectral region, the group of segments comprising a total toroid which would have as many steps as segments. Thus, the aperture for each spectral region has been reduced by the ratio of its arc to the full circle.

FIG. **8** shows an alternate means to that of FIG. **7** for extending the spectral range without reduction of the aperture as in that form. It comprises a pair of toroidal crystals **50** and **51** arranged co-axially sharing a common disc type beam stop **52.**

Although preferred embodiments of this invention have been described, it will be obvious that various modifications may be made therein without departing from the spirit of the invention and the scope of the appended claims.

What I claim is:

1. An X-ray monochromatic and focusing system comprising: a source of X-ray radiation, a tubular support for the acceptance and passage of said radiation, diffractive pieces of bent crystal arcuately enclosed within the inner periphery of the tubular support to obtain a high relative aperture of X-rays focused into emergent diffracted X-ray beams onto a desired area, means interposed within the inner periphery of the crystal lined support to intercept the undiffracted X-ray beam and to shield the entire desired area from the undiffracted radiation and define the spectral range of the X-rays emergent from the crystal, and means for performing X-ray spectral analysis.

2. An X-ray monochromatic and focusing system as claimed in claim **1,** wherein said diffractive pieces of crystal arcuately line portions of said inner periphery of the tubular support.

3. An X-ray monochromatic and focusing system as claimed in claim **1,** wherein the emergent X-ray beam is focused onto a specimen.

4. An X-ray monochromatic and focusing system as claimed in claim **1,** wherein the emergent X-ray beam is focused onto a detector.

5. An X-ray monochromator as claimed in claim **1** comprising a tubular support for the acceptance and passage of X-ray radiation, wherein said tubular support is internally stepped, the means intercepting the undiffracted X-ray beam being an externally stepped beam stop suspended within said support and extending longitudinally thereof, diffractive pieces of bent crystal arcuately enclosed within the inner periphery of the tubular support and in axially inwardly spaced relation about the beam stop to diffract incident X-ray beams and to focus the diffracted X-ray beams onto a desired area.

6. An X-ray monochromator as claimed in claim **5,** wherein the steps of the inner periphery of said support are of different depth, length and spacing.

7. An X-ray monochromator as claimed in claim **5,** wherein the diffractive crystal is frusto-conical.

8. An X-ray monochromator as claimed in claim **5,** wherein the diffractive crystal is bent about an axis perpendicular to the longitudinal axis of the housing and arranged in the form of a toroid about the axis thereof.

9. An X-ray monochromator as claimed in claim **1** having means whereby a 2:1 adjustment of a detector with respect to the specimen is attainable.

10. An X-ray monochromator as claimed in claim **1** in which the housing, crystal and beam stop combination is segmented, the segments differing for attaining different spectral regions, the segments comprising a toroid having as many steps as segments.

11. An X-ray monochromator as claimed in claim **1** comprising a plurality of toroidal crystals arranged co-

axially sharing a common axially internally positioned disc type beam stop for intercepting the undiffracted X-ray beam.

12. Apparatus for producing an X-ray monochromatic and focusing system comprising a tubular support for the acceptance and passage of X-ray radiation, diffractive pieces of bent crystal arcuately enclosed within the inner periphery of the tubular support to obtain a high relative aperture of X-rays focused into emergent diffracted X-ray beams onto a desired area, means interposed within the inner periphery of the crystal lined support to intercept the undiffracted X-ray beam and to shield the entire desired area from the undiffracted radiation and define the spectral range of the X-rays emergent from the crystal, and means for performing X-ray spectral analysis.

13. An X-ray monochromator comprising a tubular frame, an adapter adjustably rotatable with respect to said frame and internally mounted thereon, said adapter being externally mounted on a tubular housing, said housing being lined with diffracted monochromator bent crystal, a disc type beam stop suspended within said housing and axially spaced internally of the crystal, rotation of the adapter restraining the frame and tubular housing from rotation, and permitting interception and alignment of the crystal with a detector positioned on the axis of the adapter to intercept at desired points diffracted beams for any desired spectral range.

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