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[54] **SOLAR SPECTROGRAPHS**
7 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** **356/76,** 95/12.2, 95/18, 350/199
[51] **Int. Cl.** **G01j 3/36**
[50] **Field of Search** ..... 350/169, 170, 199; 356/76—79, 51; 95/12.2, 18

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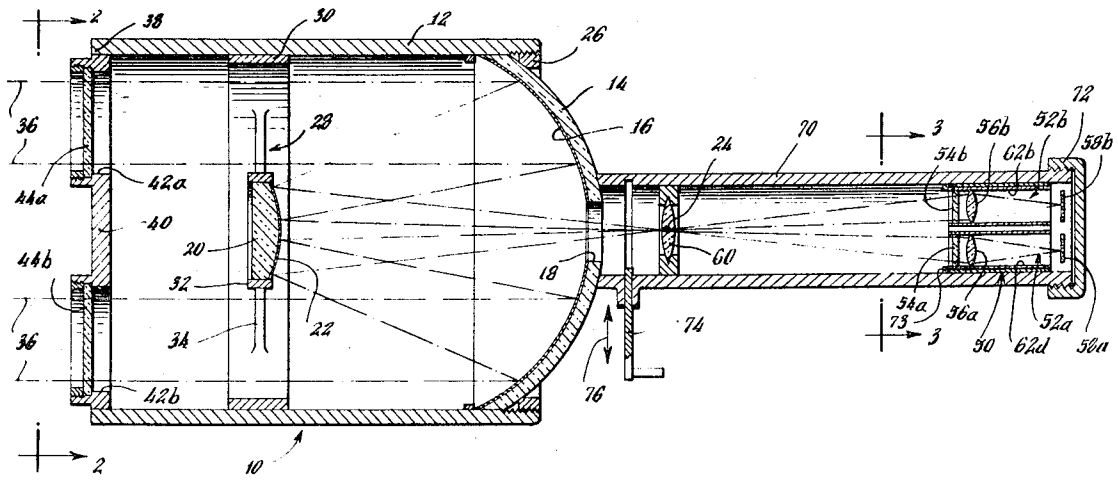
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Assistant Examiner—F. L. Evans
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ABSTRACT: In certain astronomical applications, it is desirable to photograph (or otherwise observe) a celestial body (e.g., spectroheliograms of the sun) at a very narrow spectral bandwidth (i.e., substantially monochromatically). It is proposed to modify an otherwise conventional astronomical telescope so as to allow the simultaneous photographing (or other recording) of, for example, the sun at a plurality of different extremely very narrow wave bands (i.e., discrete, substantially monochromatic spectroheliograms). This may be accomplished by providing a series (say, four) of discrete apertures at the entrance end of an otherwise conventional telescope; and means at the image or exit end of the telescope for separately forming an image from each of the four separate entrance beams. By providing different narrow band-pass filters (or other means for rendering each of the beams monochromatic at a different wavelength), a simultaneous photograph (or other measurement) of the sun at different spectral lines may be made. Comparison of such simultaneous photographs can yield information concerning relative intensity of spectral lines from any part of the sun, free from uncertainty due to, for example, the fluctuating intensity with time of the source (e.g., the sun) itself. Preferably the entrance apertures are provided with moderately broad-pass reflecting filters for rejecting (i.e., reflecting away) most of the radiant energy outside of the vicinity at which each of the separate spectral measurements are being made.



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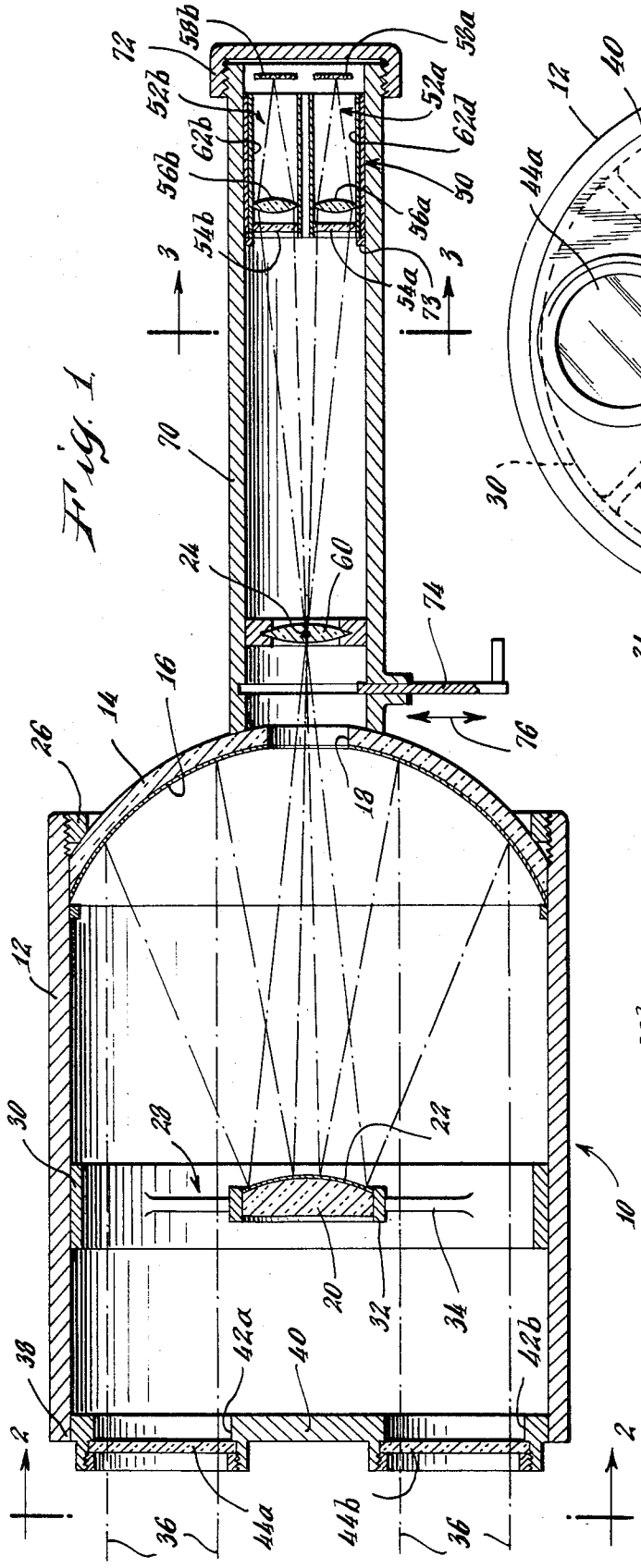


Fig. 1.

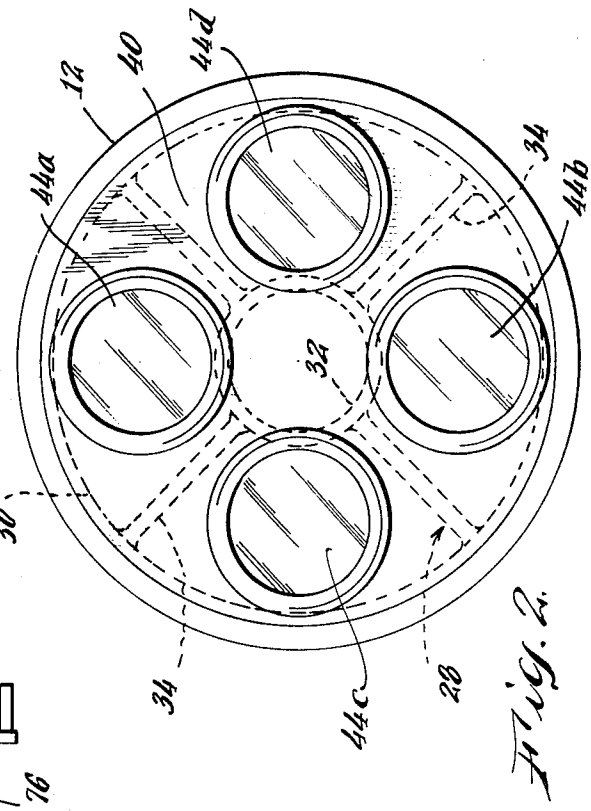


Fig. 2.

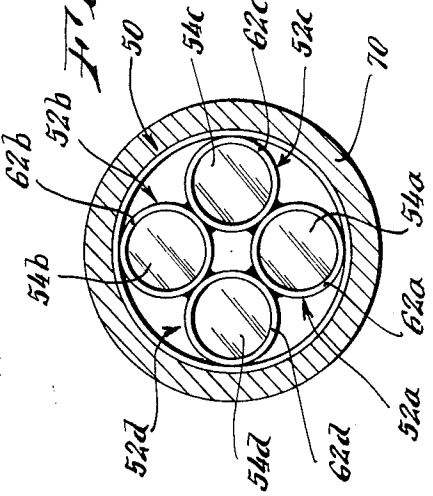


Fig. 3.

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SOLAR SPECTROGRAPHS

DESCRIPTION

This invention relates to apparatus, which may be used in conjunction with a conventional astronomical telescope, to form simultaneous photographs (or other measurements) of a celestial body (e.g., the sun) at different very narrow spectral bands or lines. More particularly, the invention may be considered a simultaneous, multiple-image spectroheliograph.

The invention provides means, including a multiple-apertured diaphragm, in front of an otherwise conventional astronomical telescope, so as to cause different distinct beams to transverse the optics of the telescope. At the exit or image side of the telescope, means are provided for forming a separate distinct image from each of these beams. In each of these separate image beams a different monochromator (which may be an extremely narrow-pass filter) may be positioned so as to cause the radiation forming the different images to be of a different narrow spectral band or line. In this manner, multiple simultaneous photographs at different very narrow spectral bands may be simultaneously made, so that they are free of any relative variation with time and intensity of the source (e.g., the sun).

Such an apparatus is particularly useful for photographing or otherwise measuring the relative intensity of certain solar emission lines. For example, an instrument according to the invention is especially useful for determining the relative intensity of the hydrogen alpha line (that is, the first line of the Balmer series for hydrogen at approximately 6563 A). Preferably, a moderately broad-pass reflecting filter is positioned in front of each of the entrance apertures so as to reflect away most of the solar radiation, allowing only the radiation in the general vicinity of the particular spectral line to be measured to enter each "channel" of the telescope; this greatly reduces the problems which would otherwise be caused by the intense radiation, especially at those positions where such radiation is subsequently focused. The original entrance apertures are preferably imaged onto the individual monochromatic optical systems, as by means of a field lens, which field lens may be positioned at or near the principal image plane of the telescope.

An object of the invention is a provision of a system for photographing or otherwise measuring simultaneously a plurality of very narrow spectral bands (e.g., spectral lines) from a celestial body, such as the sun.

A related object is a provision of such an apparatus which may be readily combined with existing conventional astronomical telescopes.

A further related object of the invention is the provision of means for adapting an otherwise conventional astronomical telescope to forming simultaneously a plurality of spectroheliograms at different very narrow wavelength bands in a relatively economical manner.

Other objects, features and advantages of the invention will become obvious to one skilled in the art upon reading the following detailed description of an exemplary embodiment of the invention, in conjunction with the accompanying drawing in which:

FIG. 1 is a vertical section through an exemplary conventional astronomical telescope, which has been modified by the invention so as to allow the simultaneous "taking" of four photographs of, say, the sun at four different very narrow spectral bandwidths;

FIG. 2 is a front elevation view of the same apparatus as in FIG. 1, as seen from the left thereof; and

FIG. 3 is a vertical section, taken along the line 3–3 in FIG. 1.

In FIG. 1, a conventional astronomical telescope, which has been modified in accordance with the invention, is generally shown at 10. For exemplary purposes, the telescope is assumed to be of a Cassegrain type; however, the invention may be utilized in conjunction with any astronomical telescope,

and is particularly adapted for use with any catoptric astronomical telescopes. The conventional structure of such a telescope may include a main tubular housing 12 which supports near one end (the right in FIG. 1) the primary mirror 14, having at 16 a polished and mirrored concave surface. In telescopes of the type shown, this primary mirror will be apertured (or at least wholly transparent) at its center, as indicated at 18 so as to allow rays to pass therethrough. The secondary mirror 20 of the exemplary telescope will have a mirrored convex surface at 22 positioned in the path of the rays converged by the primary mirror 14. The exact position, curvature and form of convex surface 22 will depend, in well-known ways, on the optical design of the telescope. In any event, the diverging power of the secondary convex mirror 22 will be less than the converging power of the primary concave surface 16 so that the rays after encountering both surfaces in turn will still converge to an image plane at the principal focal point 24 of the entire telescope. The primary mirror 14 may be supported in tube 12 by any convenient means, such as a mounting or retaining ring 26. The secondary mirror 20 may be supported by a spider 28 (compare FIG. 2), which may include an outer peripheral flange 30 attached to the interior of tube 12, a generally ring-shaped holding member 32 adjacent secondary mirror 20 and a series (shown as four) spokelike connecting arms at 34.

The structure so far described (i.e., elements 10—34) are merely the constituent parts of an exemplary conventional astronomical telescope, and as such form no part of the invention. In such a conventional telescope, the incoming radiation, exemplified by rays 36 will strike and be converged by the concave surface 16 of the primary mirror 14 so as to be directed to the convex surface 22 of the secondary mirror 20. After reflection from this surface, the rays will continue to converge to form an image of the original object in the vicinity of the principal focal point 24. As previously noted the exact form, amount of curvature, and spacing of the two mirrors (14,22) will in a given astronomical telescope be of such value as to at least partially correct or compensate the various aberrations which would otherwise be contributed by the individual mirrors, as well as to decrease the overall length of the telescope. Examples of such arrangement include the Cassegrain and the Gregorian telescope systems.

In order to adapt such an astronomical telescope to making (single) spectroheliograms, it has already been proposed to position a spectrograph behind (i.e., to the right in FIG. 1) such an astronomical telescope so as to receive radiation from the primary image (i.e., the entrance slit of the spectrograph would be positioned at point 24). Such a spectroheliograph combination would also typically include some means for attenuating the total amount of solar radiation entering the telescope (e.g., an apertured diaphragm near the entrance end 38 of the telescope). In a telescope of the type shown in FIG. 1, in which the central zone is subject to obscuration, such a limiting aperture would necessarily be positioned off center. Based on the principles of such a spectroheliograph, the present invention adapts a conventional astronomical telescope (elements 10—38) to record simultaneously a plurality of (hereinafter assumed to be four for exemplary purposes) different images, each at a discrete separate narrow spectral band, of the sun. This adaptation involves the addition of elements both at the entrance side (i.e., left-hand in FIG. 1) and exit or image side (i.e., right-hand in FIG. 1) of the original telescope.

At the left-hand or entrance end of the telescope, an opaque disc 40 is positioned at or adjacent the open end 38 of tube 12. This opaque disc 40 contains a plurality of apertures, preferably so arranged that the beams passing therethrough will avoid the various arms 34 of spider 28. For example, if the spider consists of four such radial arms in the diagonal pattern indicated in FIG. 2, the apertures 42*a*, 42*b*, 42*c* and 42*d* are preferably positioned as shown in that figure, so that the beams passing therethrough also avoid the spider arms. Associated with each of these apertures 42*a*—42*d* is a filter (44*a*,

44*b*, 44*c* and 44*d*), which reflects substantially all of the solar radiation falling thereon except in the vicinity of that wavelength at which one of the spectral images is to be photographed (or measured). Such a reflecting filter will in general eliminate over 99 percent of the radiation outside of the neighborhood of the spectral band involved in the measurement, but will pass most of the radiation in the immediate vicinity of the wavelength at which measurements or photographs are being made. Since in general each simultaneous measurement will be made at a wavelength that is relatively widely spaced from each of the other wavelengths, each of the apertures (42*a*—42*d*) will usually have a reflecting filter 44*a*—44*d*, respectively, of different spectral characteristics, so that each passes radiation at and in the vicinity of the respective wavelength desired for its "channel." An explanation of the type of reflecting filters preferably used at 44*a*—44*d* will be given hereinafter.

At the exit or image side (i.e., at the right in FIG. 1) of the telescope, a plurality of separate monochromatic image-forming units are positioned as indicated generally at 50. These spectrographic units will be of the same number and in the same geometric arrangement as apertures 42*a*—42*d* (and filters 44*a*—44*d*), or more exactly will be in an inverted geometric relationship relative to the apertures. Although in a symmetrical arrangement, such as shown in the exemplary embodiment, this inverse relationship is not apparent, the spectrographic units 52*a*, 52*b*, 52*c* and 52*d* have been so designated so as to correspond to the apertures (and filters) from which they receive the radiant beam (compare FIGS. 2 and 3). Each of these spectrographic units will comprise an element, such as filter 54*a*, 54*b*, etc. which will act as a monochromator so as to pass only an extremely narrow-band centered about the spectral line intended to be recorded by that particular unit. Such "spike" filters, which pass a high percentage of radiation only in an extremely narrow bandwidth (for example, about one or at most a very few angstroms wide) may be made by special design of so called "interference" type filters. Such filters consist of a series of extremely thin (fractions of a wavelength of light) layers, the relative thickness and index of refraction of each layer being carefully controlled so as to cause substantially complete rejection of wavelengths in the near vicinity of the extremely narrow spectral band that is passed. Preferably the filters are of a type more fully explained hereinafter.

After passing through such an extremely narrow wavelength band-pass filter, the radiation will be imaged by an individual optical system, exemplified by a simple lens 56*a*, 56*b*, etc. onto a recording device, 58*a*, 58*b*, etc. Although the individual optical system 56*a*—56*d* and the recording means 58*a*—58 may in general be identical to each other, each of the extremely narrow band-pass filters 54*a*, 54*b*, 54*c* and 54*d* will differ from the others so as to pass a specifically different spectral line. Thus, each of the different recording elements 58*1*—58 (which may merely be pieces of film or even different portions of the same photographic film or plate) will receive exclusively a different spectral emission line of the sun. Since these recordings may be made simultaneously, variations in both the intensity of the original object (i.e., the sun) and changing "seeing" conditions will have no substantial effect on the relative intensity of such simultaneous photographs.

A field lens 60 is preferably positioned at or near the original image plane 24 of the astronomical telescope and is of such dioptric power and position relative to the spectrographic units (52*a*—52*d*) that it will image each of the original entrance apertures (42*1*—42*d*) onto the entrance aperture or pupil of the corresponding unit (52*a*—52*d*). Such a field lens 60 both assists in maintaining the intended separation of the four beams, as well as simplifying the optical requirements of each unit (and in particular optical systems 56*a*—56*d*) by effectively matching the various pupils of the original telescope and the spectrographic imaging system. Each of the spectrographic units 52*a*—52*d* preferably includes its own opaque tube or generally cylindrical light baffle, as indicated at 62*a*—62*d*, the adjacent surfaces being preferably connected to form an integral assembly. The entire exit or image assembly 50 (i.e., elements 52—58) and the field lens 60 may be housed (and supported) by an opaque tube 70, having on its right-hand end a removable cap 72 so as to allow access to the spectrographic units (52*a*—52*d*) and especially the recording elements 58*a*—58*d*, when photographic film is utilized. Preferably the spectrographic image assembly 50 is removably mounted in supporting tube 70 as by being slidably inserted therein from the right-hand and say, up against an internal annular stop 73 (which may be adjustable by being in the form of a screw-threaded ring, for example). In this manner access to filters 54*a*—54*d* (for changing, cleaning, etc.) and optical systems 56*a*—56*d* may be readily obtained. Obviously, various other techniques (such as the provision of doors in tube 70) may be employed instead for permitting access to the various elements (notably, 58*a*—58*d* and 54*a*—54*d*) of the spectrographic assembly. Exposure of the photographic film may be controlled by any conventional shutter mechanism schematically illustrated as a movable slide 74 (adjacent the original image plane 24 of the telescope) which may be moved in and out of a blocking position as diagrammatically indicated by arrow 76. Obviously a leaf-type (or other symmetrical) shutter may be utilized at any desired location to cause simultaneous exposure of the photographic film or other recording devices (at 58*a*—58*d*); each of the individual spectrographic units may also be supplied with its own individual auxiliary shutter to allow less than the maximum number (four in the illustrated embodiment) of spectrograms to be recorded at once.

OPERATION

In order to make, say, four simultaneous spectroheliograms, each at a discrete very narrow wavelength band or line, the exemplary apparatus is operated as follows. Unexposed photographic film or plate material is positioned at 58*a*—58*d*, while taking the usual precautions against exposing such film to any actinic radiation. As previously noted the removable end closure member 72 will facilitate this "loading" of the spectroheliograph. Upon reclosing, the apparatus is pointed at the sun (or that portion of the sun it is desired to investigate), and a photograph made by opening the shutter (schematically illustrated at 74). Whenever the apparatus is pointed in the general direction of the sun, the moderately broad band-pass blocking filters 44*a*—44*d* will cause reflection of substantially all of the solar radiation outside of its moderately narrow wavelength band-pass back generally to the left in FIG. 1. Such a reflective moderate band-pass filter may be of the "induced transmission" layered type described by P. H. Berning and A. F. Turner in the Journal of the Optical Society of America, Vol. 47 (1957) pages 230—239. Such filters comprise one or more moderately thin metallic layers, plus one or more assemblies of extremely thin (fractions of wavelengths) multiple layers of dielectric materials.

Such a multilayer interference filter of the "induced transmission" type will have a band pass of approximately 30 to 200 A. Although in theory all of these blocking filters 44*a*—44*d* could be identical, if the individual spectral lines at which the different photographs are to be taken were close together, in general the four different spectral lines will be separated from each other by more than the 30 to 200 A that a single such induced transmission filter passes. For this reason, each of the blocking filters 44*a*, 44*b*, 44*c* and 44*d* will typically be different (i.e., pass a different, approximately 100 A band), so that each of the four spectral lines lies at least near the center of the band pass of its particular blocking filter 44*a*—44*d*.

Each of the very narrow band-pass filters 54*a*—54*d* is of the "spike" type that passes only an extremely narrow wavelength band. In particular, the band pass as measured by the half-width (the half-width being the horizontal distance between the two points on the transmission wavelength curve at which

the transmitted intensity is half of the peak intensity, the abscissa being in, say, angstrom units) may be as little as 0.1 A to at most a very few angstroms. Such "spike" transmission filters may comprise a multilayer dielectric type interference coating on both sides of a thin plane parallel transparent material (having a thickness of an integral number of half wavelengths). An example of this type of filter (having a theoretical half-width of about 1 and an actual half-width of about 3 angstroms) is disclosed in U.S. Pat. No. 3,039,362, issued on June 19, 1962, by J. A. Dobrowolski. Improved versions of this type of filter, having half-widths of fractions of an angstrom (e.g., 1/10 to ½A), are disclosed in the three following U.S. Pat. applications, all assigned to the assignee of the present application: Ser. No. 667,815 filed Sept. 14, 1967 in the name of Joseph Vrabel; Ser. No. 700,928 filed Jan. 26, 1968 by Robert R. Austin; and Ser. No. 709,661 filed Mar. 1, 1968 by the same inventor.

The basic "sandwich," comprising a first multiple layer dielectric coating, a controlled thickness transparent support, and a second multilayer dielectric coating, will pass a series of extremely narrow bands (i.e., half-widths of from a moderate fraction of an angstrom to a very few angstroms), each very narrow band being spaced from the adjacent ones by a distance more than 10 times its half-width (i.e., a typical spacing of the bands will be approximately 30 A). One of these very narrow spectral bands may be isolated by providing a narrow (i.e., about 10 -angstrom half-width) conventional multilayer dielectric filter, so as to pass the desired extremely narrow band but to reject the other narrow bands in the series. As described, for example, in the various above-mentioned U.S. Pat. applications, this auxiliary filter may be combined directly with the "sandwich" type extremely narrow-band filter.

The "blocking" reflecting filters **44***a*—**44***d* greatly diminish the overall intensity of the total radiation within the telescope and its image space. Without some provision for this purpose, the radiation flux density in certain areas (and in particular in the vicinity of the principal focal plane at point **24**) would prohibit the positioning of any element (e.g., field lens **60**) in such intense radiation. A related advantageous effect is that the individual extremely narrow pass filters **54***a*—**54***d* are exposed only to radiation in the wavelength vicinity of the desired spectral line therefore reducing the (heat) energy dissipated by these filters, as well as simplifying their design (by limiting the required breadth of the wavelength band in which radiation must be rejected, surrounding their "spike" transmission peak).

Thus, each of the moderately broad band-pass reflecting blocking filters **44***a*—**44***d* will pass approximately a 100 A band, near the center of which is the particular spectral line desired to be isolated in each of the four different spectrographs **52***a*—**52***d*. Each of the extremely narrow band-pass filters **54***a*—**54***d* will isolate a different spectral line, so that each of the four spectroheliograms will result from a different emitted spectral line of the sun. Since the apparatus of the invention allows these four different (as to spectral line) spectroheliograms to be made simultaneously, all four will be affected in the same manner by random changes in the conditions (including, for example, temporal variations in the intensity of the solar radiation, variation in the "seeing" conditions, and the like). The inventive apparatus thus allows the direct comparison of the intensity of the spectral emission by any part of the sun at four different spectral lines simultaneously.

The fact that all (say, four) spectrograms are made simultaneously assures not only that the measured relative intensities of the spectral lines will be the same as were true at the source, but also that any other effects (e.g., Doppler shifts) are also equally present, relatively, in the four simultaneous measurements. Thus, each of the various individual spectrograms acts as a "control" or reference for the others. As noted at the beginning of this specification, one of the most important spectral lines of interest is the hydrogen-alpha line (at 6562.85 A). Both the relative intensity of this line and any Doppler or other shift thereof are of interest concerning study of the physical properties of the sun for investigating such questions as the underlying thermonuclear reactions, the various phenomena near the solar surface (e.g., sunspots and related effects), as well as other fields of investigation. Other prominent solar spectral lines may also be studied for various other purposes, as well understood by astronomers.

Although the invention has been described in conjunction with a specific type of conventional astronomical telescope, it is obvious that many other types of such telescopes may be readily adapted in a similar manner. Although described in the exemplary embodiment for simultaneously forming four spectroheliograms, it is obvious that the apparatus may be readily modified to produce a different number. Typically, besides a bright hydrogen line (as already noted), one would utilize, for example, a bright calcium line, a bright iron line and the like to obtain a more definitive "picture" of the solar phenomenon (e.g., solar flare) being observed. The number of "channels" in the telescope may be varied depending on the number of such spectral lines desired to be recorded simultaneously. It should be noted that in the exemplary embodiment, the original spider arms **34** supporting the secondary mirror are no longer in the path of any light which is ultimately collected, thereby avoiding edge diffraction effects usually caused thereby.

The limiting of each "channel" to only a fractional part of the total radiation which would otherwise enter the telescope from the sun (by the provision of apertures **42***a*—*42d*) not only performs the usual attenuation of the excess intensity of the radiation of the sun, but also improves the performance of the instrument in several ways. Perhaps the most important effect is to increase the "sharpness" of the transmission "spike" of the narrow band interference filters (**54***a*, **54***b*, etc.). Thus, an exemplary filter of this type, commercially available from The Perkin-Elmer Corporation, Main Avenue, Norwalk, Connecticut and designed to pass the hydrogen-alpha line, shows a marked improvement in the narrowness of the transmission peak for smaller aperture angles (higher "*f* numbers"). For example, such a filter showed, for a zero half field angle (i.e., a point source) with the filter exactly perpendicular to the optical axis of the imaging system, the following calculated transmission curves as the acceptance cone angle of the imaging system (positioned in front of the filter) was changed. For a *f*/infinity system (i.e., a zero cone angle, so that only paraxial rays are passed by the imaging system), the theoretical curve had a maximum transmission of about 96 percent and a half-width band-pass of 0.50A; for *f*/40, the maximum transmission was about 89 percent and a half-width of 0.55A; for *f*/30, peak transmission decreased to about 79 percent and the half-width increased to 0.65A; at *f*/20, the peak fell to only about 54 percent transmission and the half-width rose to 1.1A. There was also a slight shift of the peak toward lower wavelengths (about 0.1A between each of the three "finite" *f*-number examples just given), caused of course by the fact that as the aperture cone angle increases, the "average" or most prevalent ray is no longer perpendicularly incident on the filter. Therefore, the majority of the radiation travels through the filter at a slight angle; as is well known, this causes a shift (very slight in this case) of the peak transmission wavelength of a multilayer interference filter (see, for example, U.S. Pat. No. 2,941,444 issued to R. W. Frykman on June 21, 1960). For *f* numbers less than *f*/20, the performance of this filter degrades quite rapidly so that by *f*/7 the transmission curve is not even a generally bell-shaped curve with a single maximum, but rather has a very broad (many angstroms wide) plateau region which contains several (about 9) similar height (varying from about 9 to about 19 percent) transmission "peaks," irregularly spaced about ¾angstrom apart. This irregularly peaked, plateau curve transmits at least about 5 percent over a range of approximately 4A on each side of its 19 percent transmission peak (and had a more than 10 percent peak slightly over 3A away from the 19 percent central peak). This curve could be called a 19 percent peak transmission with about a 7 A

half-width, but is more aptly thought of as an 8A band-pass filter with a series of nine peaks over the central 7A part of this band.

Thus an *f*/13.5 telescope (of, say, 24 inch clear aperture and a 324 inch effective focal length) could not practically use the straight-forward optical system of the exemplary embodiment without serious degradation of the sharpness of the band-pass characteristics of the individual filters (*54a*, *54b*, etc.) if the entire aperture were used. The subdividing of the whole aperture into, say, four *f*/40 subtelescopes (e.g., with four 8-inch diameter apertures and blocking filters at *42a*, *42b*, etc., and *44a*, *44b*, etc., respectively) causes a true "spike" type of spectral transmission by the filter. For the exemplary filter discussed, isolation of the hydrogren-alpha line is obtained to the extent desired for solar spectroscopy only for cone angles corresponding to about *f*/34 (or higher), so that by *f*/40 the sharpness of the "spike" is adequate even for the moderately small field angles utilized. To optimize performance each of the narrow band-pass filters (*54a*, *54b*, etc.) should be perpendicular to the optical axis of its own subsystem (i.e., the line from image point **24** through the center of the particular filter, **54**, the optical center of succeeding small lens, **56**, and the center of the particular utilized part of the image receiver, **58**). Although in theory there will be a slight broadening and loss of symmetry in the transmission spike if the filter is not so aligned, the primary effect of slight tilting of the filter from this relationship will be to cause a small shift in the wavelength of the transmission peak. It is therefore possible to "tune" the transmission maximum of a given filter (by a few tenths of an angstrom, for example, for the type of filter described) to compensate, say, for temperature changes or the like.

Additionally, since each of the four beams passing through the system utilized only the same zones of both the primary and secondary mirrors, the various aberrations will be less in each of the four individual images than would be the case if radiation from all parts of both mirrors (*14*, *20*) were used, since a limited zone of the system will have less relative optical "error" than different parts of the entire system do. Additionally, the fact that the system has been effectively "stopped down" (e.g., converting a, say, *f*/13.5 telescope to four *f*/40 subtelescopes) not only improves the imagery of the telescope itself, but also simplifies the design of highly corrected other optics (notably the reimaging systems, exemplarily represented by lenses *56a—56d*).

As previously pointed out, none of the details of the original astronomical telescope (i.e., elements 12—38), the exact number of individual units (i.e., the elements identified by a reference numeral followed by the letter *a*, *b*, *c*, etc.), nor in general the specific structure of the various individual elements comprising the various assemblies of the entire apparatus are in general necessary to the invention. Therefore, all of these may be changed without departing from the actual invention, which is defined by the scope of the appended claims.

I claim:

1. An apparatus for recording a plurality of simultaneous solar spectrograms, each at its own extremely narrow spectral interval, comprising:

a conventional telescopic optical system for gathering incoming solar radiation and for forming a solar image;

a plurality of first filter means positioned in front of said telescopic optical system for effectively dividing said solar radiation into a plurality of substantially separate beams passing through said telescopic optical system;

means for rendering each of said separate beams substantially monochromatic at its own different desired extremely narrow spectral interval;

reimaging means for forming a separate final substantially monochromatic image from each of said separate monochromatic beams;

and means for recording each of said separate substantially monochromatic solar images;

each of said first filter means being of such construction as to pass only a moderately narrow spectral band generally surrounding the extremely narrow spectral interval of the final solar image formed from its respective separate beam;

whereby each of said separate beams from said first filter means comprises radiation only in the spectral vicinity of the extremely narrow spectral interval of its respective final solar image, thereby greatly reducing the total intensity of the radiation in each separate beam without substantial loss of radiation within each respective extremely narrow spectral interval;

whereby a plurality of spectroheliograms at different extremely narrow spectral intervals are obtained simultaneously.

2. A spectrographic apparatus according to claim 1, in which:

each said first filter means is of such construction as to reflect substantially all of the undesired radiation outside of its respective moderately narrow spectral band-pass;

whereby said first filter means reject all such undesired outside radiation without substantial absorption and the attendant heating problems.

3. A spectrographic apparatus according to claim 2, in which:

each said first filter means is of the induced transmission type having at least one very thin metallic layer.

4. A spectrographic apparatus according to claim 1, in which:

said means for rendering each of said separate beams substantially monochromatic comprises a plurality of second filter means;

each said second filter means being of such construction as to pass only an extremely narrow spectral interval within the moderately narrow spectral band of the first filter means optically associated therewith.

5. A spectrographic apparatus according to claim 4, in which:

each said second filter means comprises an interference filter of the type comprising a plurality of extremely thin alternate layers of two different dielectric materials.

6. A spectrographic apparatus according to claim 1, in which:

a field lens means is positioned at least in the vicinity of the original solar image formed by said telescopic optical system;

said field lens means being of such dioptric power and such relative position as to form a conjugate image of said first filter means substantially onto the entrance pupil of said reimaging means;

whereby separation of each of said separate substantially monochromatic beams is more completely obtained, and the field angle requirements of said reimaging system substantially reduced.

7. A spectrographic apparatus according to claim 1, in which:

said recording means comprises at least separate portions of at least one photographic material;

whereby a permanent record is obtained of the manner in which the various parts of the sun, corresponding to the parts of the solar image formed, emit radiation in each of the extremely narrow spectral intervals photographed.