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Allington

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[54] **DUAL BEAM OPTICAL SYSTEM**

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[52] **U.S. Cl.** **250/226,** 250/578, 350/169
[51] **Int. Cl.** **H01j 39/12**
[58] **Field of Search** .... 250/204, 71 R, 220 R, 250/230; 350/169, 171

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Primary Examiner—Harold A. Dixon
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[57] **ABSTRACT**

To compensate for variations in the intensity of light emitted from different locations in or in different directions from a lamp, a radiating member is located in one focus of an ellipsoidal reflector to receive light from the lamp which is mounted with its bright spot in the other focus of the ellipsoidal reflector and to radiate in directions in line with a narrow dimension of the radiating member two oppositely directed, proportional-intensity beams of light through two aligned light-beam holes in the walls of the ellipsoidal reflector on opposite sides of the radiating member, with the radiating member having, in a first embodiment, a surface that diffuses the light so that it is radiated with proportional intensities into both beams in accordance with Lambert's cosine law, in a second embodiment, a surface that fluoreses light with proportional intensities into both beams, and in a third embodiment, a surface with flourescent particles that both diffuse the light and fluorese in response to it, all three embodiments causing the beams of light to be of proportional intensity. Interchangeable filters in the light beams of the third embodiment are selected to pass either the diffused light or the fluorescent light from the radiating member, thus enabling the system to be used for different purposes by changing filters.

46 Claims, 6 Drawing Figures

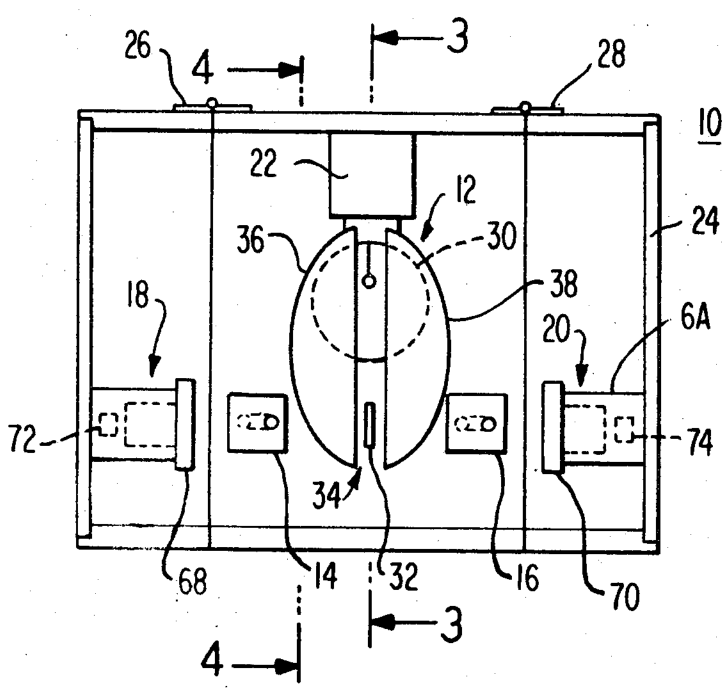


FIG. 1

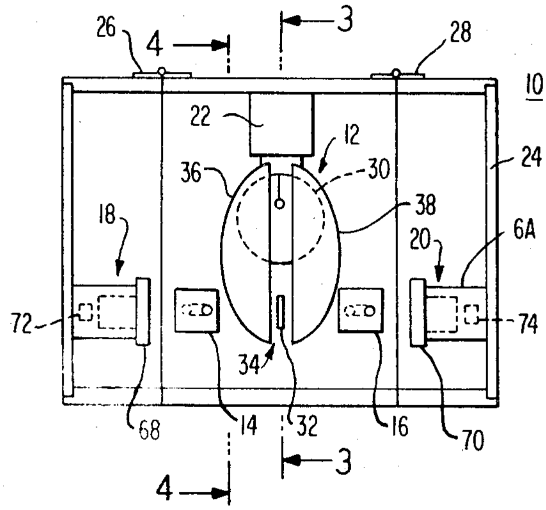


FIG. 3

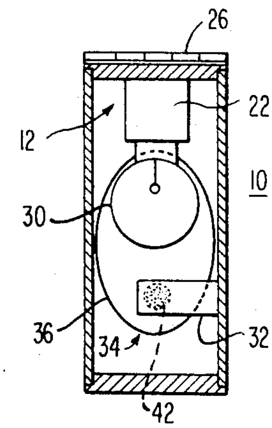


FIG. 2

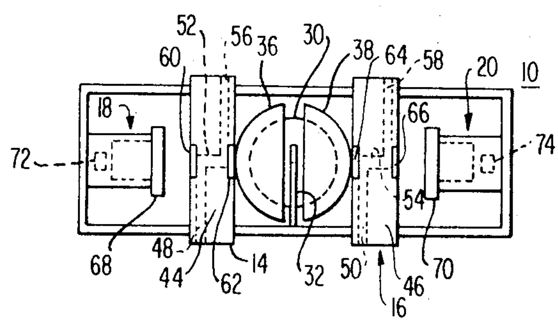


FIG. 4

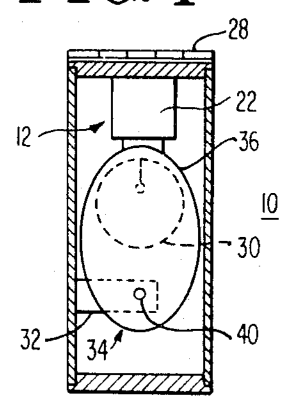


FIG. 5

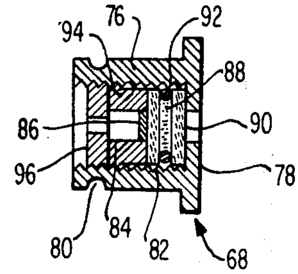
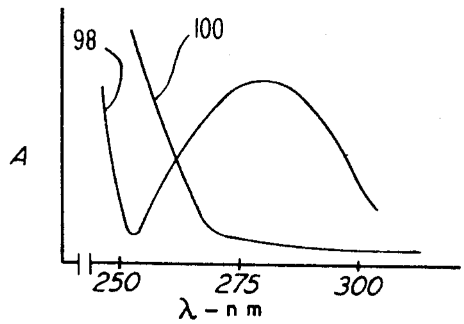


FIG. 6



DUAL BEAM OPTICAL SYSTEM

This invention relates to optical systems and more particularly relates to apparatuses for generating and controlling beams of light for use in optical systems.

For some purposes, it is desirable to generate a plurality of beams of light of proportional intensities. One such purpose is to compare the light absorbing characteristics of two substances. For example, in liquid chromatography, a comparison is made between a first beam of light transmitted through a solvent having solutes separated into zones and a second beam of light transmitted through pure solvent to locate the solutes by the difference in the light absorbing characteristics between the solutes and the pure solvent. The first and second beams of light should not change in intensity with respect to one another except for changes caused by the solutes.

The apparatus for generating the two beams of light generally includes a primary light source and an optical system for forming two beams of light from the primary light source.

Generally, the light supplied by the primary light source to some locations in the optical system fluctuates in intensity with respect to the light supplied to other locations. For example, the light from mercury vapor ultraviolet lamps fluctuates for two reasons: which are: (1) the light from one location within the lamp has, under some circumstances, an intensity that fluctuates with respect to the intensity of the light from another location within the lamp; and (2) mercury vapor moves by convection within the lamp, absorbing light that is being transmitted in the direction of the optical system so that light following a first path within the lamp on the way to one location in the optical system fluctuates in intensity with respect to light following another path from the same location within the lamp to another location in the optical system because the relative amounts of absorption of light in the two paths fluctuates.

In one type of prior art optical system, the primary light source radiates light against a long side of an elongated cylindrical fluorescent crystal, causing it to radiate fluorescent light from two rounded ends in two opposite directions.

This prior art system has the disadvantage of providing light beams that fluctuate in intensity with respect to each other under some circumstances. The light beams fluctuate in intensity with respect to each other when the light from the primary light source striking the side of the crystal at one location fluctuates in intensity with respect to the light striking another location since the light transmitted along the crystal is attenuated more when traveling to a more distant end than to a closer end, primarily as a result of absorption within the crystal. causing the intensity of the light beam emitted from one end of the crystal to be increased more than the intensity the light beam from the other end of the crystal by light striking the crystal at any point except the center of the elongated side.

In another type of prior art optical system, the primary light source is located in the focus of a large lens that collimates the light, forming parallel beams of light from light originating at the same location in the lamp.

This type of prior art also has the disadvantage of providing light beams that fluctuate in intensity with respect to each other even though the light in each beam originates generally from the same location in the lamp. The light intensities of the two beams fluctuate with respect to each other because the light in one beam travels through a different path in the lamp from the path traveled by the light in the other beam, resulting in fluctuations in the relative amounts of light absorbed. Moreover, if the lens is not properly focused on the light source, light from a wide area is applied to the parallel beams of light, and when the light from one portion of the wide area fluctuates with respect to light from another portion of the wide area, the beams of light fluctuate in intensity with respect to each other.

Accordingly, it is an object of the invention to provide a novel optical system for controlling plural beams of light.

It is a further object of the invention to provide a novel apparatus for maintaining the intensities of a plurality of light beams in a constant ratio to each other.

It is a still further object of the invention to provide a novel apparatus for radiating a plurality of beams of light having proportional light intensities from opposite surfaces of a radiating member having a dimension in line with the beams of light that is very small compared with its dimension transverse to the beams of light.

It is a still further object of the invention to provide a novel apparatus for compensating for spatial variations in the intensity of light from a light source.

It is a still further object of the invention to provide a plural light beam optical system in which the ratios of the light intensities of the different beams are independent of spatial fluctuations of the intensity of the light eminating from the primary light source.

It is a still further object of the invention to provide an apparatus for generating plural light beams of high light intensity.

It is a still further object of the invention to provide an apparatus capable of providing plural beams of light, which beams of light can be easily adjusted to provide a selected range of frequencies or a selected spectral line.

It is a still further object of the invention to provide an apparatus for producing a plurality of beams of light from a light diffusing source.

It is a still further object of the invention to provide an apparatus for producing a plurality of beams of light from a fluorescent surface.

It is a still further object of the invention to provide an apparatus for producing a plurality of beams of light from a combined fluorescent and light diffusing source.

It is a still further object of the invention to provide an optical system that includes ellipsoidal reflectors to focus light from a wide spatial angle onto a secondary source from a primary source of light.

It is a still further object of the invention to provide a dual beam optical system that is easily adjusted for different purposes.

In accordance with the above and further objects of the invention, an optical system includes a source of light beams and a filtering arrangement for selecting the same spectral line in each beam of light for use in comparing the light absorbance characteristics of two substances. The light beams are formed by focusing light from a primary source of light on one spot or a radiating member and forming or selecting two beams of light from the light radiated by the radiating member.

To form the two beams of light, the source of light beams includes: (1) an ellipsoidal reflector, having two sections, each with a light-beam hole; (2) a primary source of light having its bright spot in one of the foci of the ellipsoidal reflector; and (3) a radiating member in the other end of the foci of the ellipsoidal reflector, which radiating member transmits light in the direction of the two light-beam holes in the two sections of the ellipsoidal reflector. The radiating member is translucent and has a short dimension, in the direction of the light-beam holes so that two oppositely directed, proportional-intensity beams of light are emitted from the ellipsoidal reflector having any one of three arrangements, to radiate the light which are: (1) a light diffusing surface; (2) a surface that fluoresces; or (3) a surface that fluoresces and also diffuses light.

In operation, light from the primary source of light is reflected onto the radiating member from a major portion of the solid angle around the primary source of light by the ellipsoidal reflector since the primary source of light is one focus and the radiating member is in the other focus of the ellipsoidal reflector. The light is diffused, causes fluorescence or is both diffused and causes emission of fluorescent light upon impinging on the radiating member, with the diffused light and the fluorescent light, when present, leaving the ellipsoidal reflector in two oppositely directed proportional-intensity beams of light through the two light-beam holes in the sections of the reflector.

The two beams of light are of proportional intensity even though the primary source of light may have spatial fluctuating differences in the intensity of the light that it emits because both diffused light and fluorescent light contribute to both beams of light substantially proportionally regardless of the direction of the light before being diffused or causing fluorescence and because light is passed through the short width of the translucent member without significant attenuation.

In an optical system in which the diffused light has a wavelength of 254 nanometers and the fluorescent light has a wavelength of between 270 and 290 nanometers, for example, the filter passes a light having a wavelength of approximately 254 nanometers and blocks light having wavelengths of between approximately 270 and 290 nanometers, a wavelength of 254 nanometers being useful in some applications for dual beam optical systems. Another filter, interchangeable with the one filter, passes light having a wavelength of between 270 and 290 nanometers and blocks light having a wavelength of about 254 nanometers, the wavelengths of light between 270 and 290 nanometers being useful in other applications for a dual beam optical system.

The above noted and other features of the invention will be better understood from the following detailed description when considered with reference to the accompanying drawings in which:

FIG. 1 is a plan view of apparatus embodying the invention;

FIG. 2 is a front elevational view of the apparatus of FIG. 1;

FIG. 3 is a side sectional view of the apparatus of FIG. 1 taken substantially along the line 3—3 in the direction of the arrows;

FIG. 4 is a side sectional view of the apparatus of FIG. 1 taken substantially along the line 4—4 in the direction of the arrows;

FIG. 5 is a sectional view of an interchangeable wavelength-selecting light filter usable with the apparatus of FIG. 1; and

FIG. 6 is a graph showing the light absorbance of certain components of the light filter.

GENERAL STRUCTURE AND OPERATION

In FIG. **1**, there is shown, in a plan view, a dual beam optical system **10** having as its principal parts a dual beam light source **12**, first and second light absorbance cells **14** and **16**, and first and second light measuring cells **18** and **20**.

The dual beam light source **12** is mounted by a base **22** in a central location within a parallelepiped-shaped cabinet **24** and provides two oppositely directed beams of light, with the first light absorbance cell **14** being mounted between a first side of the dual beam light source **12** and the first light measuring cell **18** and with the second light absorbance cell **16** being mounted between a second side of the dual beam light source **12** and the second light measuring cell **20**. The first side of the dual beam light source **12**, the first light absorbance cell **14** and the first light measuring cell **18** are aligned in a first beam of light, with the first light measuring cell **18** being mounted to a first side of the cabinet **24**; and the second side of the dual beam light source **12**, the second light absorbance cell **16**, and the second light measuring cell **20** are aligned in a second beam of light, with the second light measuring cell **20** being mounted to a second side of the cabinet **24**. To provide access to the interior of the cabinet **24**, its sides are hinged at **26** and **28**, permitting it to be easily opened for assembly, repair and the replacement of parts when needed.

The dual beam optical system **10** is part of photometry apparatus of the type requiring two matched beams of light. One such type of photometry apparatus, for example, locates organic solutes such as different proteins and amino acids and the like within a chromatographic column during fractionating of the column.

In this type of apparatus, the different organic solutes are located within the column by their different light absorbances, which are determined by transmitting a first beam of light from a dual beam source of light through the column containing the solute and a second beam of light from the dual beam light source through a sample of the solvent and comparing the intensities of the light in the two beams after they have been passed through the solute and pure solvent. However, it is understood that there are other specific uses for the dual beam optical system **10** known to persons skilled in the art.

In the operation of the dual beam optical system **10**, the first beam of light from the dual beam light source **12** impinges on the first light measuring cell **18** after passing through the first light absorbance cell **14** containing a solute to be located in a chromatographic column or to have its concentration determined and the second beam of light from the dual beam light source **12** impinges on the second light measuring cell **20** after passing through the second light absorbance cell **16** containing only the solvent. The first and second light measuring cells generate first and second electrical signals respectively in response to the light that impinges upon them and these signals are compared to provide a comparison between the light absorbance characteristics of the substances in the first and second light absorbance cells. This comparison may be made by a circuit of the general type disclosed in U.S. Pat. No. 3,463,927 to Robert W. Allington for "Apparatus for Measuring Absorbance Differences."

DETAILED STRUCTURE

The dual beam light source 12 includes a lamp 30, a light intensity balancer 32, and a two-sector ellipsoidal reflector 34, with the two-sector ellipsoidal reflector 34 having a first sector 36 and a second sector 38.

To provide light for the first and second uniform beams of light, the lamp 30 is mounted to the base 22, which services as a socket for electrical connection and is centrally located within the dual beam light source 12. The lamp 30 serves as a primary light source and may be any of several different types, the particular type generally being selected for its abaility to provide light of the desired frequency.

In the preferred embodiment, the lamp 30 is a low pressure mercury vapor lamp that emits ultraviolet light which is particularly useful in some photometric apparatuses such as those that measure or compare the optical density or light absorbance of certain solutions containing organic materials such as protein, amino acid or the like. However, other types of lamps may be used as a primary light source for other purposes. This invention has particular utlity in photometric apparatuses in which the light emitted from some locations in the primary light source fluctuates in intensity with respect to light emitted from other locations or in which light emitted in some directions fluctuates in intensity with respect to light emitted in other directions.

To focus light from the lamp 30 into two oppositely directed beams, the ellipsoidal reflector 34 has the general shape of a prolate spheriod with each of the two sectors 36 and 38 being a section of the spheroid, spaced from the other sector at the center of the reflector 34 and having its concave side facing the concave side of the other. As best shown in FIG. 4, the bright spot of the lamp 30 is located in a first focus of the ellipsoidal reflector 34 to focus light on the second focus and the light intensity balancer 32 is located in the second focus, with each of the two sectors 36 and 38 having a different one of two light-beam holes aligned with each other and with the second focus to permit the first and second proportional-intensity oppositely directed beams of light to leave the ellipsoidal reflector 34, one of the light-beam holes being shown at 40 in FIG. 4.

Because the light-beam holes are aligned with the second focus of the ellipsoidal reflector 34 and with each other, light is not directly reflected in a straight line from one sector through the light intensity balancer 32 and the hole in the other sector into a light absorbance cell without being adequately diffused since there is no such light path, all straight paths of light from one reflector through the hole of the other reflector being at an angle with the first and second beams of light. Moreover, in one embodiment, the light-beam holes are each closed by a different lens that focuses on the light-intensity balancer 32 so as to increase the intensity of light transmitted to the light absorbance cells and to reduce the differences in intensity between the first and second beam by preferentially transmitting light from the screen, which is at the foci of the two lenses.

Generally the ellipsoidal reflector performs two functions, which are: (1) to focus light from the lamp 30 onto the light intensity balancer 32; and (2) to pass two oppositely directed beams of light from the light intensity balancer 32 to the light absorbance cells 14 and 15, which beams do not include light reflected directly from one reflector through the light intensity balancer and along the beam in a straight path, light along the latter direct path creating time-varying inequalities in the light intensity of the two oppositely directed beams of light under some circumstances because the light reflected in this straight path may not be adequately diffused by the light intensity balancer. While ellipsoidal reflectors are well suited for these purposes, other types of reflectors and lens are available which other types can be used for the same purposes when properly constructed.

To cause the two oppositely directed light beams to have intensities that are in a constant ratio to each other even when the intensity of the light emitted by the lamp 30 varies over a period of time from location to location in the lamp or from direction to direction, the light intensity balancer 32 includes a transparent or translucent base with a flat light radiating portion 42 (FIG. 3) mounted in one of the foci of the ellipsoidal reflector 34, the bright spot of the lamp 30 being mounted in the other of the foci. The flat light radiating portion is aligned with both light-beam holes in the sections 36 and 38 of the ellipsoidal reflector 34 in such a manner that a straight line through both light-beam holes is perpendicular to the flat light radiating portion.

To cause the intensities of the light in the light beams to be always in the same proportion, the light radiating portion 42 of the light intensity balancer 32 may include, in general, any surface or combination of surfaces that radiates light proportionally into a plurality of beams. In the preferred embodiment of the inventin, two beams of light are radiated in opposite directions through light-beam holes, and in this embodiment, no lens is necessary to focus the light into beams from the light radiating member since the beams are permitted to pass through the light-beam holes in opposite directions, thus removing the possibility of noise in the light caused by a poorly focused lens that applies light from too large an area into the beams.

Because the light is directed into two opposite directions, the light radiating member should have its smallest dimension parallel to the light beams and this dimension should be sufficiently small to avoid any significant attenuation of the light passing through the light radiating member. Generally, it is less than one millimeter thick. Usually, the performance improves if it is translucent enough so that it radiates equally in both directions regardless of which section of the ellipsoidal reflector supplies the light that impinges upon it.

In one embodiment, the light radiating portion 42 includes for this purpose a translucent light diffusing surface having a passive light radiating means such as in a layer sufficiently thin to be translucent or having other light scattering deformations. Herein, a passive light radiating means does not emit light by the changes in the state of excitation of its atoms or molecules such as happens in incandescent or fluorescent radiators but only re-radiates light.

The light diffusing surface scatters light incident upon it in a random manner, causing the light to be radiated in accordance with Lambert's cosine law, with the intensity being proportional to the cosine of the angle with respect to a normal to the light diffusing surface regardless of its location of origin in the lamp 30. Accordingly, the ratio intensity of the light in the beams is constant because the beams are all at a constant angle to the emitting surface. Moreover, because the light equalizing portion of the light intensity balancer is translucent and does not absorb much light, light from each one of the sectors **36** and **38** is reradiated from both sides of the light intensity balancer **32** to contribute to both the first and the second beams of light and thereby further equalize the beams of light.

In another embodiment, the light equalizing portion **42** includes for this purpose fluorescent particles in a layer sufficiently thin to be translucent or a transparent sheet of fluorescent material mounted to the transparent or translucent base plate of the light intensity balancer **32.** The fluorescent particles or sheet emit light in all directions so that each point contributes proportionately to the first and the second beams of light. The fluorescent particles, when used, also create a diffusing surface, causing diffused light of the frequency emitted by the lamp **30** as well as light emitted by fluorescense of the particles to be directed into the first and second beams of light. The light absorbed by the fluorescent particles reduce the constant-ratio effect some, but the performance is still adequate for most purposes.

The frequencies to be passed through the light absorbance cells **14** and **16** and to photocells within the light measuring cells **18** and **20** are selected by including filters in the path of the beams of light to selectively absorb those frequencies of light that are not to be passed to the photocells. Since the filters are easily changed, the presence of two different ranges of frequencies of light, one from fluorescence of the particles and the other from diffusion of light, each of which is useful in a different application of the dual beam optical system, enables the dual beam optical system to be easily adapted to different applications.

Another manner of constructing the dual beam optical system so that it can be easily adapted to different applications is to provide for easy selection of different frequencies for the light beams. To accomplish this in one embodiment (not shown) the light intensity balancers are readily replaceable so that any of several light intensity balancers, each having different fluorescent materials that emit light at different frequencies, may be selected for use in the dual beam optical system. In another embodiment (not shown) the light intensity balancers are readily adjustable in position within the ellipsoidal reflector and include a plurality of different fluorescent materials at different locations that emit light at different frequencies. The light intensity balancers are adjusted to position a selected one of the different fluorescent materials into the focus of the ellipsoidal reflector to select the frequency of light to be emitted into the beams. Of course, in both of these embodiments, the light filters are selected in accordance with the frequencies that are to be used.

In the preferred embodiment, the substrate of the light intensity balancer **32** is quartz because quartz is transparent to ultraviolet light which is especially useful in the preferred embodiment. However, other materials can obviously be used as the substrate.

There are many known methods for fastening particles to the surface of a substrate or for deforming a substrate to cause it to diffuse light. For example, particles may be mounted by precipitation of an adhesive binder or between two sections of a substrate. The substrate may be deformed by scratching or roughening its surfaces to cause it to diffuse light when particles are not fastened to it.

Particularly useful fluorescent materials for the light intensity balancer **32** are microcrystalline lanthanum fluoride with cerium activation as described in U.S. Pat. No. 2,450,548 to Gishoff or calcium lithium silicate, lead activated phosphor.

As best shown in FIG. **2,** the light absorbance cells **14** and **16** each include a different respective one of the two rectangular housings **44** and **46** enclosing respective ones of two, transparent, tubular, generally Z-shaped passageways, with each passageway including: (1) a respective one of the vertical entrance channels **48** and **50** extending from a point below the dual beam light source **12** in a direction parallel to the light intensity balancer **32** to a point opposite to respective ones of the light-beam holes in the sectors **36** and **38**; (2) a respective one of the two light absorbing channels **52** and **54** extending in a direction aligned with the light-beam holes and with the first and second beams of light; and (3) a respective one of the two outlet channels **56** and **58** extending vertically from points opposite to the light-beam holes parallel to the light intensity balancer **32** to points above the dual beam light source.

To permit the first and second beams of light from the dual beam light source **12** to pass from the light-beam holes through the light absorbing channels **52** and **54,** the light absorbing channel **52** has a transparent window **60** on one side and a transparent window **62** on the other side aligned with the light-beam holes to permit light to pass through the housing **44,** and the light absorbing channel **54** has a transparent window **64** on one side and a transparent window **66** on the other side aligned with the light-beam holes to permit light to pass through the housing **46,** with one end of each of the channels **52** and **54** and each of the transparent windows **62** and **64** being adjacent to different ones of the two light-beam holes.

To measure the light absorbance or transmittance of the fluid in the light absorbance cells **52** and **58,** the first and second light measuring cells **18** and **20** receive the first and second beams of light respectively after they have passed through the light absorbance channels **52** and **54** of the first and second light absorbance cells **14** and **16.** Each of the first and second light measuring cells **18** and **20** includes a different one of the filters **68** and **70** and a different one of the two photocells **72** and **74,** mounted in positions aligned with the first and second beams of light so that the first and second beams of light each pass through one of the filters **68** and **70** before exciting a respective one of the two photocells **72** and **74.**

The photocells **72** and **74** are part of a circuit for comparing the light impinging upon them and providing an indication of the relative optical density of the fluid in the light absorbance cells **14** and **16** for the purpose of locating or identifying a solute in the fluid flowing through one of the light absorbance cells as described in greater detail in the aforementioned U.S. Pat. No. 3,463,927. The filters are similar in some respects to those described in U.S. Reissue Pat. No. 26,638.

In FIG. **5,** there is shown, in a sectional view, the filter **68,** which will be described in greater detail hereinafter, the filter **70** being substantially identical to the filter **68** and not requiring a separate description. Generally the filters include a combination of filter elements, a light filtering liquid, and a fluorescent element, with: (1) one filter element and the light filtering liquid transmitting one wavelength of light that has been used for measuring the absorbance of the substance in a light absorbing cell to the fluorescent element and blocking other wavelengths including the wavelength emitted by the fluorescent element; (2) the fluorescent element emitting light of another wavelength in response to this one wavelength, which other wavelength is one to which the photocell is sensitive; and (3) a third filter element blocking the undesired wavelengths passed by the one filter element and the light filtering liquid, and passing the wavelength emitted by the fluorescent element. Superior selection of the one wavelength is provided by this combination.

More specifically, the filter **68** includes a generally cylindrical tubular casing **76** having at one end a disc-shaped front face **78** with a centrally located disc-shaped opening in it and having the opposite and open to receive filter and fluorescent elements, the internal walls of the casing **76** being threaded. To enable the tubular casing **76** to be readily attached to the first light measuring cell **18,** its cylindrical surface is provided with a cylindrical shoulder at one end adjoining the front face **78** and is provided with an annular notch **80** near its other end so that the casing **76** is received within a cylindrical opening in the first light measuring cell **18** and held thereto by a detent within the annular notch **80** with the shoulder supporting the face **78** outside of the cylindrical opening.

Within the tubular casing **76,** are two filter elements **82** and **84** and a fluorescent element **86,** each having a portion aligned with the opening in the front face **78** to receive light from the first beam of light. Moreover, a light-filtering liquid is contained at **88** within the filter **68** so that the light-beam passes through it before reaching the photocell **72** (FIG. **2**).

To hold the filter elements **82** and **84,** the fluorescent element **86** and the light-filtering liquid at **88** in place, the filter **68** includes a transparent quartz window **90** closing the disc-shaped central opening in the front face **78,** an O-ring **92** pressing against the transparent glass window **90** to form a liquid tight seal therewith, a cylindrical spacer **94** pressing the filter element **82** against the other side of the **0**-ring **92** to form a liquid tight compartment for the light-filtering liquid at **88,** and a retaining ring **96** threadedly engaging the internal threads of the tubular housing **76** to hold the spacer against the filter element **82** and to support the filter element **84** and the fluorescent element **86.**

The filter elements **82** and **84,** the fluorescent element **86** and the light-filtering liquid at **88** are selected to eliminate response to frequencies of light from the first light beam except light of a predetermined spectral line that is useful as a measure of the light absorbance of transmittance characteristic of a solute in the light absorbance cell and to provide light having a wavelength to which the photocell is especially sensitive which light has an intensity proportional to the intensity of the light in the selected spectral line. The selection may be made from a wide range of filter elements, liquids and fluorescent elements depending on the spectral line that is to be used in a particular application and the choice of photosensitive devices to measure the light emitted by the fluorescent element.

In one embodiment of filter **68,** particularly useful in locating or identifying some organic materials, the filter element **84** transmits green visible light produced by the fluorescent element **86,** with: (1) the filter element **82** being red purple silica which transmits light in the ultraviolet region to as short a wavelength as **240** nanometers, and absorbs green visible light: (2) the filter element **84** being a filter which absorbs ultraviolet light and transmits only green light; and (3) the element **86** being a fluorescent phosphor which produces green fluorescent light when radiated with ultraviolet light having a wavelength shorter than some wavelength slightly longer than 280 millimicrons such as a wvelength shorter than 285 or 290 millimicrons. Together the filter elements **82** and **84** and the fluorescent element **86** produce green visible light, in response to light in the wavelength range of 240–290 nonometers.

To obtain light having a wavelength of substantially 280 nanometers from the light produced by a light equalizing portion of the light intensity balancer **32** that includes microcrystalline lanthanum fluoride with cerium activation or calcium lithium silicate lead activated phosphor, a light-filtering liquid is included at **88** that transmits light having a wavelength longer than 280 nanometers and absorbs light having a wavelength of 254 nanometers. On the other hand, to obtain light having a wavelength of 254 nanometers from the same source of light, a light-filtering liquid is included at **88** which transmits light of 254 nanometers and absorbs fluorescent light over the wavelength region of 270 to 300 nanometers.

Although solid materials having the filtering characteristics needed to produce the frequency response required for the above two embodiments are rare, light-filtering liquids are readily available. In FIG. **6** there is shown a graph including a first curve **98** and a second curve **100** having ordinates of the absorption of light and abscissae of the wavelength of the light absorbed for two liquids, with the first curve **98** representing a light-filtering liquid that selectively transmits light having a wavelength of 254 nanometers and blocks light having wavelengths between 270 and 290 nanometers and with the curve **100** representing a light-filtering liquid that selectively transmits light having a wavelength between 270 and 290 nanometers and blocks light having a wavelength of 254 nanometers. A dilute solution of carbon disulfide has a absorbance spectrum resembling that of curve **98** and a solution of benzene in a transparent solvent has a characteristic resembling that of curve **100** although it also has several other features in its characteristic curve, not shown in curve **100,** that are significant to this invention. There are also other suitable liquids.

DETAILED OPERATION

Before operating the dual beam optical system **10,** the filters **68** and **70** are prepared and inserted into the first and second light measuring cells **18** and **20** (FIG. **2**). Generally, the filters are prepared for use in accordance with the type or types of organic solutes that are to be located in a chromatographic column that is flowing through the first light absorbance cell **44,** but, of course, the filters are chosen according to other criteria for other applications of the dual beam optical system.

To detect a solute that absorbs light having a wavelength of 254 nanometers, the filter **68** is assembled as shown in FIG. **5** with a liquid such as a dilute solution of carbon disulfide included at **88.** To detect a solute that absorbs light having a wavelength of between 270 and 290 nanometers, the filter is assembled in the same manner but with a liquid such as a solution of benezene in a transparent solvent at **88.**

In the operation of the dual beam optical system **10,** a solvent containing a solute is pumped through the light absorbance cell **14** and pure solvent is pumped through the second light absorbance cell **16.** While the solute is flowing through the light absorbing channel **52** of the first light absorbance cell **14** and the pure solvent is flowing through the light absorbing channel **58** of the second light absorbance cell **16,** the first beam of light is transmitted through the light absorbing channel **52** to the first light measuring cell **18** and the second beam of light is transmitted through the light absorbing channel **58** to the second light measuring cell **20,** with the first and second beams of light having proportional light intensities. The first light measuring cell **18** and the second light measuring cell **20** compare the intensity of the light in the first and second beams of light to obtain information about the solute flowing through the first light absorbing channel **52.**

To generate the first and second beams of light, the lamp **30** radiates light, which in the preferred embodiment is ultraviolet light, onto the light intensity balancer **32.** Since the bright spot of the lamp **30** is in one focus and the light radiating portion **42** of the light intensity balancer **32** is in the other focus of the ellipsoidal reflector **34,** light from a solid angle that is the major portion of a sphere is radiated from the lamp **30** to the light radiating portion **42** of the light intensity balancer **32.**

In a first embodiment of the ellipsoidal reflector **34,** the light radiating portion **42** of the light balancer **32** is a translucent diffusing surface that diffuses the light radiated to it and re-radiates it as two oppositely directed beams through the two light-beam holes in the first and second reflector sections **36** and **38.** The light is radiated from the light radiating portion **42** in accordance with Lambert's cosine law with light impinging upon each spot causing proportional radiation into both the first and second beams of light so that both beams have proportional light intensities. Because the two light-beam holes are in line with the first and second beams of light, no light can be directly reflected from one reflector section through the light radiating portion and into the light beam opposite from the reflector section without being diffused.

In a second embodiment, the light radiating portion **42** of the light balancer **32** includes a thin transparent or translucent layer of fluorescent particles; which defuses light and fluoresces, with the diffused light making proportional contributions to each of the first and second beams of light as in the first embodiment and with the fluorescent light making proportional contributions to each of the first and second beam of light of another frequency because the radiation of the particles from fluorescense is independent of the direction of the light causing the fluorescence.

After the light from the first and second beams of light pass through the first and second light absorbance cells **14** and **16,** they impinge on the first and second light measuring cells **18** and **20,** where they pass through filters that select a single spectral line to transmit to photocells which develop signals related to the amount of light absorbed by the solute and solvent. The filters are selected in accordance with the particular application of the dual beam optical system as explained above.

From the above description, it can be understood that the dual beam optical system of this invention has several advantages, such as: (1) it provides closely matched beams of light even if the lamp that is the primary source of the light has spatial time-varying discrepancies or directional discrepancies in the intensity of the light; and (2) the two beams of light are bright, making use of a high percentage of the light from the primary source of light.

Although a specific embodiment of the invention has been described with some particularity, many modifications and variations in the embodiment are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described without departing from the invention.

What is claimed is:

1. Apparatus for directing light from a light source into a plurality of paths, comprising;
- a light-radiating member;
- focusing means for focusing light from said light source onto a spot on said light-radiating member, whereby a substantial amount of light is radiated by said light-radiating member;
- said spot on said light-radiating member including light-radiating means for radiating light along at least a first and a second of said paths from said spot in response to said focused light with a substantially constant ratio of the intensity of the light in said first path to the intensity of the light in said second path, which ratio is substantially independent of fluctuations in the light from said light source.

2. Apparatus according to claim **1** in which:
- said light-radiating member is a passive light radiating means; and
- said passive light-radiating means includes means for substantially diffusing light.

3. Apparatus according to claim **1** in which:
- said light-radiating member is fluorescent means for emitting light at a first frequency when impinged upon by light having a second frequency; and
- said light source includes means for emitting light of said second frequency.

4. Apparatus according to claim **1** in which said light-radiating member includes a means for substantially diffusing light.

5. Apparatus according to claim **4** in which said means for substantially diffusing light comprises a plurality of particles.

6. Apparatus according to claim **5** in which:
- said plurality of particles comprise fluorescent means for emitting light at a first frequency when impinged upon by light having a second frequency;
- said light source includes means for emitting light of said second frequency, whereby diffused light of said second frequency and fluorescent light of said first frequency are directed along said plurality of paths.

7. Apparatus according to claim **6** further including:
- a plurality of interchangeable filter mounting means;
- each of said interchangeable filter mounting means being mounted in a different one of said plurality of paths; and

said filter mounting means being adapted to receive filters blocking a selected one of said first and second frequencies of light.

8. Apparatus according to claim **7** in which said fluorescent means comprises means for emitting light having a wavelength substantially in the range of 270 to 290 nanometers, and said light source is an ultraviolet lamp.

9. Apparatus according to claim **8** in which said filters include means for blocking light having a wavelength substantially of 254 nanometers.

10. Apparatus according to claim **9** further including;

a plurality of photocells;

said photocells being sensitive to a predetermined frequency;

different ones of said photocells being mounted in line with different ones of said filters and said paths; and

said filters including means for producing light of said predetermined frequency in response to light substantially in the wavelength range of 240 to 285 nanometers.

11. Apparatus according to claim **8** in which said filters include means for blocking light having a wavelength substantially in the range of 270 to 290 nanometers.

12. Apparatus according to claim **11** further including:

a plurality of photocells;

said photocells being sensitive to a predetermined frequency;

different ones of said photocells being mounted in line with different ones of said filters and said paths; and

said filters including means for producing light of said predetermined frequency in response to light substantially in the wavelength range of 240 to 285 nanometers.

13. Apparatus according to claim **1** in which:

said focusing means includes an ellipsoidal reflector having first and second foci;

said light-radiating member being located in said first focus of said ellipsoidal reflector; and

said light source including means for emitting light from said second focus of said ellipsoidal reflector.

14. Apparatus according to claim **13** in which said ellipsoidal reflector includes;

a first section having internal walls defining a first hole;

a second section having internal walls defining a second hole;

said first hole, first path and light radiating member being aligned; and

said second hole, second path and radiating means being aligned.

15. Apparatus according to claim **13** in which:

said light-radiating member is a passive light-radiating means; and

said passive light-radiating means includes means for substantially diffusing light.

16. Apparatus according to claim **13** in which:

said light-radiating member is a fluorescent means for emitting light at a first frequency when impinged upon by light having a second frequency; and

said light source includes means for emitting light of said second frequency.

17. Apparatus according to claim **14** in which said light-radiating member includes a means for substantially diffusing light.

18. Apparatus according to claim **17** in which said means for diffusing light comprises a plurality of particles.

19. Apparatus according to claim **18** in which:

said plurality of particles comprise fluorescent means for emitting light at a first frequency when impinged upon by light having a second frequency; and

said light source includes means for emitting light of a said second frequency, whereby diffused light of said second frequency and fluorescent light of said first frequency are directed along said plurality of paths.

20. Apparatus according to claim **14** in which said light-radiating means includes:

fluorescent means for emitting light at a first frequency when impinged upon by light having a second frequency; and

said light source includes means for emitting light of said second frequency.

21. Apparatus according to claim **19** in which:

said light-radiating member has at least first and second surfaces;

said first and second surfaces being spaced at their nearest points a distance less than any other distance between two opposite surfaces of the light radiating member.

22. Apparatus according to claim **20** in which:

said light-radiating member has at least first and second surfaces;

said first and second surfaces being spaced at their nearest points a distance less than any other distance between two opposite surfaces of the light radiating member.

23. Apparatus for directing light from a light source into a plurality of paths, comprising:

a light-radiating member having at least first and second surfaces;

said light-radiating member being capable of passing light;

said light-radiating member including light radiating means for responding to light impinging on said member from said light source by radiating light along at least a first of said paths from said first surface and along a second of said paths from said second surface with a substantially constant ratio of the intensity of the light in said first path to the intensity of the light in said second path, which ratio is substantially independent of fluctuations in the light from said light source;

said first and second surfaces being spaced at their nearest points a distance less than any other distance between two opposite surfaces of the light-radiating member.

24. Apparatus according to claim **23** in which:

said light-radiating member is a passive light-radiating means; and

said passive light-radiating means includes means for substantially diffusing light.

25. Apparatus according to claim **23** in which said light-radiating means includes a means for diffusing light.

26. Apparatus according to claim 25 in which said means for diffusing light comprises a plurality of particles.

27. Apparatus according to claim 26 in which:
said plurality of particles comprise fluorescent means for emitting light at a first frequency when impinged upon by light having a second frequency; and
said light source includes means for emitting light of said second frequency, whereby diffused light of said second frequency and fluorescent light of said first frequency are directed along said plurality of paths.

28. Apparatus according to claim 27 further including:
a plurality of interchangeable filter mounting means;
each of said interchangeable filter mounting means being mounted in a different one of said plurality of paths; and
said filter mounting means being adapted to receive filters blocking a selected one of said first and second frequencies of light.

29. Apparatus according to claim 28 in which said fluorescent means comprises means for emitting light having a wavelength substantially in the range of 270 to 290 nanometers and said light source is an ultraviolet lamp.

30. Apparatus according to claim 29 in which said filters include means for blocking light having a wavelength substantially of 254 nanometers.

31. Apparatus according to claim 30 further including:
a plurality of photocells;
said photocells being sensitive to a predetermined frequency;
different ones of said photocells being mounted in line with different ones of said filters and said paths; and
said filters including means for producing light of said predetermined frequency in response to light substantially in the wavelength range of 240 to 285 nanometers.

32. Apparatus according to claim 29 in which said filters includes means for blocking light having a wavelength substantially in the range of 270 to 290 nanometers.

33. Apparatus according to claim 32 further including:
a plurality of photocells;
said photocells being sensitive to a predetermined frequency;
different ones of said photocells being mounted in line with different ones of said filters and said paths; and
said filters including means for producing light of said predetermined frequency in response to light substantially in the wavelength range of 240 to 285 nanometers.

34. Apparatus according to claim 23 in which said light-radiating means includes:
fluorescent means for emitting light at a first frequency when impinged upon by light having a second frequency; and
said light source includes means for emitting light of said second frequency.

35. Apparatus according to claim 34 in which said fluorescent means comprises a clear fluorescent crystal.

36. Apparatus according to claim 3 in which said fluorescent means is a clear fluorescent means for emitting light at said first frequency.

37. Apparatus according to claim 3 in which said fluorescent means includes a plurality of particles for emitting light at said first frequency.

38. Apparatus according to 16 in which said fluorescent means is a clear fluorescent means for emitting light at said first frequency.

39. Apparatus according to claim 16 in which said fluorescent means includes a plurality of particles for emitting light at said first frequency.

40. Apparatus according to claim 34 in which said fluorescent means includes a plurality of particles for emitting light at said first frequency.

41. Apparatus according to claim 1 further including at least first and second photocells, said first photocell being positioned in one of said plurality of paths and said second photocell being positioned in another of said plurality of paths.

42. Apparatus according to claim 2 further including at least first and second photocells, said first photocell being positioned in one of said plurality of paths and said second photocell being positioned in another of said plurality of paths.

43. Apparatus according to claim 3 further including at least first and second photocells, said first photocell being positioned in one of said plurality of paths and said second photocell being positioned in another of said plurality of paths.

44. Apparatus according to claim 4 further including at least first and second photocells, said first photocell being positioned in one of said plurality of paths and said second photocell being positioned in another of said plurality of paths.

45. Apparatus according to claim 5 further including at least first and second photocells, said first photocell being positioned in one of said plurality of paths and said second photocell being positioned in another of said plurality of paths.

46. Apparatus according to claim 13 further including at least first and second photocells, said first photocell being positioned in one of said plurality of paths and said second photocell being positioned in another of said plurality of paths.

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