NASA Case Hqn.10683
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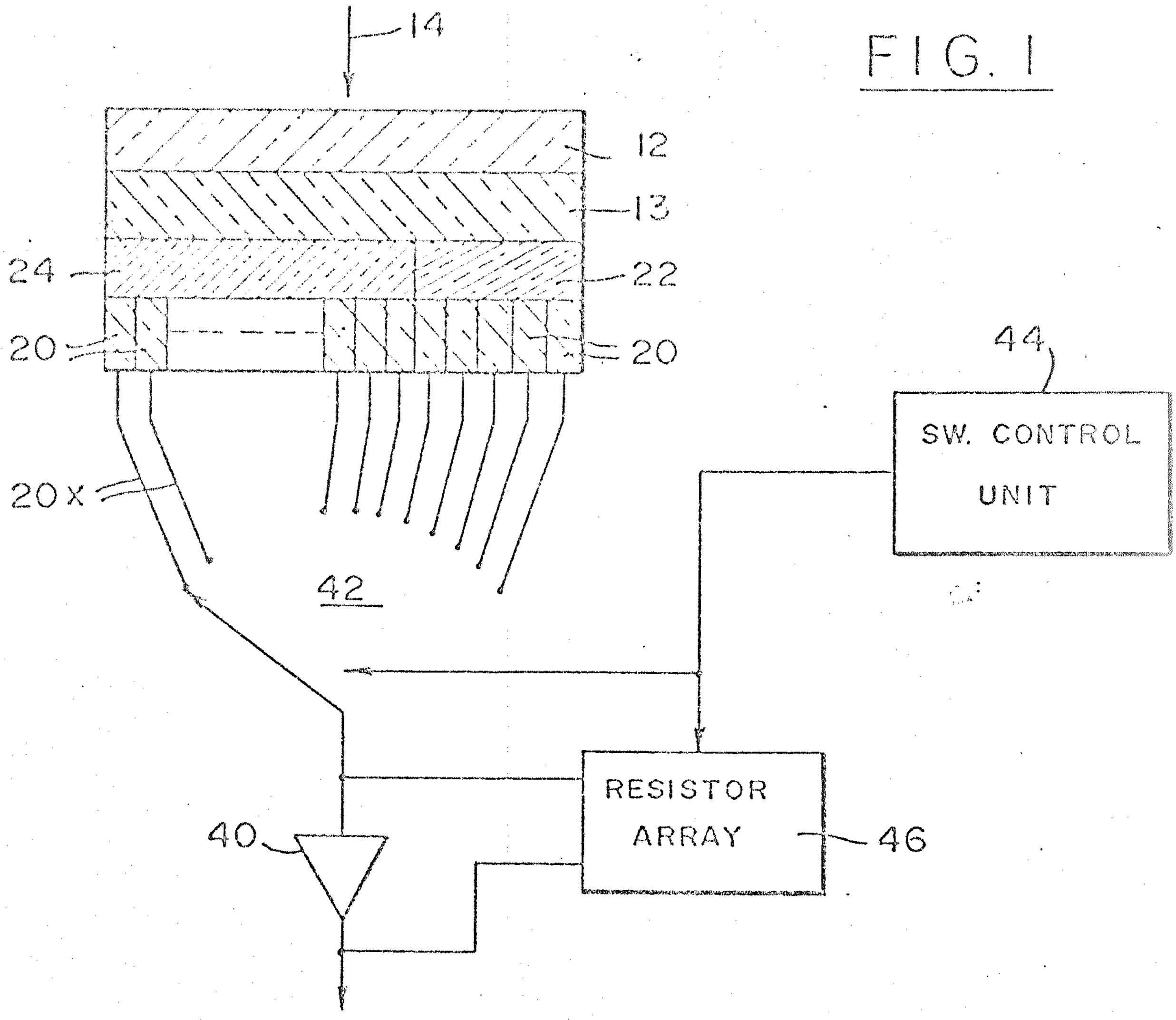

FIG. 1

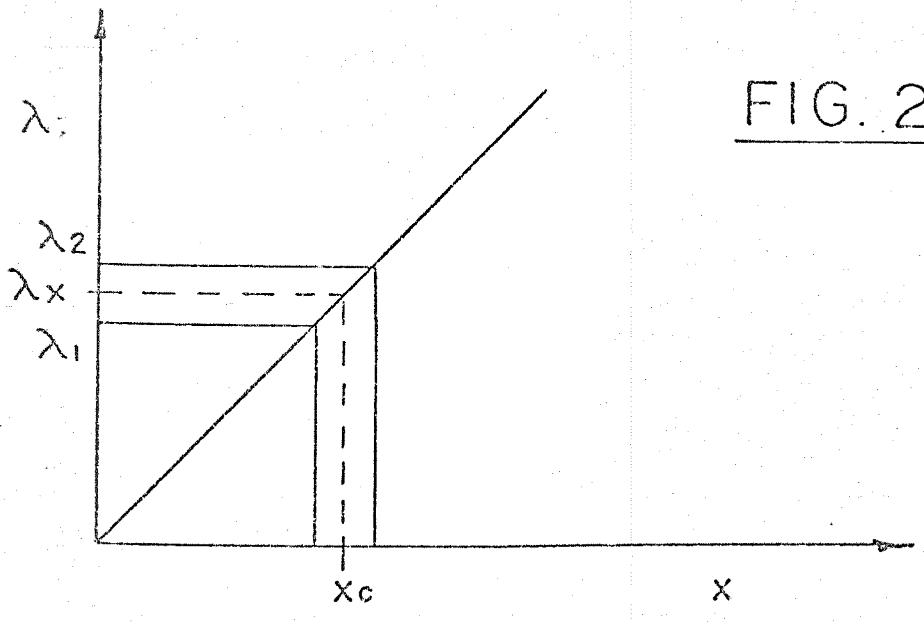

FIG. 2

FIG. 3

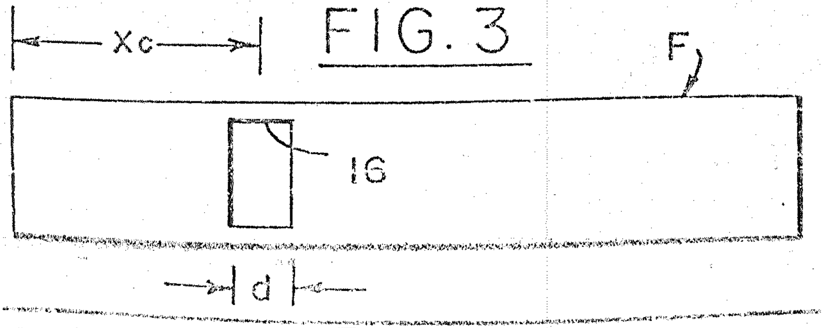

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FIG: 4

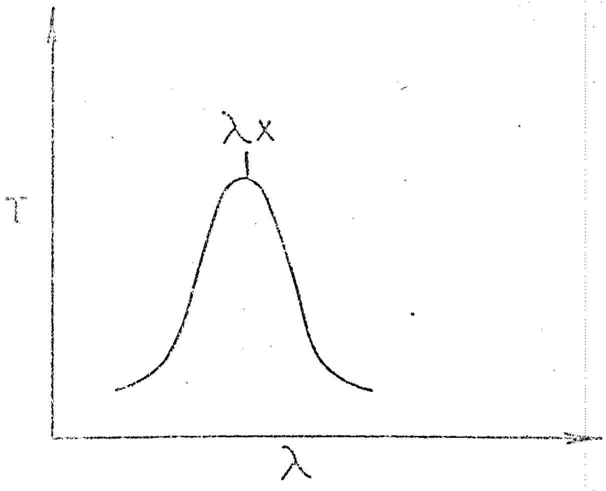

FIG. 5

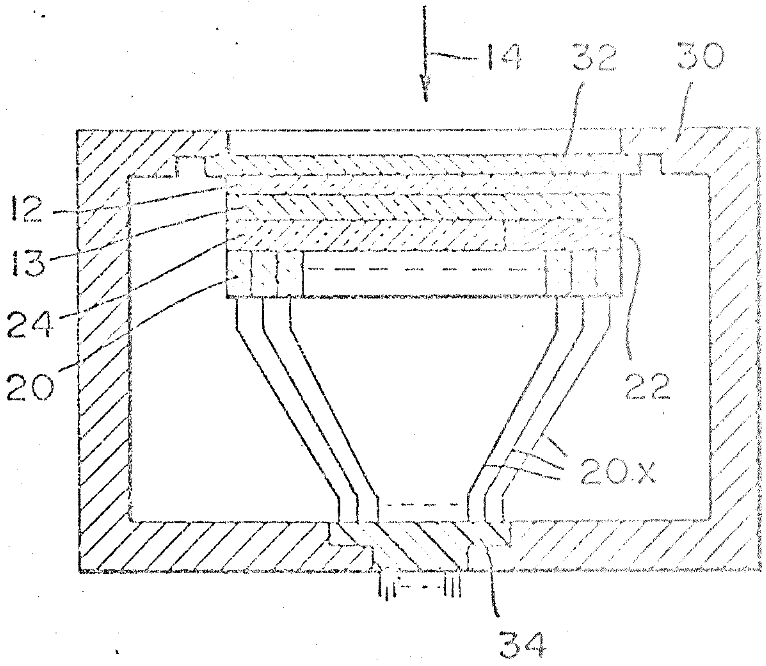

FIG. 6

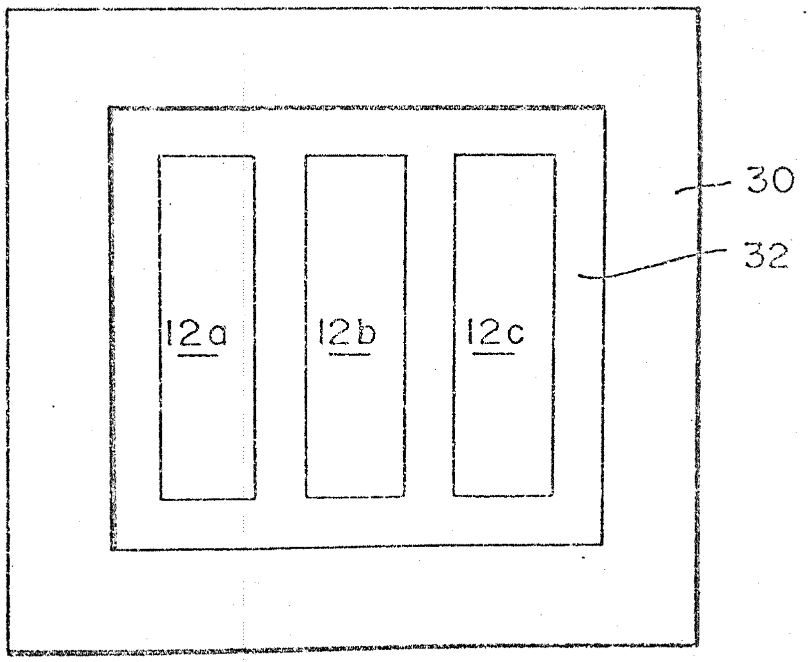

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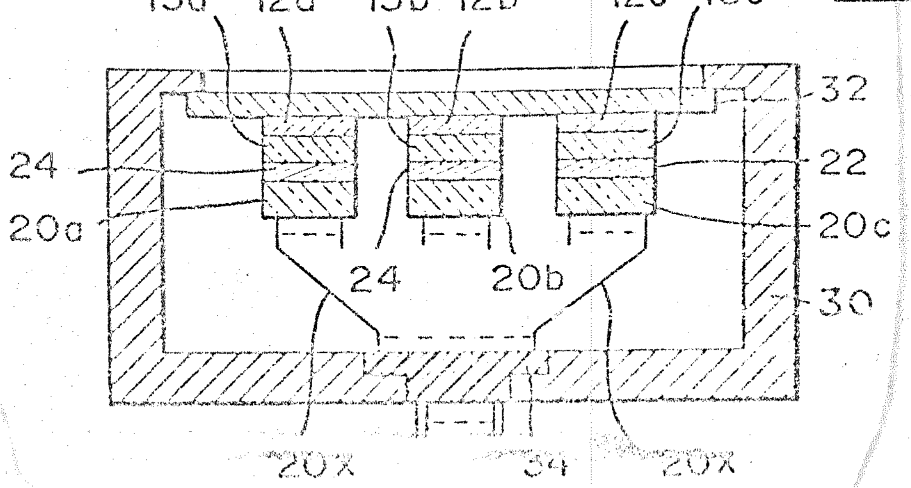
FIG. 7



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Application Serial No. 146,217
Filed: 5/24/71
Contractor: MIT
Contract: NAS12-514

71/128

AWARDS ABSTRACT

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April 29, 1971

NASA Case No. HQN-10683

Contractor: Massachusetts Institute of Technology

COMPACT SPECTRORADIOMETER

The primary object is to provide a small spectroradiometer.

The spectroradiometer consists of a pair of wedge filters 12 and 13 (Figure 1) and an array of silicon photovoltaic cells 20. Each cell provides an output which is a function of energy in a different wavelength band of light 14 which is directed to the cell through the two filters. The output of each cell is amplified by an operational amplifier 40 whose feedback resistor is selected from a resistor array 46, so that the outputs of all cells is a constant when the energy across the entire band of interest is constant.

The primary novelty resides in the use of two identical wedge filters in a spectroradiometer thereby eliminating the adverse effect caused by the tiny pinholes in the filters when a single wedge filter is employed.

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SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT HAROLD H. SEWARD, IAN G. MC WILLIAMS AND GEORGE A. DAVIDSON, are all citizens of the United States of America, respectively residing at Arlington, Arlington and Lexington, all in the County of Middlesex, State of Massachusetts, have invented a new and useful

COMPACT SPECTRORADIOMETER

of which the following is a specification:

ABSTRACT OF THE DISCLOSURE

A compact spectroradiometer is disclosed. It includes a pair of wedge filters and an array of silicon photovoltaic cells, each cell providing an output as a function of energy in a different band of wavelengths of light directed to the cells through the pair of filters. The output of each cell is amplified by an operational amplifier whose feedback resistor is chosen so that the outputs of all cells is a constant when the energy or power across the entire band of interest is constant.

ORIGIN OF INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 U.S.C. 2457).

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention is directed to an energy detector and, more particularly, to a probe for monitoring the spectral energy distribution of a source of light, such as solar simulators and other high intensity sources.

2. Description of the Prior Art:

Various devices have been designed to measure the spectral energy distribution of a source of light. Spectrometers are among the most well known of such devices. The prior art devices are generally quite large, complex and expensive. Also, in most prior art devices, the final spectral energy distribution can be plotted or measured only after accounting for the spectral response curves of energy detectors in the devices. A need exists therefore for a small device or probe which is capable of monitoring the spectral energy distribution of light from a source, such as solar simulators and other high intensity sources. The desired properties of such a device which is generally referred to as a spectroradiometer, in addition to compactness, are reliability, simplicity and one which is relatively inexpensive. Another desired property of such a device is that its output or outputs enable the direct plotting of spectral energy distribution without external accounting for detectors' spectral response curves.

OBJECTS AND SUMMARY OF THE INVENTION

It is a primary object of the present invention to provide a new improved spectroradiometer.

Another object of the present invention is to provide a compact spectroradiometer which is highly reliable and relatively inexpensive.

A further object of the present invention is to provide a small probe for measuring spectral energy distribution from a source of light, with the probe's outputs representing directly the spectral energy distribution without having to account for the detectors' individual spectral response curves.

These and other objects of the invention are achieved by providing a spectroradiometer consisting of a pair of wedge filters and a red filter through which light is directed to an array of light detectors. The outputs of the detectors each of which responds to light energy in a different bandwidth are selectively coupled to the input of an amplifier whose feedback resistor is selectively controlled so that for an irradiance equal to a selected level, e.g., one solar constant, the amplifier's output is the same, irrespective of which detector output is coupled thereto.

The novel features of the invention are set forth with particularity in the appended claims. The invention will best be understood from the following description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a diagram useful in explaining the present invention;

Figures 2-4 are curves and diagrams useful in explaining the properties and characteristics of a wedge filter.

Figure 5 is a cross-sectional view of one embodiment of the invention; and

Figures 6 and 7 are top and cross-sectional views of another embodiment of the invention which was actually reduced to practice.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Attention is first directed to Figure 1 wherein numeral 10 designates the novel spectroradiometer. It is shown comprising a pair of wedge filters 12 and 13 to which light, represented by arrow 14, is directed. As is appreciated a wedge filter is a multilayer thin-film optical filter whose wavelength of peak transmission varies linearly with distance along the filter. A typical curve of wavelength (λ) versus (X) is shown in Figure 2.

When a slit 16 of a width d (shown in Figure 3) is placed on a wedge filter F, assumed to have the curve shown in Figure 2, centered at a distance X_c, the bandwidth of the light through the slit is not as small as the slit width would indicate. That is the bandwidth is not equal to $\lambda_2-\lambda_1$, but rather depends on the slit-width and the spectral transmission characteristics of the filter as represented in the graph of Figure 4. Therefore, when an array of light detectors is placed under the wedge filter so that light passes to the detectors through the filter, the bandwidth of each detector is a function of its width along the filter length and the filter's spectral transmission (T) characteristics.

Typically, wedge filters have tiny pin holes which allow broadband energy to leak into the various detectors thereby disturbing the bandwidth of each detector. Thus, a single wedge filter cannot be used with an array of detectors to provide an indication of the spectral energy distribution of the light since the presence of the tiny pin holes disturb the bandwidths of the detectors. It has been discovered that the problem created by the presence of the pin holes in wedge filters can be eliminated by directing the light to the detectors through a pair of wedge filters.

As seen from Figure 1, the spectroradiometer 10 of the present invention includes such a pair of wedge filters 12 and 13. Light 14 which is transmitted thereto is directed to an array of detectors 20. If the sensitivity of the detectors includes in its band harmonics of the short wavelength sections of the filters 12 and 13, a fixed filter has to be placed between the bottom filter 13 and the detectors. For example, assuming a wedge filter with a band from a wavelength of 393nm to 900nm and detectors each with a peak sensitivity in the 800 to 900nm range, a filter 22 is placed between the short-wavelength section (assumed to be on the righthand side) of filter 13 and detectors 20 to insure that harmonics 786 to 900nm of the short-wavelengths between 393 and 450nm do not pass to those detectors designed to detect energy in the 393 to 450nm band. To insure proper alignment of filter 13 and the detectors 20, a spacer 24 occupies the space between the filter 13 and the detectors which is not occupied by filter 22.

In practice the wedge filters 12 and 13, filter 22, spacer 24 and detectors 20 are assembled in a housing 30 (Figure 5) with a window 32 and with a plug 34 to which leads 20x of the detectors are connected. Appropriate bonding materials are used to bond or cement the filters 12 and 13 to each other and to window 32, as well as to cement filter 22 and spacer 24 to the detectors 20 and to the bottom side of filter 13. In order not to damage the wedge filters which are heat sensitive, a bonding material which cures at room temperature is chosen. One example of such a material is Canada balsam. Heat curing lens cement such as Lens Bond can be used to bond the filter 22 and spacer 24 to the detectors 20. After cementing all the parts, the housing is preferably filled with an appropriate potting compound.

In one particular embodiment actually reduced to practice, a commercially available wedge filter such as model VERIL B 60 which is 60mm long and over 25mm high was cut into three sections each 20mm long and split lengthwise into four parts each 5mm high. Two parts of each corresponding section were cemented together to form filters 12 and 13 which together represent a double wedge filter. Thus, a single wedge filter was cut to produce two sets of double filters each of three sections. They were then cemented to the window in parallel alignment as shown in Figures 6 and 7. In Figure 7, the three sections of each of filters 12 and 13 are designated by the suffixes a, b and c. The filter 22 was Schott model BG-38. In the particular embodiment Hoffman-Centerlab model HPC silicon photovoltaic readout assemblies were used for detectors 20. In Figure 7, the three assemblies are designated by 20a, 20b and 20c. To stagger the rear surfaces of these assemblies so that the detector leads could be brought out, spacers 24 were employed between sections 13a and 13b and assemblies 20a and 20b. Also, a spacer 24 was placed between section 12b and window 32. The entire assembly was housed in housing 30 of dimensions of 1.5"x1.5"x0.75".

Each detector assembly such as 20a which contains 8 cells is 19.9mm long by 4.11mm high. The filters 12 and 13 have a bandwidth of 7nm/mm. Thus, the bandwidth due to the active width of each cell is 14.2nm. However, due to the spectral transmission characteristics of filters 12 and 13, the cell bandwidth is closer to 20nm. The active area of each cell was found to be about 8.35 square mm.

As shown in Figure 1, the output leads 20x of the various cells are selectively connectable to an operational amplifier 40 through a stepping switch 42 which is controlled by a control unit 44. The latter also controls the feedback resistor from a resistor array 46 which is connected across amplifier 40. Briefly, the operational amplifier operates as an inverter such that a current tending to drive the amplifier input positive produces a negative output voltage, with this voltage draining almost all of the input current through the feedback resistor. Such a small part of the current goes into the amplifier that it can be neglected. Thus it can be stated that the output voltage is the product of the cell current and the feedback resistor.

As is known, each cell has a spectral response curve which is typically bell-shaped rather than linear. Also, the wedge filters have other than linear transmission response characteristics over their entire transmission bands. Thus, in order to obtain a constant output voltage for each cell output, when the spectral energy distribution is constant across the entire band of interest, the feedback resistor need be changed depending on the particular response band of the cell whose output is fed to the amplifier, the cell's spectral response curve and the properties of the particular wedge filters. This is accomplished in the present invention by selecting, by means of unit 44, a resistor from the resistor matrix or array 46 which depends on the particular cell whose output is being measured. In such an arrangement the actual outputs of amplifier 40 in response to the outputs of all the cells can be plotted to provide a direct plot of the spectral energy distribution which is not disturbed by the detectors' spectral response curves or by non-linearities in the transmission characteristics of the wedge filters.

Although particular embodiments of the invention have been described and illustrated herein, it is recognized that modifications and variations may readily occur to those skilled in the art and consequently it is intended that the claims be interpreted to cover such modifications and equivalents.