*Short Communication*

# Four Low-Cost Monochromatic Sources of Known Equal Intensities[1]

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The lack of an inexpensive system to provide monochromatic radiation of known wavelength, and known, equal intensities led to a modification of the filter system described by Klein (1). These Carolina Monochromatic Light Filters, Carolina Biological Supply Company (CBS), were described by Klein (1) as giving monochromatic light of known wavelengths and intensities. We recently measured the radiation passed by these filters and found values (table I) which differ significantly from those reported by Klein. The present paper describes the apparatus used and the modifications necessary to obtain sources of known wavelengths and intensities.

The apparatus used in developing the modified filters is shown in figure 1. A 33 × 33 × 15 cm glass tank constructed with single strength window glass bonded by Silastic (Dow-Corning) was placed directly on the primary filter and contained the appropriate 10 cm deep aqueous filter.

Table I. *Comparison Between the Described and Measured Radiant Flux Densities Obtained Using Carolina Monochromatic Light Filters*

| Filter* | Source Wavelengths | Radiant flux density Described** | Measured*** |
|---|---|---|---|
| | nm | $\mu w \cdot cm^{-2}$ | |
| Blue | 400-517 | 250 | 15 |
| Green | 500-610 | 250 | 20 |
| Red | 600-708 | 250 | 7 |
| Far-red | 690-1000 | 250 | 6000 |

* CBS filters used in conjunction with the appropriate aqueous secondary filter contained in a glass tank.
** Klein (1).
*** Measured when using a 120 v, 500 w reflector flood bulb at 118 v, 69 cm from the direct incidence probe of the spectroradiometer.

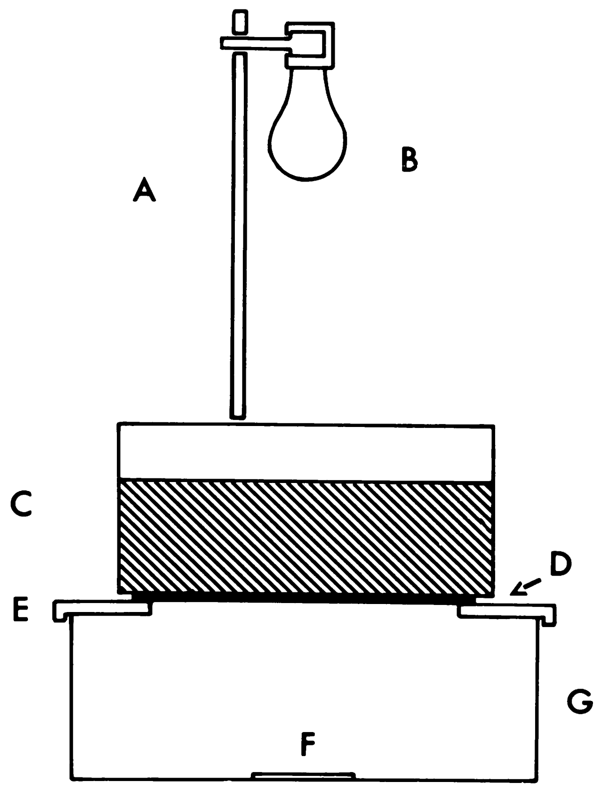


FIG. 1. Diagram of a cross section of the apparatus used to develop monochromatic sources. A) support stand for lamp; B) lamp; C) glass tank containing a 10 cm depth of the secondary aqueous filter; D) primary filter; E) plywood top of box; F) direct incidence probe of spectroradiometer; G) wooden box .

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Table II. *Conditions Used to Obtain Radiant Flux Densities*

| Radiant flux density | Blue* | | Green** | | Red*** | | Far-red† | |
|---|---|---|---|---|---|---|---|---|
| | Lamp size | Distance | Lamp size | Distance | Lamp size | Distance | Lamp size | Distance |
| $\mu w \cdot cm^{-2}$ | w | cm‡ | w | cm‡ | w | cm‡ | w | cm‡ |
| 0.1 | 40a | 70 | 25a | 67 | 25a | 85.5 | 25a | 80 |
| 0.2 | 60a | 67.5 | 40a | 63.5 | 25a | 62.5 | 40a | 73 |
| 0.5 | 100a | 60 | 60a | 58 | 60a | 65.5 | 100a | 73 |
| 1 | 75b | 60.5 | 100a | 54.5 | 100a | 62 | 75b | 85 |
| 2 | 150b | 79 | 75b | 60.5 | 75b | 69.5 | 75b | 62 |
| 5 | 300b | 71.5 | 150b | 68 | 150b | 77 | 150b | 69.5 |
| 10 | 500b | 71 | 300b | 66 | 300b | 77 | 300b | 63 |
| 20 | 500b | 55.5 | 500b | 63 | 500b | 71 | 500b | 63 |

* CBS blue plus 10 cm (1 % w/v) $CuSO_4 \cdot 5H_2O$.
** CBS green plus 10 cm (1 % w/v) $CuSO_4 \cdot 5H_2O$.
*** Two CBS red filters minus their neutral density components plus 10 cm (1.1 % w/v) $CuSO_4 \cdot 5H_2O$.
† Two CBS far-red filters plus 1 neutral density component from a CBS red filter plus the Cinemoid component from a CBS blue filter plus 10 cm ferrous ammonium sulfate solution. (1.8 kg $Fe(NH_4)_2\ (SO_4)_2 \cdot 6H_2O$ plus 200 ml concentrated $H_2SO_4$ in 10.5 l. water).
‡ Measured from the spectroradiometer probe to the base (junction between glass and metal of the lamp).
a 120 v standard frosted glass incandescent lamp at 118 v ± 0.5 v.
b 120 v reflector flood lamp at 118 ± 0.5 v.

The radiant energy sources used were either 120 v reflector flood lamps (500, 300, 150, or 75 w) or 120 v standard frosted glass incandescent lamps (100, 60, 40, or 25 w). They were suspended by a stand directly over the direct incidence probe of the spectroradiometer at distances (table II) measured to the nearest 0.5 cm from the probe to the base of the lamp (junction between the glass and metal of the lamp). The source voltage was maintained at 118 v ± 0.5 v by a constant-voltage power supply or variable autotransformer.

Spectral intensities were measured with a model SR Spectroradiometer, Instrumentation Specialties Company (ISCO), at West Virginia University, by means of the direct-incidence probe which was inserted in a hole cut in the base of a 41 × 38 × 15 cm wooden box. This box was covered with a 1.3 cm plywood top with a 27 × 27 cm window over which the filters were placed. The low-intensity sources were measured in the same manner as above but with a spectroradiometer of a different design (2) at Beltsville which had been modified to provide the necessary sensitivity. Both instruments were calibrated against standard lamps from the Bureau of Standards.

Intensities were measured at 25 nm intervals between 400 nm and 1000 nm. The value given by the spectroradiometer at each point was converted by the appropriate calibration factor into spectral intensity values in $\mu w \cdot cm^{-2} \cdot nm^{-1}$. Graphs of spectral intensity plotted versus wavelength were integrated to convert this information into total radiant flux density.

The final conditions for obtaining the 8 different intensity levels (20, 10, 5, 2, 1, 0.5, 0.2, and 0.1 $\mu w \cdot cm^{-2}$) with each of the 4 modified filter combinations (blue, green, red, and far-red) are given in table II. Graphs of the radiant energy from the 4 filter sources are given for 1 intensity level, 20 $\mu w \cdot cm^{-2}$, in figure 2.

These sources were measured within an accuracy of ± 5 %. The expected accuracy in setting up 1 of these sources using new lamps at 118 v ± 1 v should be within ± 15 %. Additional error from lamp ageing can be minimized by using relatively new lamps. Changes in lamp output with age can be checked with a light meter. Fluctuations in line voltage can be a major source of error since a 10 % change in voltage can give a 30 % change in light output.

No appreciable bleaching of the primary filters has been observed after over 6 months of use. Changing the copper sulfate solution every 6 weeks has been adequate in preventing the precipitation of a significant quantity of copper as the hydroxide.

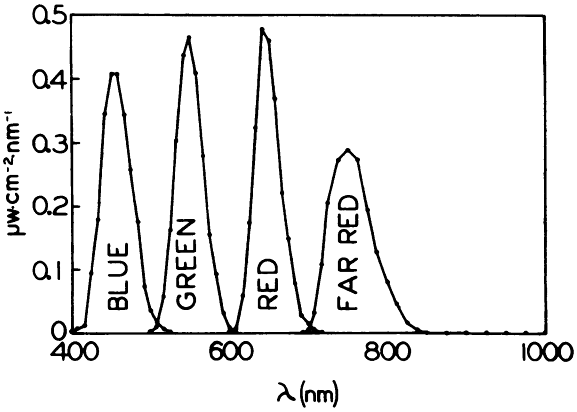


FIG. 2. Spectral distribution of energy from 4 monochromatic sources with radiant flux density of 20 $\mu w \cdot cm^{-2}$ from each source.

These sources give a uniform circular distribution of radiation over the sample area within the wooden box. The maximum variation within a circle of 6 cm radius was 10 %. These lamp and filter sources have stray light of less than 0.1 %, but care must be exercised in excluding external sources of radiation.

The plastic filters used were combinations of the components in the filters used by Klein (1) since these were readily available from the Carolina Biological Supply Company and were relatively inexpensive. The total cost of the components of 4 of the lamp-filter sources excluding the constant-voltage power supply and variable autotransformer was about $175.00. Each of the monochromatic sources is small enough to fit into a constant-temperature apparatus if necessary.

In summary: Components from the filters described by Klein (1) were used in designing simple monochromatic filter sources, adjusted so that equal intensities (20, 10, 5, 2, 1, 0.5, 0.2, and 0.1 $\mu w \cdot cm^{-2}$) can be obtained under blue (400–525 nm), green (500–610 nm), red (600–715 nm), and far-red (690–850 nm) filters.

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