Monochromator or graded spectrum filter?

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Summary. The suitability of monochromators for visual applications in petrographic mineralogy is discussed, and a new and inexpensive instrument employing a graded interference filter is described.

OF the apparatus required for the determination of indices of refraction by the Double Variation Method (Emmons, 1943, pp. 90 ff.), the monochromator represents the most expensive item. Other disadvantages of this instrument for this application include the critical nature of its adjustment in relation to the rest of the apparatus, and also the rather low light output intensity of the normal prism monochromator if full advantage is to be taken of the narrow bandwidth attainable by careful adjustment. A reasonably restricted bandwidth is, of course, desirable in a 'monochromatic' source, but is not essential for visual applications such as that envisaged here. Indeed, to quote Emmons (op. cit., p. 92) on the employment of the monochromator slit adjustment: 'Suitable results may be had by opening wide the ocular slit and closing the collimator slit. . . . On closing the ocular slit one colour band alone is chosen. Further adjustments of intensity should be made mainly with the ocular slit.' It is obvious that the high precision of adjustment of which the prism monochromator is capable is not usefully employed under this procedure: there is, however, no alternative if adequate light output is to be achieved without recourse to the provision of ultimate light sources of very high intensity. For these reasons it has been found desirable to consider possible alternatives to the standard prism-type monochromator.

The use of the quartz monochromator described by Hurlbut and Rosenfeld (1952) offers an eminently practical alternative. Unlike the prism monochromator, that of Hurlbut and Rosenfeld employs the optical rotatory power of quartz elements, each cut accurately normal to the optic axis. With four such elements the monochromator gives a bandwidth of about 150 Å (Hurlbut and Rosenfeld, op. cit., pp. 164–165); such a bandwidth does not appear to be excessive for use in the Double Variation Method for which the apparatus was specifically designed. A very real advantage offered by the Hurlbut and Rosenfeld monochromator is its relatively large areal aperture, limited only by the size of the quartz elements, which permits the transmission of a collimated beam such as may readily be produced by a suitably-adjusted high-intensity microscope lamp. Unfortunately the Hurlbut and Rosenfeld instrument is marketed at a price comparable with that of the highest quality prism monochromators.

Bandwidths of the same order as those effective, in practice, with the more expensive monochromators adjusted to give adequate output light intensity can be attained by the employment of optical interference filters of the metal-dielectric type. A filter of this kind consists essentially of a thin, uniform layer of a transparent dielectric substance —usually zinc sulphide—sandwiched between semi-transparent metal films, deposited *in vacuo* in the order metal: ZnS: metal on a plane glass surface. With this type of filter, the transmitted bandwidth may be of the order of 150 Å or possibly narrower, depending upon the particular spectral region concerned, with a transmission which may be as high as 30 % of the incident light over that bandwidth. The characteristics of filters of this type are discussed in a recent article by Henderson (1960). Although the minimum bandwidth realized in practice requires the incident light to be transmitted in a path normal to the filter plane, the high index of refraction of the dielectric ensures the absence of any serious adverse effect on the performance of the filter for angles of incidence less than 20° to the normal to the filter. For this reason, and since such 'monochromatic filters' may be had with apertures up to 2 in. diameter, they may be employed in conjunction with relatively large light sources. A set of such optical interference filters could therefore be chosen to give a series of transmission bands distributed at suitable intervals over the visible spectrum.

If, however, it is desired to retain the advantages which accrue from the ability to vary continuously the mean wavelength for the transmitted band, a Graded Spectrum Filter (1st order) may be employed. This may take the form of a strip filter in which the dielectric thickness varies uniformly along the length of the filter, so that the position of a transverse slit with respect to the latter may be used to select the required transmission band, the rest of the filter being suitably masked. As in the normal prism monochromator, the bandwidth of the light transmitted by the filter is necessarily affected by the width of slit employed and consequently this width requires to be adjusted to the minimum compatible with the adequate illumination of the 'work'. The calibration of such a filter (reproduced as fig. 1, curve *A*) shows that the variation of mean wavelength of the transmitted band is a nearly linear function of distance along the filter between wavelengths 4200 Å and 6700 Å, this range corresponding to about 4 in. of the length

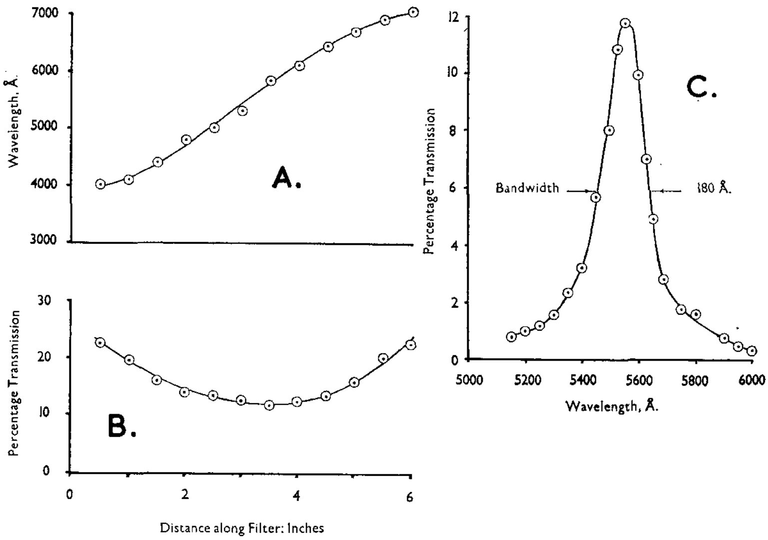

FIG. 1. Characteristic curves for graded spectrum interference filter of strip form (6 in. × 1½ in.) masked 1·5 mm slit width. *A*, variation of wavelength of peak transmission along length of filter. *B*, variation of percentage transmission with position along length of filter. *C* transmission/wavelength characteristic for mid-point of filter.

of the filter. The minimum percentage transmission (12 %) with slit 1·5 mm wide occurs about midway along the length of the filter (compare fig. 1, curve *B*) and corresponds to a minimum bandwidth of 180 Å as shown in fig. 1, curve *C*. At the ends of the filter, higher transmission is associated with increased bandwidth; nevertheless, over the most useful range of the spectrum the bandwidth remains sufficiently restricted for visual purposes. An annular graded spectrum filter, in which the visible spectrum may be extended to over two feet long (according to size), is now available with transmission bandwidth of the same order as in the strip filter already described.

In order to utilize the strip-form 1st order graded filter, a simple form of holder has been devised (see fig. 2). As it is convenient to hold the mask and slit stationary and to move the filter with respect to the slit, a metal masking plate pierced centrally by a one-tenth inch wide vertical slit is supported by an adjustable arm, which in its turn is clamped to a vertical column projecting from a wide baseplate. The filter

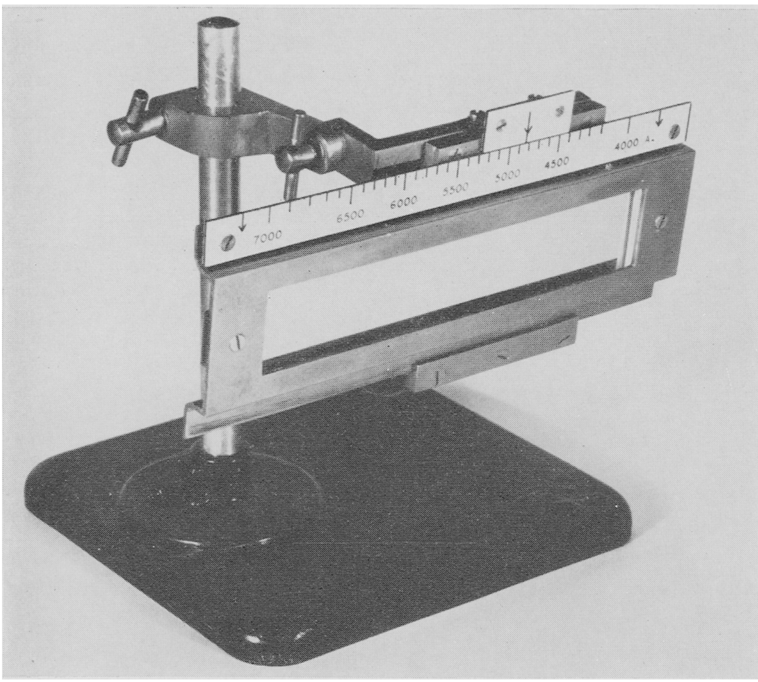

FIG. 2. Graded spectrum filter in adjustable mounting.

element, its length horizontal, is mounted in a carrier, the horizontal (long) edges of which slide in grooves mounted at the upper and lower edges of the slotted masking plate. The upper edge of this plate bears an index mark aligned with the centre-line of the slit, and the upper edge of the filter carries the corresponding wavelength scale. The edges of the slit and the surfaces of the masking plate are blackened with a matt paint in order to reduce stray reflections, especially between the latter and the almost specular surface of the filter. An elongated window in the front of the carrier exposes about five-and-a-half inches length of the filter strip. In use, the light-source (a focusable high-intensity microscope lamp is suitable) is arranged to illuminate the slit from the rear. With a slit one-tenth of an inch wide, the bandwidth of the light transmitted is about 250 Å for a setting near to the middle of the filter (5500 Å). An adjustment to the slit width could be incorporated to limit the bandwidth to a lower value, but it is doubtful if this refinement is called for in practice.

The apparatus just described has been used with completely satisfactory results in index of refraction determinations, and has also proved valuable in the demonstration of optic axial dispersions of minerals in convergent light. For such purposes it represents at once a highly effective and economical alternative to the very much more costly monochromators.

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