THE CHRISTIANSEN EXPERIMENT*

THE present article is concerned with the phenomena observed in the well-known optical experiment embodying the principle of the so-called Christiansen filters used for isolating monochromatic radiation from white light. A transparent isotropic solid is powdered and placed inside a flat-sided cell of glass, and the latter is then filled up with a liquid of which the refractive index is adjusted to equality with that of the powder for any desired wavelength in the spectrum. The cell then becomes optically transparent for such wavelength, which the rest of the spectrum is not transmitted but only diffused in its passage through the cell.

The material usually recommended for use in Christiansen filters is powdered glass which needs to be specially prepared. We have found that a convenient substance to employ in experimental studies of the Christiansen effect is hexamethylenetetramine, also known as hexamine or urotropin, which is both inexpensive and readily available as a crystalline powder. Hexamine is optically isotropic and its refractive index is intermediate between those of benzene and carbon disulphide in either of which it is nearly insoluble. Beautiful chromatic effects are observed when hexamine powder is placed in a cell and filled up with a mixture of benzene and carbon disulphide in the proportion of roughly one to four. For visual observations, it is convenient to employ, instead of a flat-sided cell, a stoppered hollow prism of 60° angle to contain the material. The advantage of doing this is that the prism functions both as a containing cell and as a dispersing apparatus. All that is necessary is to view the incandescent filament of an electric lamp from a distance through the prism held close to the eye. The spectral character of the transmitted light then becomes immediately evident, and by moving the eye to different positions on the prism face, the various effects described and illustrated below may be observed.

---

* Sir C. V. Raman, "The Theory of the Christiansen Experiment," *Proc. Ind. Acad. Sci.*, 1949, **29A**, 381-90. See also, *1949*, **30**, *211-15* and *277-83*.

The spectral character and intensity of the transmitted light in the Christiansen experiment is influenced by several factors, of which the depth of the column through which the light filters is of particular importance. The set of six spectrograms reproduced in Fig. 1 exhibits

FIG. 1

the sharpening of the spectral band of transmission with increasing thickness of the filter; the uppermost corresponds to a thickness of 18 millimetres and the lowest to 1·5 millimetres. The exposure given had to be greatly increased with increasing thickness of the material so as to record the transmitted light with approximately the same intensity.

The size of the particles of the powder is also of great importance in determining the spectral character of the transmitted light. This effect is illustrated in the series of four spectrograms reproduced in Fig. 2. These were obtained with

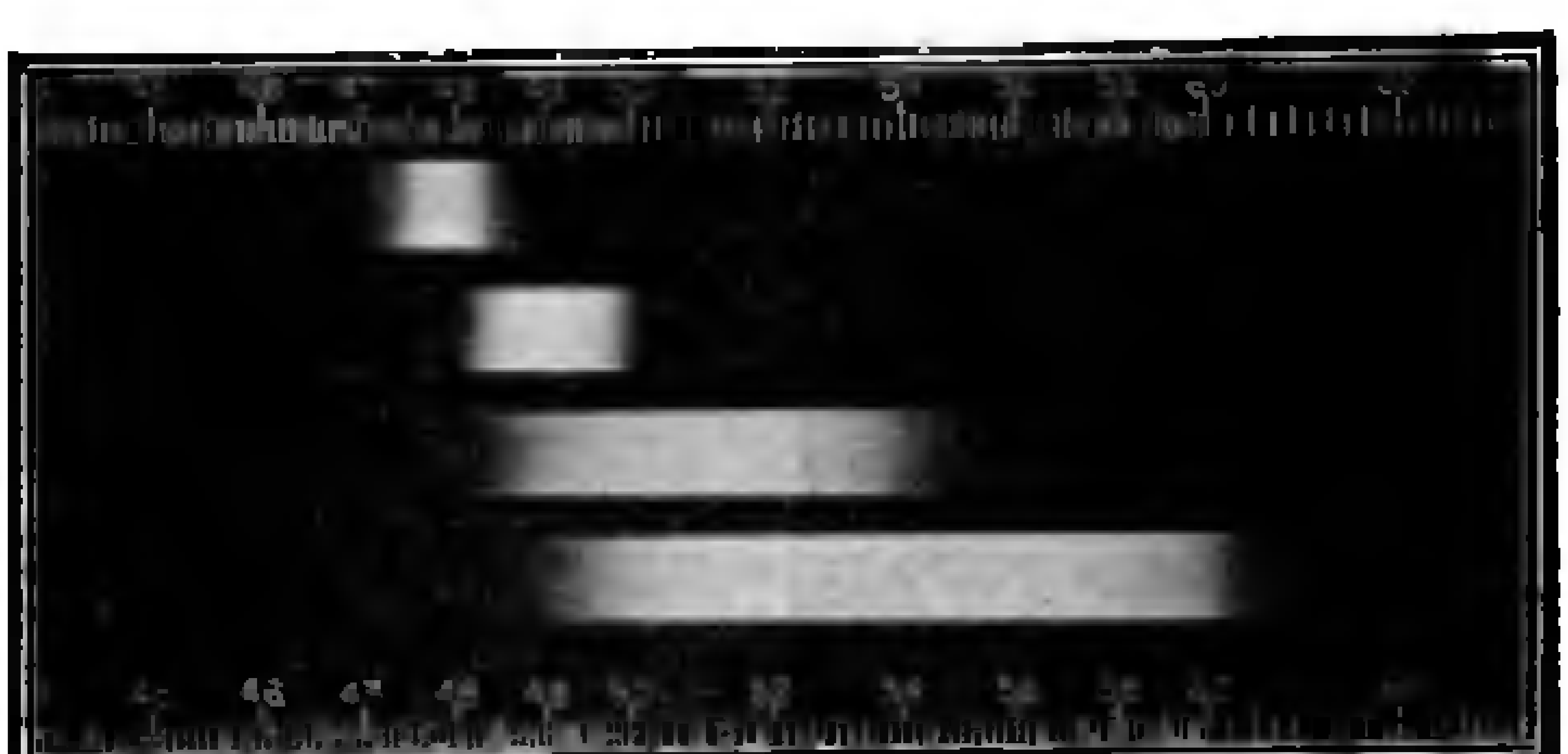

FIG. 2

powdered glass the particles of which had been graded by sieving and elutriation into four groups having respectively as average diameters 300 μ, 100 μ, 18 μ and 9 μ, the thickness of the layer traversed being the same, *viz.*, 3 mm. The composition of the benzene-carbon disulphide mixture covering the powder was also adjusted to be as nearly as possible the same in the four cases. From the figure it will be seen that spectral width of the transmitted light becomes very great when the particle size is small. The widening is also totally unsymmetrical; the spectrum stretches further and further towards the red, while its short wavelength limit remains unaltered.

The series of spectrograms reproduced as Fig. 3 exhibits another effect of interest. They

FIG. 3

were obtained by focussing the light of a carbon arc on the slit of a spectrograph after passage through a cell containing hexamine powder suspended in a considerable excess of a benzene-carbon disulphide mixture. In the first of the series, the powder was distributed more or less uniformly throughout the entire volume of liquid. The subsequent spectrograms were recorded at short intervals of time following each other as the powder settled down in the cell, finally leaving the region traversed by the light beam nearly free of suspended powder except for the finest particles of all. The progressive increase in the spectral width of the transmitted light is particularly conspicuous in the last few spectrograms. The unsymmetrical character of this broadening is also strikingly evident. The effects noticed are a consequence of the diminishing quantity of suspended solid which is effective as well of the increasing fineness of its particles. The former of the two effects can be demonstrated separately by comparing the character of the transmitted light when the powder has all settled down to the bottom of the cell with that observed when the powder is distributed uniformly throughout the volume of the liquid.

The difference in the dispersive powers of the solid and the liquid also plays a decisive role in the Christiansen experiment. This becomes particularly obvious when this difference is very small. The series of spectrograms reproduced in Fig. 4 shows the spectral character of the light transmitted through different thickness of potassium chloride powder immersed in tetrachloroethane (symmetric), to which a few drops of carbon tetrachloride had been added. Practically the whole of the spectrum appears in the transmitted light when the thickness of the layer is a millimetre or two. A thickness of nearly a centimetre is necessary before any concentration of intensity in the region of equality of refractive indices of the solid and the liquid becomes noticeable. Even so, the transmission extends to the extreme limit of sensitiveness of the photographic plate in the red, while on the other hand, there is a complete cut-off on the violet side. Very different results are obtained when, instead of tetrachloroethane, either toluene or an acetone-carbon disulphide mixture is employed. These liquids have a much higher dispersive power than potassium chloride.

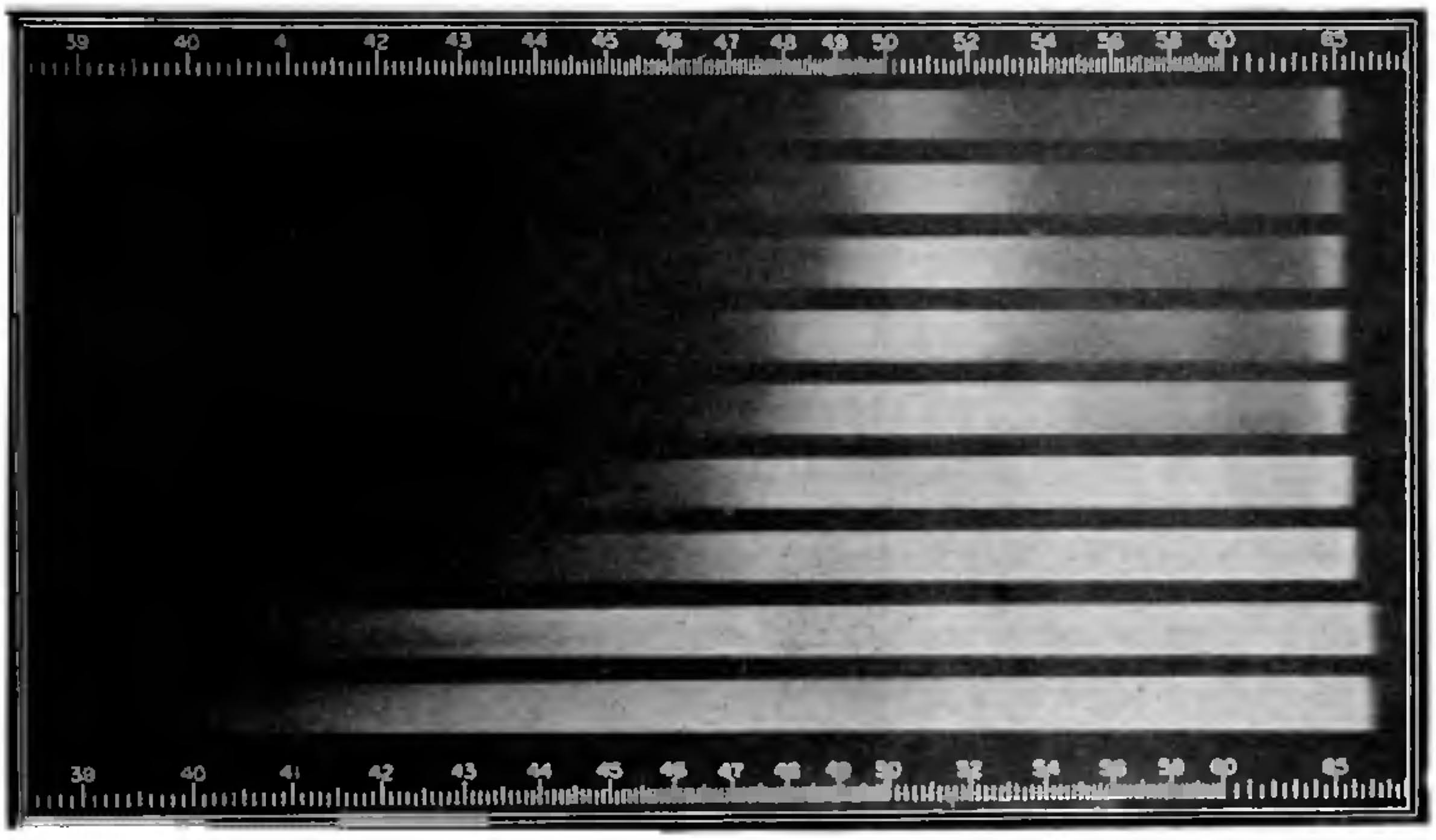

Fig. 4

On a superficial view, one may be tempted to believe that the optical behaviour of a Christiansen filter is a matter of geometrical optics, the part of the spectrum at which there is equality of refractive index coming through without deviation, while the rest of the light is diffused as a result of multiple reflections and refractions. Such an explanation of the action of the filter is, however, not only inadequate but definitely misleading as can be seen from the facts set out and illustrated in this article. In a paper published recently and referred to above, an attempt has been made to deal with the subject from the standpoint of wave-optics. The expressions developed in that paper for the extinction coefficient of a Christiansen filter afford at least a general explanation of the facts of observation set forth in the present article. It appears not unlikely however that a fresh approach from the standpoint of the electromagnetic theory of light may be necessary to give a more complete account of the observed phenomena.

C. V. Raman.
M. R. Bhat.