High Dispersion Prism Spectra. By J. Evershed, F.R.S.

In designing a spectrograph and a spectroheliograph for my observatory at Ewhurst five years ago, I was faced by a very serious difficulty in providing for sufficient dispersive power for the work I intended to undertake. I had available two 45° prisms of 6-inch aperture, which I had used successfully in Kashmir for photographing prominences and calcium flocculi in the H or K lines. For this purpose sufficient dispersion was obtained by single transmission through the prisms and a camera lens of 7 feet focal length. In my new observatory I intended to photograph the sun in the hydrogen line α, which requires much greater dispersion in the red, and in addition I wished to continue the study of line-of-sight motions in prominences and sunspots which was begun at Kodaikanal. To make any progress in this kind of work very great dispersive power is essential.

It seemed doubtful whether sufficient dispersion could be obtained

with the prisms, especially for work at the red end of the spectrum, and the obvious course was to procure a grating, such as I had been accustomed to use in Kodaikanal. Large gratings are, however, very difficult to obtain at the present time, and negotiations proving unavailing, I was compelled to make the attempt with prisms.

In order to get a reasonably high dispersion, I arranged the prisms in an auto-collimating Littrow spectrograph with a plane mirror to return the light, giving the equivalent of four prisms. The result was disappointing, for I found the definition of spectrum lines, although good enough with single transmission and a 7-foot camera, failed entirely with double transmission and a 16-foot camera, owing to the want of homogeneity in the large blocks of glass.

The next step was to have the prisms reannealed and refigured, an expensive and rather risky proceeding, which might or might not give good results. Fortunately the reannealing, in the hands of the Parsons Optical Company, and the figuring by Adam Hilger Ltd. was entirely successful. On receipt of the perfected prisms, in June 1925, I was able to complete the construction of the spectroheliograph. The definition of spectrum lines then appeared perfect, and spectroheliograph work was started in the autumn of that year. I was able to photograph prominences at the limb, and markings on the disc in Hα light. In the H and K region the dispersion was sufficient for line shift work in the prominences.

The dispersive power between H and K was 0·8 mm. to the angstrom unit, and at Hα about 1 mm. to 8 angstroms. This dispersion in the red is too small for the best results with the spectroheliograph for hydrogen images, as a very narrow second slit has to be used to isolate the central part of the red hydrogen line. In practice, the second slit should not be much narrower than $\frac{1}{10}$th of a millimeter, which is about the width of the hydrogen line on this scale.

It appeared that a great improvement would result if I could replace the silvered mirror at the back of the prisms by a 30° reflecting prism, of equal aperture, which would add the equivalent of a 60° prism to the dispersing train, and secure the advantage of an internal reflecting surface. I was most fortunate at this stage to receive a visit from Professor Turner, who strongly advised an application to the Government Grant Committee of the Royal Society for funds for the construction of a large reflecting prism. The trouble was to produce a large block of glass of the necessary homogeneity, and after a year or so of ineffectual attempts this appeared a rather hopeless undertaking. I consider that it is entirely due to Professor Turner's continued interest and helpful influence that finally, this year, a beautiful piece of glass has been produced by the Parsons Co., and worked to perfection by Messrs. Hilger.

The prism was installed in my spectroheliograph in September, and has proved a great success. The hydrogen line is now considerably wider than the second slit, and the definition of spectrum lines is as perfect as could be wished.

Using the instrument as a spectrograph, the angular dispersion in

the H and K region now exceeds that given by the third order of a grating of 15,000 lines to the inch, so that if I had a large grating in the place of the prisms, and the same 16-foot lens, I should get nothing better, nor so good, as grating spectra in the higher orders give a certain amount of scattered light, to say nothing of ghosts. The prism spectrum gives beautiful contrast and perfectly defined emission lines of arc spectra. Of course the prisms cannot compete with a grating for work in the visible part of the spectrum towards the red end.

The actual linear dispersion between H and K is just over 1 mm. to the angstrom unit, but it falls off rapidly towards the blue, so that at λ 4500 it is about $\frac{1}{2}$ mm. to the angstrom. For studying line-of-sight movements in sunspots, in the region between Hβ and Hγ, at least double this dispersion is necessary, and for this work I have for long been experimenting with a hollow prism containing ethyl cinnamate.

This liquid has a remarkably high dispersive power. I find the refractive index is equal to that of the glass walls of the prism for green light, but greatly exceeds ordinary glass in the violet. As the liquid is non-volatile, it is not difficult to maintain a uniform temperature, even when the surface is exposed to the air. I find that it is possible to maintain absolutely uniform refracting power throughout the prism for an hour or two. This condition of uniformity has never been secured in large blocks of glass, especially the denser kinds which give comparable dispersion. In using the prism it is necessary to employ a small stirrer worked by an electric motor, to mix the liquid occasionally.

Until recently I have had only partial success with the cinnamate prism. It has, in fact, entailed a large amount of wasted effort, ending with a bad but not fatal accident to the prism, which might well have put an end to further experiments, but actually gave me a clue which has led to final success.

The most serious difficulty was the distortion of the surfaces of the prism, due to the action of the cement; and another trouble was the short time after stirring the liquid that definition remained good.

After many experiments I have now, I think, completely overcome these defects.

A new prism was made by Messrs. Hilger, in which the sides are worked to perfect planes, and the edges of the plates, and the other parts of the prism, are carefully worked true and polished. By a clever manipulation the prism was assembled and fitted together without cement, the parts being pressed into optical contact. This prism gave perfect definition, but failed after a few weeks, from the fact that the cinnamate slowly made its way between the parts in optical contact, and finally the prism leaked. I then took the plates apart, cleaned them, and reassembled the prism, using a cement that does not require strong heating. This up to the present has proved quite successful, and the prism is now permanently installed in an underground chamber, ready for high dispersion work. It is only necessary to run the stirrer for one minute, after which it may be left for an hour or two before a second stirring becomes necessary.

The effective aperture of the prism is nearly 4 inches, and it is backed by a 30° glass reflecting prism in an auto-collimating spectrograph of about 16 feet focal length. Spot spectra taken with this instrument are comparable with the best grating spectra. The scale is 1 mm. to the angstrom at λ 4500, and the definition of the lines is perfect. In the H and K region the scale is 2 mm. to the angstrom, but the exposure time here is four minutes, instead of about as many seconds, which is all that is required at λ 4500. I might mention that commercial cinnamate is usually slightly coloured, and is very absorptive for the H and K region. To get over this difficulty, a chemical friend, Mr. Saville of the Royal Institution, very kindly redistilled my cinnamate at an extremely low pressure, producing a perfectly colourless liquid. This reduces exposure times to a minimum. I hope eventually to use both cinnamate prisms in train together. This would give over 2 mm. per angstrom at Hγ, and 1⅓ mm. at Hβ.

From the experience I have gained in working with these prisms, I am hopeful that a much larger prism could be made, and successfully used in a spectroheliograph or spectrograph.

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