ART. XXIX.—*A Spectroscope without Prisms or Gratings*;
by A. A. MICHELSON.

THE resolving power of a diffraction grating is proportional to the product of the total number of lines by the order of the spectrum observed. But little effort seems to have been made to make a decided step in the direction of increasing the *order* of the spectrum observed, and this is doubtless because for a grating acting by *opacity* the brightness of the spectrum diminishes very rapidly as the order increases. This difficulty has been successfully overcome by ruling the lines in such a way as to concentrate the greater proportion of light in one spectrum, but so far as I am aware such attempts have been limited to the first, second or third spectrum and the results even here are somewhat fortuitous.

It seems nevertheless quite possible to construct gratings which shall throw a quite large proportion of the light in very high orders of spectra—say the hundredth—in which case the grating space must be of the order of a hundred waves or say twenty to the millimeter, instead of a thousand. The lines would have to be drawn with no more accuracy than before, and the grating could be completed in a very short time and temperature changes would have a much smaller effect than at present.

It may be that there are more serious practical difficulties in the way of such a ruling as is represented in fig. 1 than would

be anticipated. Especially may this be true if the greater part of the light is to be returned in the direction from which it

came; for that the grooves must be correspondingly deep, and the grating space would vary with the depth. Fig. 1 at once suggests a possible method of effecting the same result, by building up the steps by equal thicknesses of optical glass. Here the difficulty, even supposing the optical work to be practically perfect, would be the joining of the separate plates in such a way as to have always the same distance between them.

By using the same arrangement for transmission instead of reflection this difficulty is avoided—and there remains absolutely nothing but the difficulty of making a considerable number of plane-parallel plates of the same thickness—to an order of accuracy only one-fourth that required in the former arrangement, or even one-tenth of this if the other medium be water or oil instead of air.

Probably the surprising thing is the smallness of the number of plates required to give results which are comparable with those of the best gratings. This can be shown as follows:

let abd (fig. 2) be one step in the series of plates and let $ab = s$ and $bd = t$. If m is the order of the spectrum observed, $m\lambda = \mu \cdot bd - ac$ or

$$m\lambda = \mu t - t \cos \theta + \delta \sin \theta.$$

$$\frac{d\theta}{d\lambda} = \frac{m - t \frac{d\mu}{d\lambda}}{t \sin \theta + \delta \cos \theta}$$

$$\frac{d\theta}{dm} = \frac{\lambda}{t \sin \theta + \delta \cos \theta}$$

and if $\delta\theta$ is the displacement corresponding to $\delta\lambda$ and $\delta\theta$, that corresponding to $\delta m = 1$, assuming Cauchy's formula $\mu = a + b/\lambda^2$, and taking the approximate value of $m = (\mu - 1)t/\lambda$, we have

$$\delta\theta/\delta\theta_1 = [(\mu - 1) + 2(\mu - a)] \frac{t}{\lambda} \cdot \frac{\delta\lambda}{\lambda}.$$

For ordinary glass the coefficient of t/λ is approximately equal to unity; so that if $\frac{\delta\lambda}{\lambda} = .001$ as in the case of the two sodium lines, and $t = 5^{\text{mm}} = 10000 \lambda$, then $\delta\theta = 10 \delta\theta_1$, that is, the sodium lines would be separated by ten times the distance between the spectra.

The resolving power of such a combination is mn , exactly as in the case of gratings; so that with but *twenty* elements 5^{mm} thick and hence $m = 5000$ the resolving power would be 100000, which is about that of the best gratings.

The experiment was actually tried with but *seven* elements, placed between a collimator and an observing telescope and the collimator slit illuminated with light from a sodium flame. The images were so distinct that the broadening of the lines could be very easily detected, and the Zeeman effect was readily observed when the sodium flame was placed in a magnetic field.

It is important to note that the resolving power is independent of the number of plates but depends only on the total thickness, and the only advantage in a large number of elements is the greater separation of the spectra. The overlapping of spectra is doubtless a disadvantage, which however could be overcome by a preliminary analysis; and for the examination of single lines and especially in the investigation of effects of broadening, shifting or doubling of lines, the method seems especially well adapted. A battery of twenty plates has been ordered and it is hoped that further results will be obtained within a few weeks.

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