

XVIII.—*On the Bands formed by the Superposition of Paragenic Spectra produced by the Grooved Surfaces of Glass and Steel.** PART I. By Sir DAVID BREWSTER, K.H., F.R.S. Lond. and Edin. (Plate XXII.)

(Read 7th March 1864.)

In examining the colours produced by thin laminæ of the crystalline lens of fishes, I observed a series of rectilineal serrated fringes perpendicular to the direction of the fibres, and produced by inclining the laminæ in a plane cutting these fibres at right angles. I was thus led to imitate these fringes or bands by combining grooves or striæ cut upon glass or steel surfaces, or grooves taken from these surfaces upon isinglass or gums.

In my first experiments I combined a system of grooves on glass, executed for me by Mr DOLLOND, with a similar system on steel executed by Sir JOHN BARTON, both of them containing 2000 divisions in an inch. The plate of glass was placed above the plate of steel, and slightly inclined to it, as shown in Plate XXII. figs. 1 and 2. The glass plate ABCD, fig. 2, was covered with grooves, but the steel plate below it was grooved only on the shaded portion *abcd*, the parts *AaCc*, *BbdD* being polished so as to reflect to the eye at E (fig. 1), the grooves on the glass when illuminated by rays, *Rr*, proceeding from the first pair of the paragenic spectra produced by the grooves.

When the direction of the grooves *ac* is nearly parallel to the plane of reflexion, and to one another, a series of minute serrated bands is seen on the space *abcd*, where the light has been transmitted twice through the grooves on glass, and reflected once from those on steel; but no bands are seen upon *AacC*, *BbdD*, where the steel was only polished.

When the grooves were slightly inclined to the plane of reflexion, large serrated bands appeared upon the spaces *AacC*, *BbdD*, and when this inclination was increased, these large bands became smaller and more numerous, crowding towards *Cc* and *dD*. On the other hand, they become larger and larger as the direction of the grooves returned into the plane of reflexion. In the azimuth of 0° they become straight, and by increasing the azimuth, they pass, as it were, to the right hand, as shown in fig. 3.

When the direction of the grooves is inclined to the plane of reflexion, the minute serrated bands upon *abcd* become smaller and less serrated.

* In a very interesting paper on the Spectra produced by Gratings or Grooved Surfaces, M. BABINET has given them the appropriate name of *Paragenic*, in order to distinguish the Spectra produced by refraction from those produced by the lateral propagation of light. “*Sur la Paragenie ou propagation laterale de la lumiere.*” Paris, 1864. Extrait du Cosmos.

When the inclination $mnNM$ of the grooved plates is increased, the large bands become smaller and smaller, and when it is diminished, they become larger and larger, getting inclined as in fig. 3, and becoming parallel at 0° of inclination.

Having been provided, by the kindness of Sir JOHN BARTON, with two grooved plates of glass containing 500 divisions in an inch, I was enabled to examine the fringes on the paragenic spectra under different circumstances.

When the grooved surfaces of the plates were placed in contact, and the grooves formed a small angle with one another, the middle or principal image, A (fig. 4), when observed with a lens whose anterior focus coincided with the grooves, had no bands, but the paragenic spectra a, c, b, d , on each side had numerous serrated bands or fringes perpendicular to the direction of the grooves, the number on the first spectra a, b , being at the rate of 19 in an inch of the luminous disc, and increasing in arithmetical progression.

When the luminous object is rectangular, and the rectangular paragenic spectra are brought nearly into contact, as at ab and cd (fig. 5), the bands, as seen at nearly a perpendicular incidence, are shown in this figure.

When the incident light is inclined to the direction of the grooves, the bands suffer no change, and appear immoveable on the surface of the glass plates.

When the ray of light is perpendicular to the direction of the grooves, and the surface of the glass on which they are cut is inclined to the ray of light, the bands all descend from a to b (fig. 5), moving off, as it were, at b , and d , and succeeded by others when the angle of incidence increases, while they ascend from b to a , and from d to c ; moving off at a and c , when the angle of incidence diminishes. In this case, the grooves of the plate next the eye are turned to the left, the opposite motions taking place when they are turned to the right.*

The bands correspond to the intersection of the one set of grooves with the other set, and consequently they diminish in number, and recede from one another when the inclination of the one set of grooves to the other diminishes, becoming parallel to the grooves when the grooves on both plates are parallel.

Interference bands, parallel to the grooves, may be seen by transmitted light upon the paragenic spectra, when two systems of grooves are placed parallel to each other, and when the grooves in the one system are parallel to those in the other. They are seen both at a perpendicular incidence and when the plates are inclined in a plane parallel to the grooves.

These bands become narrow as the distance of the two grooved surfaces is increased, and they are seen at all angles of incidence, and in all planes of reflexion from the grooved surfaces.

I have observed those bands, which are generally more or less serrated, in com-

* This motion of the bands is not seen when the grooved surfaces are perfectly parallel.

binations of 1000 with 1000, 1000 with 2000, 1000 with 500, 2000 with 500, and in the combination of four surfaces of 2000, 1000, 100, and 500.

In the combination of 1000 and 500, and in no other, a very peculiar system of bands is seen with a lens. They are not serrated, and not perpendicular to the grooves. The system consists of two sets equally inclined to the direction of the grooves, when the grooves in one plate are slightly inclined to those in the other. By diminishing the inclination of the grooves, the inclination of the bands to the direction of the grooves diminishes, and when the grooves become parallel, the bands become parallel and disappear.

These bands must have a different origin from those previously described, as they are similar in number upon all the prismatic images.

In these experiments the duplication of the bands on the second spectrum, and their increase in arithmetical progression on the other spectra, is a remarkable fact which it is difficult to explain. The second spectrum differs only from the first, and the third from the second, only in their length; and we can hardly suppose that they have a property in a direction perpendicular to their length, or to FRAUNHOFER'S lines, which would increase the number of their bands.

The bands which we have described are more distinct when the spectra are pure or formed from a narrow line or bar of light; but when we wish to see the bands on the bar of light or the central image *O* (fig. 4), the spectra must be formed from wide spaces which gave impure spectra.

In order to examine the interference bands under different conditions, I placed (as in fig. 6) a plate of polished steel at different distances from another plate of steel, containing six systems of grooves executed by Sir JOHN BARTON, varying from 312·5 divisions in an inch to 10,000. When the light was reflected twice from the grooved surface and once from the plain steel surface, the bands which covered the colourless image and the paragenic spectra were splendid beyond description, and unlike anything of the kind that I had previously seen.

1. The bands were parallel to the grooves, or to the lines in the spectra.
2. They are smaller and more numerous when the grooves are wider or fewer in an inch.
3. They become smaller and more numerous when the distance of the plates is increased.
4. They are smaller and more numerous when the angle of incidence is increased.
5. They become more numerous by increasing the number of reflexions.
6. They appear like minute black lines upon the colourless image, but when their magnitude is increased, they appear like blue or pink bands on a ground of a different colour, which is generally white or whitish blue.

These bands were visible on the systems of grooves, 312·5, 625, 1250, and 2500 in an inch, but not on the systems of 5000 or 10,000 in an inch.

When the spectra had suffered three, four, five, and six reflexions, the central and other images were covered with the same number of bands, as with two reflexions from the grooved steel; but another series of wider bands was superposed.

The following results were obtained with grooved surfaces having 1250 divisions in an inch:—

Distance of plates,	0.11 inch.	Angular breadth of each,	7° 50'
Distance of circular disc,	115.5 inches.	Distance of plates,	0.22 inch.
Diameter of disc,	1.317 inch.	Angle of incidence,	63° 30'
Angle of incidence,	63° 30'	Number of fringes on the disc, and } on the first spectrum,	10
Angular diameter of disc,	39° 30'	Angular breadth of each,	3° 55'
Number of fringes on disc, and } on the first spectrum,	5		

In order to observe the effect produced by varying the angle of incidence, I placed a luminous disc three inches and six-tenths in diameter* at the distance of nine feet six inches from the grating, and obtained the following results:—

Angle of Incidence.	No. of Bands on the Disc.	Angle of Incidence.	No. of Bands on the Disc.
70	29	50	17
60	21	40	14

The bands were seen at an incidence of $87\frac{1}{4}^\circ$, when the plates were nearly in contact.

The following were the colours seen on the two spectra on one side of the colourless image; but I have not measured the precise angle of incidence at which they were seen, nor mentioned in my journal whether they were seen with the 625 or the 1250 grating:—

First Spectrum.		Second Spectrum.	
Great Incidences	White. Pale Red. Red. Purple. Blue. Bluish. Less Blue.	Great Incidences	Blue. Bluish. Less Blue. Bluish White. White. Pale Red. Red.
Lesser Incidences	White.	Lesser Incidences	{ Purple. Blue.

At small angles of incidence, about 42° , the bands become less distinct, and paler in colour, the white becoming yellow and the blue brownish.

In the systems of grooves, whether on glass or on steel, employed in the preceding experiments, the part of the original surface not removed by the grooves bears a very considerable proportion to the part removed; but when the grooves occupy a large part of the surface, and the intermediate parts a very small one, a new set of phenomena are produced, which must change in a remarkable manner all the bands of interference. The execution, however, of such systems

* This disc included part of the spectrum on each side of the bright image.

of grooves is very difficult. Sir JOHN BARTON, with all his experience, failed in producing good specimens ; but even with those which he executed for me, phenomena of a remarkable kind were exhibited, not only on the middle or colourless image, but upon all the paragenic spectra, varying with the number of grooves, but still more remarkably with the angle of incidence.*

P.S.—The preceding experiments were made in 1823 and 1827, and those described in p. 223, were repeated in 1838. Having lost or mislaid the glass gratings which I then employed, I am not able to compare the bands which they produced with a more remarkable series which I have recently obtained with new gratings, and which will be the subject of another communication.

* See Phil. Trans. 1829, p. 301.

Fig. 1

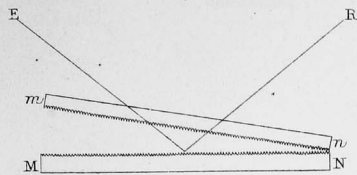


Fig. 2

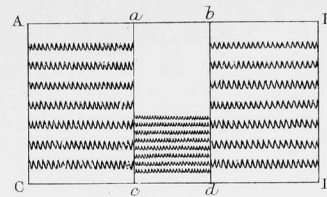


Fig. 3

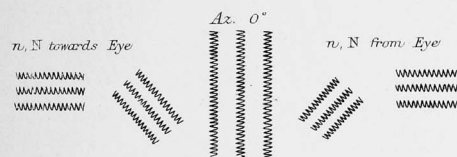


Fig. 4

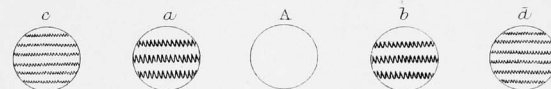


Fig. 5

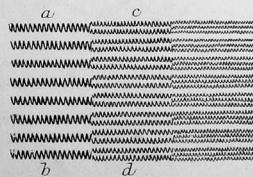


Fig. 6

