XXV. *On a new series of periodical colours produced by the grooved surfaces of metallic and transparent bodies.* *By* DAVID BREWSTER, *L.L.D. F.R.S. L. & E.*

Read May 21, 1829.

IN the year 1822, when I received from Mr. BARTON some very fine specimens of his Iris ornaments, I availed myself of the opportunity of performing a series of experiments on the action of grooved surfaces upon light. As the subject was to a certain extent new, many of the results which I obtained seemed to possess considerable interest, and I accordingly communicated to the Royal Society of Edinburgh a general account of them, which was read on the 3rd of February 1823. The interruptions, however, of professional pursuits prevented me, but at distant intervals, from pursuing the inquiry; and having found that M. FRAUNHOFER was actively engaged in the very same research, with all the advantages of the finest apparatus and materials, I abandoned the subject, though with some reluctance, to his superior powers and means of investigation. During a visit paid to Edinburgh by the Chevalier YELIN, a friend of FRAUNHOFER's and a distinguished member of the Academy of Sciences of Munich, I showed him the general results which I had obtained; and as he assured me that the phenomena which had principally occupied my attention had entirely escaped the notice of his friend*, I was thus induced to resume my labours, the results of which, in relation to one branch of the subject, I shall now submit to the consideration of the Society.

When a flat and polished metallic surface is covered with equal and equidistant grooves, we may characterize it by the relation of two quantities, one of which m represents the breadth of each groove, or of the surface that is removed, while the other n represents the breadth of the intermediate space, or

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* The memoir of M. FRAUNHOFER was read to the Bavarian Academy of Sciences on the 14th of June 1823; and has no relation to the subject of this paper.

of the original surface that is left. If the image of a candle is seen by reflexion from such a surface, the trace of the plane of reflexion being parallel to the grooves, we observe the colourless image of a candle in the middle of a row of prismatic images arranged in a line perpendicular to the grooves. The colourless image of the candle is formed by the original portions n of the metallic surface, while the prismatic images are formed by the sides of the grooves m. This may be demonstrated ocularly by increasing m, and consequently diminishing n till the latter nearly disappears. In this case the intensity of the prismatic images rises to a maximum, while the ordinary colourless image becomes extremely faint, and vice versâ. The general phenomena of the prismatic images, such as their distance from the common image, and the dispersion of their colours, depend entirely on the magnitude of $m + n$, or the number of grooves and intervals that occupy any given space; and the laws of these phenomena have been accurately determined by M. Fraunhofer.

In the course of my examination of the prismatic images, I observed in some specimens an unaccountable defalcation of particular colours, varying with the angle of incidence, and sometimes affecting one of the images and not the others. It sometimes appeared in close and sometimes in wide systems of grooves, and from the symmetry of its effects, it became obvious that it was not owing to any accidental cause. In the specimen in which it was most distinctly seen, I was surprised to observe that the white image reflected from the original surface of the steel was itself slightly coloured; that its tint varied with the angle of incidence, and had some relation to the defalcation of colour in the prismatic images.

Hitherto I had used a small disc of light, but in order to observe through a great range of incidence I employed a long narrow rectangular aperture, which gave a convergent beam of 30° or 40°. I thus saw a series of very interesting phenomena. The ordinary image of the aperture, as formed by the spaces n, was crossed in a direction perpendicular to its length, with broad coloured fringes varying in their tints from 90° to 0° of incidence. This remarkable effect I observed in various specimens, having from 500 to 10,000 grooves in an inch. In a specimen with 1000 grooves in an inch, or in which

$m + n =$ 1000dth of an inch, no less than four complete orders of colours were developed as shown in the following Table.

	°	′		°	′
White	90	00	Bluish green	54	30
Yellow	80½		Yellowish green	53	15
Reddish orange	77½		Whitish green	51	
Pink	76	20	Whitish yellow	49	
Junction of pink and blue	75	40	Yellow	47	15
Brilliant blue	74	30	Pinkish yellow	41	
Whitish	71		Pink red	36	
Yellow	64	45	Whitish pink	31	
Pink	59	45	Green	24	
Junction of pink and blue	58	10	Yellow	10	
Blue	56		Reddish	0	

These colours are obviously those of the reflected rings in thin plates. By turning the steel plate round in azimuth, the very same colours are seen at the same angles of incidence, and they suffer no change either by varying the distance of the luminous aperture, or the distance of the eye of the observer.

I now examined various other specimens which possessed the same property. In some there were three orders of colours, in others two, and others one, while in some only one or two tints of the first order were developed. These different effects are more minutely detailed in the following Table.

Number of grooves in an inch.	Orders and portions of orders of colours developed from 90° up to 0° of incidence.
500	Citron yellow of the first order.
625	One complete order, and up to reddish yellow of the second order. Colours very dilute.
1000	Four complete orders of colours.
1000	One complete order, together with blue green and yellowish green of the second order.
1250	One complete order, together with blue and bluish green of the second order. Colours exceedingly faint and diluted.
2000	One complete order, together with blue green and greenish yellow of the second order.

Number of grooves in an inch.	Orders and portions of orders of colours developed from 90° up to 0° of incidence.
2000 on wax.	One complete order, together with greenish yellow of the second order.
2000 on wax.	One complete order, together with gamboge yellow of the second order.
2500 ———	One complete order, together with the full blue of the second order.
3333 ———	Gamboge yellow of the first order.
5000 ———	One complete order, together with bluish white of the second order. Colours more dilute than in No. 5.
10,000 ———	One complete order, together with blue and fainter blue of the second order.

It is obvious from the preceding Table that the diversity of effect produced by different specimens does not depend upon the quantity $m + n$, but upon n. The more that the original surface is ploughed away by the cutting diamond, the more brilliant were the tints, and the more numerous the orders of colours.

I was now desirous of seeing what effect would be produced when the original surface was almost wholly removed; and Mr. Barton was so obliging as to execute for me a specimen containing 2000 grooves in an inch, in which this was nearly effected. His diamond point, however, having unfortunately broken before he had executed any considerable space, I was unable to make all the experiments with it which I could have wished.

This specimen produced four complete orders of colours, all of which were developed at much greater angles of incidence than those in the preceding Tables.

	° ′		° ′
White	90 00	Red.	
Straw yellow.		Pink.	
Faint red.		Second limit of pink and blue	69 40
Pink.		Blue.	
First limit of pink and blue	80 00	Green.	
Blue.		Yellowish green.	
Green.		Yellow.	
Yellow.		Orange.	

	° ′		° ′
Scarlet.		Brilliant green.	
Purple.		Yellowish green.	
Third limit of pink and blue .	48 00	Yellow.	
Blue.		Reddish	10 00

Such being the phenomena exhibited by the ordinary image formed by reflexion from the original spaces *n*, I now proceeded to examine the prismatic images in the first specimen with 1000 grooves, and I observed the following appearances.

Let A B, Fig. 1, be the reflected image of the rectangular aperture from the spaces *n*, and $a\ b$, $a'\ b'$, $a''\ b''$, $a'''\ b'''$, the prismatic images of it, $v\ v$, $v'\ v'$, &c. being the violet sides, and $r\ r$, $r'\ r'$, &c. the red sides of these spectra. Then in the

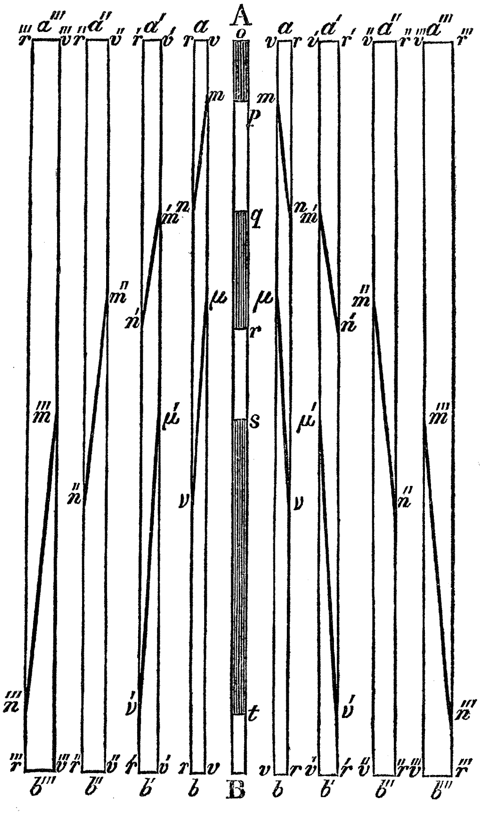
1st spectrum $a\ b$, the violet rays are obliterated at m at an incidence of 74°, and the red rays at n at an incidence of 66°, the intermediate colours, blue green, being obliterated at intermediate points between m and n, and at angles of incidence intermediate between 74° and 66°. In the

2nd spectrum $a'\ b'$, the violet rays are obliterated at m' at an incidence of 66° 20′, and the red at n' at 55° 45′. In the

3rd spectrum $a''\ b''$, the violet rays are obliterated at m'' at 57°, and the red at n'' at 41° 35′. And in the

4th spectrum $a'''\ b'''$, the violet rays are obliterated at m''' at 48°, and the red rays at n''' at 23° 30′.

Fig. 1.



Another similar succession of obliterated tints takes place on all the prismatic images at a lesser incidence, as shown at $\mu\ \nu$, $\mu'\ \nu'$, the violet being obliterated at μ, and the red at ν, and the intermediate colours at intermediate points. In this second succession the line $\mu\,\nu$ begins and ends at the same angle of incidence, as the line $m''\,n''$ in the third prismatic image $a''\,b'$; and the line $\mu'\,\nu'$ on the second prismatic image corresponds with $m'''\,n'''$ on the fourth prismatic image.

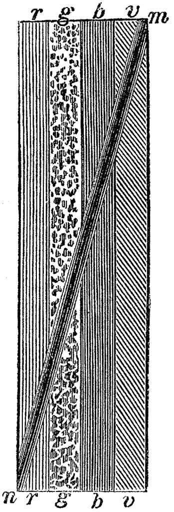


Fig. 3.

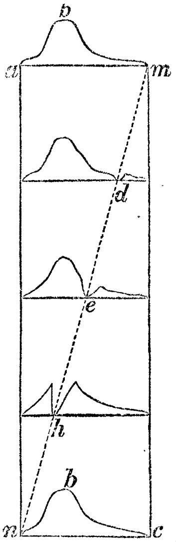


Fig. 4.

This singular obliteration of the colours is shown more clearly in Fig. 3, where *r m v n* is a part of one of the prismatic images, *r v* the red space, *g g* the green space, *b b* the blue, and *v v* the violet space. The line of obliteration *m n* in beginning at *m* obliterates the extreme violet at *m*; so that the curve of illumination *a b m*, Fig. 4, is just affected at one extremity *m*. The line advances into the spectrum, and at the point corresponding to *d*, Fig. 4, a portion of the blue and violet is obliterated, as shown by the notch in the curve; at *e* a portion of the green and blue; at *h* a portion of the red and green, and at *n* the extreme red.

A similar obliteration of tints takes place on the ordinary image A B.

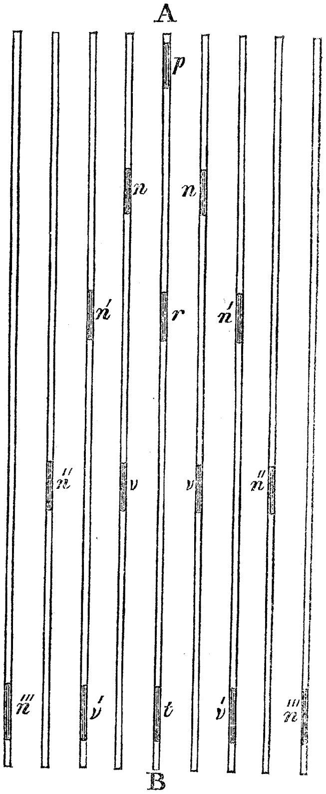
The 1st obliteration, viz. that of the violet, takes place at *o*, Fig. 1, and that of the red at *p*; while the intermediate colours disappear at intermediate points. This first space of obliteration has no corresponding one at the same incidence in any of the prismatic images.

The 2nd obliteration of the violet in A B takes place at *q*, and that of the red at *r*, and this corresponds in incidence with the obliterations $m'\,n'$, $m'\,n'$ on the second prismatic image.

The 3rd obliteration of the violet takes place at *s*, and that of the red at *t*, and this corresponds in incidence with the four obliterations on the second and fourth prismatic images, viz. $\mu\,\nu$, $\mu'\,\nu'$, $m'''\,n'''$, $m'''\,n'''$.

In all these phenomena the points *m*, *n*, μ, ν, &c., are only the points of minimum intensity, or of maximum obliteration; for the tints never entirely disappear, and those obliterated at each line *m n* form an oblique spectrum containing all the prismatic colours.

Fig. 2.



The analysis of these curious and apparently complicated phenomena becomes very simple when they are examined under homogeneous illumination. The effect produced in red light is represented in Fig. 2, where A B is the image of the rectangular aperture reflected from the faces *n* of the steel, and the four images on each side of it correspond with the prismatic images. All these nine images, however, consist of homogeneous red light, which is obliterated at the fifteen shaded rectangles, which are the minima of the new series of periodical colours which cross both the ordinary and the prismatic images. The centres *p*, *r*, *t*, *n*, ν, &c. of these rectangles correspond with the points marked with the same letters in Fig. 1; and if we had drawn the same figure for violet light, the centres of the rectangles would have corresponded with *o*, *q*, *s*, *m*, μ, &c. in Fig. 1. The rectangles should have been shaded off to represent the phenomena accurately, but the only object of the figure is to show to the eye the position and relations of the minima of the periods.

If it should be practicable to remove a still greater portion of the faces *n*, the first minimum *p*, Fig. 2, would commence at a greater angle of incidence; and other two rows of minima, namely, rows of five and six, would be found extending to the fifth and sixth prismatic images. The arrangement and succession of these is easily deducible from Fig. 2, where the law of the phenomenon is obvious to the eye.

The following table contains the angles of incidence reckoned from the perpendicular at which these minima occur in the extreme rays.

Position of the minima in red light.

	Ord. Im.	1st Prism. Im.	2nd Prism. Im.	3rd Prism. Im.	4th Prism. Im.
First minima *p*	76 0′	66° 0′	55° 45′	41° 35′	23 30′
Second minima *r* ..	55 45	41 35	23 30		
Third minima	23 30				

Position of the minima in violet light.

	Ord. Im.	1st Prism. Im.	2nd Prism. Im.	3rd Prism. Im.	4th Prism. Im.
First minima	81° 30′	74°	66° 20′	57°	48°
Second minima. . . .	66 20	57	48		
Third minima	48				

When the steel with 1000 grooves is exposed to common light, and the incident ray is very near the perpendicular, the 5th, 6th, 7th, and 8th prismatic images are combined into a mass of whitish light terminated externally by a black space. As the angle of incidence increases, the 6th, 7th, 8th, and 9th images are combined into this mass, then the 7th, 8th, 9th, and 10th images, and so on, the black space which terminates this mass receding from the axis or image A B, Fig. 1, as the obliquity of the incident ray increases.

Having covered the steel plate with water and oil of cassia in succession, I found the angular distances of the black space to be as follows at the same incidence.

Air	12° 23′
Water	17 15
Oil of cassia	21 22

The sines of which are inversely as the indices of refraction of the fluids.

Phenomena analogous to those above described take place on the grooved surfaces of gold, silver, and calcareous spar, &c.

In order to study this subject under a more general aspect, I was desirous of examining the phenomena exhibited by grooved surfaces of different refractive powers. It was obviously impossible to procure systems of lines upon transparent bodies in which the grooves should have exactly the same distance and magnitude; but I conceived it practicable to impress upon different substances the very grooves which produced the preceding phenomena, and I succeeded in impressing the system of 1000 grooves upon tin, realgar, and isinglass.

The following results were obtained with Tin, the colours being those upon A B, Fig. 1.

White	90° 0′	1st junction of pink and blue	76° 20′
Yellow.		Greenish blue.	
Pink.		Yellow.	

	°	′	
Pink.			Yellow.
2nd junction of pink and blue	57	40	Orange.
			Pink.
Bluish green.			3rd junction of pink and blue.

	°
First minimum of red	76
Second ———	61

The following results were obtained with Realgar.

	°	′		°
White	90	0	Yellow	63
Yellow	80		Bright pink	54
Pink	75	30	2nd junction of pink and blue	47
1st junction of pink and blue	73	10	Bluish green	41
Blue	72		Yellow	36
Bluish green	70	15	Pink	32
			More and more pink.	

	°	′
First minimum of red	72	0
Second ———	61	15

The following results were obtained with Isinglass. The colours were generally the same as in the steel.

	°	′
The first limit of pink and blue was at	75	45
The blue of second order	73	45
The second limit of pink and blue was at	54	30

In these experiments the tin gave nearly the same results as the steel; but in the realgar and the isinglass similar tints were produced at a less angle of incidence than in the steel. The minima of the periods were exhibited very finely on the isinglass, and were produced at smaller angles of incidence.

In a specimen with 1000 grooves upon isinglass, the third pink, or that seen upon steel at 36°, was the highest; but after drying, the pink descended to yellow, and subsequently to green.

If the isinglass is removed from the steel when it is still soft, the edges of the grooves get rounded and lose their sharpness, and only one prismatic image is seen on each side of the ordinary image, as in mother-of-pearl.

The mass of white light is finely seen in the impressions taken upon tin, but never appears upon isinglass.

The preceding experiments do not afford any precise data for determining the influences of refractive power. The realgar and the isinglass give fewer periods of colour so as to indicate that, cæteris paribus, a diminution of refractive power, produces a diminution in the number and orders of colours, or causes the minima to be developed at a less incidence. This indication, however, is opposed by the fact, that as the isinglass dries and consequently increases in refractive power, the periods diminish in number, and the minima are produced at less incidences. The modification of the tints by a change of refractive power is here masked by the influence of other causes, namely, an inferiority in the sharpness of the impression to that of the original surface, and a rounding of the narrow spaces *n* subsequently produced by induration. In the specimen of isinglass, therefore, already mentioned, which gave the first limit of pink and blue at nearly the same angle as the steel, it is probable that it would have developed the same limit at a greater inclination had the impression been as sharp as the original.

In this uncertainty I conceived that the influence of a variable refractive power would be best obtained by placing different fluids on the surface of the grooved steel; and upon using alcohol and oil of cassia my expectations were fulfilled.

The following were the results:

Number of grooves in an inch.	Maximum tint without a fluid.	Maximum tint, with water, alcohol, and oil of cassia.
312	No colour	1. Water. Tinge of yellow. 2. Alcohol. Tinge of yellow. 3. Oil of cassia. Faint reddish yellow.
500	Citron yellow of first order	1. Water. Tinge of red. 2. Alcohol. Diluted pink. 3. Oil of cassia. A bluer pink.
625	Reddish yellow of second order	1. Water. Faint pink of second order. 2. Alcohol. Ditto more pink. 3. Oil of cassia. Bluish pink of second order.
1000	Yellowish green of second order	1. Water. Pinkish red, second order. 2. Alcohol. Brilliant pink, ditto. 3. Oil of cassia. Greenish blue, third order.
1250	Bluish green faint	1. Water. Yellow of second order. 2. Alcohol. Yellower. 3. Oil of cassia. Yellowish pink.

Number of grooves in an inch.	Maximum tint without a fluid.	Maximum tint, with water, alcohol, and oil of cassia.
2000	Greenish yellow of second order	1. Water. Brownish red, second order. 2. Alcohol. Pinkish red, ditto. 3. Oil of cassia. Greenish blue.
2500	Blue, second order	1. Water. Dilute green. 2. Alcohol. Greenish white, second order. 3. Oil of cassia. Bright gamboge yellow.
3333	Gamboge yellow of first order	1. Water. Pinkish red, first order. 2. Alcohol. Reddish pink. 3. Oil of cassia. Bright blue, second order.
5000	Bluish white of second order	1. Water. Pale yellow. 2. Alcohol. Yellow with tinge of orange. 3. Oil of cassia. Yellowish pink, second order.
10,000	Fine blue of second order	1. Water. Greenish white of second order. 2. Alcohol. Yellowish white. 3. Oil of cassia. Brilliant gamboge yellow.

I obtained similar results with grooves impressed upon wax; so that we may now safely draw the conclusion that more orders of colours, and consequently higher tints at a given incidence, are developed by diminishing the refractive power of the grooved surface.

The influence of refractive power on the tints of the ordinary image being thus determined, it became interesting to ascertain its effects on the obliterated tints of the prismatic images. As these tints never appeared unless when that of the ordinary image exceeded the blue of the second order, I took the specimen with 10,000 grooves, which had for its maximum tint a blue of the second order, but which exhibited no obliterated tints in the prismatic images. Having placed upon it a film of oil of cassia, I raised the blue to a gamboge yellow, and I found that the fluid developed the phenomena of obliterated tints on the first prismatic image. Owing to the great breadth of the spectrum, the distinct separation of the colours which composed it, and the great length of the line of obliteration, this phenomenon was one of the most beautiful and remarkable that I have ever witnessed.

Hitherto I had examined the minima in the prismatic images as symmetrically related in position to the minima in the ordinary image, as shown in Figs. 1 and 2; but in studying some specimens in which the spaces n were very broad, and the grooves or spaces m comparatively narrow, I was surprised to observe obliterated tints on the prismatic images, while the ordinary image was entirely free of colour. This took place in two specimens, one of which had 312, and the other 625 grooves in an inch. The spaces *n* were here far too wide to produce the new tints, and so were the spaces *m*; but upon applying the microscope to the grooves *m*, I saw that they were formed by two or more grooves ploughed out by the cutting point; so that each space *m* actually consisted of smaller reflecting spaces, which were sufficiently minute to produce the periodical colours.

Although in these specimens, therefore, when *m* is nearly equal to *n*, we observe a beautiful coincidence between the positions of the minima on the ordinary and on the prismatic images, yet the fact above described seems to show that they are separate phenomena, and depend, when the grooves are single, on the relation between *m* and *n*.

The preceding observations relate solely to rays reflected from grooved surfaces; but in consequence of the almost perfect transparency of isinglass in thin plates, I have been enabled to examine the transmitted tints. The colours which are thus seen on the ordinary image are extremely brilliant, but they seem to have no relation whatever, either in number or in quality, to the reflected tints. In the specimen which gave by reflexion three orders of colours, those seen by transmission were only the following.

Fine blue	85° of incidence.
Purple.	
Red.	
Orange.	
Yellow	0 vertical incidence.

Another specimen from the same steel plate gave, when soft and newly taken off, a bright purple at a perpendicular incidence, which passed through pink and blue at greater incidences. But in the process of induration, the vertical purple became red, orange and yellow. In a third impression the perpendicular tint was a bright pink when soft, which descended to yellow when drier.

In order to observe the relation between the reflected and transmitted tints, I took a fresh impression on very transparent isinglass, and obtained the following results.

Reflected tints.	Transmitted tints.	Angles of incidence.
Yellow	Deep blue	90
Orange	Paler blue.	
Pink	Blue.	
First limit of pink and blue	Blue.	
Blue	Pink.	
Green	Orange pink.	
Yellow	Orange.	
Orange	Yellow.	
Pink	Yellow.	
Second limit of pink and blue	Yellow.	
Blue	Yellow	0

The comparison of these tints affords the most satisfactory evidence that they are not complementary to each other. The transmitted tints of the ordinary prismatic images always increase in brightness as the angle of incidence diminishes, while the reflected tints become fainter.

As I had preserved the different specimens of isinglass with which these experiments were made, it became interesting to observe the changes which their colours had undergone after a lapse of six years. The following was the result.

1. A specimen with 1000 grooves exhibited no colours on the ordinary image either by reflexion or transmission. The prismatic images of a candle were very faint, and the 4th could scarcely be seen.

2. Another specimen of 1000 grooves gave by reflexion one period of colours from white at great incidences through yellow up to purple at a vertical incidence. By transmission a little yellow only was seen at a great incidence.

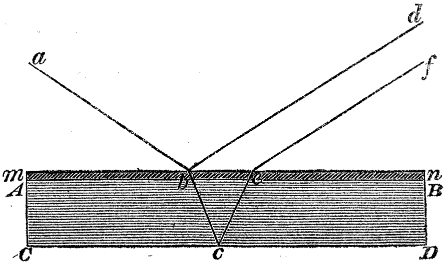
3. A third specimen of 1000 grooves which had been a fine sharp impression, gave by reflexion two orders of colours, the first limit of pink and blue being at 57° 45′, and the second limit nearly at a vertical incidence, a deep pink appearing at 10°. By transmission the isinglass gave a bluish green at the greatest incidence which passed at lesser incidences through purple to yellow, which was the maximum tint.

In all these specimens the colours remain the same in all azimuths, provided the angle of incidence is invariable.

As the steel plate from which all these impressions had been taken was much injured, I resolved to grind down its surface by a polishing powder, and to observe the changes which took place. As the effect of this was to increase the spaces *n*, the colours on the ordinary image soon disappeared. The phenomenon of the obliterated tints was no longer seen, the mass of white light disappeared, and from the rounding of the edges of the grooves the prismatic images were fewer in number, though their distance was unchanged.

When one of the impressed films of isinglass *m n*, Fig. 5, was laid upon a plate of glass A B C D, and was in optical contact with it, a series of fringes was seen across the images reflected from the second surface C D of the glass. These fringes seen by the eye at *d f*, and formed by the rays *a b c e f*, are parallel to the grooves on the isinglass, and their breadth diminishes as the thickness A C of the glass is increased. When the grooves were 1000 in an inch, these fringes were nearly as distinct as the prismatic images, one fringe appearing to bisect each image when the thickness A C was about $\frac{1}{20}$th of an inch. They were much more numerous, and even crossed the principal image when A C was $\frac{1}{7}$th of an inch; but when A C was $\frac{1}{4}$th of an inch, no fringes were seen across the second image.

Fig. 5.



These fringes have the same origin as those which I have described in the Edinburgh Transactions. In the first specimen, where A C was $\frac{1}{20}$th of an inch, its two surfaces were not parallel, and the direction of the grooves in the isinglass was accidentally perpendicular to the common section of the two surfaces of the glass. Hence the fringes produced by the glass were parallel to the prismatic images from the isinglass. But when the specimen is turned round, the isinglass fringes reflected from the back of the glass are crossed by those produced by the glass, giving to the former the appearance of a coloured rope, in which the coils pass along the longitudinal spectra with singular beauty.

Such are the leading phenomena of this new and remarkable class of periodical colours; but though their general law and the circumstances upon which they depend seem to be pretty clearly shown in the preceding experiments, yet

I feel great difficulty in assigning a satisfactory cause for their production. That they are not owing to the diffraction and interference of the rays reflected from two or more of the surfaces *n*, considered as narrow slits or apertures, is obvious; for in that case they would be affected by the distance of the luminous object and the distance of the eye, and the colours would form bands parallel to the direction of the grooves.

In my experiments on the production of the complementary colours by the metallic reflexion of polarized light, I have shown that one reflexion from a plate of silver, &c. is equivalent in its action to a given thickness of a crystallized film, and that the tints descend in the scale by increasing the angle of incidence as if the equivalent film had diminished in thickness. That these colours are produced by the interference of two pencils, one of which suffers reflexion later than the other, cannot be doubted; but whether these two portions are reflected within the sphere of reflecting activity, at such distances as to produce colours by their interference, or whether the one is reflected in the usual manner, while the other is not reflected till it has penetrated a certain thickness of the polished metal, it is not easy to ascertain.

If either of these effects takes place with polarized light, an analogous effect should be produced with common light, though the intensity of the interfering pencils might in this case be very inconsiderable.

If we suppose that the spaces *n* are smaller than the distance to which the reflecting force extends, the removal of the metal from the adjacent grooves must diminish the reflecting force of these spaces. That this is the case may, we think, be inferred from direct experiment. At the separating surface of the steel and a fluid, we observe a certain change in the action of the steel surface, which can be ascribed to no other cause than the diminution of the refractive and reflective power of the surface. Now it is manifest from experiment that the diminution of the spaces *n* has exactly the same effect, the colours not only being rendered brighter by each of these causes, but the minima being produced at greater angles of incidence.

Since in a system of grooves with only 312 in an inch, oil of cassia developes colours which did not previously exist, it is evident that if we had fluids of much higher refractive power, colours would be produced when the spaces *n* were much larger, and when the fluid approached in refractive density to that of the metal, we should witness the periodical colours without any grooves at all on the reflecting surface; so that the phenomena would then become identical with those which are developed at the separating surface of transparent bodies.

We can scarcely, therefore, avoid the conclusion, that the removal of the substance from the grooves, whether they are made on metal or on transparent bodies, diminishes the refractive power of the intermediate spaces. On the hypothesis of emission, this abstraction of the reflecting matter may be regarded as equivalent to a diminution of the density of the surface; while on the undulatory hypothesis, the effect may be ascribed to the condition of the ether arising from a variation in its density or elasticity towards the extremities of a number of salient points.