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## LXXVI. *Facts relating to Optical Science. No. IV.* By H. F. Talbot, *Esq., F.R.S.**

### § 1. *Experiments on the Interference of Light.*

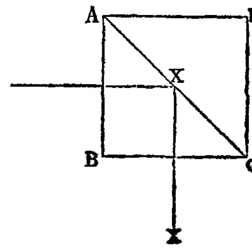
ALTHOUGH so much has been explained in optical science by the aid of the undulatory hypothesis, yet when any *well-marked phænomena* occur which present unexpected peculiarities, it may be of importance to describe them, for the sake of comparison with the theory.

Such appears to me to be the case with those which I am about to mention, in which, by means of a remarkable compensation of some kind or other, common solar light appears to play the part of homogeneous light, and *to achromatize itself*, if I may use such an expression, in a very high degree of perfection.

Sir William Herschel was, I believe, the first who took notice of the very beautiful coloured bands which are seen by looking through two prisms placed in contact. Thus, let A B C, A D C be two equal right-angled glass prisms in contact. We will suppose the sides A B, B C to be equal, and the thickness of the prisms to be equal to A B, in which case the combination of the two will form a cube. Let the two prisms be gently pressed together by their face A C, which must be previously well cleaned from any adhering dust, and

* Communicated by the Author.

let them be fixed firmly in this position. Then if the observer looks through the cube at a bright white object, or at the sky, he will see a number of coloured parallel bands, the direction of vision being supposed to be perpendicularly through two opposite sides, as A B, C D. If instead of this he looks through A B at a light coming from the direction X X and then reflected internally on the face A C, he will again see numerous coloured bands upon A C, but these will be complementary in their tints to the former ones.




These coloured bands are analogous in their nature to Newton's rings, differing only in being formed between two *plane* surfaces either parallel or very nearly so, and viewed by the observer at an incidence of 45°.

But the beauty of the appearances may be surprisingly increased by transporting the apparatus into a dark chamber, and suffering a single pencil of the brightest solar light to pass through the prism, or to be reflected from the face A C. If then a sheet of white paper be held up, at any distance from the prism, the coloured bands are depicted upon it with the greatest vivacity and distinctness. The transmitted bands have altogether a different *character* from the reflected ones, so that it is impossible to mistake one for the other, even without reference to the path of the ray.

This experiment, easily tried, is one of the most beautiful in optical science; I shall not, however, dwell upon it, because I believe it is sufficiently well known, and that it has been exhibited in some public lectures.

Now, in making this experiment with care, I have observed some remarkable circumstances.

The coloured bands are not, as has been supposed, *isochromatic* lines. The deviation is sometimes very marked, so that a band in the course of its progress acquires very different tints from those which it possessed originally. This fact may be considered of some importance with respect to the theory. It takes place when the prisms are in close contact, and the bands few in number. But the following is still more deserving of attention. When the contact of the prisms is diminished by interposing a hair between them, (still pressing them together,) the coloured bands depicted upon the paper, become more numerous, narrow and crowded. Frequently they alternate a great number of times with two complementary colours. This appeared to me so remarkable that I repeated the experiment with additional care. The radiant point of solar light was made smaller, by transmitting the ray through a lens of short focus, and the position of the combined prisms was slowly altered by turning them round on their centre. The appearance of the bands on the paper was all the time carefully noted. I soon found a position of the prisms in which the remarkable phænomenon occurred of a complete compensation of colour: that is to say, that the bands were black and white. At the same time they were become exceedingly narrow and numerous. A friend, who had the kindness to count the lines, found *one hundred and ten* of them in the space of two inches. On another occasion they were evidently much closer, so that we estimated their number at *two hundred* in the same space of two inches. The aid of a lens was requisite to see them distinctly. They resembled more than anything else the closely-ruled parallel lines by which *shadows* are produced in some kinds of engraving, and which are often employed in maps to represent the sea.

Now, it requires in ordinary circumstances the employment of *very homogeneous* light, in order to produce bands anything like these in number and distinctness. In the present instance, on the contrary, common solar light was employed. The result therefore is quite unexpected, and it will be interesting to learn in what manner it is explained by theory.

These bands are best seen in the light *reflected* from the face A C. And since the reflected ray does not enter the prism A D C at all, it cannot matter, I think, of what kind of glass it is composed. With respect to the other prism, it appeared to me that the experiment succeeded equally well whether it were of crown or of flint glass.

### § 2. *Experiments on Diffraction.*

In the original experiments of Grimaldi and Newton the diffracted images of objects were merely received on screens of white paper, by which method a great part of their brightness was necessarily lost. Fraunhofer first introduced the use of the telescope in these observations; and Fresnel, I believe, that of the lens or microscope. Both these were very great improvements, though of an opposite character, and have caused the discovery of numerous most curious phænomena.

In order to see these appearances in their perfection, it is requisite to have a dark chamber and a radiant point of intense solar light, which, for the sake of convenience, should be reflected horizontally by a mirror. I will relate a few, out of several experiments which were made in this manner.

1. About ten or twenty feet from the radiant point, I placed in the path of the ray an equidistant grating* made by Fraunhofer, with its lines vertical. I then viewed the light which had passed through this grating with a lens of considerable magnifying power. The appearance was very curious, being a regular alternation of numerous lines or bands of red and green colour, having their direction parallel to the lines of the grating. On removing the lens a little further from the grating, the bands gradually changed their colours, and became alternately blue and yellow. When the lens was a little more removed, the bands again became red and green. And this change continued to take place for an indefinite number of times, as the distance between the lens and grating increased. In all cases the bands exhibited two complementary colours.

It was very curious to observe that though the grating was greatly out of the focus of the lens, yet the appearance of the bands was perfectly distinct and well defined.

This however only happens when the radiant point has a *very small* apparent diameter, in which case the distance of the lens may be increased even to one or two feet from the grating without much impairing the beauty and distinctness of the coloured bands. So that if the source of light were a mere mathematical point it appears possible that this distance might be increased without limit; or that the disturbance in the luminous undulations caused by the interposition of the grating, continues indefinitely, and has no tendency to subside of itself.

2. Another grating was then placed at right angles to the first, and the light transmitted through both was examined by the lens. The appearance now resembled a tissue woven with red and green threads. It seemed exactly as if each colour disappeared alternately behind the other. An alteration in the distance of the lens, altered the tints of the two complementary colours.

3. A plate of copper pierced with small circular holes of equal diameter and in regular rows, was substituted for the gratings. When this plate was held perpendicular to the ray, it produced a beautiful pattern consisting of rows of circles divided by coloured lines or bars. When the lens was approached to the plate, there was a particular distance between them at which there appeared in the centre of each circle a

* A plate of glass covered with gold-leaf, on which several hundred parallel lines are cut, in order to transmit the light at equal intervals.

black spot, as small and well defined in appearance as a *full point* in a printed book, being a curious instance of the well-known fact, of the interference of rays of light producing darkness. This black spot was seen in all the circles at once, in consequence of their having equal diameters.

4. When the copper-plate was placed obliquely and held in various positions, a great variety of very singular patterns were displayed, which can be compared to nothing so well as to tissues woven with threads of various colours. It would be impossible to describe these, any more than the ever-changing figures of the kaleidoscope. They seem to vary *ad infinitum*, and in whatever position the plate is placed, they appear always as distinct as if they were in the focus of the lens.

5. In most optical experiments it is essential that vision should be performed along the axis of the lenses which are employed, or very nearly so. But in these experiments this singularity occurs, that the lens may be placed in any position; so that when held *even very obliquely* the only effect is a considerable alteration in the pattern, which in other respects remains as distinct to the eye as before. The experiments hitherto related, are some which I had the pleasure of showing to some distinguished members of the British Association a short time previously to the late meeting at Bristol; and are communicated in the hope that they may prove interesting to the cultivators of optical science.

§ 3. *Remarkable Property of the Iodide of Lead.*

This substance possesses a property of a singular nature, which I believe differs from anything previously described; or if it is reducible to known laws of chemical and molecular action, offers at least a very striking and beautiful example of them.

If a solution of acetate of lead is mixed with a saturated solution of hydriodate of potash, and the mixture well stirred, the iodide of lead which is formed in abundance, though at first yellow, speedily grows pale, and afterwards becomes perfectly white. If a small quantity of this is taken when freshly made and moist, and squeezed between two plates of glass, it may be seen by the help of a microscope to be entirely composed of very delicate capillary crystals; and if in this state it be laid aside, I do not find that it undergoes any change after being kept several months.

But if, while fresh, it be warmed over a spirit-lamp, it suddenly turns yellow, the first impression of the heat being sufficient to produce that effect. As soon as this happens, it should be removed from the lamp and again examined with the microscope, and it will be seen, not only that the colour is changed, but that all trace of the white capillary crystals has vanished, and instead of them the field of view of the microscope is covered with an assemblage of transparent yellow crystals which are in shape *thin flat regular hexagons.*

But after a few minutes, as the plates of glass grow cool, the white colour returns as before, and the microscope now shows again a multitude of white capillary crystals, the hexagonal ones having in their turn entirely disappeared.

The singularity of this change, which may be repeated several times,—the remarkable fact of being able to view the same substance, alternately of two different colours, and with different *forms* belonging to those colours, induced me to endeavour to see in what manner such a singular metamorphosis took place. I therefore took the plates of glass when cold and adjusted the microscope upon one of the capillary crystals contained in them. It looked, when much magnified, like a cylindrical thread of glass, of a clear white colour and transparent. I then, without deranging the adjustment, placed a small spirit-lamp beneath the glass, at a moderate distance, and watched the effects of the heat. After a short time I observed the cylindrical thread shrink in diameter, and at the same moment the axis of the cylinder split open, and a yellow crystalline plate protruded itself through the opening, increasing in size every moment, while the remainder of the white crystal quickly dissolved and disappeared. This happened at several points of the axis of the cylinder, so that when the change was complete, the yellow hexagons were not unfrequently found arranged in a row or straight line indicating the position of the former crystal. When the heat is more suddenly applied, the dissolution of the white crystal is proportionably more rapid, and the yellow hexagons start into existence before the observer's eye with a suddenness which is very surprising, and increase so rapidly as to triple or quadruple their diameter in a second of time, preserving all the time the exact figure of the regular hexagon. Most of them are of a full yellow tint, but some are of a greenish yellow, and some of a peculiar light brown, which variety of tint appears a circumstance worthy of remark, but I do not know upon what cause it can depend.

There is something in this experiment which is very peculiar. We are accustomed to see salts dissolved or melted by heat; or if they are of an insoluble nature, at any rate they remain inert and passive when heated.

But here we have a salt which crystallizes when heated, and the more rapidly the greater the heat. I have described the manner of change of this substance from its white to its yellow crystalline form. And the following is nearly what happened during its return to its former state.

When it cools, the white crystals begin to shoot, and if the microscope is adjusted upon one of the yellow hexagons, it is seen to remain quiet and undisturbed until one of the white needles, which elongate rapidly, passes near it. But when the needle passes it, even at what appears in the microscope a considerable distance, the hexagon becomes corroded on its edges, and then breaks up irregularly, and quickly dissolves.

I observed that when a needle, during its growth, happened to strike a hexagon, this seemed to check it for an instant, and then it subdivided itself into a number of ramifications or smaller needles which diverged from that point; as if the force (probably of an electrical nature) which caused the growth or formation of the needle-crystal had been deranged or subverted by the disturbing influences which it had met with.

The change from the white to the yellow form may be repeated four or five times; but when too much water has been evaporated by the heat, it ceases to occur. The white crystals then merely dissolve when heated, without the formation of the yellow ones.

*Remarks.*—Are the white and yellow crystals identically the same substance, assuming different forms at different degrees of temperature? Is this a case of what has been termed dimorphism? If I may venture a conjecture, I should say that the yellow crystals are a definite compound of the white crystals with water. But however this may be, it appears to me that this and other properties of the iodide of lead are worthy of being more particularly examined.*

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## LXXVII. *On the Carboniferous Series of the United States of North America.* By Richard Cowling Taylor, *Esq., F.G.S., &c.*†

I HAD just completed two articles on the upper series of transition rocks, and the relative positions of the depositories of bituminous and anthracitous coals in Pennsylvania, with various detailed illustrative sections, which I had pro-

* These two forms of iodide of lead are noticed in Dr. Inglis's "*Extracts from his Prize Essay on Iodine*;" Lond. and Edinb. Phil. Mag., vol. viii. p. 19.—Edit.

† Communicated by the Author.