A large number of visual observations were made with a variety of specimens of diamond. Many of these were photographed. A Microdak photographic equipment supplied by Eastman Kodak Co., was used for this purpose. A selection of these photographs representing the main results of the investigation is reproduced in the plates accompanying the paper. The magnification in each case is given in the legends describing the photographs.

3. STUDIES ON THE GEOMETRIC CHARACTERS OF THE BIREFRINGENCE

As already remarked, observations of Raman and Rendall on the birefringence patterns of diamonds have brought to light the existence of 'geometric' birefringence in which lines or parallel striations are seen running at 60° or 90°. It is therefore natural to suppose that these striations must be associated with the crystallographic planes of the crystal. For instance, with plates of octahedral cleavage (most of the plates studied had this cleavage), the three other sets of octahedral planes intersect the surface along lines which run at angles of 60° to one another. That the streaks in the birefringence pattern actually arise in this manner was recognised early in the course of the present investigation by determining the orientation of the crystal plate by means of X-rays. It was then found that the directions of the lines in birefringence are invariably parallel to the intersections of one or more octahedral (111) planes with the surface of the diamond. In less common cases, they were parallel to the intersections of some of the dodecahedral (110) planes with the surface.

An interesting point arises in this connection. Let us consider the intersections of the various octahedral and dodecahedral planes with the (111) plane. These would be as shown in Fig. 1. Of these, the three directions *a a′*, *b b′*, and *c c′*, are those along each of which one octahedral and one dodecahedral plane intersects the surface, *e.g.* $[01\bar{1}]$ is the intersection of the $(\bar{1}11)$ and the (011) planes with the surface (111) plane. However, A A′, B B′ and C C′ can represent only the intersections of dodecahedral planes, these having the indices $(01\bar{1})$, $(10\bar{1})$ and $(1\bar{1}0)$ respectively. One thus sees that a knowledge of the azimuth α of the intersection (*viz.*, the angle made by the line with a reference line on the surface) alone is not sufficient to fix the orientation of the laminations completely. It is also necessary to know the inclination i of the laminæ to the normal to the surface. For dodecahedral planes intersecting along OA, OB and OC this angle is 0°, while for the other dodecahedral planes it is 35° 16′. For all the octahedral planes, the inclination is 19° 28′.

microscope. In addition, quantitative data regarding the sign and magnitude of the birefringence have been obtained by the use of a Babinet compensator, together with the above apparatus. These studies have brought out new facts and have helped in understanding the nature and origin of the laminations.

2. EXPERIMENTAL PROCEDURE IN GENERAL

The present investigation can be divided into two parts: (*a*) a detailed study of the birefringence exhibited by diamond with special reference to the orientation of the laminæ and of the axes of birefringence, and (*b*) a study of the magnitude of the birefringence and of the nature of the stresses that give rise to this.

The experiments were all carried out with a Winkel-Zeiss petrological research microscope, model VI M, which had a large range of adjustments and had facilities for the use of a Federov universal stage and a Babinet compensator in conjunction with it. On account of the fact that the birefringence phenomena were observed with a microscope which has a relatively small field of view, only sensibly parallel plates of diamond could be studied. With wedge-shaped diamonds in which the two surfaces were appreciably inclined to each other, the incident light was refracted away so that it did not enter the microscope at all.

The Federov stage was a large one capable of rotation about four axes, and was mounted on the rotating stage of the microscope. The specimen of diamond was placed on the central glass disc of the Federov stage, with or without the pair of hemispherical glass segments. For rapid comparison of different diamonds, and for studies where the crystal was not inclined very much, the glass segments were dispensed with. The segments with a suitable immersion liquid were, however, useful in studying phenomena which could not be observed without them. The spherical glass segments used had a refractive index $\mu = 1\cdot649$ (the maximum that was available) and α-monobromonaphthalene with $\mu = 1\cdot65$ was used as the immersion fluid.

The microscope was invariably used at a small magnification, the objective having a magnification $2\cdot5$ and the eye-piece 6, 9 or 12 as was found convenient. With the glass spheres, a special achromatic objective having a magnification 7 was sometimes used, with the same eye-pieces as before.

The Babinet compensator was in a form in which it could be mounted on the microscope in place of the eye-piece. Measurements with this could be taken either visually using the micrometer screw of the instrument, or photographically. Either method was used, as was found convenient.

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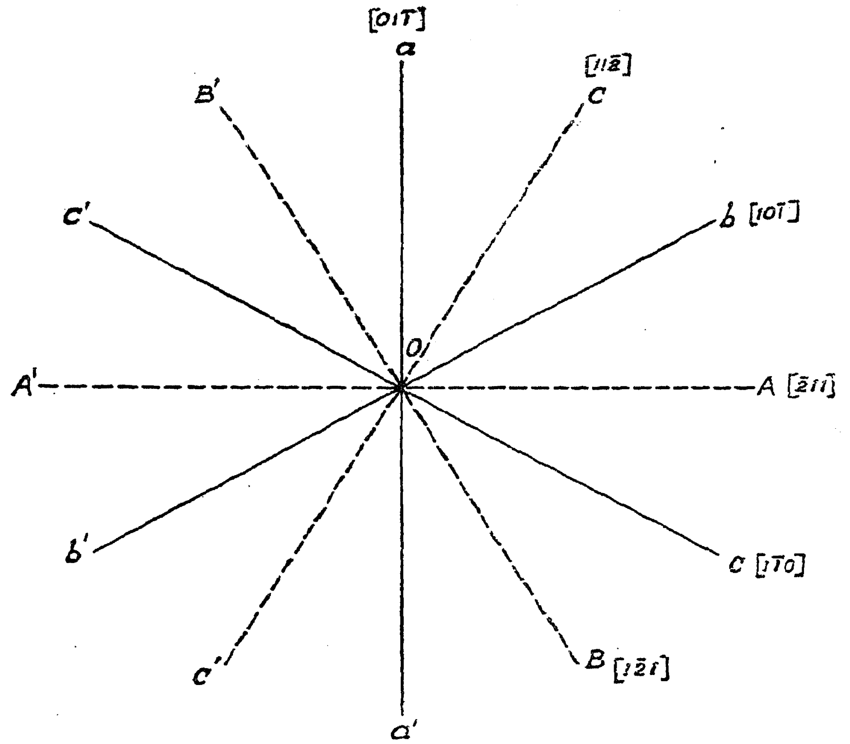

FIG. 1

The determination of the azimuth and inclination is most accurately done by using the Federov stage. The diamond was placed on the central glass plate of the Federov stage, and the birefringence pattern between crossed nicols was observed by means of the polarising microscope under low magnification. The Federov stage was adjusted so that the principal horizontal axis was parallel to one of the cross-wires of the microscope. The axis of rotation of the tilting stage was also made parallel to the principal horizontal axis. Keeping the tilting stage horizontal, the inner glass disc on which the diamond was placed was rotated in such a way that the birefringence streak (or set of lines as the case may be) was parallel to the cross-wire of the microscope to which the axes of the Federov stage were parallel. (Hereafter, by the term cross-wire of the microscope, we shall always mean this cross-wire). The crossed nicols were also rotated together until the required set of lines in the birefringence pattern were seen most clearly. Now on inclining the stage, it was found that the birefringence pattern either sharpened up or became more diffuse. If the latter happened, the stage was rotated in the opposite direction, when it sharpened up. It was generally found that the lines were sharpest at a certain angle, beyond which they became more and more diffuse.

The reason for the sharpening at certain inclinations is obviously that the laminations which give rise to the birefringence are oriented in a particular direction. When the light passes parallel to these laminæ, the pattern is sharp and well resolved. On the other hand, if the crystal is tilted away from this position, then the light traverses across a few of the laminæ, and the pattern overlaps portions of itself, thus becoming confused. Hence, the position at which the birefringence pattern is clearest and most well-defined is that at which the light passes parallel to the laminæ inside the crystal. From the measured inclination of the tilting stage, which should be the same as the angle which the light emerging from the crystal makes with the normal to the surface, the inclination i of the laminæ to the normal can be calculated. The relation between i and θ is obviously

$$\sin \theta = \mu \sin i,$$

where μ is the refractive index of the diamond (2·417), or the relative refractive index between the diamond and the surrounding medium (1·466), if the glass spheres with homogeneous immersion is used. The azimuth of the laminæ could also be measured by adjusting the tilting stage of the Federov rotation apparatus horizontal, and measuring the angle between the cross-wire and the reference line, *viz.*, one of the edges of the diamond.

The remarkable way in which the sharpening occurs can be seen from Figs. 2 (*a*) and (*b*) which represent the birefringence patterns of N.C. 124 when the diamond plate is normal to the axis of the microscope and is at the best position respectively. It will be seen that in the normal position there is practically no trace of the fine laminations, while on inclining the plate they come out prominently as fine sharp streaks. These photographs were obtained with the glass spheres, the tilting angle being 24°, which corresponds to an inclination of 16° 7′. It may be mentioned that X-ray measurements gave a value 16° for the inclination of the corresponding octahedral plane to the surface. (The surface was slightly inclined to an octahedral plane due to errors in polishing.)

The particular specimen of diamond referred to above was unique in that there was only one set of laminations shown in Fig. 2 (*b*). In general however, many diamonds exhibited laminæ parallel to 2 or 3 sets of octahedral planes and also sometimes to the dodecahedral planes. Details of these will be given in a later section on the results of the investigation.

Having thus determined the orientation of the laminations, the nature of the birefringence exhibited by them was next investigated. As already remarked, in the adjustments described above, the polariser and analyser were crossed, and they were rotated together until the required streaks in the birefringence pattern were most clearly seen. It was found that the axes of the nicols made an angle of 45° to the direction of the laminations when this happened. If the nicols were now rotated together, a cycle of phenomena occurred, all the streaks vanishing when the axis of the polariser or analyser was parallel to them, and appearing in the intermediate positions. These observations clearly showed that the principal axes of birefringence in all the laminæ were parallel, and were respectively parallel and perpendicular to the intersection of the laminæ with the plane normal to the axes of the microscope. This phenomenon was found in all the cases of regular geometric birefringence. An illustration of the vanishing of the parallel streaks is provided by Figs. 3 (*a*) and (*b*). It will be seen that in both there is an irregular pattern which does not vanish at any setting of the nicols. But the regular parallel streaks vanish completely when the axis of the polariser or analyser is parallel to them.

To obtain more specific information regarding the nature of the birefringence in the laminæ, the following experiments were performed:

(i) Having verified that the axes of birefringence were parallel and perpendicular to the cross-wires in the sharpest position, the tilting stage was rotated so that the pattern was no longer sharp. Still the laminæ could be observed. Now also, on rotating the crossed nicols, extinction occurred four times in a revolution, respectively when the axes of the polariser and analyser were parallel to the cross-wire. This was found to be the case whatever be the angle through which the tilting stage was rotated.

(ii) The beam of light was also made to pass through the laminæ in different directions parallel to their plane, and the extinction directions were determined in each case. For this, the axis of the tilting stage was set perpendicular to the cross-wire, and by rotating the glass disc and inclining the tilting stage, the birefringence pattern was obtained as before in the sharpest position, but with the streaks running perpendicular to the cross-wire. The Federov stage was then rotated through an angle (say of about 20°) about the principal horizontal axis. The previous adjustments were repeated to obtain the streaks in the sharpest position and the effect of rotating the nicols was studied. It was found that now also the principal axes of birefringence were parallel and perpendicular to the lines in the birefringence pattern. The same was found to be the case for different settings of the crystal in which the light traversed it in various directions parallel to the laminæ.

From these experiments, one can conclude that *the laminæ behave like uniaxial crystals with the optic axis normal to them.*

4. STUDIES WITH THE BABINET COMPENSATOR

The "order of birefringence" of the laminations, *viz.*, the difference in the refractive indices for vibrations along directions parallel and perpendicular to the optic axis, was determined by means of a Babinet compensator, which was relatively a simple matter since the direction of the optic axis was known from the previous studies. But the usual methods of determination with uniaxial crystals had to be modified to suit the purposes of the present investigation. This was so because one is interested here in the *variations* of the order of birefringence from place to place *over the area of the crystal plate.* The method employed could be described as follows. The crystal plate was first adjusted by means of the Federov stage so that the laminations were seen most clearly by the method of the previous section. The plane normal to the direction of propagation of the light within the crystal then contained the optic axis (which was perpendicular to the cross-wire, the laminations being parallel to it). The crossed polariser and analyser were rotated to extinguish the laminations, and were then set accurately at 45° from this position. By the transverse motion of the microscope stage the diamond plate was moved off the field of the microscope. The Babinet compensator was put in with its length parallel to the cross-wire, the analysing nicol was removed and the eye-end nicol put on the compensator and adjusted to – 45°. The bands in the compensator should then be at right angles to the cross-wire. The diamond was then moved into the field, when *a focussed image of the diamond was thrown on the plane of the quartz wedge of the compensator.* Then it was found that the bands in the field of view of the compensator were not straight, but assumed a zig-zag shape. This occurs because the phase difference between the two polarised components varies from place to place, and the displacement of the Babinet fringes parallel to the cross-wire is a measure of this relative phase difference. Fig. 2 (*d*) is the photograph of what happens to the Babinet fringes with the diamond N.C. 124, the same specimen which was described in the last section in connection with the study of the laminations. This pattern might be called the "Babinet pattern" and gives a picture of the distribution of the magnitude of the birefringence over the area of the crystal plate. It may be mentioned that in this photograph, as well as in the photograph of the laminæ under crossed nicols [shown in Fig. 2 (*b*)], the microscope could not be focussed sharply over the whole field of view on account of the inclination of the crystal. Only a portion was accurately focussed.

If t is the thickness of the plate, i the inclination of the laminations to the normal to the surface, and if ϵ is the phase difference and μ_1 and μ_2 the principal refractive indices, then

$$\epsilon = 2\pi (\mu_1 - \mu_2)\, t/\lambda \cos i \text{ or } \Delta\mu = \mu_1 - \mu_2 = \epsilon\lambda \cos i/2\pi t.$$

$\Delta\mu$, the order of birefringence, is thus directly proportional to the phase difference and hence to the displacement of the Babinet fringes from their zero position.

It will be noticed that the fringes have two types of displacements—one varying slowly over the length and breadth of the crystal, and the other having a rapid fine variation. The former is irregular and on a large scale; it must be attributed to accidental strains, etc., which gives rise to the irregular birefringence. The latter is what we are interested in; in this diamond, it is characterised by the fact that the Babinet fringes alternately go one way and the other about the mean position. This means that $\Delta\mu$ in the laminæ is alternately positive and negative, that is to say, the alternate laminæ behave as positive and negative uniaxial crystals. Anticipating a little from a later section, it may be remarked that the obvious explanation of this is that the alternate layers are under tension and compression. The fine variations assume different shapes in other diamonds; these and their interpretation will be discussed in the next section.

The effect of tilting the diamond away from the sharp position is much more pronounced with the Babinet pattern than with the birefringence pattern. The fine variations all vanish and the appearance of the fringes with N.C. 124 kept normal to the light is as shown in Fig. 2 (*d*). The contrast between this and Fig. 2 (*c*) is striking. So also, the sharp peaks seen in Fig. 4 (*d*) vanish in Fig. 4 (*b*) when the diamond is made normal. This phenomenon explains why the birefringence pattern is so confused when viewed normally in many of the diamonds.

5. Description of the Results

As a result of the observations on a number of diamonds, it was found that they could be divided into a few typical classes, as far as their behaviour in the polarisation microscope was concerned. We shall briefly describe the properties of these in general, illustrating them by one or two examples.

(i) First, there is the variety of diamond completely transparent to the ultraviolet upto 2250 Å.U. The birefringence patterns of these diamonds, when viewed normally, invariably show a large restoration of light and often contain sets of streaks running in different directions. It is found that, in every case, laminations are present parallel to either octahedral or dodecahedral planes, or both, and that they can be brought out prominently by the technique described above. There may be only one set of laminations, as for example in N.C. 124 shown in Fig. 2. The appearance of this diamond when viewed normally under the polarisation microscope is shown in Fig. 2 (*g*). It will be seen that, apart from the fact that all the broad bands run in the same direction, there is no suggestion of the fine laminæ brought out so strikingly in Fig. 2 (*h*) by appropriate methods of observation. Figs. 2 (*a*) and (*b*) are photographs of the same phenomenon under greater magnification using the glass spheres of the Federov stage. This was the only diamond in the collection of Sir C. V. Raman which exhibited laminations in one direction only. All the other diamonds of this type had laminæ running in different directions, *e.g.*, with N.C. 126 three such sets could clearly be seen. These are illustrated in Figs. 3 (*d*), (*e*), (*f*) when in their sharpest position, descriptions of which are given in the legends accompanying the photographs. To illustrate the accuracy with which the orientation could be fixed, the table below gives the readings obtained for three diamonds with the microscope, which could be compared with the values to be expected for octahedral and dodecahedral planes from X-ray measurements. The X-ray values for the azimuth are correct only to 5° while those for the inclination are correct to a degree.

TABLE I

	N. C. 124		N. C. 125						N. C. 126			
	a	*i*	*a*	*i*	*a*	*i*	*a*	*i*	*a*	*i*	*a*	*i*
Birefringence ..	61°	15° to 17°	53°	18° to 21°	23°	−5° to 5°	48°	18° to 20°	−11°	18° to 21°	−42°	−5° to 5°
X-ray ..	60°	16°	50°	19½°	20°	0°	50°	19½°	−10°	19½°	−40°	0°
Parallel to ..	(111)		(111)		(110)		(111)		(111)		(110)	

In every one of the cases, the axes of birefringence were parallel and perpendicular to the laminations. The disappearance of the laminæ when the axis of the polariser or the analyser is made parallel to them is illustrated by Figs. 3 (*a*) and (*b*). It will be noticed that in Fig. 3 (*b*), which was photographed with the polariser parallel to the laminæ, the bright streaks in Fig. 3 (*a*) have completely vanished.

With all the diamonds, the Babinet pattern has the zig-zag shape described in the previous section. It is most pronounced in N.C. 124 which has only one set of laminæ.

(ii) The birefringence patterns of some ultra-violet opaque diamonds consist of a dark field crossed by a small number of bright streaks. An examination of such diamonds with the Federov stage showed that the streaks invariably had their origin in thin laminæ running parallel to octahedral planes. They sharpen up remarkably when tilted so that the light passes parallel to them, as may be seen for example from Figs. 4 (*a*) and (*c*), which are the photographs of the appearance of one set of laminæ in N.C. 94 when viewed through the polarising microscope normally and in the sharpest position respectively. The axes of birefringence in laminæ of this type were also found to be parallel and perpendicular to the laminations. The Babinet patterns are very interesting. It is found that, corresponding to every one of the laminations, the dark fringe of the Babinet compensator has a sharp hump on one side or the other. Two such humps towards the right hand side may be seen in Fig. 4 (*d*) corresponding to the two bright streaks in Fig. 4 (*c*) with diamond N.C. 94. There are six such sets of laminæ running along the sides of a hexagon in N.C. 94, and with every one of them the hump was towards the right. However, with the lamina found in N.C. 99, illustrated in Fig. 4 (*e*), the hump was to the left. It is not uncommon to find some laminations producing humps on one side and some on the other in the same diamond. For example, in B 1 two laminæ quite close by produce displacements of the Babinet fringe on opposite sides. The photograph of the laminæ in the sharpest position is shown in Fig. 4 (*g*) and their Babinet pattern is reproduced below them in Fig. 4 (*h*).

The humps in the Babinet pattern disappeared when the diamond was tilted away from the correct orientation, as for example in Fig. 4 (*b*). In general, it was found that the displacement of the Babinet fringe was greater with a thinner lamina than with a thicker one. It may also be remarked that the broad lamina in N.C. 99 is ultra-violet transparent. Rendall (1944) has obtained a streak of transparency in this position in the ultra-violet transparency pattern. Presumably, the streaks in the other diamonds are also transparent, but being very thin and lying obliquely to the surface of the diamond, it is difficult to verify whether they are transparent or not. By using a technique similar to that employed in the present investigation, *viz.*, by holding the diamond at the appropriate angle to the beam of ultra-violet light, it may be possible to detect the transparency of these laminations.

(iii) In a large number of ultra-violet opaque diamonds, a restoration of light sometimes accompanied by one or more series of bands was found when viewed normally under crossed nicols. These diamonds were generally yellow luminescent, the bands of yellow luminescence running parallel to those in birefringence (Rendall, 1946). These plates, when viewed at the proper angle with the Federov stage, exhibited a series of laminations running in one or more directions, generally parallel to the octahedral planes. The axes of birefringence were parallel and perpendicular to the laminæ. The Babinet pattern had in general a number of humps, some going one way and some the other way, the displacement, however, being smaller than with those classed under (i). These diamonds could be considered as being similar to those in (ii), but in which a large number of laminæ occur.

(iv) There were a few diamonds of the ultra-violet opaque class which exhibited only feeble birefringence and which produced very little restoration of light under crossed nicols. These failed to show any laminations under the experimental conditions adopted by the author.

It may not be out of place here to give some idea of the thickness of the laminæ as also of the order of birefringence produced by them. Both were variable and it is only possible to give the order of magnitude of the quantities. The laminæ had thicknesses varying from about 10μ to 100μ or a little more, being similar for both the ultra-violet transparent as well as the ultra-violet opaque diamonds. By using a standard quartz plate, it was found that a shift of the Babinet fringes to the right meant that the refractive index for vibrations parallel to the laminæ (μ_o) was less than that perpendicular to it (μ_e) and *vice versa* for a displacement to the left. Thus, if the laminæ behaves like a positive uniaxial crystal, *i.e.*, $\mu_e - \mu_o$ is positive, then the shift will be to the right and *vice versa*. As already remarked, the displacement was either to the right or to the left in diamonds of the types (ii) and (iii), the magnitude varying from 0·5 mm. to about 2·5 mm. Allowing for the thickness of the diamond and the inclination of the light to the surface, these correspond to orders of birefringence of 0·00006 to 0·00031. With ultra-violet transparent diamonds in which the Babinet fringe alternately goes one way and the other, the maximum relative displacement is about 5 mm., nearly double that found in the opaque diamonds. All these measurements are only rough and are intended only to give an idea of the orders of magnitude of the quantities concerned.

6. DISCUSSION AND INTERPRETATION OF THE RESULTS

As already remarked, many diamonds exhibit an irregular birefringence pattern produced as a result of flaws and accidental strains in the crystal, which gives rise to a coarse and irregular displacement in the Babinet pattern. We shall leave this aside and consider only the fine laminations which may be observed by the techniques described above.

The important points to be considered in this connection are that (*a*) the laminæ behave as uniaxial crystals with the optic axis along their normal and (*b*) as is seen from the behaviour of the Babinet fringes they may behave either as a positive or a negative uniaxial crystal. In ultra-violet opaque diamonds, the laminæ usually occur interspersed in the bulk of the crystal, these producing either a positive or a negative hump in the Babinet pattern. On the other hand, ultra-violet transparent diamonds possess a laminated structure throughout their volume, the alternate laminæ being positive and negative. The obvious explanation for such a behaviour of the laminæ is that the birefringence is a photo-elastic effect produced as a result of stresses acting on them. If the photo-elastic constant were known it would be possible to calculate the magnitude of the stresses. Even in the absence of such information, it is possible to have an idea of the nature of the stresses. Assuming that the photo-elastic constant concerned is positive, it would mean that the positive laminæ are under compression and that the negative laminæ are under tension along a direction normal to them. In any case, *it is clear that the laminæ that occur in the ultra-violet opaque diamonds are of two classes*, viz., *those that are under compression and those that are under tension*. Similarly, the laminæ in the ultra-violet transparent diamonds are alternately under compression and tension.

As was mentioned in the last section, there is strong reason to suppose that the laminations found in the ultra-violet opaque diamonds are transparent. Since the intrusion of this variety sets up stresses which may be either tensile or compressive, it is reasonable to suppose that there are really two variants of the transparent type, which are both in some way (probably in their lattice spacing) different from the opaque type and also from one another. This would immediately explain why the laminæ in the ultra-violet transparent diamonds are alternately under compression and tension —the alternate laminæ are composed of the two different variants of this type.

All these deductions are beautifully in accord with the theory put forward by Sir C. V. Raman (1944) regarding the structure of diamond. According to this theory, diamond can have four possible structures, two of which, TdI and TdII, possess tetrahedral symmetry, while the other two, OhI and OhII, possess octahedral symmetry. The former two are physically identical, but differ only in orientation. They are infra-red active and are also opaque to the ultra-violet below 3000 Å.U. The latter two are, however, transparent to the ultra-violet upto 2250 Å.U. They are both geometrically and physically different from each other, as well as from the tetrahedral varieties. The differences, however, are so small that it is possible for the different structures to co-exist side by side in the same specimen of diamond.

If one studies these structures carefully (see for example Fig. 1 on p. 191 in the paper by Raman quoted above), it will be seen that the tetrahedral structures are intermediate between the two octahedral structures. Thus, designating the two interpenetrating lattices of carbon atoms in the diamond structure by A and B, then starting from OhI, if one reverses the direction of the axes of all the atoms in the B lattice, one gets TdI (or reversing the axes of all the atoms in the A lattice, one would get TdII). After this, if the axes of the atoms in the A lattice are reversed (or of those in the B lattice in the latter case), one now obtains the OhII structure. Hence, it is reasonable to suppose that the two Td structures have properties intermediate between those of OhI and OhII.

For example, the lattice spacing of the tetrahedral varieties would be less than that of one of the octahedral structures (say OhI) and greater than that of the other (OhII). This is exactly what is required to explain the phenomena observed with the laminations. Thus, if a lamina occurring in the midst of tetrahedral ultra-violet opaque diamond consists of the OhI variety only, then its lateral dimensions would be larger than the surrounding, there being thus stresses along the two boundaries tending to decrease the area of the lamina. These stresses would be present along all directions in the plane of the lamina and are equivalent to a tensile stress normal to it. On the other hand, if the lamina consists of the OhII variety, then the stresses acting on it would be equivalent to a compressive stress normal to it. Thus, one of them would behave as a negative uniaxial crystal and the other as a positive one respectively, exactly as is found to be the case.

In the ultra-violet transparent diamonds, however, the OhI and OhII structures alternate in the laminations giving rise to compressive and tensile stresses in alternate laminations, as is in fact found. It also follows from the above argument that the difference in the birefringence and hence the relative shift of the Babinet fringes for an octahedral lamina in a tetrahedral diamond should be about half that between the two alternate laminæ in an octahedral diamond. That this is roughly the case is shown by the measurements reported in a previous section.

The small magnitude of the birefringence, *viz.*, less than 1 in 10,000, shows that the differences in the properties of the four diamond structures should be very small. This fits in with the results deduced by the author (1946) regarding such differences from X-ray and other data. Thus it is in concordance with the fact that the infra-red absorption coefficient of the tetrahedral diamonds is very small compared with other infra-red active crystals (Ramanathan, 1946). So also, these ultra-violet opaque diamonds have a relatively small absorption coefficient upto 2250 Å.U., the transmission extending upto this wavelength with thin plates. The results of the present investigation thus lend great support to Raman's theory. In particular they show very clearly that there are two variants of octahedral diamond, a result which is a direct outcome of the theory.

7. LAMINATIONS IN LUMINESCENCE

Raman (1944 *b*) has pointed out that bands of yellow luminescence often appear sharp and clearly defined when viewed at certain angles and diffuse at others. This must be due to the fact that the luminescence is located in laminæ having a definite orientation. An attempt was made to see whether the technique of using the Federov stage can be used to bring out the laminæ in luminescence. The difficulty was that the diamond had to be sufficiently luminescent to be seen under the microscope. However, the phenomenon sought for was found. Figs. 5 (*a*) and (*b*) represent respectively the luminescence of diamond N.C. 154 when seen normally and in oblique position at which the bands are sharpest. Owing to the depth of focussing being small, only a few sharp bands are seen in Fig. 5 (*b*). The laminæ were verified to be parallel to a set of octahedral planes.

In conclusion, I wish to thank Sir C. V. Raman for the encouraging interest that he took in the investigation.

SUMMARY

The birefringence patterns of many plates of diamond show sets of bright parallel streaks which have been attributed to the existence of definitely orientated laminations inside the crystal which are under strain. These laminæ are most clearly seen when the light beam is made to pass parallel to them inside the crystal, which has been achieved in the present investigation by the use of a Federov stage and a polarising microscope. By properly inclining the plate of diamond placed on the Federov stage, it is found possible to observe the laminary structure even in diamonds which do not exhibit any streaks when viewed normally. From measurements made with the Federov stage and with X-rays, the orientation of the laminæ was fixed. The laminæ are in general parallel to octahedral or dodecahedral planes. The same specimen of diamond may possess laminations in more than one direction, each of which appears prominently when viewed properly. Quantitative studies of the birefringence of the laminæ have also been made with a Babinet compensator. The studies show that the laminæ behave either as a positive or a negative uniaxial crystal, with the optic axis normal to them. They usually have a thickness between $10\,\mu$ and $100\,\mu$ and the order of birefringence varies from 0·00006 to 0·0003. In ultra-violet opaque diamonds, octahedral laminæ of the transparent diamond are found, which

have either positive or negative birefringence, laminæ of both types being sometimes present in the same specimen. On the other hand, the ultra-violet transparent diamonds are completely laminated, the alternate laminæ being positive and negative. These observations support the ideas of Raman that there are two varieties of the ultra-violet transparent diamond which are different from each other and from the opaque type. Also, it is seen that one of them has a larger and the other a smaller lattice spacing than the opaque diamond. Laminæ having a definite orientation have also been found to be exhibited in luminescence.

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DESCRIPTION OF THE PLATES

FIG. 2. (*a*) Birefringence pattern of N.C. 124 when viewed normally, taken with the glass hemispheres of the Federov stage × 28.

(*b*) Ditto when viewed at the proper inclination × 28. Note that the laminæ which come out so prominently in this are practically unobservable in (*a*).

(*c*) Babinet pattern corresponding to (*a*) × 20.

(*d*) Ditto corresponding to (*b*) × 20.

(*e*) Babinet pattern of same diamond at smaller magnification, covering practically the whole of the diamond, at normal incidence, taken without the glass spheres × 10.

(*f*) Same as (*e*) at the sharpest position × 10.

(*g*) Birefringence pattern of N.C. 124 showing the whole diamond at normal incidence × 5.

(*h*) Ditto at the proper inclination × 5.

FIG. 3. (*a*) Birefringence pattern of one of the laminations in N.C. 125 at the sharp position with the axes of polariser and analyser at 45° to the laminæ × 10.

(*b*) Ditto with the axis of the polariser parallel to the laminæ × 10. Note that the fine streaks have disappeared.

(*c*) Babinet pattern corresponding to (*a*) × 25.

(*d*) Photograph of a set of dodecahedral laminæ (the thin horizontal streaks) in N.C. 126 × 7·5.

(*e*) Photograph of a set of octahedral laminæ × 7·5. These are the same as the coarse vertical bands seen in (*d*), but in the sharp position.

(*f*) Photograph of a third set of laminæ parallel to the octahedral planes in this diamond × 7·5.

FIG. 4. (*a*) Birefringence pattern of a portion of N.C. 94 viewed normally × 10.
(*b*) Babinet pattern of the same × 10.
(*c*) Birefringence pattern at the proper inclination of the region shown in (*a*) × 10. Note the sharpness of the laminæ.
(*d*) Babinet pattern of (*c*) × 10. Note the humps in the fringes going to the right.
(*e*) A broad lamina in N.C. 99 at the sharp position × 10.
(*f*) Babinet pattern of (*e*) × 10. The hump here goes to the left.
(*g*) Two laminæ in diamond B.1 at the sharp position × 28.
(*h*) Their Babinet pattern. One hump goes to the right and the other to the left × 20.

FIG. 5. (*a*) Luminescence pattern of N.C. 154 when viewed normally × 10.
(*b*) Ditto at the correct inclination for a set of octahedral planes × 10. A few laminæ are seen sharply.

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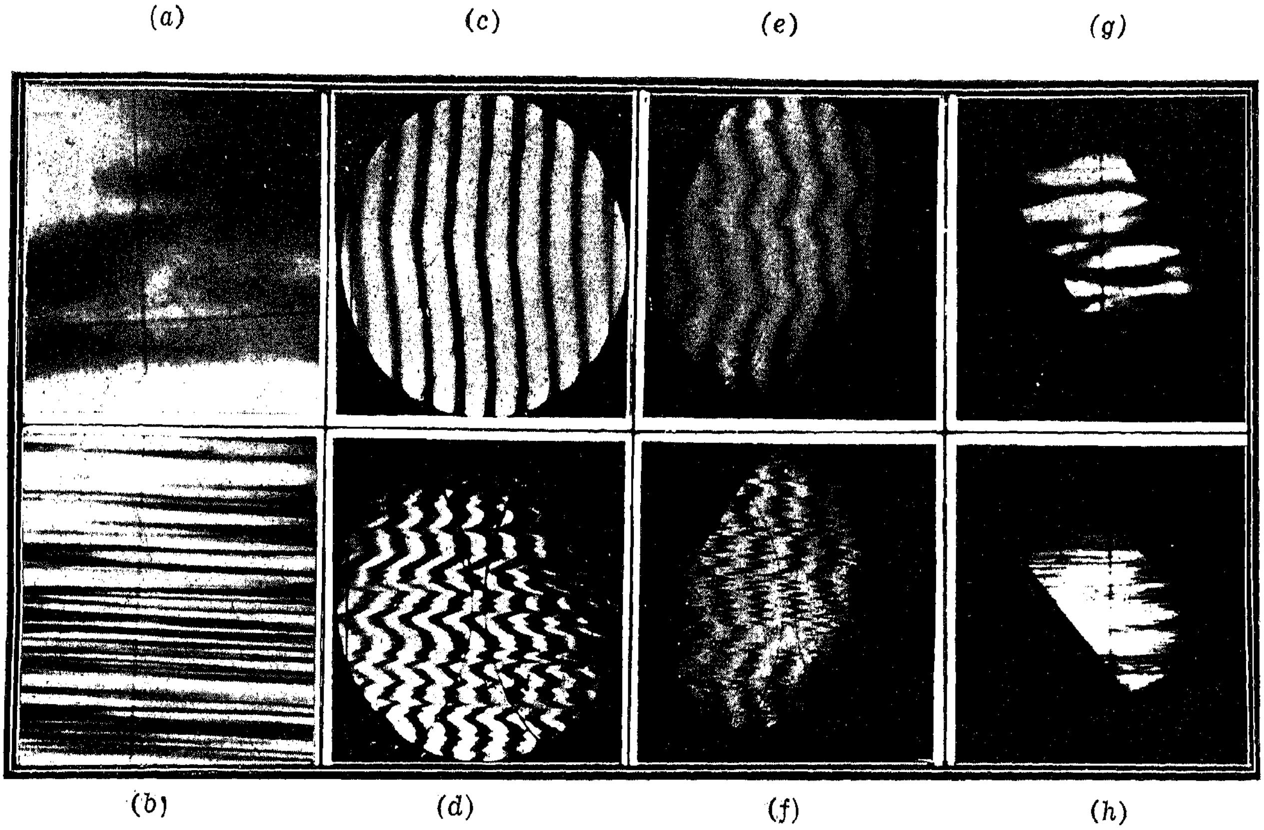

FIG. 2

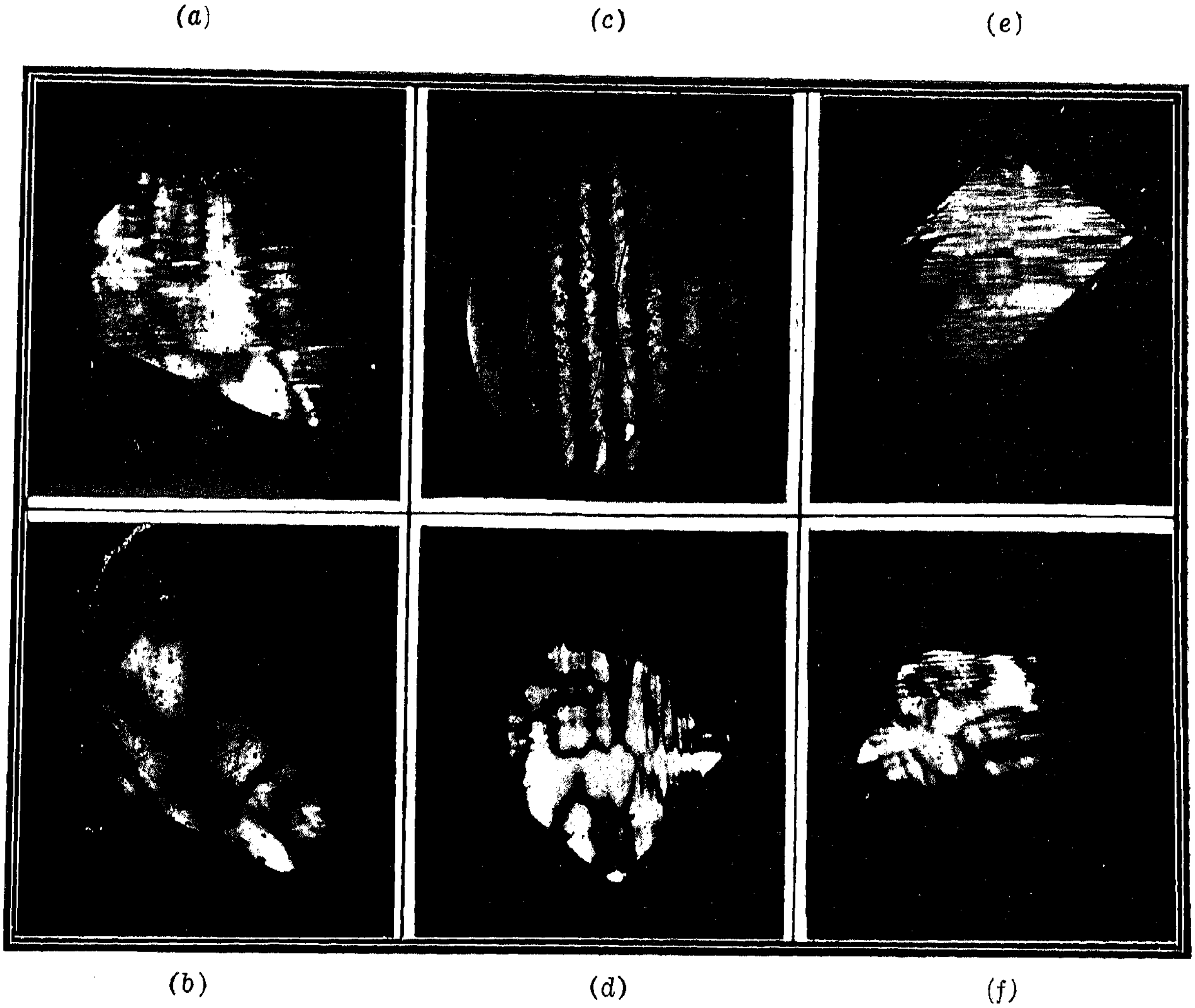

FIG. 3

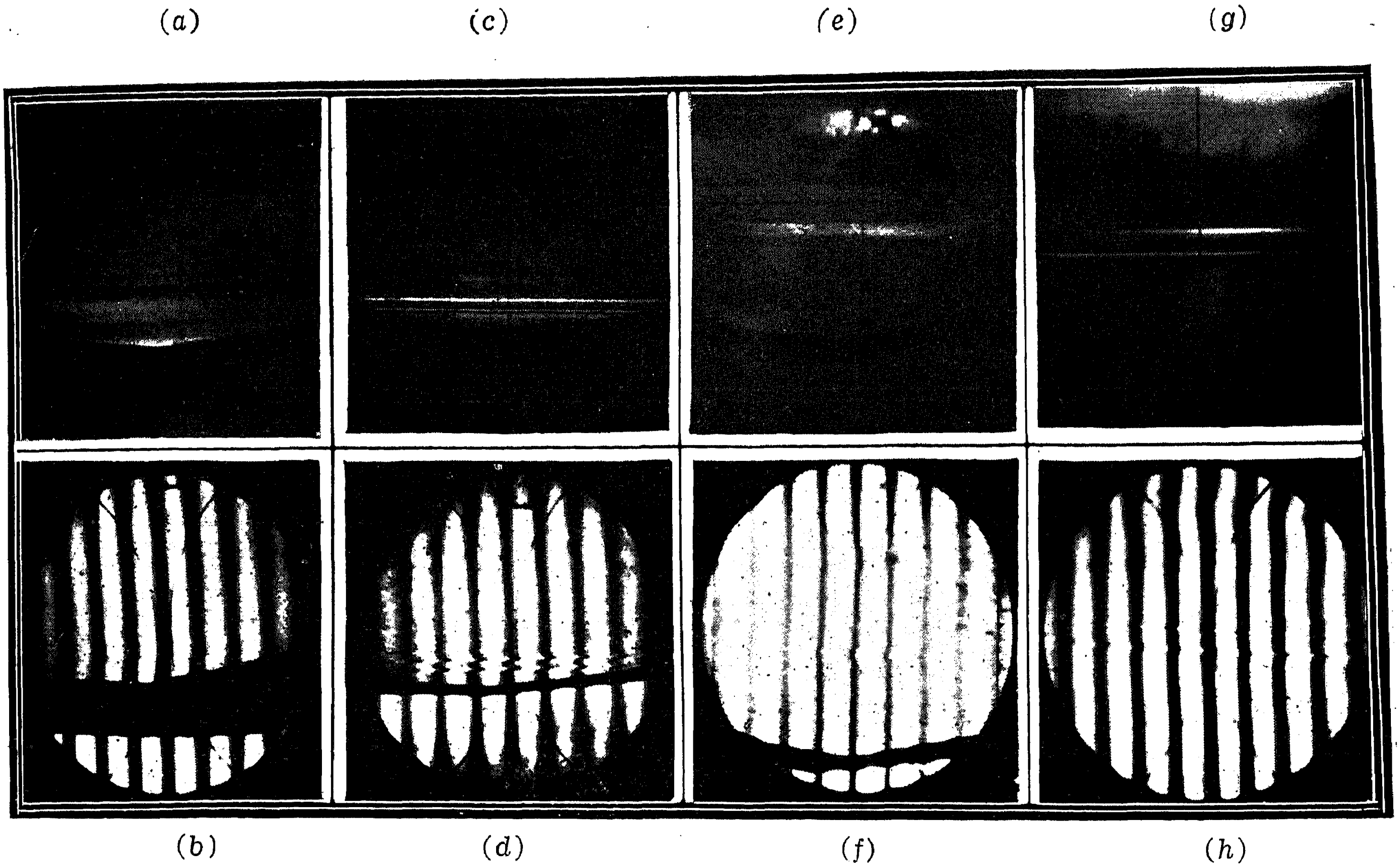

FIG. 4