JOURNAL

OF THE

ROYAL MICROSCOPICAL SOCIETY.

MARCH, 1923.

TRANSACTIONS OF THE SOCIETY.

I.—THE PRESIDENT'S ADDRESS: THE EARLY HISTORY OF THE POLARISCOPE, AND THE POLARIZING MICROSCOPE.

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(*Read January* 17, 1923.)

EIGHT TEXT-FIGS.

THE Institute of France, known earlier and also later as the French Academy, announced on January 4, 1808, that it would give a prize, to be decided in 1810, for the best essay submitted to it, and which was required "to give the mathematical theory confirmed by experiment, of the double refraction which light undergoes after passing through different crystallised bodies."

To understand the optical speculations and investigations which had led up to the state of knowledge on the subject of double refraction, which existed at the date of this announcement, it is necessary to go back to the year 1669, when some clear transparent crystals, which had been brought from the Bay of Roërford in Iceland, to Copenhagen, were handed over to Bartholinus, the Physician to the Danish King, for examination. These crystals were cleavage rhombs of the transparent variety of carbonate of lime, now known as Iceland spar, because of its unique occurrence. Bartholinus (*4*)* was at once struck with the extraordinary power that these crystals possessed of giving two images of anything

* The figures in brackets refer to the bibliography at the end of the address.

B

seen through them. He measured with great care the various angles of the cleavage rhomb of spar, and he also satisfied himself that one of the two rays into which a single incident ray was divided obeyed the ordinary sine-law of refraction, whilst the second ray did not. Bartholinus however failed to find any law by means of which the path of this second ray could be determined.

Some twenty years later, in the year 1690, Christian Huygens, the famous mathematician and physicist, published his classical "Traité de la lumière" (*20*), in which he devoted a chapter to the consideration of the "strange refraction of Iceland spar." He had, at this time, just given to the world his famous undulatory, or wave-theory of light, in opposition to the corpuscular theory of Newton. The two young and unfledged theories were thus called upon to stake their very existence in giving a satisfactory explanation of the newly discovered phenomena. Huygens, by a brilliant flash of genius, was led to a theory of the wave-propagation in Iceland spar, which has triumphantly survived more than two centuries of criticism by the acutest intellects that have ever been devoted to the solution of physical problems. He discovered, in effect, that the wave-motions, complicated as they are, originating at a point, say, in a mass of Iceland spar, are symmetrical about a line and a plane passing through the point, the line being parallel to the optical axis of the crystal, and the plane being at right angles to it. Huygens' conclusion was that a point-source in the crystal originates two wave-surfaces, one a spheroid, or ellipsoid of revolution, with its major axis parallel to the optical axis, and the other, a sphere, enclosed by the spheroid, and having a radius equal to the minor axis of the spheroid. This form of the wave-surfaces, theoretically advanced by Huygens, was subjected to the most critical experimental examination by Wollaston (*28* and *28a*), who invented a now well-known type of refractometer for the purpose, and in later times by Glazebrook, with the result that it has, so far, been vindicated to a high order of accuracy.*

Huygens, however, soon encountered an insuperable difficulty. He superposed two small rhombs, and found, as he expected, that when oriented with their principal sections parallel to one another and in the same sense, they acted simply as a single rhomb of twice the thickness, giving twice the linear separation of the two rays on emergence; whilst when superposed in the opposite sense, still with their principal sections parallel, they gave but one image. When, however, he superposed the rhombs with their principal sections at right angles to one another, he discovered, to his great surprise, that the ordinary ray in the first

* In modern times ray and wave velocities have been differentiated, and the principle of Huygens' construction extended to meet the case of bi-axial crystals which were unknown, as such, in Huygens' time.

rhomb passed through the second rhomb as an extraordinary ray, and, similarly, the extraordinary ray in the first rhomb became an ordinary ray in the second one. He had, in fact, discovered the polarization of light.*

Huygen's theory failed to give any satisfactory explanation, in this case because it was based upon the supposition that the vibrations in a light wave take place in the direction of propagation, and it was not until Fresnel in 1821 (*18*) assumed that the vibrations were transverse, that the wave theory of light, for the first time, could explain simply and completely the experimental facts of polarization. Young, in 1802 (*30* and *31*), by assuming

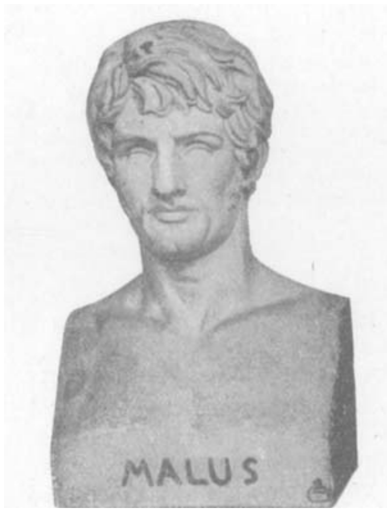

FIG. 1.—Malus, from a bust in the Conservatoire Nationale des Arts et Métiers, Paris.

with Huygens that the vibrations in a light wave were longitudinal, had succeeded in explaining the phenomena of interference, but he too failed, just as Huygens had done, to explain polarization.

To return now to the challenge to optical science of the Institute of France. Étienne Louis Malus, born in 1775, a Captain of Engineers in the French Army, who had just returned to Paris, broken in health by his services in the Egyptian campaign, decided to compete for the prize offered by the Institute, and by one of those happy, so-called, chances which, however, come to the deserving more often than they do to the undeserving,

* The word "polarization" was first used in its optical sense by Malus in 1811.

made a discovery which I cannot better describe than in the words of Arago, quoted in Malus' biography (*21*) as follows :—

> Malus, who lived in a house in the Rue d'Enfer, set himself one day to examine with a double-refracting crystal, the rays of the sun reflected by the windows of the Luxembourg. Instead of two bright images which he expected to see, he perceived but one only, the ordinary image or the extraordinary image, according to the position of the crystal in front of his eye. Our friend was much struck by this strange phenomenon: he tried to explain it by the help of certain modifications, which the solar light might have received while passing through the atmosphere. But when night came, he caused the light of a candle to fall on the surface of water at an angle of 35° [55° angle of incidence], and he proved, by means of a double-refracting crystal, that the reflected light was polarized as it would be if issuing from a crystal of Iceland spar. An experiment made with a glass mirror gave him the same result. From this moment, it was proved that double-refraction was not the only means of polarizing light, or of making it lose its property of dividing into two rays when passing through Iceland spar. Reflection by transparent substances — a phenomenon of everyday occurrence, as ancient as the hills—produced the same property without anyone ever having suspected it.
>
> During the night which followed the fortuitous observation of sunlight reflected by the windows of the Luxembourg, Malus created one of the most important branches of optics.

Malus read a preliminary notice of his discovery on the 12th December, 1808 (*22*), and his essay presented in 1810 gained the prize offered by the Institute. The Royal Society of England was amongst the first to recognize the value of Malus' contribution to optical science, with the result that on March 22nd, 1811, he was advised by Dr. Thomas Young, then foreign secretary to the Society, that the Council had decided to award him the Rumford Medal. Malus, unfortunately for science, died in 1812, at the early age of thirty-seven years. Arago, referring to Malus, spoke of him as one "whose name will be perpetuated by an immortal discovery, so long as physical science shall be honoured among men." Curiously enough, Malus was throughout "a declared and immovable partisan of the theory of emission." Fresnel and Arago in 1816 (*18a*) established the experimental fact that oppositely polarized beams did not interfere with one another and produce fringes, as did two beams of ordinary light in Young's experiment. Finally, in 1821, as we have already pointed out, the undulatory theory of Huygens was so modified by Fresnel as to place it in the impregnable position which it occupies to-day.

It is difficult for us, at the present time, to appreciate fully the importance of Malus' discovery. The discovery that polarized light can be produced by simple reflection from a glass surface, put an instrument of great power into the hands of physicists for the exploration of vast fields of research, the very existence of which had never been suspected. The result was that practically every physicist of repute took up the work enthusiastically, more especially in England, and in France. Discovery after discovery was made, and these followed so closely upon the heels of one another, that it is now, in many cases, almost impossible to decide the questions of rival claims for priority. Brewster in England, and Biot in France, each wrote some scores of papers during the half century following Malus' discovery, and these were aided by such men as Arago, Fresnel, Airy, Herschel, Amici, Nörrenberg, Nicol, Lloyd, Dove, Fox Talbot, Herapath, and a number of others.

Fig. 2 shows the apparatus used by Biot and described by him in 1816 (*7*). The polarizer A, and analyser B, were mounted to tilt about transverse axes in caps C and D, adapted to fit and rotate upon the ends of a tube E. In place of the reflecting

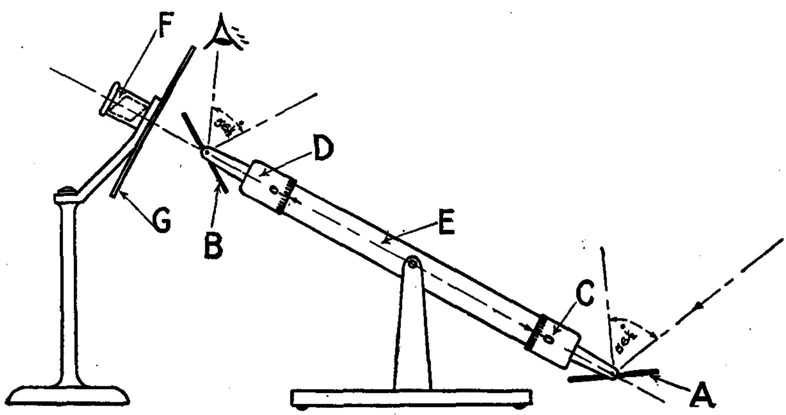

FIG. 2.—Biot's Polariscope.

analyser B, a rhomb, or in some cases an achromatized prism F, of calc spar was employed, mounted to rotate in a divided circle G.

To use the rhomb of spar and divided circle it was only necessary to remove the cap D, with its mirror B, from the tube E.

With an instrument of this type, a large amount of research work was done in the period 1808 to 1828, that is, until the invention of the Nicol prism. Immediately after Malus' discovery of polarization by reflection it was realized that a substance—if such were to be found—giving a single polarized beam by transmission, would greatly increase the power of the polariscope. The search was taken up keenly, with the result that Brewster (*8* and *9*) found such a substance in agate,* and Biot (*6*) in tourmaline.

The use of tourmaline thus became general. Brewster applied it to the simple microscope by cementing it to the plane face of a

* In all the specimens that I have been able to examine, agate polarizes very imperfectly.

plano-convex magnifying lens, and using a piece of black glass, inclined at the polarizing angle, to illuminate the object.* With this instrument he made many of his discoveries. Before this, however, it is interesting to note, Brewster had succeeded in seeing the ring system with a simple black-glass analyser, about a quarter of an inch square, the analyser and the crystal plate being held as closely as possible to the eye.

Polarizing tourmaline, however, is always coloured, generally very deeply so, and this fact prohibited its use for many purposes, so that many attempts were made to replace it by an optical element which transmitted a beam of white polarized light. Rhombs of spar, sometimes of from 3 to 6 in. in length, were used as polarizers, and even as analysers, one of the two beams given by them being stopped out mechanically. Brewster adopted the ingenious device of roughening, and even grooving, the two faces of the rhomb through which the light passed, and then sticking on these faces, plates of glass with an oil between having a refractive index as nearly equal as possible to that of the extraordinary ray (1·49). This ray then passed through the rhomb whilst the ordinary ray ($n = 1 \cdot 66$) was dispersed by the rough face. Piles of glass were also used both for polarizing by reflection and by transmission, but as we know to-day, when they act by transmission, they are useless as analysers, and nearly useless as polarizers.

To summarize the state of the art which obtained just before the invention of the Nicol prism:—polarizers were available acting by (1) reflection—plates and bundles of glass and of mica; (2) transmission—bundles of glass, agate, tourmaline, spar with one image stopped out, or with roughened ends; and (3) double-image rhombs or achromatized prisms of spar.

Industrial applications of the polariscope were not forgotten. As early as 1816, Brewster had carried out a classical investigation (*11*), on the nature of the polarizing properties conferred upon glass by heating; and a second one (*12*), on the communication of double-refracting power to glass and other substances by mechanical pressure. It was suggested that the results obtained could be variously applied, as, for example, to the determination of the distribution of stresses in structures.

We have now sketched the early history of polarization down to the end of the first quarter of the 19th Century. The next decade saw a very remarkable advance along the whole front of the sciences of polarization and microscopy. The principle of achromatization was successfully applied to microscope objectives; the dependence of resolving power on aperture rather than on magnification was realized; the Nicol prism was invented and the

* A pair of tourmalines mounted in tongs permitted of the examination of crystals in so-called convergent light, and the observation of ring-and-brush systems given by plates of crystal cut at right angles to the optical axis.

polariscope improved; thin rock-sections were cut and examined; and, finally, the combination of the high-power microscope with the polariscope for general microscopical work was effected. Up to the period in question the compound microscope had not entirely succeeded in ousting the single lens. The latter was still used, and in many cases preferred, by serious workers such as Brewster and Nicol. Wollaston in 1828, (*29*), had invented his famous doublet and combined it with an efficient substage condenser. An exceedingly interesting and amusing sidelight is thrown upon the science of microscopy as it existed at this time, by the exordium written by Dr. Goring for Pritchard's "Microscopic Illustrations," which appeared first in 1829. Dr. Goring says, *inter alia*:—

> I shall conclude this introduction by a vindication of microscopic science and its votaries, from the aspersions which have been cast upon them by the inconsiderate; many of whom have been pleased to assert that microscopes have, of late, received a degree of patronage from the most illustrious and distinguished *savans*, to which they are not legitimately entitled. Were they applicable to no other purposes than the dissection of blackguard vermin, the observation of stinking ditch-water, or the amorous passions of ants and worms, I should perhaps, for argument's sake, admit that they were but the tools of a puny, pitiful pedant, whose passions and amusements were of a trifling, if not of a degrading complexion.

Finally he finishes with this furious flourish—

> *Trifles* are said to take only with frivolous minds: but *minutiæ are not necessarily trifles*, as it will be easy to prove. It is not only, in my opinion, unscientific, but even swinish and ridiculous, to contemn anything merely on account of its minuteness.

The work of Goring, Lister and Tulley in England, Selligue and Chevalier in France, and Amici in Italy, in the period 1823–30, in introducing the achromatic objective with what was then a wide angle of aperture, is well known.

In 1828 William Nicol (*24*) invented the Nicol prism by taking a rhomb of Iceland spar and slitting it diagonally from one obtuse angle to the other, and then cementing the halves together with Canada balsam.* In this way, for a given angular aperture, he threw out the ordinary ray by total internal reflection, whilst the extraordinary ray passed through. The value of Nicol's invention was immediately realized, and it quickly replaced all other forms of polarizers. Its position to-day, either as originally designed, or as modified by later workers, is still unchallenged. Herapath (*19*), in 1852, succeeded in producing what were called artificial tourmalines, by adding an alcoholic solution of iodine to a solution of bi-sulphate of quinine in acetic acid, and crystallizing out the product. Promising as they were, these artificial tourmalines

* In the case of very small rhombs one half is usually ground away.

have not stood the test of time, but we shall refer to the matter later.

We will now consider in detail a few of the typical polariscopes of the period *circa* 1830.

POLARISCOPES.

Fig. 3 shows the earlier form of Nörrenberg's polariscope, which appears to have been invented about the year 1830, perhaps earlier. Between uprights A, a plane glass reflector B, a stage C, and a rotating disc carrying a black-glass reflector D, are mounted, the mirrors B and D being adjustable about horizontal axes. The base carries a reflector E. In use, sky-light falling upon the mirror B at the polarizing angle is reflected vertically downwards on to the mirror E, which reflects it back again. Part of the

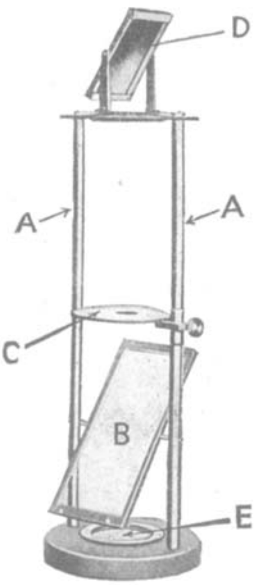

FIG. 3.—Nörrenberg's earlier Polariscope.

polarized beam passes through the reflector B to the upper reflector D, which thus acts as an analyser. Any object placed on the stage C is observed in the usual way, but an object placed upon the mirror E is traversed twice by the polarized beam before it reaches the analyser D. In later forms this apparatus was fitted with lenses for enabling observation of ring-and-brush systems. In 1871 it was modified by Wheatstone (*32*) for the purpose of carrying out experiments with circularly and elliptically polarized light.

Fig. 4 shows an interesting form of polariscope invented by Airy in 1831 (*1*). This figure has been taken from an example of the instrument, now in the Science Museum at South Kensington. The rude goniometric device for measuring axial angles was possibly added by the Rev. N. Brady.

In this apparatus, light falling upon the plate P is polarized, and then in succession passes through the lenses L_1, and L_2, to the analyser A, by which reflection takes place through the lens L_3. All these lenses have the same focal length, and the axial separation of each adjacent pair of lenses is equal to twice that focal

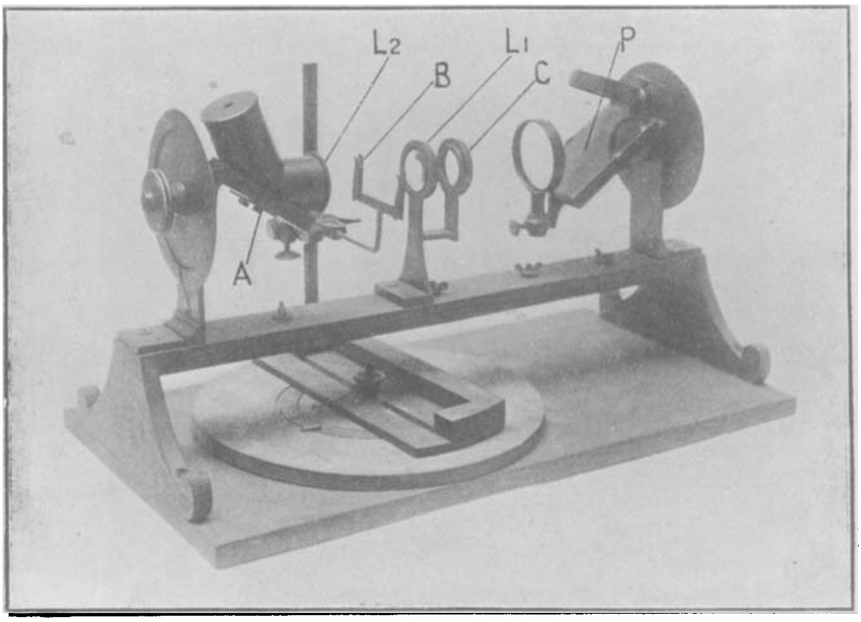

FIG. 4.—Airy's Polariscope.

length, thus the three lenses are arranged as "in the old three-glass eye-piece," first used in the middle of the 17th Century, for terrestrial, i.e. erecting telescopes. The analysing plate, with the "second and third lenses, turns on a spindle parallel to the rays polarized by the first plate, whose direction passes through the centres of the first and second lenses." For the examination of the ring-and-cross system given by an axis-cut plate, the plate is placed in the position marked B, whilst examination of the macled structure of quartz, amethyst, topaz, etc., is effected by placing the crystal-plate in the position C, where also a micrometer may be placed so that it will be seen distinctly with the rings produced by an object at B. Sufficient space is left between the plate P and the plane C to permit of the introduction of a Fresnel rhomb to allow of experiments in circularly and elliptically polarized light. When used with artificial light a collimating lens is introduced between the light and the plate P.

It will be noticed that in the microscope the lenses L_1, L_2 and L_3, are represented by the substage condenser, the object-glass, and the combination of Bertrand lens and ocular, respectively. The lower focal plane of the condenser in the microscope corresponds with the "micrometer," etc., plane C of fig. 5.

Airy's polariscope, described above, deserves much more attention than it has apparently received. It is probably the simplest possible combination with which the alternative examination of objects in parallel and convergent light can be achieved.

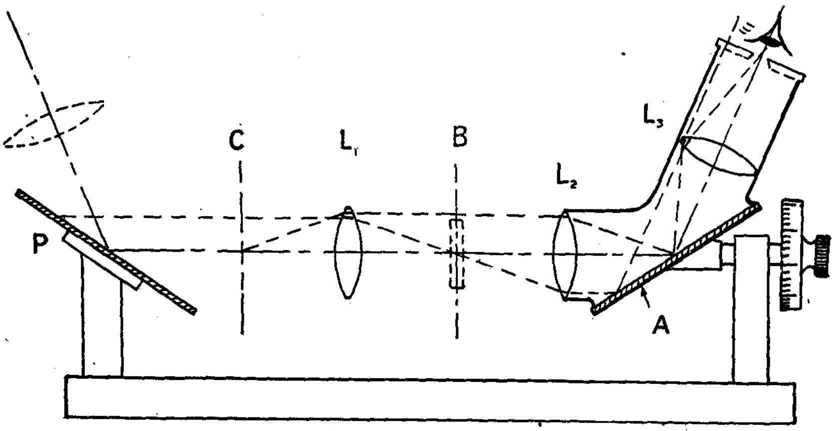

Fig. 5.—Optical System of Airy's Polariscope.

This polariscope was subsequently fitted with a Nicol prism and sold with the names of several opticians upon it, but I have never found one with Airy thus honoured.

Fig. 6 shows Amici's polariscope or polarizing microscope, which was constructed about the year 1830, but apparently was not fully described until 1844 (*2* and *3*).

In this apparatus the polarizer consisted of eight or ten plates of glass with parallel faces, mounted in a frame AB, adapted to tilt about a horizontal axis, the angle being indicated on a scale C. This polarizer is carried by a ring E, upon which rotates a graduated ring F, carrying the object-plate G, adapted also to rotate about a horizontal axis, the angle being indicated by a disc I. The analyser is formed by a rhomb of Iceland spar, placed over the eye-piece at R, and in such a position that two images of the Ramsden circle are produced, one of which may be blotted out by means of a pivoted disc and aperture Q. The microscope itself is adapted to rotate about its own axis, a pointer indicating its position on the fixed scale L. Experiments with circularly-polarized light may be carried out by placing a Fresnel rhomb on the object stage.

To adapt the instrument for use with convergent light, a second objective, made up of two or three lenses, Y, is added. This

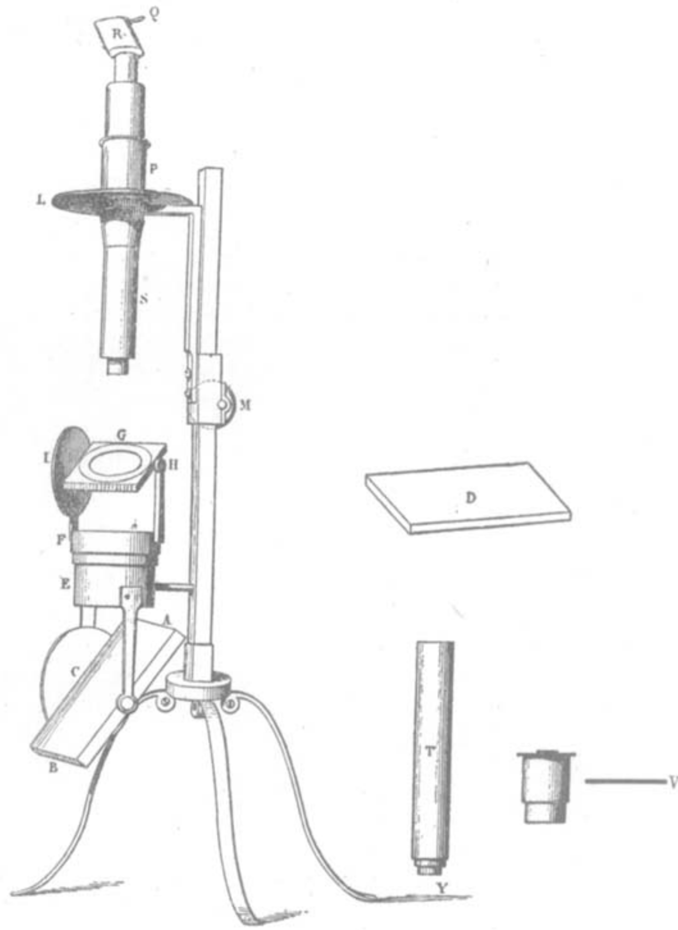

FIG. 6.—Amici's Polariscope.

auxiliary lens system has a short focus, and is mounted in a tube T, adapted to slide on a cylinder S, the interval between the two systems being usually made equal to about double their focal lengths. The added system thus acts as the upper of two condensing systems. The interference figures are projected into its upper focal plane, and the microscope P is then adjusted to examine the figures in this plane.

The interference figures observed can be seen under different magnifications by altering the distance between the auxiliary lens

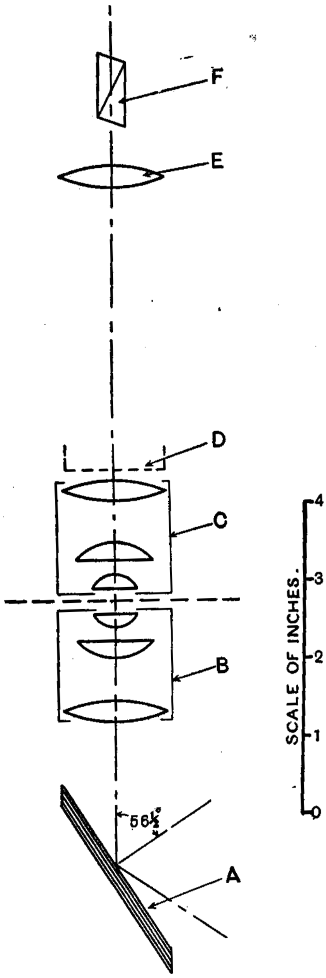

Fig. 7.—Nörrenberg's later Polariscope.

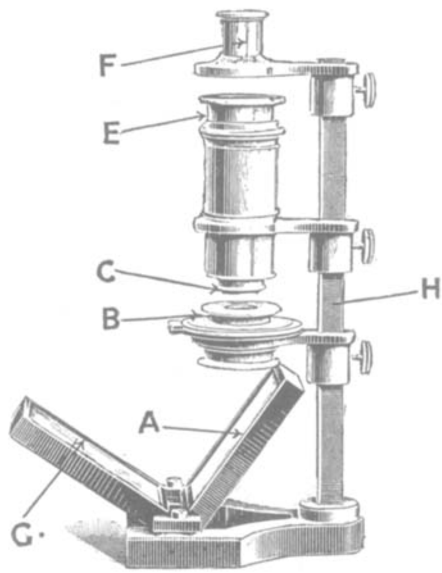

Fig. 8.—Optical System of Nörrenberg's later Polariscope.

system mounted in the tube T, and that mounted at the bottom of the tube S.

The microscope fitted with the tube T is capable of receiving a cone of rays of 150° of aperture. To present this cone to the microscope, however, it is necessary to place in the central opening of the object stage, a tube containing a system of convex lenses, V, upon the uppermost of which the crystal is placed. It will be seen that by placing a plane mirror (horizontal) upon the ring F, to carry the crystals, and upon the object-carrier G a reflecting plate with parallel faces inclined at the polarizing angle, one can convert this apparatus into that of Nörrenberg, with the advantage that the images can be observed magnified by the microscope.

Fig. 8 shows a Nörrenberg polariscope (*5*) of a later type, as made by Steeg and Reuter. Fig. 7 shows the optical system of the same to scale. The reflecting polarizer A receives light from a more or less horizontal reflector G. The polarized beam passes through a pair of lenticular condensing systems, B and C, of the Abbe type, and the interference figures are observed in the upper focal plane of the upper condenser in the usual way, by means of a simple magnifying lens E, carried by a sliding tube. The analyser F is carried by a separate mount fitted with an angular scale. All the fittings are adjustable on a vertical bar H, of triangular section, to which they are clamped. The object under examination may be attached to a goniometer, and thus tilted as required with respect to the axis of the polariscope. The optical system shown by Fig. 7 is interesting on account of its simplicity. Each of the condensing systems consists of three lenses, as shown, with an equivalent focal length of 0·75 inch. Cross-wires are mounted in the upper focal plane of the upper condensing system C, and the interference figure in this plane is examined in the usual way by means of the magnifying lens E, with a focal length of 4 in., and an analyser F. The angular aperture of each of the condensers is about 110°.

The Petrological Microscope.

In the early days of the 19th century, rocks, especially those which were hard and compact, were pounded into minute fragments as a preliminary to their examination in the microscope. In 1826, however, William Nicol (*23*),* the inventor of the Nicol prism, succeeded in cutting thin sections for the first time, and gave a detailed account of his method. He achieved some brilliant results: he taught the zoologist how to obtain thin sections of teeth; to the botanist he supplied sections of silicified wood, and to the mineralogist sections of agate. Nicol's method, however, was very little used, and almost unknown, when Sorby, in 1858, (*26*) used it for the purpose of cutting the specimens he required in a brilliant research which he carried out on liquid and other inclusions in crystals. The sections used by Sorby varied in thickness from one-hundredth to one-thousandth part of an inch.

* I am indebted to my friend, Mr. A. W. Sheppard, for this reference.

They were smoothed on Water-of-Ayr stone and cemented to the glass with Canada balsam, all polishing powders being avoided. The seed thus sown soon bore fruit. Sorby made the acquaintance of Zirkel on the Continent, who became his devoted disciple, and carried on his (Sorby's) work with great success. It is interesting to note that neither Nicol nor Sorby used the polarizing microscope in their researches. Indeed Sorby, near the end of his paper, considers himself called upon to defend the use of the microscope—not the polarizing microscope, be it noted—in petrological work. He says: "Although with a first-rate microscope, having an achromatic condenser, the structure of such crystals and sections of rocks and minerals as I have prepared for myself with very great care can be seen by good daylight as if visible to the naked eye, still some geologists, only accustomed to examine large masses in the field, may perhaps be disposed to question the value of the facts I have described, and to think the objects so minute as to be quite beneath their notice, and that all attempts at accurate calculations from such small data are quite inadmissible. Whatever science, however, has prospered by adopting such a creed? What physiologist would think of ignoring all the invaluable discoveries that have been made in his science with the microscope merely because the objects are minute?"

Fouqué (*17*), writing in 1879 of the work of Zirkel and Vogelsang, the latter of whom died in 1872, says: "Up to that time they had never applied to the examination of rocks that special variety of light which physicists called polarized light. They worked almost entirely with natural light." It thus appears, strange as it may seem, that the polarizing microscope, specially adapted and regularly and systematically used for the examination of rock sections, did not come into use before the year 1870.

The Polarizing Microscope as Used for the Examination of General Objects.

It was very early recognized that the polarizing microscope, even in its simplest form, was not restricted in its use to the examination of objects provided by the mineral kingdom. Brewster as early as the year 1814, (*10*) had carried out extensive researches on animal and vegetable products, amongst which were animal and vegetable fibres, hairs and bristles, cuticles and corns, glue, isinglass, horn, paper, gums and balsams, waxes and organic acids. The classical contribution to the subject, however, was due to Talbot, of photographic renown (*27*), who, in 1834, published a paper the opening sentence of which reads: "Among the very numerous attempts which have been made of late years to improve the microscope, I am not aware that it has yet been proposed to illuminate the objects with polarized light"; and he goes on to say: "And it cannot be without interest for the physiologist and natural historian to present him with a method of microscopical inquiry which exhibits objects in so peculiar a manner that nothing resembling it can be produced by arrangements of the ordinary kind." Talbot fitted the microscope, either with a pair of tourmalines, or, preferably, a pair of the then newly invented Nicol prisms. He describes the application of his apparatus to the examination of a hair, and states that many organic substances of animal and vegetable origin appear luminous in a similar way. The paper, however, principally deals with the examination of various forms of crystals and crystallographic growth. Brewster, in 1837 (*14*), generously gives Talbot credit for being the first to fit up a compound microscope "in the completest manner and for the express purpose of examining structures by polarized light." It is hoped that Brewster did not regret his generous recognition of Talbot's invention, but it is significant that we find him, in 1853 (*16*), saying of the polarizing microscope: "Such a microscope cannot properly be called an invention, although the invention of it has been claimed by several persons who certainly did not invent it."

Brewster, later in 1848 (*15*), proposed to get rid of glare, and the consequent indistinctness of vision in the microscope, by using polarized light. He had discovered, to his surprise, that some animal and vegetable fibres which he was examining could be seen with greater distinctness with polarized light than with ordinary light, although he admits that the observer is justified in removing the Nicol prisms in ordinary cases when he wishes to obtain the most perfect definition his instrument is capable of. He explains the diminution of glare, and the consequent greater distinctness of the image, by pointing out that in ordinary light, the light which passes close to the edge of the object without passing through it, produces diffraction which results in indistinctness in the image. Between crossed Nicols, however, this light is stopped by the analyser with a resultant gain in distinctness. He points out also the further advantage of being able to examine objects in liquids without a cover-glass. He admits that this method is only applicable to objects which depolarize light, but says that "there is scarcely an animal or vegetable fibre which does not possess this property." Brewster concludes by claiming that his microscope sub-stage condenser (*13*), which should be "as perfect as its magnifying apparatus," also removes indistinctness by converging the illuminating rays upon the object, "thus practically making it self-luminous." Finally Quekett, in 1855 (*25*), urges that all structures, whether animal, vegetable or mineral, should be investigated by polarized light. Mr. Conrad Beck, as you are aware, has quite recently shown *amphipleura* resolved into dots by the use of polarized light between crossed Nicols.

The Future of the Polarizing Microscope.

In concluding this address it will not be out of place for us to inquire briefly as to the direction in which improvement of the polarizing microscope is called for, or is possible. So far as the polarizing elements are concerned, something still remains to be done. The present polarizer is efficient in its performance, but it undoubtedly could be replaced by a single black-glass plate, and still remain efficient for many uses. A disc of black-glass, in many cases, could be substituted with advantage for the more or less useless concave reflector. The trouble arises with the analyser. This has never been altogether satisfactory. When placed above the eye-piece it cuts down the field of view, and when mounted above the objective, it seriously interferes with the definition and focal adjustment, and necessitates an expensive fitting to permit of its rotation and withdrawal when not in use.

What is wanted to simplify this design and cheapen production is a tourmaline that transmits copiously a beam of polarized white light. But in nature when a tourmaline becomes white it becomes useless for polarizing purposes. But is the case hopeless? Talbot, and more particularly Herapath, nearly succeeded in producing the desired crystal, and I think that their work should be continued. Since 1852 an enormous number of organic crystallized compounds have been added to the list of the chemist. These substances should be systematically examined for the purpose of discovering a polarizing crystal to meet the requirements of the optician and petrologist. The crystals produced by Herapath, with a thickness of 0·002 inch, appeared as "black as midnight" when crossed. If stable crystals with these properties can be discovered and produced cheaply, as they almost certainly would be, efficient polarizers and analysers would be produced of the dimensions of a cover-glass, and could be applied with great economic, optical, and mechanical efficiency, to the polarizing microscope. Should this address result in the initiation and carrying out of such a research it will not have been given in vain.

But here, finally, let me digress for a moment. In discussing this question of the polarizing microscope, with practical ends in view, we must take into consideration the peculiar and difficult conditions of our time. It is quite easy for us as users of microscopes to formulate demands which it may be quite impossible for the manufacturer to satisfy—at the price. Again, it must be remembered, that whilst the bulk of the demand for microscopes in this country is for instruments of the student's type, the student himself, the potential purchaser, is poorer than he has been for many years past. How then are we to reconcile these conflicting conditions? There is, I think, only one answer—simplification and standardization. The student and his teacher must take the responsibility for the one, and the manufacturer for the other Now as regards the petrological, or polarizing microscope, a good deal has already been done by the manufacturer, and he is prepared to do more, always assuming that having made his microscopes he can sell them. The student, however, does not buy on his own responsibility; he very properly defers to the judgment of his teacher. I think, therefore, that the time is ripe for action. Teachers and manufacturers should meet at a round table, with a chairman well acquainted with the broad aspects of the question from both points of view, and thrash the question out. I would have no fear as to the result. The question, I think, is one which might very well be taken up by the British Science Guild.

My thanks are due to Mr. Thos. Court for the generous way in which he has placed his unique collection of apparatus and books, etc., at my disposal.

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