moon appears to indicate an elevation of temperature through 500° Fahr.* In deducing this result allowance has been made for the *imperfect* absorption of the sun's rays by the lunar surface.

In the present imperfect state of these observations it would be premature to discuss them at greater length; but as some months must elapse before any more complete series can be obtained, and the present results are sufficient to show conclusively that the moon's heat is capable of being detected with certainty by the thermopile, I have thought it best to send this account to the Royal Society; and I shall be most happy to receive suggestions as to improvements in the method of working, and as to the direction in which it may be most desirable to carry on future experiments.

IV. "On a New Arrangement of Binocular Spectrum-Microscope." By William Crookes, F.R.S. &c. Received April 23, 1869.

The spectrum-microscope, as usually made, possesses several disadvantages: it is only adapted for one eye†; the prisms having to be introduced over the eyepiece renders it necessary to remove the eye from the instrument, and alter the adjustment, before passing from the ordinary view of an object to that of its spectrum, and *vice versâ*; the field of view is limited, and the dispersion comparatively small.

I have devised, and for some time past have been working with, an instrument in which the above objections are obviated, although at the same time certain minor advantages possessed by the ordinary instrument, such as convenience of examining the light reflected from an object, and comparing its spectrum with a standard spectrum, are not so readily associated with the present form of arrangement.

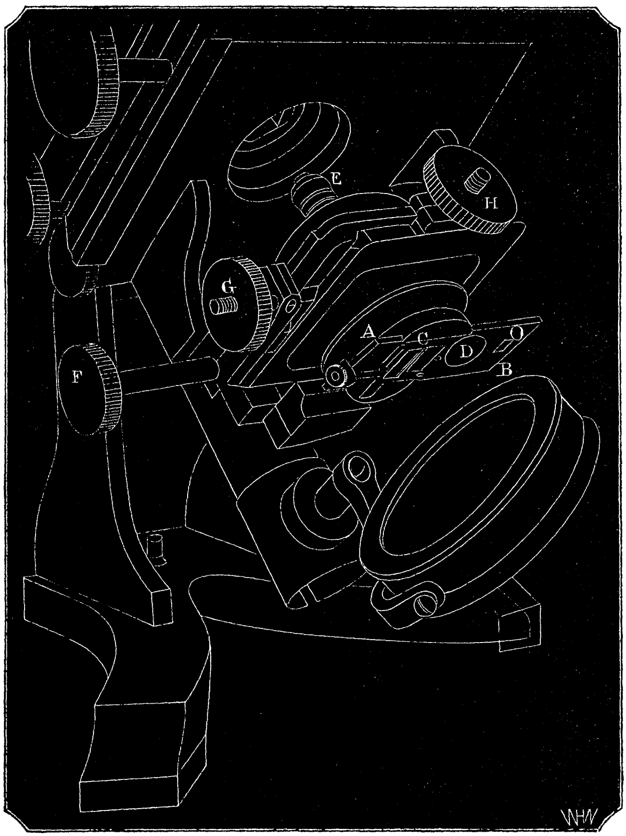
The new spectrum-apparatus consists of two parts, which are readily attached to an ordinary single or binocular microscope; and when attached they can be thrown in or out of adjustment by a touch of the finger, and may readily be used in conjunction with the polariscope or dichrooscope; object-glasses of high or low power can be used, although the appearances are more striking with a power of $\frac{1}{2}$-inch focus or longer; and an object as small as a single corpuscle of blood can be examined and its spectrum observed.

* This may seem a very large rise of temperature; but it is quite in accordance with the views of Sir John Herschel on the subject (Outlines of Astronomy, section 432 and preceding sections), where he says that, in consequence of the long period of rotation of the moon on its axis, and still more the absence of an atmosphere, "The climate of the moon must be most extraordinary, the alternation being that of unmitigated and burning sunshine, fiercer than that of an equatoreal noon; and the keenest severity of frost, far exceeding that of our polar winters, for an equal time." And again, ". . . . the surface of the full moon exposed to us must necessarily be very much heated, possibly to a degree much exceeding that of boiling water."

† Mr. Sorby in several of his papers (Proc. Roy. Soc. 1867, xv. p. 433; 'How to Work with the Microscope,' by L. Beale, F.R.S., 4th edition, p. 219) refers to a binocular spectrum-microscope; but he gives no description of it, and in one part says that it is not suited for the examination of any substance less than $\frac{1}{10}$ of an inch in diameter.

The two additions to the microscope consist of the substage with slit &c., and the prisms in their box. The substage is of the ordinary construction, with screw adjustment for centring, and rackwork for bringing it nearer to or withdrawing it from the stage. Its general appearance is shown in fig. 1, which represents it in position. A B is a plate of brass,

Fig. 1.



sliding in grooves attached to the lower part of the substage; it carries an adjustable slit, C, a circular aperture, D, 0·6 inch in diameter, and an aperture, O, $\frac{1}{8}$ inch square. A spring top enables either the slit or one of the apertures to be brought into the centre of the field without moving the eye from the eyepiece. Screw adjustments enable the slit to be widened or narrowed at will, and also varied in length. At the upper part of the substage is a screw of the standard size, into which an object-glass of high power is fitted. E represents one in position. I generally prefer a $\frac{1}{2}$-inch power; but it may sometimes be found advisable to use other powers here.

The slit C and the object glass E are about 2 inches apart; and if light is reflected by means of the mirror along the axis of the instrument, it is evident that the object-glass E will form a small image of the slit C, about 0·3 inch in front of it. The milled head F moves the whole substage up or down the axis of the microscope, whilst the screws G and H, at right angles to each other, will bring the image of the slit into any desired part of the field. If the slide A B is pushed in so as to bring the circular aperture D in the centre, the substage arrangement then becomes similar to the old form of achromatic condenser. Beneath the slit C is an arrangement for holding an object, in case its surface is too irregular, or substance too dense, to enable its spectrum to be properly viewed in the ordinary way*.

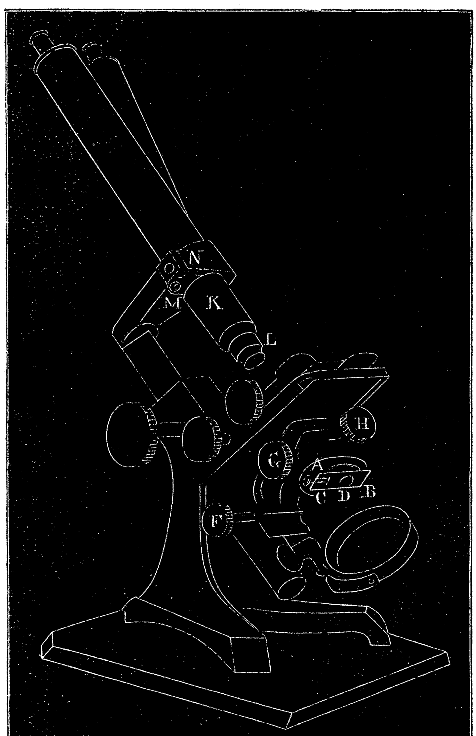
Supposing an object is on the upper stage of the microscope (shown in fig. 2) and viewed by light transmitted from the mirror through the large aperture D and the condenser E, by pushing in the slide A B so as to bring the slit C into the field, and then turning the milled head F, it is evident that a luminous image of the slit C can be projected on to the object; and by proper adjustment of the focus, the object and the slit can be seen together equally sharp. Also, since the whole of the light which illuminated the object has been cut off, except that portion which passes through the slit, all that is now visible in the instrument is a narrow luminous line, in which is to be seen just so much of the object as falls within the space this line covers. By altering the slit-adjustments the length or width of the luminous line can be varied, whilst by means of the rackwork attached to the upper stage, any part of the object may be superposed on the luminous line. The stage is supplied with a concentric movement, which permits the object to be rotated whilst in the field of view, so as to allow the image of the slit to fall on it in any direction. During this examination a touch with the finger will at any time bring the square aperture O, or the circular aperture D into the field, instead of the slit, so as to enable the observer to see the whole of the object; and in the same manner the slit can as easily be again brought into the field.

The other essential part of this spectrum-microscope consists of the prisms. These are enclosed in a box, shown at K (fig. 2). The prisms are of the direct-vision kind, consisting of three flint and two crown, and are altogether 1·6 inch long. The box screws into the end of the microscope-body at the place usually occupied by the object-glass; and the object-glass is attached by a screw in front of the prism-box. It is shown in its place at L. The prism-box is sufficiently wide to admit of the prisms being pushed to the side when not wanted, so as to allow the light, after passing

* In carrying out the experiments which were necessary before this spectrum-microscope could be made in its present complete form, I have been greatly assisted by Mr. C. Collins, Philosophical-Instrument Maker, 77 Great Tichfield Street, to whom I am also indebted for useful suggestions as to the most convenient arrangement of the different parts, so as to render them easily adapted to microscopes of ordinary construction.

through the object-glass, to pass freely up the tube K. A pin at M enables the prisms to be thrown either in or out of action by a movement of the finger. As the prisms are close above the object-glass, the usual sliding box, carrying the binocular prism and the Nicol's prism (shown at N), may be employed as usual, and the spectrum of any substance may thus be examined by both eyes simultaneously, either by ordinary light, or when it is under the influence of polarized light. The insertion of the prism-box between the object-glass and the body of the microscope does not interfere with the working of the instrument in the ordinary manner. The length of the tube is increased 1 or 2 inches, and a little additional rackwork may in some instruments be necessary when using object-glasses of low power. The stereoscopic effect when the Wenham prism is put into action does not appear to be interfered with.

Fig. 2.



For ordinary work both these additions may be kept attached to the microscope, the prisms being pushed to the side of the prism-box, and the large aperture D being brought into the centre of the substage. When it is desired to examine the spectrum of any portion of an object in the field

of view, all that is necessary is to push the slit into adjustment with one hand, and the prisms with the other. The spectrum of any object which is superposed on the image of the slit is then seen.

The small square aperture at O (fig. 1) is for the examination of dichroic substances. When this is pushed into the field, by placing a double-image prism P between A B and E, two images of the aperture are seen in juxtaposition, oppositely polarized; and if a dichroic substance is on the stage, the differences of colour are easily seen.

When the spectrum of any substance is in the field and the double-image prism P is introduced, two spectra are seen, one above the other, oppositely polarized, and the variations in the absorption-lines, such as are shown by didymium, jargonium, &c., are at once seen.

A Nicol's prism, Q, as polarizer, is also arranged to slip into the same position as the double-image prism, and another, R, as analyzer, above the prism-box. The spectra of the brilliant colours exhibited by certain crystalline bodies, when seen by polarized light, can then be examined. Many curious effects are then produced, a description of which I propose to make the subject of another paper. Both the prisms P and Q are capable of rotation.

If the substance under examination is dark coloured, or the illumination is not brilliant, it is best not to divide the light by means of the Wenham prism at N, but to let the whole of it pass up the tube to one eye. If, however, the light is good, a very great advantage is gained by throwing the Wenham prism into adjustment and using both eyes. The appearance of the spectrum, and the power of grasping faint lines, are incomparably superior when both eyes are used; whilst the stereoscopic effect it confers on some absorption and interference spectra (especially those of opals) seem to throw entirely new light on the phenomena. No one who has worked with a stereoscopic spectrum-apparatus would willingly return to the old monocular spectroscope*.

If the illumination in this instrument is taken from a white cloud or the sky, Fraunhofer's lines are beautifully visible; and when using direct sunlight they are seen with a perfection which leaves little to be desired. The dispersion is sufficient to cause the spectrum to fill the whole field of the microscope, instead of, as in the ordinary instrument, forming a small portion of it, the dispersion being four or five times as great; whilst, owing to the very perfect achromatism of the optical part of the microscope, all the lines from B to G are practically in the same focus.

As the only portion of the object examined is that part on which the image of the slit falls, and as this is very minute (varying from 0·01 to

* It is not difficult to convert an ordinary spectroscope into a binocular instrument. The rays after leaving the object-glass of the telescope are divided into two separate bundles and received on two eyepieces properly mounted. As it is immaterial whether the spectrum be stereoscopic or pseudoscopic, a simpler form of prism than Mr. Wenham's arrangement can be used.

0·001 inch, according to the actual width of the slit), it is evident that the spectrum of the smallest objects can be examined. If some blood is in the field, it is easy to reduce the size of the image of the slit to dimensions covered by one blood-disk, and then, by pushing in the prisms, to obtain its spectrum.

If the object under examination will not transmit a fair image of the slit (if it be a rough crystal of jargoon for instance), it must be fixed in the universal holder beneath the slit and the light concentrated on it before it reaches the slit. If the spectra of opaque objects are required, they can also be obtained in the same way, the light being concentrated on them either by a parabolic reflector or by other appropriate means.

By replacing the illuminating lamp by a spirit-lamp burning with a soda-flame, and pushing in the spectrum-apparatus, the yellow sodium-line is seen beautifully sharp; and by narrowing the slit sufficiently it may even be doubled. Upon introducing lithium or thallium compounds into the flame, the characteristic crimson or green line is obtained; in fact so readily does this form of instrument adapt itself to the examination of flame-spectra, that for general work I have almost ceased to use a spectroscope of the ordinary form. The only disadvantage I find is an occasional deficiency of light; but by an improved arrangement of condensers I hope soon to overcome this difficulty.

V. "On some Optical Phenomena of Opals."

By William Crookes, F.R.S. &c. Received April 23, 1869.

When a good fiery opal is examined in day-, sun-, or artificial light, it appears to emit vivid flashes of crimson, green, or blue light, according to the angle at which the incident light falls, and the relative position of the opal and the observer; for the direction of the path of the emitted beam bears no uniform proportion to the angle of the incident light. Examined more closely, the flashes of light are seen to proceed from planes or surfaces of irregular dimensions inside the stone, at different depths from the surface and at all angles to each other. Occasionally a plane emitting light of one colour overlaps a plane emitting light of another colour, the two colours becoming alternately visible upon slight variations of the angle of the stone; and sometimes a plane will be observed which emits crimson light at one end, changing to orange, yellow, green, &c., until the other end of the plane shines with a blue light, the whole forming a wonderfully beautiful solar spectrum in miniature. I need scarcely say that the colours are not due to the presence of any pigment, but are interference colours caused by minute striæ or fissures lying in different planes. By turning the opal round and observing it from different directions, it is generally possible to get a position in which it shows no colour whatever. Viewed by transmitted light, opals appear more or less deficient in transparency and have a slight greenish yellow or reddish tinge.

Fig. 1.

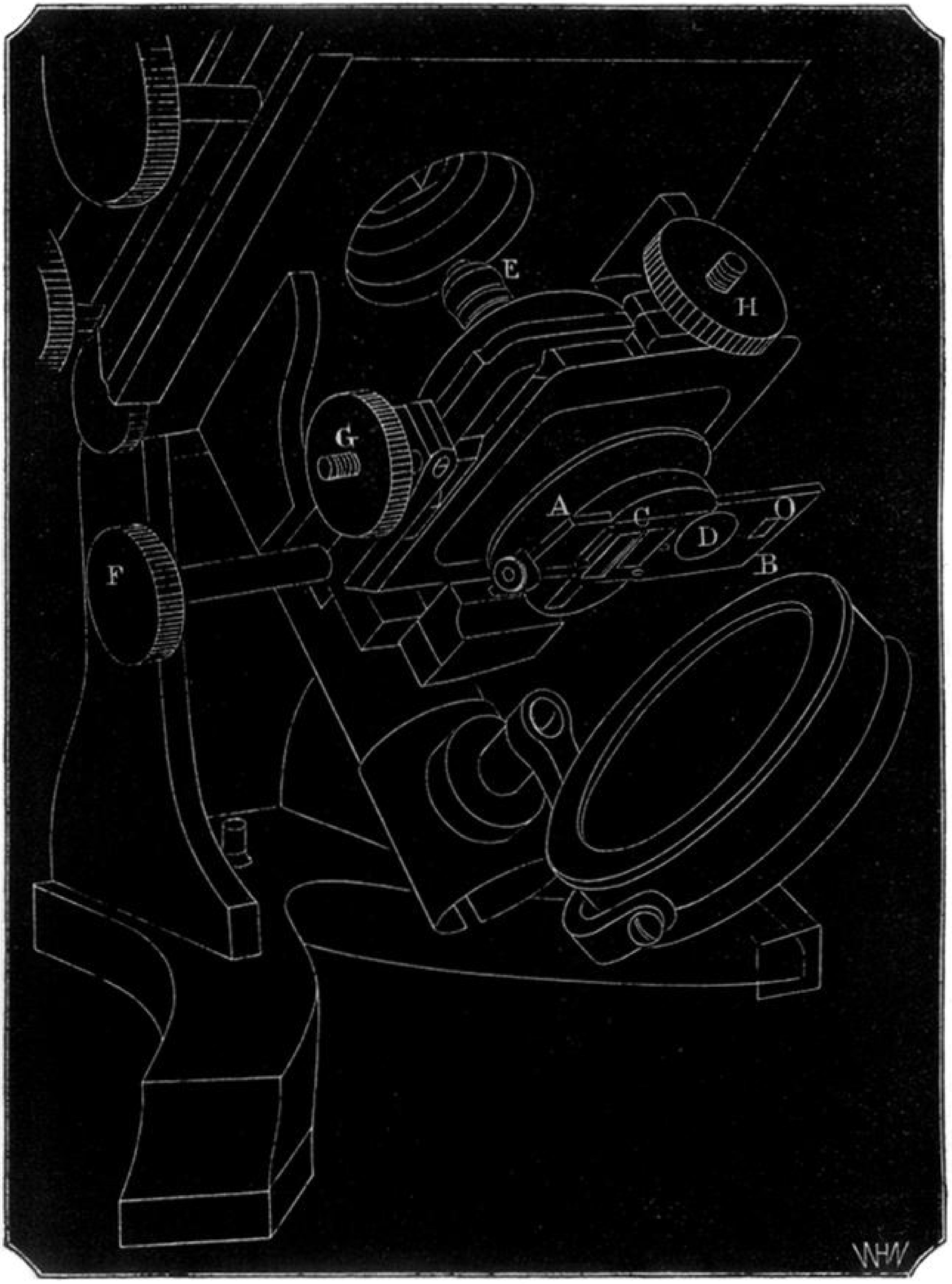


Fig. 2.