XLI.—*Description of a Double Holophote Apparatus for Lighthouses, and of a Method of Introducing the Electric or other Lights.* By Sir DAVID BREWSTER, K.H., D.C.L., F.R.S. (Plate XXXVIII.)

(Read 29th April 1867.)

In the year 1812 I described an apparatus, by which the light of the sun, or of any luminous body concentrated in the focus of an improved lens, could be returned by reflection from a spherical mirror into the same focus, thus increasing the light and heat produced by the cone of refracted rays. The apparatus contained also a double system of lenses and plain mirrors, by which additional beams of light could be concentrated in the same focus.*

In 1827 I described the very same apparatus as applied in the dioptric system of lights, *the whole of the light* which issues from a lamp being thrown into one wide and parallel beam, constituting what has been called a *holophote*, now in use in every part of the world.†

This apparatus consists of *three* different parts:—

1st, Of a lens which refracts into a parallel beam of light a cone of rays, which has for its base the surface of the lens, and for its apex the source of light.

This use of a common lens was made in the lighthouse in the Isle of Portland in 1789.

2d, Of a spherical mirror placed behind the flame, which throws into the parallel beam a similar cone of rays, whose base is the mirror, and whose apex is the flame.

3d, Of two systems of lenses and plane mirrors, by which the cones of rays, which would otherwise be lost, are thrown into cylindrical beams, which widen the principal parallel beam.

If the single holophote has been found so useful in lighthouse illumination, a double or even a triple holophote, in which all the lenses and mirrors may be reduced in size, must, in particular circumstances, have a peculiar value.

A double holophote, in which the light of two flames is condensed into a wide beam, is shown in Plate XXXVIII. Fig. 1, where F, F' are the two flames surrounded by lenses either of one or more pieces, and by plane and spherical reflectors, which may be made of speculum metal, of prisms, or of glass silvered behind or before. The cone of rays FPS, issuing from the flame F, is converged

* Edinburgh Encyclopædia, Art. BURNING INSTRUMENTS.

† Edinburgh Transactions, 1827, vol. xi. pp. 55, 56.

to the focus F' , from which it diverges, and falling upon the lens AB , is refracted by it, and the lens LL into the parallel beam RR , or, if we use only the lens AB , into the parallel beam rr .

The cone of rays FQR , which radiates from F , is thrown back to F by the part QR of the spherical mirror $HQRK$, and falling upon the lens PSP , is refracted like the direct cone FPS into the parallel beam RR or rr .

The two cones of rays FKK , FHH , intercepted by the lenses KK , HH , are refracted into parallel beams, which, falling upon the plane reflectors cd , ef , are reflected into the parallel beams $r''r''$, $r'r'$. In like manner, the cones of rays FWW , FYY are refracted by the lenses WW , YY into parallel beams, which, falling upon the plane reflectors $c'd'$, $e'f'$, are thrown into the parallel beams $\rho''\rho''$, $\rho'\rho'$.

The cone of rays FRY , falling upon the part RY of the spherical mirror $HQRY$, is returned through the flame F , from which it diverges, and falls as a second cone upon the lens KK , which throws it into a parallel beam, which is reflected into the beam $r''r''$ by the reflector cd . In like manner the cone of rays FHQ is, by means of the lens WW , and reflector $c'd'$, thrown into the beam $\rho'\rho'$.

The eight cones of rays which issue from the flame F , being the whole of its light, thus passes into the wide compound beam $r'\rho'$, consisting of the principal beam RR , and the four beams $r'r'$, $r''r''$, $\rho'\rho'$, $\rho''\rho''$. The beams $r'r'$ and $\rho'\rho'$ are each composed of *one* cone of rays FHH , FRY , and the beams $r''r''$, $\rho''\rho''$ of two cones of rays, the one direct, and the other reflected.

If we now place a second flame at F' , and surround it with the lenses and reflectors shown in the figure, it will become a second holophote. The cone of rays $F'AB$, refracted by the lenses AB , LL , will add its light to the central beam RR , and the opposite cone $F'PS$, refracted by the lens PS' to F , from which it falls upon the mirror QR , will be reflected through the flame F' , from which it diverges and enters into the beam RR , like the direct cone $F'AB$.

The cone $F'CC$, refracted by the lens CC , is reflected by the plane mirror ab , so as to form a new beam $r'''r'''$, filling up the space between the beam $r''r''$, and the central beam RR . In like manner the cone $F'DD$ is made to fill up the space between $\rho''\rho''$ and RR , by means of the lens DD and the reflector $a'b'$.

The cone of rays $F'GM$, intercepted by the spherical reflector GM , as reflected through the focus F' , and by means of the lens DD and the reflector $a'b'$, is thrown into the beam $\rho''' \rho'''$. In like manner the cone of rays $F'EN$, reflected by the spherical mirror EN to the flame F , will pass into the beam $r'''r'''$, by the refraction of the lens CC and the reflector ab .

If it is desirable to have, for any special purpose, a more intense and a wider beam, we have only to substitute a lens in place of the mirror QR , and introduce through it the light of one or more holophotes, the cones of rays passing through the lens at QR , adding to the intensity of the central beam RR , the

other cones of rays which issue from the new flames producing hollow cylindrical beams, surrounding those shown in the figure.

If we wish to have a beam of great intensity, and of equal brightness throughout, the holophote principle is inapplicable; but in dispensing with the secondary lenses and the lateral reflectors, we obtain a less complex and more manageable apparatus, to which the name of *Cratophote* may be given, from the great intensity of the light which it is capable of producing.

This instrument is shown in Fig. 2, where M, N, O, P, Q are five flames, the light of which we wish to concentrate into one beam RR, MN, a concave mirror, and AA, BB, CC, DD, EE, &c., five, or any other number, lenses. The lenses BB, CC, DD, EE have the same focal length, but the focal length of AA is only one-half that of the rest. The light of the *first* flame M, or the cone of rays MAA, is refracted into the parallel beam RR. The light of the *second* flame N, or the cone of rays NBB, is refracted by the lens BB into its conjugate focus M, and, passing through it, falls upon the first lens AB, and is thrown by it into the beam RR.

In like manner all the other flames or cones of rays, OCC, PDD, and QEE, are converged by the lenses which intercept them to their conjugate foci, and finally enter the beam RR, into which the light of the five cones of rays is concentrated.

By placing a concave mirror RS in the instrument, so as to reflect the cone of rays QRS to Q, they will pass through all the other lenses into the beam RR. In like manner the other cones of rays PEE, ODD, NCC, MBB will be converged to the conjugate foci of the lenses which intercept them, and fall upon the mirror RS, which will send them back by the same process into the beam RR.

The intensity of the beam RR may be increased by diminishing the diameter and the focal length of the lens AB, which, when placed nearer N, will refract the cone of rays MAA into a beam of the same diameter as the lens.

The intense beam of light produced by this apparatus is obviously very different in its character from the compound beam obtained from the single or the double holophote. In the single holophote the beam consists of the central beam RR, Fig. 1, and of the hollow cylindrical beam $\rho'''\rho'''$, which, being less intense, will not be seen at such a distance as RR. In the double holophote the beam consists of the central beam RR, and of *three* cylindrical beams, each of which has a different intensity, and will, therefore, cease to be seen at different distances. It might, therefore, be desirable that each part of a lighthouse beam should have the same intensity, and, consequently, the same penetrating power as in the catoptric system, where the beam is produced by several parabolic reflectors of the same size, placed close to each other. In the dioptric system we can only approximate to this, and that very imperfectly, by combining several small holophotes, and thus producing a wide beam, in which we have several central beams,

each of which is surrounded by its feeble cylindrical ones. In this construction we might dispense with the use of large built-up lenses, and employ small lenses of flint-glass, which can now be manufactured at a moderate expense, and of great excellence.

The suggestion to introduce the Drummond or the electric and magnesian lights as *permanent* lights in our lighthouses is not likely to be adopted. Oil and gas light, concentrated optically into a powerful beam, has a sufficiently penetrating power in ordinary states of the weather, and more brilliant lights are required only in fogs and states of the weather when feebler lights cannot be seen.

In my paper on the Illumination of Lighthouses, in our *Transactions* for 1827, I have shown in Plate III. Fig. 1, two methods of occasionally introducing the electric or other light into the central beam of a holophote, without interfering with its ordinary action.* If we consider the front holophote in fig. 1 to be the ordinary dioptric light, the second holophote, with the electric or other light at F, might be used in place of the simpler and less effective one above referred to.

* The method of doing this by lenses, whose conjugate focus is F', Fig. 1, or by an ellipsoidal mirror, one of whose foci is F, when the spherical mirror (MN, Plate III. Fig. 1, above referred to) is removed, is distinctly shown; but the note describing it was accidentally omitted by the printer.

Fig. 1

Fig. 2