by means of the above simple formulæ and the measured dispersive and refractive power of the glass of the lenses. (The method of determining *μ,* &c., is given under Optics, vol. xvii. p. 800. ) The form generally adopted (see fig. 4) in the best modern object-glasses is extremely simple, viz., an equi-convex crown lens and a flint lens whose first surface has the same radius of curvature as the surfaces of the crown lens — this radius depending on the focal length which it is desired to give to the object-glass. Since in order to fulfil the conditions of achromatism the focal lengths of the two lenses have to be proportional to their dispersive powers (for the rays which it is desired to unite), and as in the two de­scriptions of glass in question the dispersion of flint glass for C to rays between F and G is very nearly twice that of crown glass, the posterior surface of the flint lens becomes nearly a plane. The final correction for achromatism is made, if necessary, by departing slightly from a plane in the curvature of the last surface of the flint lens, and the final correction for spherical aberration in the figuring of the surfaces. In a lecture delivered at the Royal In­stitution on 2d April 1886 Sir Howard Grubb, optician, of Dublin, said :

“ A truly spherical curve is the exception, not the rule. When I tell you that a sensible difference in correction for spherical aberration can be made by half an hour’s polishing, corresponding probably to a difference in the first place of decimals in radii of the curves, you will see that it is practically not necessary to enter upon any calculation for spherical aberration. We know about what form gives an approximate correction ; we adhere nearly to that, and the rest is done by figuring of the surface. To illustrate what I mean. I would be quite willing to undertake to alter the curves of the crown or flint lens of any of my objectives by a very large quantity, increasing one and decreasing the other so as to still satisfy the conditions of achromatism, but introducing theoretically a large amount of positive or negative spherical aberration, and yet to make out of the altered lens an object-glass perfectly corrected for spherical aberration. . . . I may remark that it is sometimes possible to make a better objective by deviating from the curves which give a true correction for spherical aberration, and correcting that aberration by figuring, rather than by strictly adhering to the theoretical curves.”

When an object-glass is designed for use as an ordinary telescope it is usual to select for the rays of different colour to be united

those near C and those be­tween F and G, since rays of lower and higher re­frangibility produce a com­paratively faint impression on the sense of sight. In such a telescope of any considerable aperture the image of a bright star at focus is surrounded by a halo of bluish or violet­coloured light,—a defect which is unavoidable in an object-glass composed of a crown and flint lens on ac­count of the irrationality of their spectra (Light, vol. xiv. p. 592). There seems to be no doubt that differ­ent eyes are differently im­pressed by rays of different wave-length.@@1 Thus two observers will often have different opinions as to the chromatic corrections of the same object-glass : the observer whose eye is ab­normally sensitive to vio­let light will pronounce the chromatic aberration over- corrected in an object-glass which another will consider perfect in this respect, and *vice versa.* Probably it is partly owing to this cause

that the object-glasses of different makers show systematic differ­ences in their colour correction. An exceedingly sensitive method of testing this correction devised by Professor Stokes is given under Optics, vol. xvii. p. 804. Another method, due to Professor Hark­ness and first carried out by Dr Vogel, is the following. Place behind the eye-piece a direct vision prism (*cf.* Optics, p. 801). The image of a star in the field will then be converted into a narrow spectrum, which, if there were no chromatic aberration, would when focused be represented by a faint coloured straight line, uniformly sharp and narrow. But in an ordinary object-glass only two points in the spectrum can be perfectly focused simultaneously ; therefore all its other parts are spread out, forming a coloured band of variable breadth. If we focus on the brightest part of the spectrum, both

its extreme ends become spread out into a more or less trumpet­shaped form, enabling the observer to note the range of the spec­trum over which precise definition can be expected. The amount of this extension will depend in some degree on the form of the object-glass, but much more (if the achromatism is fairly well corrected) on the irrationality of the spectra of the glass of which the lenses are composed. If we then focus, for example, on the C line, we shall have the band of light contracted at C and at another point (probably between F and G), widening to a slightly trumpet-shaped form below C, and markedly so above G. This second point of greatest contraction gives the wave-length of the ray which has the same focus as C. If the telescope has a focusing scale, we can also measure directly in this way the change of focus for rays of different colours. The chromatic aberration will be best corrected for the rays of minimum focus, and this minimum focus should for an ordinary telescope correspond with the brightest part of the spectrum, viz., with rays between D and E. A com­parison of the chromatic correction of object-glasses by different makers is given by Dr Vogel (*Monatsber. der Berliner Akad.,* April 1880), obtained in the manner just described. The tele­scopes compared are—

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Maker. | Observatory to which Instru­ment belongs. | Aperture of Object-Glass. | Focal Length. | No. of Aper­tures in Focal  Length. |
| Schröder  Grubb  Fraunhofer .... | Potsdam  Berlin | m.  0∙298  0∙207  0∙243 | m.  5∙4  316  4∙331 | 18∙1  15∙3  17∙8 |

Fig. 5, taken from the above-quoted paper, affords most interest­ing information as to the colour-correction of these three typical object-glasses. The curves of the diagram show the variation of the focal point for rays of different wave-lengths in the case of each object-glass. It will be seen that Fraunhofer has united the rays about C with those of wave-length 525 millionths millimètres, Grubb with those about wave-length 494, and Schröder about wave­length 463. The object-glasses of Grubb and Schröder are com­

posed of modem glass, which is comparatively colourless, whilst Fraunhofer’s glass is decidedly green in colour. The minimum focus in Fraunhofer’s telescope is placed near D (rather at wave-length 585), because the absorption of the blue and violet rays of the spectrum by the flint lens renders the brightest part of the spectrum less blue than in an objective composed of modern glass by Chance or Feil, which is nearly colourless. This circumstance enabled Fraunhofer to apply a very large over-correction for colour,—that is, to unite as perfectly as possible the red and central part of the spectrum, and to leave the outstanding violet rays to be in great part absorbed by the colour of the glass. The colour-corrections in the object-glasses of Grubb and Schröder are very different in character. In Grubb’s object-glass the minimum focus is for rays of wave-length about 545, that of Schroder’s is about wave-length 533, which appears to prove that Grubb’s eye is more sensitive to

@@@1 See Abney and Festing, Bakerian Lecture, *Phil*. *Trans*., 1886 ; also *Photo*- *graphic News,* May 1886, p. 332.