V. *A Defcription of a new Conftruction of Eye-glaffes for fuch Telefcopes as may be applied to Mathematical Inftruments.* By Mr. Ramfden; *communicated by Sir* Jofeph Banks, *Bart. P. R. S.*

Read December 19, 1782,

TO correct the errors in eye-glaffes, arifing from their fpherical figure, and alfo from the different refrangibility of light, it has been held abfolutely neceffary to have two, placed in fuch manner, that the image formed by the object-glafs of the telefcope fhould be between them; but in thofe telefcopes that are applied to mathematical inftruments, the interference of the firft eye-glafs before the image is formed is productive of many bad confequences; fhould that eye-glafs have the leaft fhake or motion whatever, it totally alters the adjuftment of the inftrument; and the diminifhing alfo of the image by this pofition, obliging us to fhorten the focus of the nearer eye-glafs, the wires in the focus of the telefcope are thereby confiderably more magnified than they would have been with the fame power, had both the eye-glaffes been put between the image and the eye.

Many defects in the micrometer with moveable wires are caufed by the conftruction of the eye glaffes of the telefcope to which it is applied. If only one eye-glafs is ufed, the field is fo contracted, that it is impoffible to meafure the diameter of the fun or moon with precifion, if the telefcope magnifies above 30 times;

times; and if, to enlarge the field, we uſe the preſent conſtruction of two eye-glaſſes, the conſequence is yet worſe; becauſe equal ſpaces between the wires will not then correſpond to equal ſpaces on the objects it repreſents, as thoſe converſant in the theory of optics well know; and this inequality depending on the form, poſition, and refractive power of the firſt eye-glaſs, it will be impoſſible to have data ſufficiently exact to allow for that error.

Thoſe who were ſenſible of this defect have thought to correct it by the application of an achromatic eye-glaſs, on the principle of that kind of object-glaſs, not ſuppoſing it poſſible to correct the aberrations from the different refrangibility of light, and alſo from the ſpherical figure of the lenſes by any other means than combining a concave lens with the convex ones; but the violent and contrary refractions from the neceſſary large ſize of the lenſes in proportion to their focal lengths, not only occaſioned great loſs of light, but rendered it impoſſible to correct the ſpherical aberration ſo as to obtain an angle of viſion much larger than could be had by a ſingle eye-glaſs: yet, however abſurd it may have appeared to attempt correcting both aberrations, when the lenſes are both convex, and are on the near ſide of the wires, the following obſervations will ſhew the practicability of it, and may throw ſome light on the theory of eye-glaſſes which ſeems hitherto not well underſtood.

Sir ISAAC NEWTON has ſhewn in his *Lectiones Opticæ*, in that ſection *De Phænomenis lucis per priſma in Oculum tranſmiſſæ*, that the appearance of colours on the edges of objects when viewed through a priſm depends on the proportion of the diſtance between the priſm and the object, compared with that between the priſm and the eye, that is to ſay, the nearer the object is

brought

brought to the priſm, the leſs will be the bordre of colours on the contours of the object.

To apply this to practice I placed a plano convex lens *a* (*vide* fig. 1.) with its plane ſide near an object, or an image IN formed by the object-glaſs of a teleſcope, and thus magnified the image which, from the poſition of the lens, was ſenſibly free from colour; but the reſpective foci of a lens ſo placed being very near each other, and on the ſame ſide, the emergent pencils diverge on the eye, and give indiſtinct viſion: this was remedied by placing a ſecond lens *k* a little within the focus of the former, the combined foci of the two lenſes being in the place of the image, the rays were thereby made to fall parallel on the eye, and to ſhew the object IN diſtinctly. If, by putting the lens *a* very near the image, any imperfection in it becomes too viſible, that diſtance may be conſiderably increaſed, without producing any bad effect; for theory, as wellas experiment, ſhews, that a ſmall aberration from the different refrangibility of light is of little conſequence compared with the ſame quantity of aberration cauſed by the ſpherical figure of the lenſes, but even that colouring may be corrected in the nearer eye-glaſs: for let a ray (fig. 2.) from an object *o*, by paſſing through a lens B, be ſeparated into colours, *ac* being the direction of the violet rays, and *a t* that of the red; if another lens be put at *c*, the violet rays paſſing through its center will ſuffer no refraction, while thoſe of the red, paſſing at ſome diſtance from thence are refracted, and the emergent red and violet will be parallel, when the mean refracting angle of the lenſes at the incidence of each pencil are to one another inverſely as the diameters of thoſe pencils.

If we attend to this poſition of the eye-glaſſes, it will be found equally advantageous for obviating the ſpherical aberration

of

of an oblique pencil as that from colour. In both, where there is a neceſſity for having a large portion of a ſphere, we have only to make the pencil on ſuch lens as ſmall as poſſible, and we may regulate the direction of the rays in each pencil at pleaſure when they approach the axis of the teleſcope.

To illuſtrate this, let us compare the effect of the ſpherical aberration of a lens on an oblique pencil in this poſition with that produced by the ſame lens, placed as uſual at its focal diſtance from the image. Let AC, fig. 3. repreſent the ſemi-object-glaſs of a teleſcope, CT its axis, E an eye-glaſs, and F the common focus of both the object-glaſs and eye-glaſs. Let AFC be an oblique pencil of homogeneous rays, G and H the points where the axis and the extreme rays paſs through the eye glaſs: the aberration of this pencil from the ſpherical figure of the lens E will be $EG^3 - EH^3$; but as the lens approaches towards F, EG and GH, becoming equal, this cauſe of aberration vaniſhes accordingly. The effects of the lens *k* will be altogether inſenſible from the ſmallneſs of its aperture; or it might be corrected in the figure of the object-glaſs, by making its aberration negative as much as this is affirmative.

It has been uſual to conſider that form and poſition of the eye-glaſſes beſt that would make the pencils from every part of the field interſect each other in the axis of the teleſcope at the place of the eye; but this will be found of little conſequence, ſeeing the diameter of a pencil here is generally much leſs than the pupil, nothing more is requiſite than that the eye may take in the pencils from the different parts of the field at the ſame time: but the field of a teleſcope will be moſt perfect when the conſtruction of the eye-glaſſes is ſuch, that the focus of an extreme and of central pencil are at the ſame diſtance from the eye. The diſpoſition above deſcribed will be found conformable to that idea.

Let AB (fig. 4.) repreſent an image formed by the object-glaſs of a teleſcope, V the firſt eye glaſs, as already deſcribed, with its plane ſide towards the image; let AC be the axis of a pencil of rays incident on the firſt ſurface of the lens V, and A*e* an extreme ray of the ſame pencil. Take CF to CA as the ſine of incidence out of air into glaſs is to the ſine of refraction, and F will be the focus of this pencil after paſſing through the firſt ſurface of the lens V. From the point F draw the angle CF*e*, the incident pencil on the ſecond ſurface of this lens, continue the lines FC and F*e* to *b* and *r* reſpectively, and draw the perpendiculars OI and OK on the point C, deſcribe the arc *nd*, and making *cd* to *ab*, as the ſine of refraction out of glaſs into air is to the ſine of incidence, draw *cd* continued till it cuts the axis in P. In like manner, on a center *e* deſcribe the arc *mg*, and making *yg* to *or* as the ſine of the angle of refraction is to that of incidence, draw the line *eg*Q; continue it and the line C*d* backward till they meet each other in *h*, and it will be the focus of the emergent pencil from the ſecond ſurface of the lens V. On the axis CF ſet off the diſtance C*ds* equal to C*h*, and draw *es* and C*e*. Now it is evident from the figure, that the focus of the emergent pencil will be nearer to C than the object itſelf, in the proportion the angle C*se* exceeds the angle CA*e*.

Thus, from the great angle of incidence of the oblique pencil on the ſecond ſurface of the lens, the focus of the emergent pencil is brought nearer to P the ſecond eye-glaſs, while that of the principal pencil remains the ſame, or very nearly ſo; and the image will become more diſtinct towards the edge of the field the nearer P*h* and PT approach to equality.

Fig. 2.

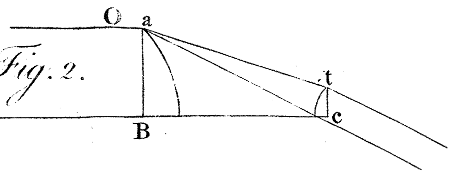


Fig. 1.

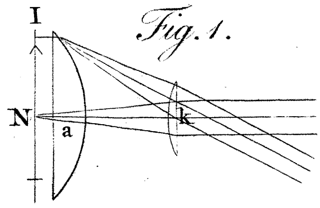


Fig. 3.

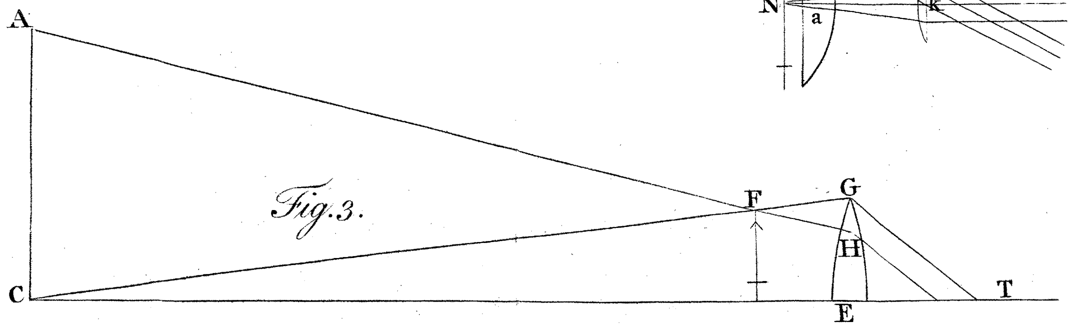
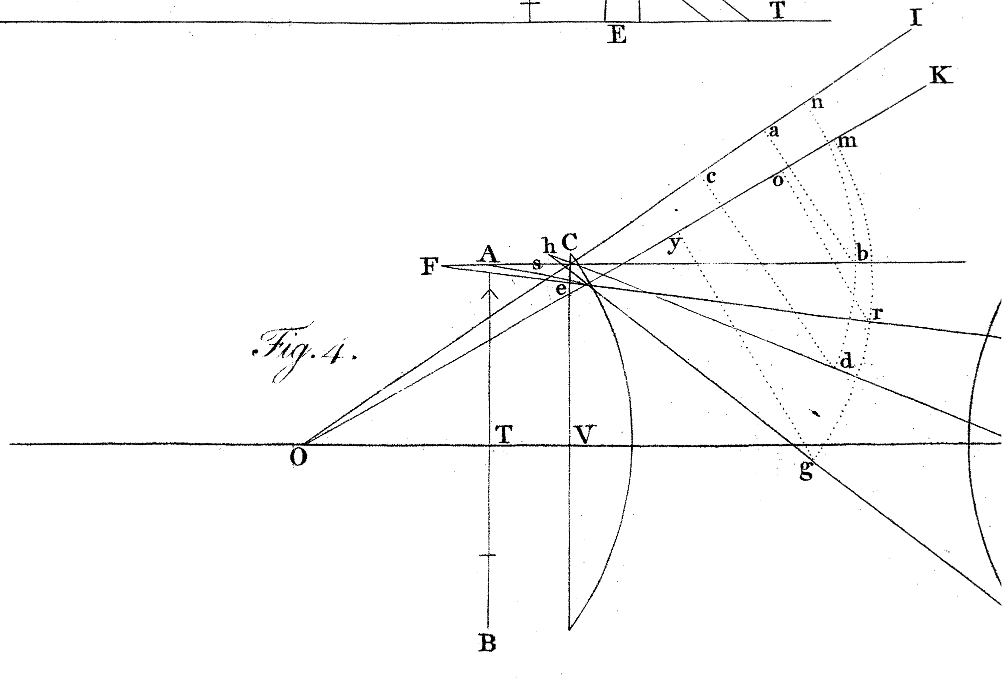
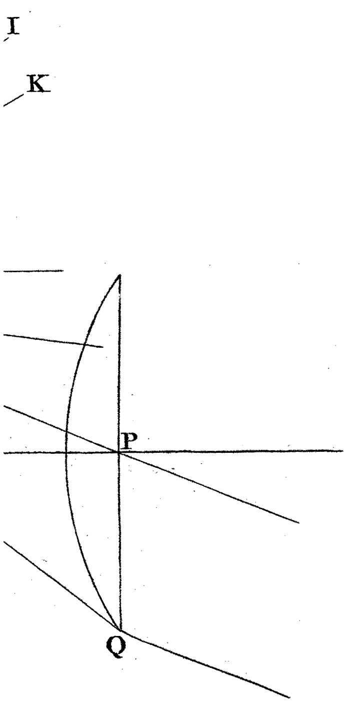


Fig. 4.





I
K
P
Q

To give a proper demonstration and theorem for the exact form of the first lens, according to its distance from the image, would require more leisure than is consistent with the situation of one not very conversant with mathematics. That distance, in proportion to the focal length of the lens, so that any unavoidable defect in it may become invisible, must be determined by experiment. If any variation be made in the form of this lens, it will be better to make the plane side rather a little convex than concave. By the latter the image would be distorted by the too great obliquity of the rays near the extremity of the lens.

Thus we have a system of eye-glasses which may be taken out of the telescope, in order to wipe them at pleasure. Or the magnifying power of the telescope may be varied without affecting the line of collimation, or in any manner altering the adjustment of the instrument to which such telescopes may be applied with many other advantages. In the present improved state of telescopes too, the disagreeable appearance of the wires from the great power of the eye-glasses is in a great degree remedied. The same principle may be usefully employed in many other cases. What is herein contained is only to be considered as an explanation of this very useful construction, and which is given in hopes that some person of more abilities in the science of optics will favour us with a general theorem, in order that its application may be more universal.

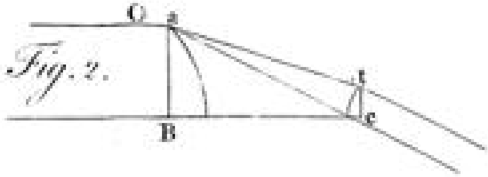


Fig. 2.

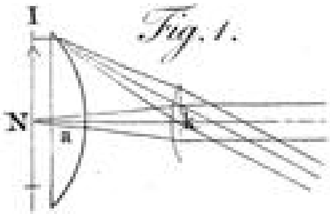


Fig. 1.

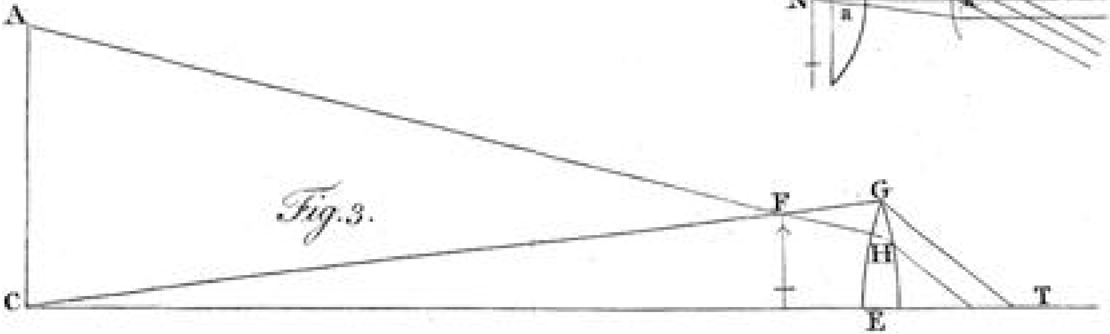


Fig. 3.

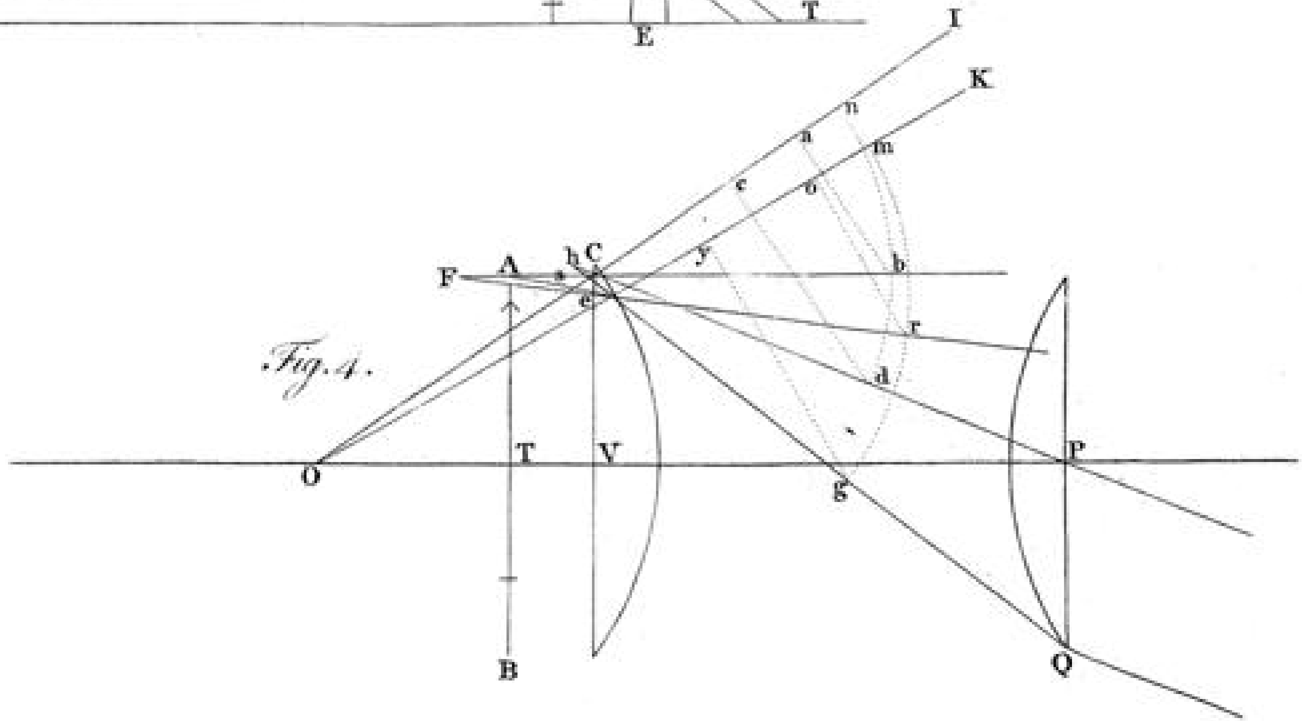


Fig. 4.