Fig. 23 shows tho mounting of the 8-inch refractor, of 9-feet focal length, at the private observatory of Dr Engelmann, Leipsic. The object-glass is by Messrs Clark of Cambridge, Mass., the mounting by the Repsolds of Hamburg. The declination circle reads from the eye end, and four handles for clamp­ing and slow motion in right ascension and declina­tion are situated near the observer’s hands. The tube is of sheet steel, light, stiff, and free from tremor. The eye end carries the micrometer with an illuminating apparatus similar to that previously described under Micrometer, vol. xvi. p. 246 *sq.,* figs. 16, 17, 20, and 21.

The lamp near the eye end illuminates the field or the wires at pleasure, as well as the position circle of the micro­meter and the declination circle : a separate lamp illuminates the hour circle. An excellent fea­ture (see fig. 24) is the short distance between the eye-piece and the declination axis, so that the observer has to follow the eye end in a comparatively small circle ; an­other good point is the flattening of the cast-iron centre-piece of the tube so that the flange of the declination axis is attached as near to the axis of the telescope tube as is consistent with free passage of the cone of rays from the object-glass. For purposes of micrometric research with the ordinary micrometer this instrument is the most ele­gant, satisfactory, and useful that we know, as was shown by the exceedingly accurate observa­tions of the minor planets Vic­toria and Sappho for solar paral­lax, by Galle’s method (see Parallax, vol. xviii. p. 249), made by Dr Engelmann in 1882. The substitution of small incan­descent electric lamps for the oil lamps would be an improvement.

(2) *Telescopes of Moderate Size for General Purposes.—*The modern equatorial should for general purposes be capable of carrying spectro­scopes of considerable weight, so that the strength of the axis and the rigidity of the instrument generally have to be considerably increased. Grubb has realized our ideas of what such an instru­ment should be in an equatorial of 6-inches aperture which he has recently made for the royal observatory at the Cape of Good Hope. The principal features are its great strength and rigidity, with special precautions to ensure preservation of the instrumental declination. The observations of Victoria and Sappho in 1882 revealed the great deficiency of most modern equatoriale in this respect. That is to say, if a star near the meridian is first made to run along the measuring web of the micrometer, the clockwork then set in action, and the star brought back to the centre of the field by the slow-motion handle in right ascension, it will be found that the perfection of the bisection is no longer preserved. Thus at most observatories the measures of difference of declination when the clockwork was employed were far inferior to those made with the telescope at rest. The reason seems to be that in most equatorials the lower pivot is cylindrical, and enters an ordinary cylindrical bearing which cannot be a perfect fit. Also the cross­head, telescope, counterpoise, &c., generally together overbalance the polar axis about the upper bearing, so that the lower pivot presses upwards in its bearing, and its rotation, under the action of the clock or slow motion coupled with the friction of the sur­faces, gives rise to a small rolling freedom which creates the errors in question. In this telescope the lower pivot is of steel, made slightly conical, and carefully ground to fit a long conical bearing, in whieh it would work very tightly, or even jam, but for spring pressure brought to bear on its lower hardened flat end, which relieves the greater part of the thrust ; and the polar axis is accu­rately balanced about its upper bearing by a weight at the lower end of the polar axis, so that the thrust is exactly in the axis of the cone. The upper pivot (4 inches in diameter) is also of steel, finished with the same care as that of a transit circle, so that the telescope rotates with the precision of a meridian instrument. Unusual rigidity has also been given to the declination clamping arms, and the new slow motion in declination is by far the best yet contrived ; it is a recent invention of Grubb’s, and is de­scribed below in his own words. The eye end, suitable for heavy spectroscopes, &c., is fitted to the butt end of the telescope by bayonet joints and tightening screws, so that it can be exchanged for a micrometric eye end with almost as little trouble as the ex­changing of an eye-piece. The illumination of the circles and the micrometer is by electric incandescent lamps. The instrument may be adjusted to any latitude and is probably the most practical and serviceable equatorial made. The subjoined description of the new slow motion in declination is taken from *Proc. R. Dubl. Soc.,* 1886, p. 107.

“The slow motion arrangements usually used in equatorials are of either of two forms, viz., (*a*) an endless screw working into a sector or portion of a toothed circle of long radius, or (*b*) a screw applying or pushing directly against an arm, that arm being kept in contact with the screw by a spiral or some other form of spring having a considerable range of motion. The first (*a*) possesses the disadvantage that, however carefully made, it is impossible it is quite free from ‘loss’ or ‘back lash'; and consequently the position of the telescope is not perfectly determinate in declination, which fault is incon­venient when delicate measures are required. The second (*b*) has practically no ‘back lash,’ as spring keeps the arm in perfect con­tact with screw, but it has the disadvantage that, what­ever range of motion is re­quired, the spring must be capable of working through the same range; consequently the spring will be much stronger in action at one end of the range than the other, unless it be made very long indeed, in which case its ac­tion is uncertain and un­pleasant. To remedy these defects the author [Grubb] has devised the following, which possesses the advan­tages of both:— ABCD (fig.

25) is a portion of the arms attached to telescope, or cradle, on which is planted the block (*b*), forming the bearing of the screw. The nut (n) is in the form of a ball working in a socket on the extremity of the clamp-arm EFG. A short stiff spring (S) is attached to this clamp-arm, bearing, not directly against any part of other arm, but against end of a second screw of same pitch as the main screw, the nut of which (*oo*) is toothed on edge, and works into a wheel of equal size *(pp)* on main screw. The point of this second screw, therefore, advances as much in one direction as the frame ABCD is carried in other, according as the milled head is turned ; and consequently the point of the screw does not sensibly vary in its position with respect to the clamp-arm EFG. A short stiff spring can therefore be used, and the dis­advantage above mentioned disappears.”

This form of slow motion could be applied with advantage to the right ascension also, and probably to the separation of the segments of heliometers.

(3) Of large equatorials we name first the great refractor at Washington of 26-inches aperture and 32½-feet focal length.@@1 The mounting appears to be unworthy of the well-known excellence of the object-glass. To illuminate the micrometer an assistant is required to hold a lamp in his hand. No convenient means are provided for illuminating the declination axis ; and in order to point the telescope in declination the following elaborate process lias to be performed :—

“ The instrument is brought into the meridian and set by the observer within a degree by means of coarse divisions painted on the edge of the declination circle. These divisions are rendered visible by lighting one or two of the gas burners of the dome, and viewed by the astronomer with an opera-glass. Then an assistant mounts by a ladder to a high platform and holds a gas lamp near the vernier, and the fine setting is accomplished by the observer seated in the observing chair, the declination clamp and slow-motion screw being convenient to his hand ” (*Washington Observations,* 1874, Appendix I., p. 33).

The polar and declination axes are of steel, only 7 inches in diameter at the thickest point, and the driving arc, which is far too small, is placed at the lower end of this slender axis. There must thus be considerable liability to tremor in right ascension. However well the instrument may act in specially practised hands with an excellent Clark’s micrometer (art. Micrometer, vol. xvi. p. 245), the instrument must be considered wanting in the rigidity and convenience which a modern equatorial should possess. In his official report on the instruments of European observatories New­comb defends the want of solidity and convenience of this instru­ment as compared with the Vienna telescope, because its smaller axes (notwithstanding Grubb’s anti-friction arrangements) permit it to turn more easily and the mounting to be of far simpler design. But at the time of Newcomb’s visit the Vienna telescope had not been brought into work, and cannot have been in proper working order if the motion in declination was so stiff as he describes it, at least when the present writer tested the instrument in Dublin that motion was surprisingly easy.

The great Pulkowa refractor (fig. 26) erected in 1885 is of 30- inches aperture and 45-feet focal length. The object-glass is by Clark, the mounting by the Repsolds. The tube is cylindrical, of riveted steel plate, graduated in thickness from the centre to its extremities, and bolted by very powerful flanges to a strong short cast-iron central tube, in which, as in Dr Engelmann’s telescope (fig. 23), the attachment to the flange of the declination axis is placed as close as it can be to the axis of the tube without inter-

@@@1 Described and figured in the *Washington Observations,* 1874, App. I.