Lenses

This issue of GIM International presents the annual Product Survey on High-end Total Stations (see page 41). One of the essential parts of a Total Station is its telescope, a system of lenses. A lens: I know what it is, I know what it does, but how is it manufactured?

The term lens stems from Latin and means â€˜lentilâ€™, the shape of which pulse resembles a lens; indeed it is the curvature that turns a piece of transparent material into a lens. The ancient Greek Aristophanes mentions a â€œburning glassâ€ in his play â€˜The Cloudsâ€™ (424 BC). Pliny the Elder (23â€“79AD) mentions what is possibly the first use of a corrective lens: Emperor Nero using an emerald, presumably a concave gem, to correct his myopia whilst watching gladiatorial games. Around the year 1600 lenses were used to construct telescopes, with Galileo the first to construct and use one for astronomical observations. His telescope consisted of a convex object lens and a concave eye lens, known as the Galilean telescope.

Manufacturing Lenses
Manufacturing a lens is a delicate task and most total-station vendors contract out production to highly specialised firms. The glass must be of the highest quality and the workmanship perfect. Optical glass leaves the oven rough and broken. The chunks are tested for imperfections and then cut with a glass-saw or slitting disk into pieces of the desired type. The pieces are chipped to roundness or heated to softness, rolled to roundness and pressed in a mould to obtain the desired size and surface curvature. The surfaces are then lapped to the final form using emery, carborundum or diamond, progressively finer grades of one of these abrasives being employed while the lens surface is ground on an iron tool, flat or suitably curved. During the grinding process a cup-shaped tool rotates so that its axis of rotation intersects the centre of curvature of the lens. As both tool and lens rotate, a spherical surface of the desired curvature is generated. Fine grinding, or smoothing, is done using emery flour. A number of fine-ground lens blanks are then mounted with pitch on a block so that they can be polished together. The polishing of glass is done by oscillating lenses back and forth, sometimes for hours, against the rotating polisher, which is covered with a thin layer of pitch, wax, or even coarse cloth, while wet rouge or other mineral oxides are also used. After polishing the two sides the lens is ground around the edge to centre it and give it the correct diameter. In constructing a lens system several single lenses must be mounted together in a precise coaxial arrangement, and their thickness, separations and centring must be kept very close to the prescribed values.

Aberrations
Lenses have imperfections or aberrations.Spherical aberrationcauses light rays impinging near the edges of the lens to cross the optical axis closer to the lens than those passing through its centre, resulting in increasing spot size and causing best focus to occur at another place than the calculated Effective Focal Length. Spherical aberration is a function of lens shape, lens orientation and lens index of refraction and can thus be remedied by changing curvature or by combining convex and concave lenses into what is termed an â€˜aplanatic doubletâ€™. Although this remedy works for rays parallel to the optical axis, it does less for oblique rays of light resulting in a comet-shaped image at the focal plane, called â€˜comaâ€™. The refraction of light leaving one medium (glass) and moving into another (air) depends on the wavelength, observed aschromatic aberration. When white light, which contains the wavelengths between 0.4 m and 0.7 m, impinges on a lens the shorter violet waves are brought to focus closer to the lens than are waves of red light. Other colours are focused between these extremes, resulting in their blurring.

Images used in all figures, courtesy Wikipedia.