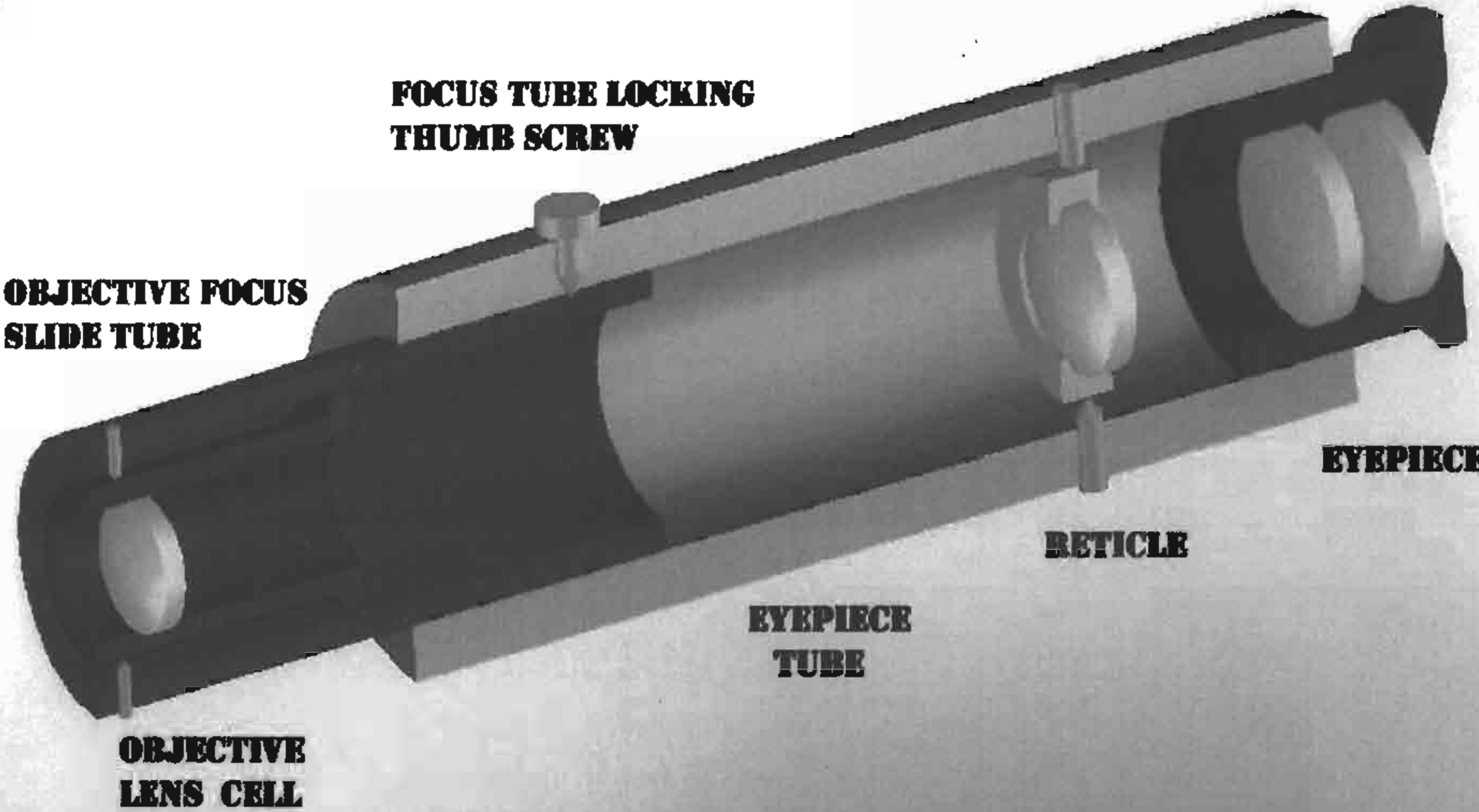

TELESCOPE OPTICAL REFLECTING COLLIMATOR

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GLOSSARY OF TERMS AND ABBREVIATIONS

COLLIMATOR

A telescope-like instrument fixed at infinity focus, and having one or more reticles to be sighted as reference targets by the Test Instrument.

ALIGNMENT TELESCOPE

An optical tooling telescope used to established optical reference lines. Its outer diameter is accurately controlled for precision in mounting, and its line-of-sight is exactly positioned on its mechanical center line. Alignment telescopes may have integral or separate optical micrometers for measuring linear displacement.

COLLIMATE

To make two instruments' lines of sight parallel, when focused at infinity and facing each other. The word collimate, or collimation, always implies infinity focus.

COLLINEAR

Literally, "on the same line-of-sight". Two telescopes are collinear when they are physically placed on the same center line. Differs from "collimated" which means "parallel".

COLLIMATION

The condition of being collimated.

AUTOREFLECTION

Establishing an optical axis perpendicular to a mirror.

AUTOCOLLIMATION

Register of an instrument's reticle with its own reflected image, when the instrument is focused at infinity. Achieved by using a lighting attachment to project an image of the reticle out of the telescope. This image is then reflected from a mirror, back into the telescope, and superimposed on the reticle.

EYEPIECE

That part of the telescope into which the observer looks. Adjustment is normally provided to allow the eyepiece to be moved in or out so that accurate focus on the plane of the reticle may be achieved. Also parallax correction.

AUTOREFLECTION

Establishing an optical axis perpendicular to a mirror.

OPTICAL TOOLING
BASIC PROCEDURES

1) Aim the scope at a mirror (first surface optical quality) and tilt the mirror and/or move the scope (depending on the application) so the line of sight is approximately square with the mirror.

2) Place an autoreflection target on the end of the scope. In a pinch you can use the scope barrel itself as the target.

3) Sight on the target's reflection in the mirror (focus distance will be the distance from the scope to the mirror and back). Put your reticle on the center of the target. Wether you move the scope or the mirror to achieve this will depend on the application.

Autocollimation is much more accurate than autoreflection and requires only a light source instead of the autoreflection target, so this procedure is useful mainly as a first step in autocollimation.

In cases where it is difficult to get the mirror roughly aligned it is useful to use a simple variation of autoreflection where the target is you and your surroundings. By indentifying some part of your surroundings in the image reflected from the mirror you can determine which way to tilt the mirror to pick up your scope. Indulge yourself in some hand-waving.

COLLIMATION

Put the axes of two scopes parallel to each other.

OPTICAL TOOLING
BASIC PRINCIPLES OF OPTICS

If a scope is focussed at infinity and a light is shined into its eyepiece, an image of the reticle will come out as a column of parallel light.

This column of light will not form an image if it is shined onto a screen or surface. You will see only a spot of light.

If another scope is aimed into the column and focussed at infinity, the image of the reticle of the first scope will be visible. The parallel light is gathered back to a focus.

This image will be visible no matter where the second scope is placed in the column, so long as enough of the column enters to provide a bright enough image to see.

If the image of the first scope's reticle is made to coincide with the reticle of the second scope, then the optical axes of the two scopes will be parallel. They will be collimated.

Note that this means only that the second scope is intersecting some of the column of light from the first scope. The two axes are NOT on the same line.

Autocollimation

Autocollimation is using a mirror (at any distance) to reflect the column of light back into the scope it came from. The scope focusses on the image of its own reticle.

Collimation accomplishes two things: it puts the focus at infinity and it puts the axis parallel to the axis of another scope. In the case of autocollimation there is only one scope and its axis is made perpendicular to a mirror (or the mirror is made perpendicular to the axis of the scope).
A common use of autocollimation is to focus a scope to infinity. A mirror can be hand-held against the end of the barrel while the scope is focussed. Note that this is not true autocollimation since the reticle is not made to coincide with the reflected image.

When a search is made for the causes of optical path length in a telescope, the following are found:

1. Temperature differences in the atmosphere (seeing).
2. Errors in the surface curvature of the objective.
3. Errors in the surface curves of any secondary mirror, diagonal, prism or mirror, or Barlow lens.
4. Aberrations in the eyepiece.
5. Imperfections in the lens of the observer's eye.
6. Errors in collimation of the optical parts.

Values of Collimation Tolerance (a) in inches, based on a maximum path difference of 1/8th wavelength

D \ F/D	3	4	5	6	8	10	12
6"	0.006	0.014	0.027	0.045	0.103	0.19	0.30
10"	0.006	0.014	0.027	0.046	0.106	0.20	
20"	0.006	0.014	0.027	0.047	0.109		

Mark and "offset" the secondary mirror

Note: While offsetting the secondary is technically correct, it has little to no noticeable effects in a visual telescope. Only for large values of offset (>0.20") do we suggest incorporating it. In most cases the secondary spot will be centered, to offset the following instructions apply. Offset is the repositioning of the secondary mirror in the light cone coming from the primary mirror (see **Figure 1**). To make better use of the full light gathering ability of the primary mirror and more fully illuminate the edge of the low-power eyepiece field, the secondary mirror is positioned a small distance away from the focuser and an equal distance towards the primary. To realize why this offset is necessary we see that the light returning from the primary mirror is shaped like a *cone*. When this cone is intercepted at a 45 degree angle the shape is larger in area on the side towards the primary and smaller on the side towards the open end of the telescope. The diagonal is shaped like a 45 degree cut through a *cylinder* and so it is uniform in area front to back and side to side. Obviously these two shapes are not the same, so shifting the secondary mirror towards the "fat" side of the light cone will increase the illumination at the image plane.

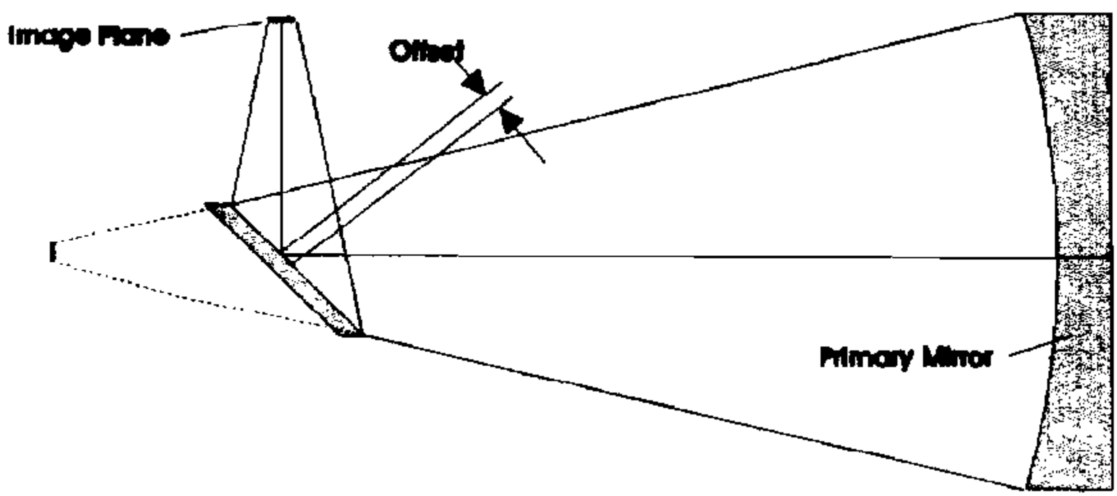

Figure 1. The center of the secondary mirror is offset away from the focuser and towards the primary.

To calculate the amount of offset to maximize illumination of the field use the following formula:

$$s' = \frac{N(D - N)}{4(F - L)}$$

s' = the secondary mirror offset
N = Secondary mirror minor axis
D = Diameter of primary mirror
F = Focal length
L = Intercept distance measured from the secondary mirror to focal plane.

An example using the above formula:
A 20" telescope has a focal length of 100 inches. The tube outside diameter is 22", the secondary minor axis is 3.1", and the focuser height is 1.5". The focal plane is 1/4" above the fully racked in focuser, this distance is known as "in-travel."

N = 3.1"
D = 20"
F = 100"
L = 11" + 1.5" + 0.25" = 12.75"

By inserting the values in the example we have:

$$s' = \frac{3.1\,(20 - 3.1)}{4\,(100 - 12.75)} = \frac{3.1\,(16.9)}{4\,(87.25)} = \frac{52.39}{349} = 0.15"$$