Q: What is a *collimator*?

A: Let's start at the very beginning

Consider the operation of a simple lens. The lens collects light from an illuminated target and redirects it light to create an image of the target. In other words, all the light from a single point on the illuminated target is focused to a single point[1] in the image.

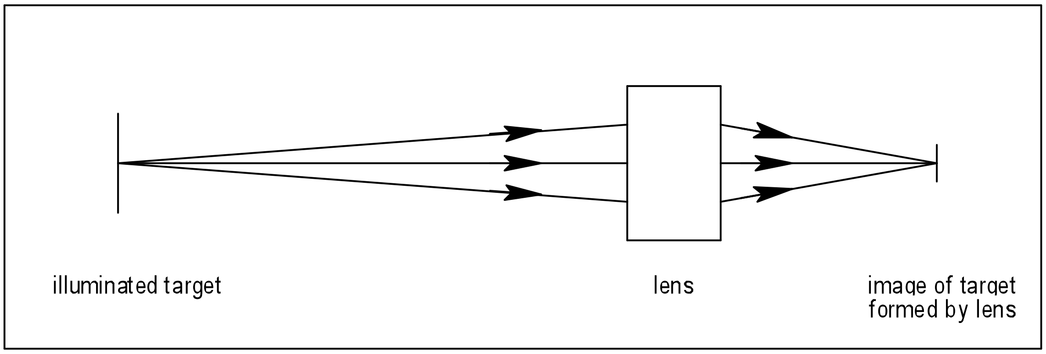

Figure 1. "relay lens" configuration[2]

For simplicity figure 1 only shows light from a single point on the illuminated target. With most lenses we are interested in light from multiple points on the target as shown above. Figure 2, below, shows light from two points. A real-life image would be made up of many more points, but the general idea is the same.

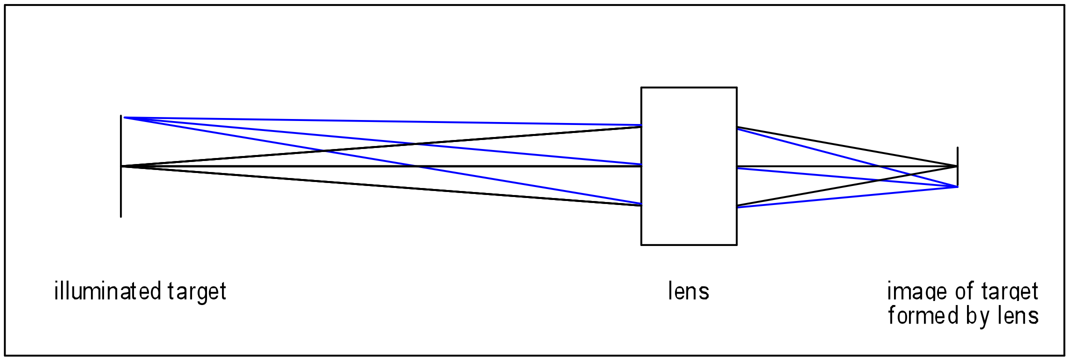

Figure 2: relay lens with off axis points included

[1] We can make the illuminated target arbitrarily small. For example it is relatively simple to etch a 1/10 micron hole in a thin chrome layer on a sheet of glass.

However, we even the most perfect lens cannot focus this light to a true point. The wave nature of light sets a limit to how small a spot can be formed, regardless how much we spend for a lens.

[2] In figure 1 the target is located relatively close to lens. This is sometimes called operating "at finite conjugates."

The reticle

Figures 1 and 2 show an "illuminated target." A "reticle" is a just a target which is illuminated from behind. In the OS-00 the reticles are made on a precision glass substrate. The actual pattern is consists of transparent areas in a very thin black coating. The pattern is created photographically, using very precise equipment originally developed for making semiconductor chips.

Camera lenses

In most cases we want to test lenses where the object is quite far away. A camera lens is a classic example of this situation.

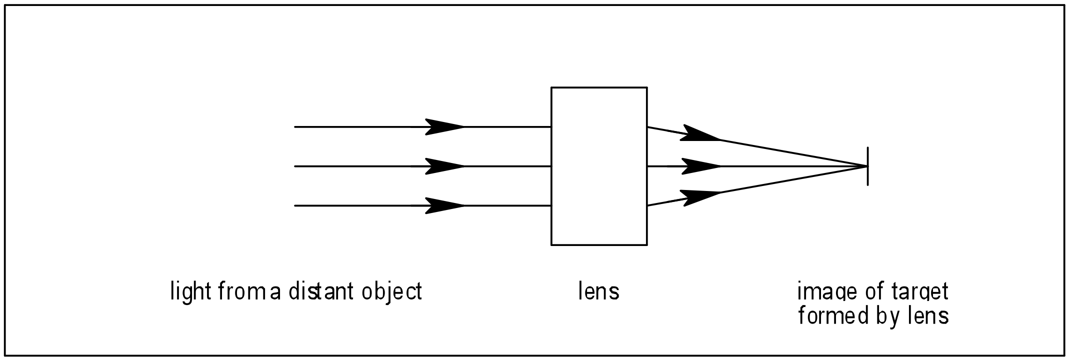

Figure 3: camera lens

The lens is designed to focus rays from a single point on the distant object to a single point in the image plane. In the case where the object is truly far away (like a landscape photo) the rays from a single point on the object are essentially parallel by the time they reach the lens. This is sometimes called operating with the object at infinity.

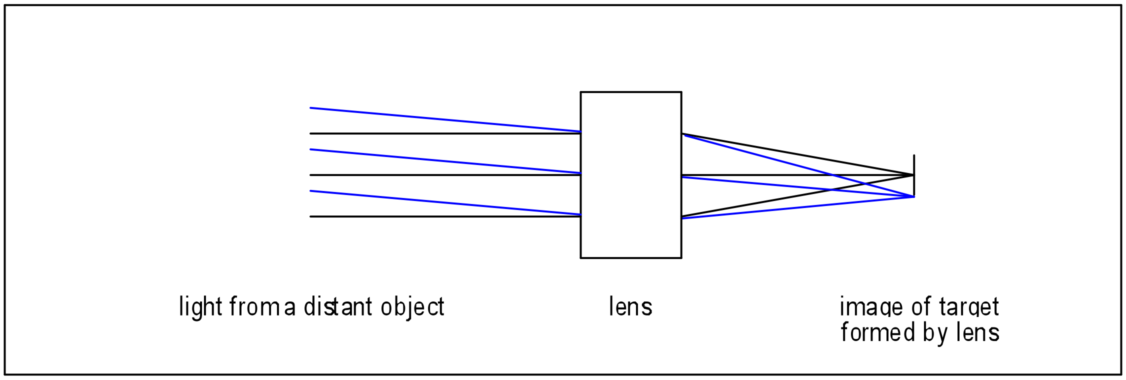

Figure 4: camera lens with off axis points included

For simplicity Figure 3 only shows light from a single point on the illuminated target. With most lenses we are interested in light from multiple points on the target as shown above.

Testing lenses

Now consider the problem of testing a lens. To start with, we will need a well-defined test target. It is possible simply to place a paper target a long distance from the lens.. Unfortunately, this is inconvenient for a number of obvious reasons. A better solution is to use a collimator to simulate a distant target.

Which finally brings us back to the question ***"what is a collimator?"***

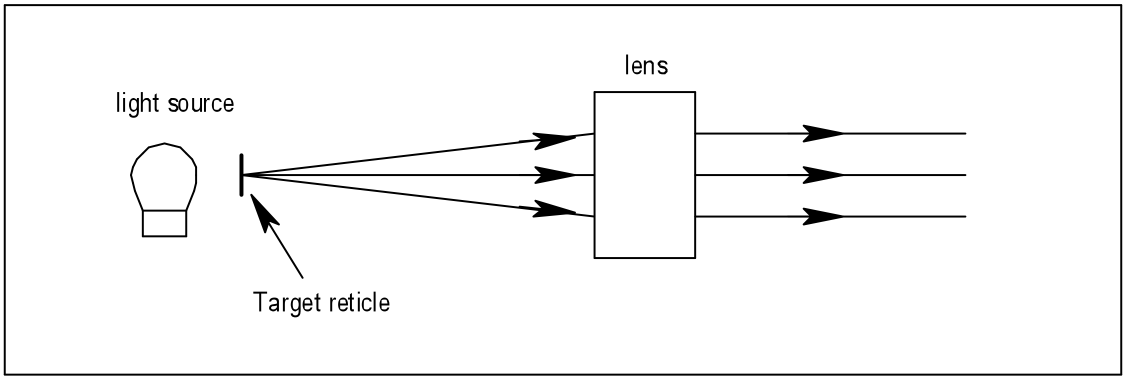

Figure 5: Collimator principle of operation

Figure 5 shows the conceptual operation of a collimator. Notice the similarity to Figure 2. If the target reticle consists of a single tiny hole, then the situation will be exactly as drawn above. Rays leaving the collimator will all be essentially parallel. Such rays are said to be "collimated.

An observer looking into the collimator would see a single point of light, rather like looking at a star in the night sky. Because the rays of light are parallel, the observer would conclude that the object must be very far away.

Occasionally all we need is the image of a single star-like point. However, in most cases we want to use a test target that is more complicated than a simple pinhole.

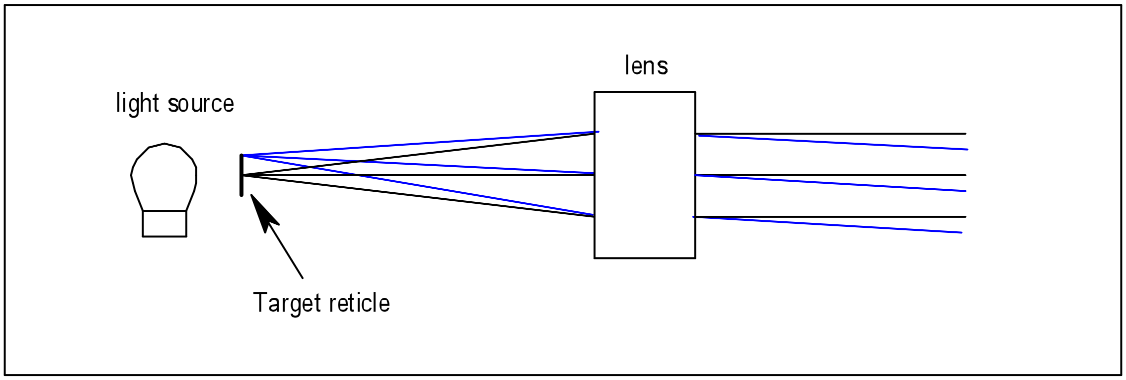

Figure 6: Collimator with off-axis points shown

In Figure 6 we've added an off axis point, shown in blue. Let's take the simplest step possible, and assume that the off axis point is just another pinhole. The rays leaving the collimator from this pinhole are also essentially parallel, and are also "collimated."

An observer looking into the collimator would now see two stars.
A common misconception is that all the rays of light leaving a collimator are parallel. It is easy to see that this is not quite true: Consider the blue and black rays leaving the lens in figure 6. They are hardly parallel.

A more precise statement is that *the rays from any particular point on the reticle are parallel* when they leave the collimator.

Using a collimator for lens testing

The sketch below shows how a collimator might be used for actually testing a lens.

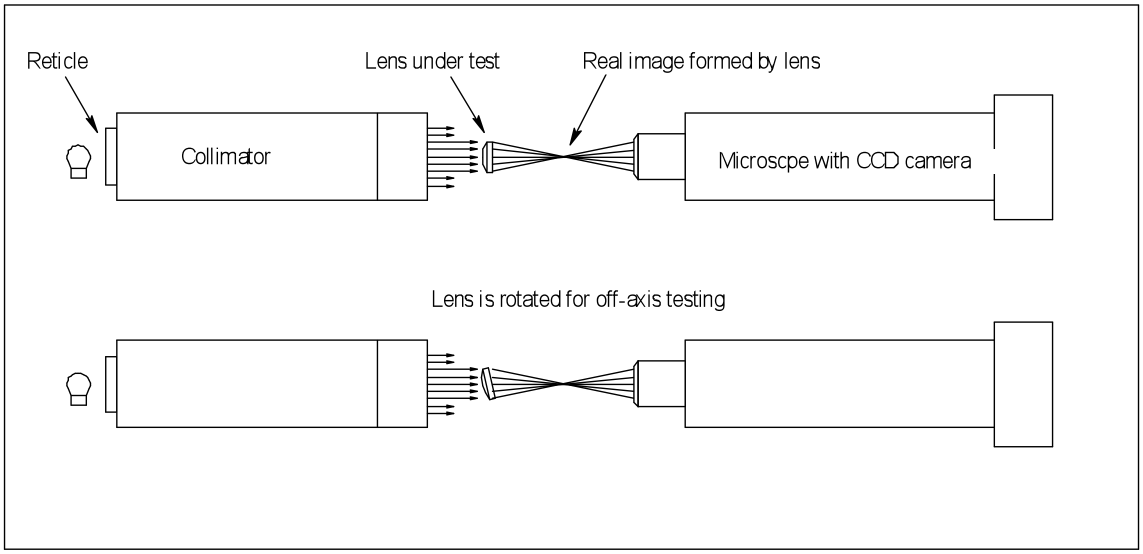

Figure 7: typical test configuration

To summarize:

Light from the collimator simulates the appearance of a distant object
The lens-under-test forms an image of the target reticle
The microscope is used to observe this image

If the lens-under-test is good quality then the image will be a faithful reproduction of the reticle.

The collimator field-of-view is generally very small, usually about +/- 1 degree. To check the lens-under-test at larger field angles the lens may be rotated as shown in figure 7.

Real-world reticles

In most testing situations we wouldn't use a reticle as simple as two pinholes. We would chose a reticle with a pattern designed to test some characteristic of the lens imaging performance. A classic choice is the so-called USAF target, shown on the screenshot below

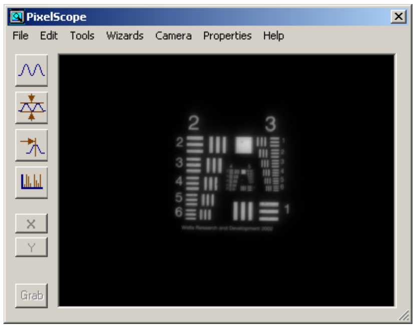

Figure 8: USAF test pattern