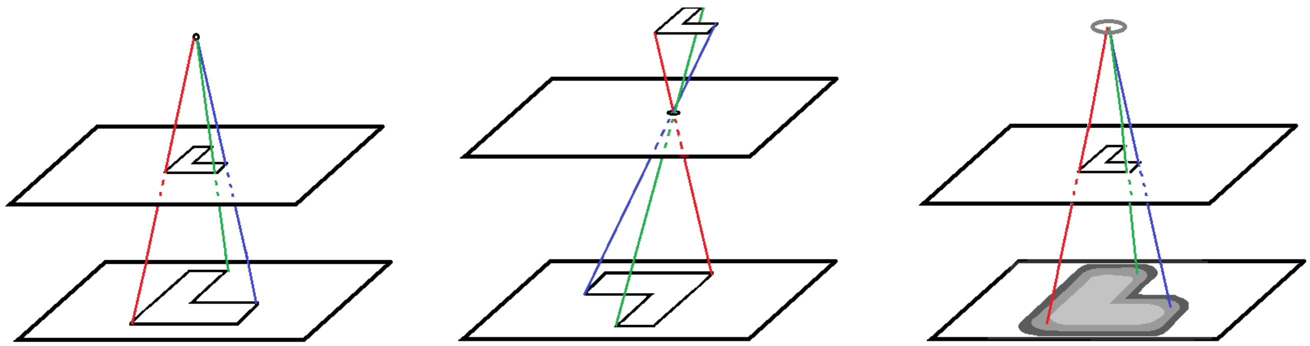
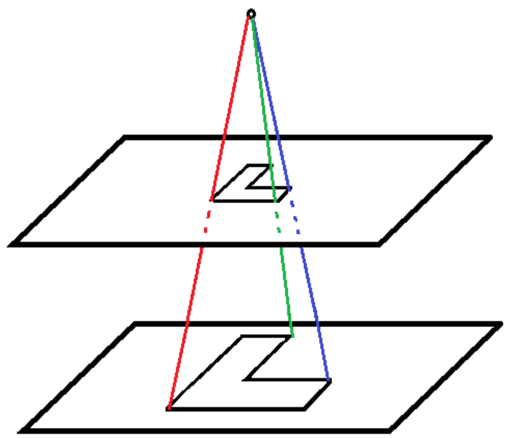


Left: point object, extended aperture
Center: extended object, point aperture
Right: extended object, extended aperture

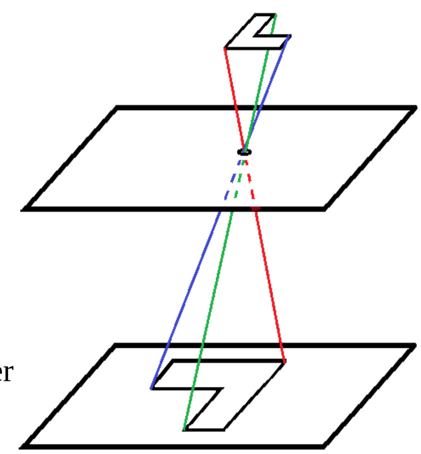
Small light source, extended aperture



If the light source is very small (a point source), then all rays must trace back to a single focal point. The image is therefore an enlarged version of the aperture.

Because the triangles formed by any two points on the image and the aperture are similar, the magnification factor will be $M = \frac{s_i}{s_a}$ where s_i and s_a are the distances from the focal point to the image and the aperture, respectively.

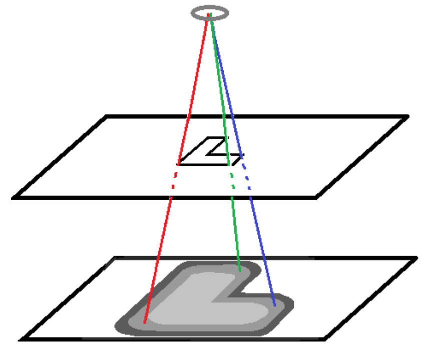
Extended light source, small aperture



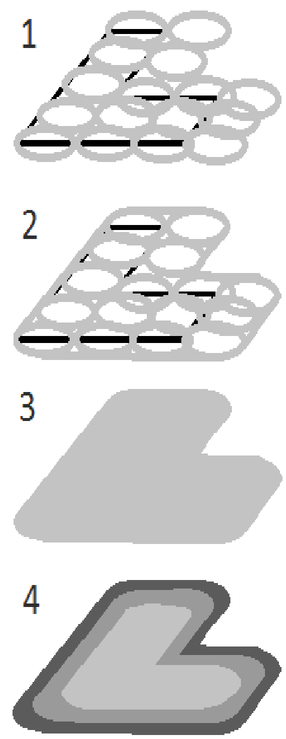
If the aperture is very small (a pinhole) then every ray must trace through a single point. After passing through the pinhole each ray will land at a position opposite to the starting position, resulting in an image which is rotated 180° in the image plane.

The magnification factor is now $M = \frac{s_i}{s_o}$ where s_i and s_0 are the distances from the focal plane to the image and source respectively. M may be greater or less than unity.

Extended light source, extended aperture



If the light source is comparable in size to the aperture, then things get more complicated. Each point on the object acts as a point source for the aperture, or equivalently each point in the aperture acts as a pinhole for the source. The resulting image is a copy of the source drawn over each point in the aperture, or equivalently a copy of the aperture drawn over each point in the source. The image has the appearance of the object "smeared over" the aperture or vice versa. Mathematically, this procedure is called the convolution of the image with the aperture.



Here is how the image was sketched:

1) Draw several copies of the object at several representative points over the aperture. (The object is still rotated 180° as in the pinhole case, but the aperture is not.)

2) Connect the outside edges of the drawing to produce a closed shape.

3) Fill in the interior and remove construction lines.

4) Points that contain light from several overlapping copies of the object are brighter than points on the edge which only receive light from the outermost copy.

Side notes:

- In real life imaging applications, this blurring effect is a major problem. Typically, cameras and telescopes use small apertures to achieve a sharp focus; on the other hand, smaller pinholes are able to capture less light, resulting in a dimmer image.
- Light from a point source passing through a circular aperture does not provide an image with uniform brightness, but instead a spot with brighter light in the center and dimmer light at the edges. Since stars are very far away, the produced on an astronomical photograph is actually gets its shape and brightness from the size and shape of the aperture, not from the star itself. Except for a few very close stars, all surface details are completely lost in the blur.
- In all the above we haved assumed that the wavelength of the light used is much smaller than the diameter of the aperture. If the aperture is comparable in size to the wavelength, then diffraction effects can occur which further limit the resolution.
- In all the above, we have assumed that the material that contains the pinhole is much thinner than the size of the aperture. If this is not the case, light from the edge of the object may be blocked by the sides of the pinhole, resulting in a cropped image. This effect is known as *vignetting*.