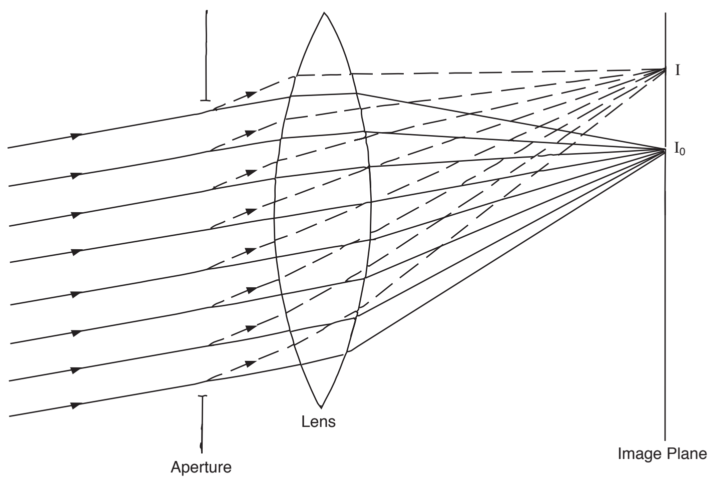
Diffraction Effects

Before we discuss the aberrations of an optical system, it is necessary to point out that even for a perfect system there is still a fundamental limit to the resolving power or spot size due to the influence of diffraction.
The ray theory of light is an approximation to the true physical situation. More accurately light is made up of electromagnetic waves, which can exhibit effects such as interference and diffraction. The rays, however, still have an important role in the theory as they indicate the normal to the wavefront.
The figure shows the rays associated with a plane wavefront arriving at an aperture in close proximity to a lens. The aperture modifies the wavefront emerging on the output side. It becomes a combination of the undisturbed portion plus additional components which are scattered by the rim of the aperture. The net effect is to produce a wavefront which is effectively the superposition of an infinite number of plane wavefronts, each having an amplitude which depends on its direction.
The action of the lens is to focus each of these plane wavefronts at a different lateral location in the back focal plane of the lens. The undiffracted component is the strongest in the example shown and focuses at position I_0. One of the diffracted plane waves is shown focusing at position I.

The geometrically predicted infinitely small spot focus at position I_0 becomes a finite sized spot with a complicated variation of intensity located near to, though not necessarily centered about, I_0. The intensity at any point depends on the strength of the component plane wave which is focused there.



Airy Pattern

For an incident wavefront from an axial object position, arriving at a well centered lens with a circular aperture, the image takes on the familiar Airy pattern shown in the figure. The oscillatory nature of the intensity arises due to scattered contributions from the edges of the aperture moving progressively in and out of phase as the radial distance from the geometrically predicted image is increased.

The form of the Airy pattern is given by

$$I(\rho) = \left(\frac{2J_1(\rho)}{\rho}\right)^2$$

where $J_1(\rho)$ is a Bessel Function of the first kind. The first zero of $I(\rho)$ occurs at $\rho=3.833$. The quantity is related to the actual radial distance r from the center of the geometrical spot by

$$\rho = \frac{2\pi NAr}{\lambda}$$

where λ is the wavelength, and NA is the numerical aperture.

The radius to the first dark ring is therefore $\frac{0.61\lambda}{NA}$