FRAUNHOFER DIFFRACTION

Diffraction by a long narrow slit

In this example we consider the Fraunhofer diffraction of a plane wave caused by a long, narrow slit.

$size \equiv 50 \cdot mm \quad \lambda \equiv 1000 \cdot nm \quad N \equiv 300$

$$Field := LPBegin\left(\frac{size}{m}, \frac{\lambda}{m}, N\right)$$

The width of the slit is $a \equiv 1.5 \cdot mm$, and the length of the slit equals the size of the calculation grid.

$$Field := LPRectAperture\left(\frac{a}{m}, \frac{size}{m}, 0, 0, 0, Field\right) \quad I_0 := LPIntensity(2, Field)$$

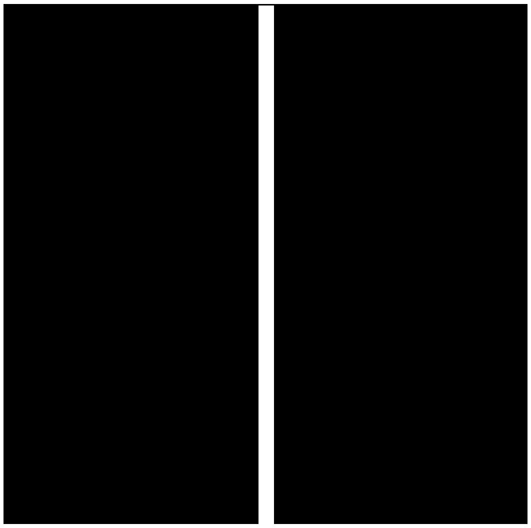
To calculate the intensity distribution in the focal plane of a lens we apply a trick to enhance the accuracy of the calculation. Because the extension of the field in the focal plane is very small compared to the grid dimension the number of grid points in the focus to describe the field is very small. Fortunately LightPipes offers a method to overcome this problem using 'spherical coordinates', implemented in the LPLensForvard and LPLensFresnel commands. When one of these comands is called it 'bends' the coordinate system in such a way that it follows the divergent or convergent wave front and propagates the field to a distance z in the transformed coordinates. The resulting field fits in a reduced (converging beam) or in a increased (diverging beam) grid size but with the same number of grid points. The new grid size can be extracted from the resulting field.
In what follows we calculate the diffraction to the focus of a lens with focal length $f \equiv 1 \cdot m$. It is the combination of a weak lens, $f_1 \equiv 15 \cdot m$, followed by a strong geometrical coordinate transform using spherical coordinates with $f_2 := \left(\frac{1}{f} - \frac{1}{f_1}\right)^{-1}$:

$$Field := LPLens\left(\frac{f_1}{m}, 0, 0, Field\right) \qquad Field := LPLensFresnel\left(\frac{f_2}{m}, \frac{f}{m}, Field\right)$$

The new grid size is: $size_{new} := Field_{N,0} \cdot m$, or $size_{new} = 3.333 \cdot mm$.

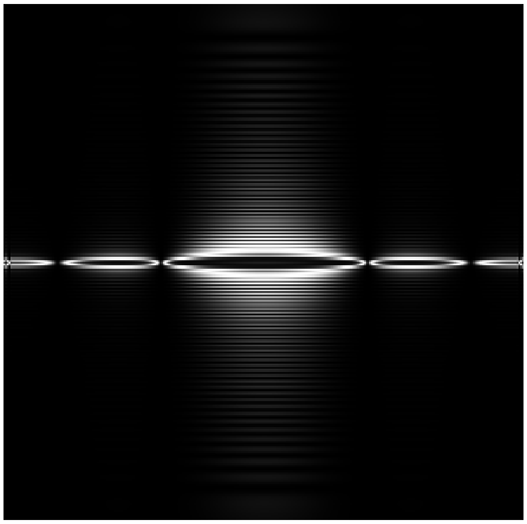
To plot the intensity distribution in the focal plane of the lens we use a saturable gain sheet to suppress the very intens central lobe. The effect is that the side-lobes will be amplified more than the central part of the field.

$Field := LPGain(40, 10, 1, Field)$ $I := LPIntensity(2, Field)$



The intensity distribution just after the slit.

I_0



Intensity distribution on a screen in the focal plane of a $f = 1\,m$ *len s. Note that the new grid size is reduced due to the use of spherical coordinates. It is:*

$size_{new} = 3.333 \cdot mm$