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Experimental physics 3 for physicists

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https://www.mpl.mpg.de/divisions/leuchs-division/teaching/

Problem sheet 10

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Problem 1: Fraunhofer diffraction

A double slit (slit width $a = 10\,\mu\text{m}$, separation of slit centres $b = 30\,\mu\text{m}$) is illuminated by a plane wave with wavelength $\lambda = 600\,\text{nm}$. What is the far-field intensity distribution?

a. Consider the scalar field strength E_0 just before the double slit and the resulting field strength though absorption E_1 just after the double-slit.

b. Compare the angular spectrum of the plane wave $\tilde{E}(k)$ just before and after the double-slit.

c. The plane wave after the double slit is known to propagate according to the wave equation in k-space: $\tilde{E}(k_x, k_y, z) = \tilde{E}(k_x, k_y, z = 0)\mathrm{e}^{\mathrm{i}k_z z}$ with $k_z = \sqrt{\left(\frac{2\pi}{\lambda}\right)^2 - k_x^2 - k_y^2}$.
How does the field strength $\tilde{E}_1$ propagate? How is the field strength $E(z)$ in real space obtained from this?

d. In so-called Fraunhofer diffraction, two approximations are used to solve the problem: First, in the paraxial approximation the root can be approximated as $\sqrt{k^2 - k_x^2 - k_y^2} \approx k - \frac{k_x^2 + k_y^2}{2k}$. Second, in the far field only the components with $k_x = k\frac{x}{z}$, $k_y = k\frac{y}{z}$ arrive at the observation screen. Use this approximation to determine the intensity distribution $I(x, y, z) \propto |E(x, y, z)|^2$ at the screen.