Experimental Physics III

Submission due: December 01, 2022, before the lecture starts

Exercise Sheet 7

7.1

Polychromatic light in the wavelength range of $\lambda \in [400, 600]$ nm impinges normally on a transmission grating with 500,000 groves per meter. A lens that is positioned nearby the grating creates a Fraunhofer diffraction pattern on a screen at its focal point.

- Calculate the focal length of the lens such that the second-order spectrum is spread out by 2 cm in length.
- Discuss the sequence of colors in the pattern in relation to the central axis.

7.2

The radiation of a mercury arc lamp is studied with the help of a grating that contains 2000 groves per centimeter.

- Calculate the angular difference of the two lines at $\lambda_1 = 579$ nm and $\lambda_2 = 577$ nm in the first-order spectrum.
- Calculate how large the diameter of the light beam that impinges on the grating has to be to yet resolve these both lines (Hint: $\lambda = 0.5 \cdot (\lambda_1 + \lambda_2)$).

7.3

A circular Fresnel zone plate (radius $R = 1$ cm) shall be used to image a small object, that is irradiated by a wavelength of $\lambda = 85$ nm, from $g = 40$ cm in front of the zone plate to a position of $b = 10$ cm behind the zone plate. Calculate the grating constant at the farthest position on the zone plate.

7.4

The radiation of a laser ($\lambda = 600$ nm) is shaped into a parallel beam at a diameter of 1 m using the combination of a telescope (to create the enlarged parallel bundle) and a circular aperture (to truncate the beam into a diameter of 1 m) and sent to the moon (average distance earth to moon: $3.8 \cdot 10^8$ m).

- Calculate the size of the laser spot on the moon. Neglect fluctuations due to the atmosphere. (Hint: Most of the laser intensity is found under the central maximum.)
- Calculate how much laser power the telescope receives if the laser light was reflected by a retroreflector (area: 0.5×0.5 m^2) on the moon. Assume an initial laser power of 10^8 W.
- Calculate the laser power received by the telescope if the laser light was diffusely reflected by the surface of the moon (i.e., without a retroreflector) into the solid angle $\Omega = 2\pi$. Furthermore, assume the moon surface having a reflectivity of $R = 0.3$.

7.5

Assume a light source sending out a spherical wave that hits an aperture with Gaussian-like aperture function, i.e.,

$$U_\mathrm{s}(x,y) = \mathrm{e}^{-(x^2+y^2)/W_0^2}. \tag{1}$$

Calculate the diffraction pattern (intensity distribution) for this situation in the near-field approximation.