Experimental Physics III

Submission due: November 24, 2022, before the lecture starts

Note: Homework that is submitted too late will not be graded.

Exercise Sheet 6

6.1

In a Michelson interferometer an optical path difference of 127 times the value of the wavelength emerges for sodium light ($\lambda = 589.3$ nm) if one of two equally-sized measurement chambers ($l = 50$ cm) is filled with a particular gas. Calculate the refractive index of this gas if the second (reference) chamber is filled with air ($n = 1.000292$).
Hint: If both chambers are empty or filled with the same medium, there is no path difference.

6.2

During a lens grinding process a concave lens L is tested in an inspection procedure (see Figure 1): The lens (radius of curvature r_1) is positioned on a spherical comparison surface S with $r_2 = 25$ cm. As r_1 and r_2 are not completely equal the first Newton ring for green light ($\lambda = 550$ nm) has a radius of $a = 12$ mm (in reflection with illumination from above). Calculate the radius of curvature r_1.

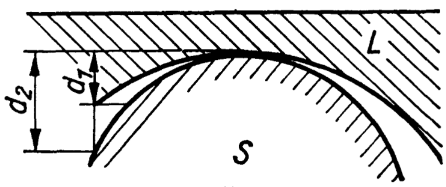

Figure 1: Inspection procedure for a concave lens during lens grinding.

6.3

A Fabry–Pérot interferometer (Figure 2) consists of two parallel mirrors that are coated with silver from one side and which are separated by a distance a. Both mirrors transmit 50 % of the light while the remaining light is reflected. Show that light that has an incident angle of θ on the interferometer has a maximal transmission if

$$2a\cos(\theta) = m\lambda \tag{1}$$

with $m \in \mathbb{N}$.

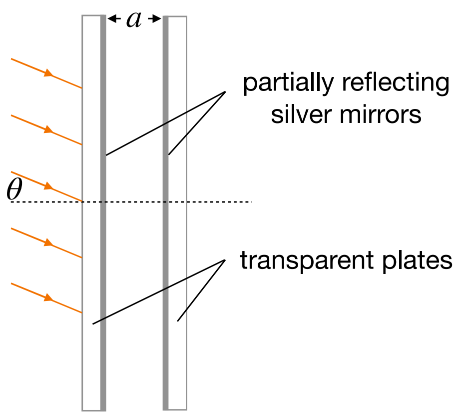

Figure 2: Simplified sketch of a Fabry–Pérot interferometer.

6.4

A collimated laser beam with a wavelength of $\lambda = 650$ nm shines on a blend with two circular holes of the same size. At a distance of $L = 4$ m behind the blend the interference pattern appears as alternating bright and dark concentric rings. The first dark ring (from the center) has a radius of $R_1 = 4$ cm. The bright rings in turn consist of fine, equidistant bright and dark rings, from which 20 fine, bright rings span over 5 cm

- Calculate the diameter of the holes.
- Calculate how far these holes are apart from each other.

6.5

The resolution y_{min} of an optical microscope shall be compared to the one of an electron microscope. Initially it is assumed that both microscopes have an opening angle of $2\alpha = 120°$. The light microscope is operated with light of a He-Ne laser (i.e., $\lambda_{\text{L}} = 632.8$ nm), the electrons have a kinetic energy of 100 keV (kilo electronvolt).

- Calculate the resolution $y_{\text{min,L}}$ of the optical microscope if no immersion liquid is used.
- Using the ansatz of the relativistic total energy calculate the momentum p and the matter wavelength (de Broglie wavelength) λ_{E} of the electrons. Compare quantitatively how much better the resolution of the electron microscope is compared to the optical microscope assuming both setups utilizing the same opening angle.
- Due to imaging errors of the electron optics solely much smaller opening angles are realizable for the electron microscope. Calculate the resolution $y_{\text{min,E}}$ for the case that the opening angle is $2\alpha = 1°$.