MI The microscope

1. Motivation

The microscope is an optical instrument, which can be used for the examination of the laws of geometrical optics and their restrictions, as well.
The microscope is an indispensable equipment in the natural sciences: on one hand the range of the human senses is substantially extended, on the other hand it is simple to use, since the resulting picture is directly an increased image of the microscopic structure.

2. Bases/Theory

- Geometrische Optik und Wellenoptik
  (Staudt Skript II, Kap. 8.1 oder E. Hecht, Optik, Kap. 4.2.3, 5.1)
- Abbildungsgleichung von Linsen
  (Staudt Skript II, Kap. 8.2.3 oder E. Hecht, Optik, Kap. 5.2)
- Lupe und Mikroskop
  (Staudt Skript II, Kap. 8.2.3 und Gerthsen, Kap. 9.2.4, 9.2.5, 9.2.6
  oder E. Hecht, Optik, Kap. 5.7)
- Auflösungsvermögen des Mikroskop
  (Staudt Skript II, Kap. 8.5 oder E. Hecht, Optik, Kap. 10.2.6)

Questions

- How large is the resolution of the human eye? By what is it limited? How can smaller objects be seen?
- How is the course of beam trough the loupe?
- How is the course of beam trough the microscope?
- How does the magnification formula in a microscope read? How is the maximally accessible magnification of an optical microscope approximately?
- By what is the resolution of a microscope limited? How does the picture of a pointlike source of light look like trough an optical instrument?
- According to the Helmholtz theory of resolution, what is the condition that two objects can be still separated?
- According to the Abbe theory of resolution, what is the condition that the structures of the object are still distinguishable?

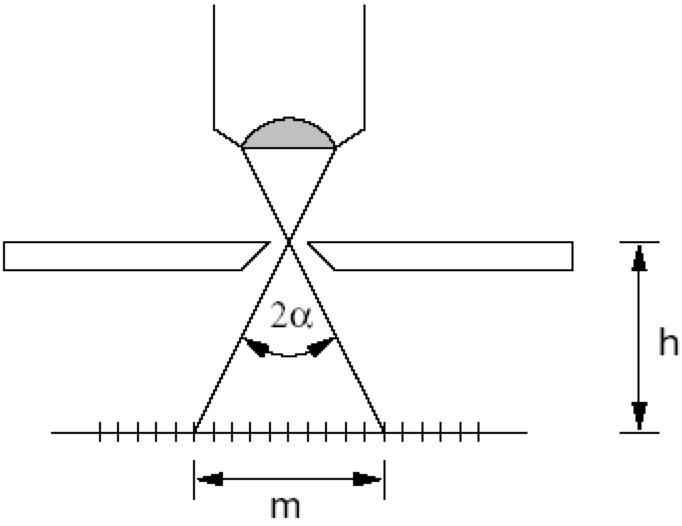
3. Description of the experiment

Firstly the magnification of the microscope has to be estimated by determining the angle of vision with and without microscope. Subsequently, the numeric aperture of the objectives has to be determined, in order to measure from it the resolution of the microscope.
Finally, as an example of an application of the microscope, the length of the traces of the desintegration fragmens from a nuclear reaction are measured.

4. Measurements

1. Determination of the magnification of the microscope for the four combinations of two different oculars and the two objectives.

   Look with one eye at the object micrometer (fine scale with division of $\frac{5}{100}mm$) in the microscope. Look at the same time with the other eye at a scale which is at the height of the object table (for a covering visual range take a distance of s_0 = 25cm) and estimate thus by comparison the visual angle under which you see the micrometer in the microscope.
2. Calibrate the ocular micrometer for both objectives, by looking at the object micrometer.
3. Determination of the numeric aperture of both objectives:
   Replace the condenser lens by a tube with scale (detach carefully the screw on the side of the condenser; careful, it is hot!). Put the aperture on the object table and place the upper border sharply. Remove the ocular and look into the tube; the scale is then visible in a circlularly limited field. Measure the visible range m and the height h for 5 different height adjustments.



4. Investigation of fragments of desintegration from a nuclear reaction:
   Measure under the microscope (normal condenser lens, ocular with micrometer) the length of 25 traces of fragments of desintegration.

5. Tasks for evaluation

- Represent the optical path in the microscope. Take the distance to the subject as 1,5 focal length of the objective.
- To measurement 1: Compute the four different magnifications from the measurements with the different oculars and objectives. The magnification results in each case from the relation $\frac{\tan(\varepsilon_{mit})}{\tan(\varepsilon_{ohne})}$, where $\varepsilon_{ohne} = \frac{G}{s_0}$ is the visual angle without the instrument and ε_{mit} is the measured visual angle with the instrument. Also compute the magnification of the two objectives.
- To measurement 3: Compute the aperture angle α for both objectives (in each case with standard deviation). What minimum object size results from it according to the Helmholtz theory for the resolution (for an average optical wavelength of 500 Nm)?
- To measurement 4: Calculate from the measured lengths of the traces of the desintegration fragments the average initial energy of the fragment of desintegration (with error). Compute from it the initial velocity, with which the fragment penetrated into the foil (also with error).

Appendix A: Nuclear physics

The atomic nucleus ${}^{252}_{98}Cf$ (Californium) desintegrates spontaneously into two approximately equally heavy fragments, which shortly after desintegration (within 10^{-15} s) emit on average two fast neutrons each. The fragments of desintegration are slowed down in a plastic foil and thereby leave traces.
The length of the traces results from the energy range relation:

$$R = aE^{2/3} \text{ with } a_{foil} = 0.89 \frac{\mu m}{(MeV)^{2/3}} \ .$$

Thus the energy of the fragment of desintegration can be computed from the length of the traces, where the rubble is incident on the foil under an angle of 20^0 and therefore the traces appear to be shortened.
Conversion relations**:**
nucleon mass = $1.67*10^{-27}$kg
1eV = $1.602*10^{-19}$J