GI The diffraction grating

1. Motivation

Interference with multiple-slit configurations and grid shows clearly that light possesses the characteristics of a wave. In the experiment this fundamental property of light is examined more exactly by several examples. In addition, we show the use of the interference with grid for the spectral decomposition of light.

2. Bases/theory

- Light als elektromagnetische welle
  (Staudt Skript II, Kap. 8.1 oder E. Hecht, Optik, Kap. 3.2, 3.4)
- Unterschied geometrische Optik/Wellenoptik
  (Staudt Skript II, Kap. 8.1 oder E. Hecht, Optik, Kap. 4.2.3, 5.1)
- Interferenz von Wellen
  (Staudt Skript II, Kap. 8.4.1 oder E. Hecht, Optik, Kap. 9.1, 9.2, 9.3)
- Interferenz am Mehrfachspalten
  (Staudt Skript II, Kap. 8.4.2)
- Beugung am Einzelspalt
  (Staudt Skript II, Kap. 8.4.4 oder E. Hecht, Optik, Kap. 10.1, 10.2, 10.5)
- Functionsprinzip eines Lasers
  (Gerthsen Physik, Kap. 12.2.9)

Questions:

1) When are the optical phenomena described with geometrical optics? When is the wave characteristic of the light needed for the explanation? By what is a light wave described? How does the light propagate?
2) What is the Huygens principle? What are the limitations of this model?
3) How do the interference patterns from double gap, three-fold gap and grid look like (neglecting the width of the individual slit)? How does the condition for intensity maxima read in each case?
4) Does destructive interference harm the energy theorem? Where does the energy go?
5) Under which conditions does the interference arise? How are these conditions fulfilled in the experiment?
6) How does the interference pattern of a narrow single slit look like? By which formula is it described? How does the finite width of the individual slit of a grid affect the interference pattern?
7) Why can a grid be used to the spectral resolution of light? On what does the resolution depend?
8) What are the characteristic differences between the spectra of grids and prisms? (see also data interpretation)
9) What is the operational principle of a laser? What are the properties of the light sent by a laser?

3. Description of the experiment

Firstly the grid constant of a grid of lines is determined, by magnifying the grid by projection on the screen.
Subsequently, the interference pattern of the grid is examined. For this the grid is lighted up with light from a conventional lamp made coherent by suitable arrangements.
In the end is examined the interference pattern of a cross grid lighted up with a laser.

4. Measurements

1) Determination of the grid constant of the grid of lines:
   The grid of lines is light up with the lamp and projected sharply by the objective on the screen (e.g. the wall); the magnification should be as high as possible. At the correct optical path the source of light (filament) is illustrated (mapped) into the objective; in this case the largest brightness is obtained.

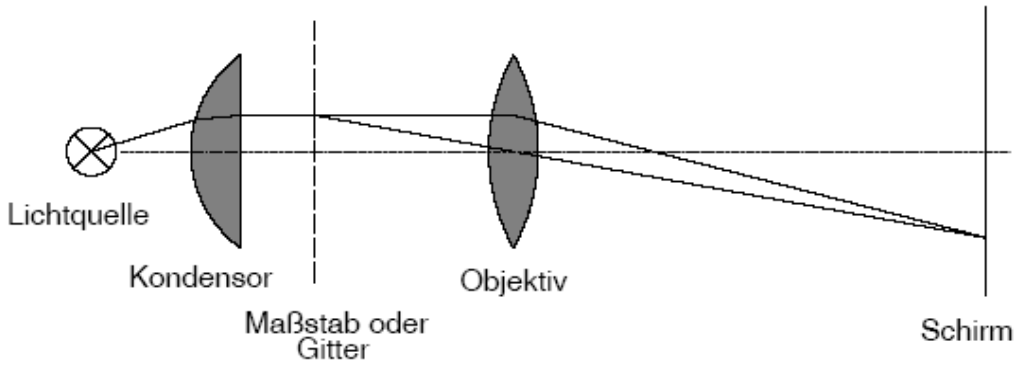

   Fig GI.1: Instrument for the determination of the grid constant g
   Measure two times the width of 20 grid periods and estimate the error. For the determination of the magnification the grid is changed to a scale with mm division. The magnification is then v = B / G (B: Picture dimension, G: Object dimension). Here also estimate an error.
2) Determination of the middle wave-lengths of three different filters (red, green, blue) with the grid of lines:
   The slit is projected by the objective on the screen. For the achievement of maximum brightness the filament is projected by the condenser lens on the slit. Then the colour filter is placed into the path of rays (refocus the slit pattern) and the grid is placed between objective and screen.

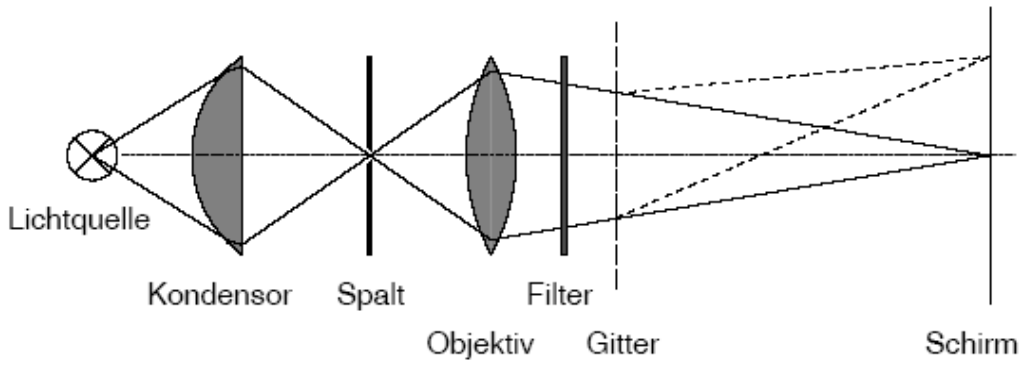

   Fig. GI.2: Measuring instrument for the determination of the wavelength λ
   Measure the distance between two (arbitrary) maxima 2 to 3 time, and determine from it

the distance between two neighbouring maxima. Estimate an error for this distance. Also measure the distance between grid and screen.

3) Interference at cross grid:
   Use for this the Helium-Neon Laser (λ = 632.8 Nm) and replace the strichgitter by a cross grid. How does the experimental setup has to be changed, in order to observe an interference pattern? Measure the horizontal and vertical distance of each maxima 2 to 3 times and estimate an error.
   Measure in each direction the distance between the first minima of the superposing (interfering) diffraction patterns of one single slit. Also do not forget to determine the distance between grid and screen!

5. Tasks for evaluation

1) Determine from measurement 1 the grid constant with error.
2) Determine from measurement 2 the middle wavelengths of the three filters, also with error.
3) Determine from measurement 3 the two grid constants of the cross grid with error. Also estimate from the measured positions of the minima the width of the single slits in both directions.
4) How would the picture on the screen look, if in measurement 2 one omits the slit or filter? Why does the focus has to be changed after inserting the filters?
5) What are the main differences (at least 3) between grid and prisma regarding the spectral decomposition of light and the resulting spectra?