Exercise 11
Diffraction and polarization of light

Aim

Observation of a single slit diffraction pattern, investigation of the slit width influence on the position of diffraction maxima, determining of the slit width. Investigation of light polarization and Malus' law.

Required theoretical knowledge

Electromagnetic wave, Maxwell's equations, interference and diffraction of electromagnetic wave, interference and diffraction phenomena, diffraction by a single slit, locating the minima and maxima, intensity in the single slit diffraction, polarization of light, Malus' law, usability of polarized light.

Equipment

Gas laser He-Ne with wavelength 632.8 nm (L), optical bench, adjusted slit (1S), polarizer (2P) and analyzer (2A), screen (E), photodiode with power supply and display (F).

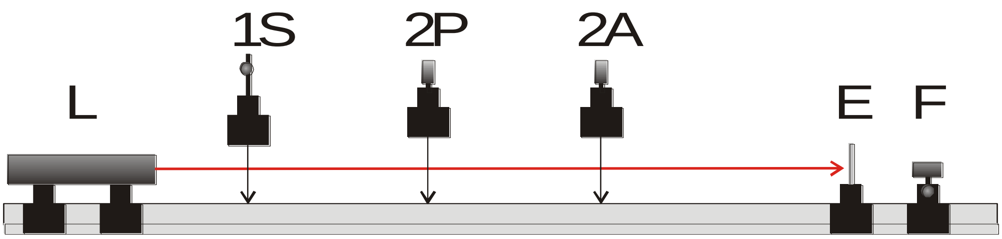

Fig. 1. Measurement setup.

Measurement plan:

Introduction:

1. Check whether all elements are present.
2. Place a screen E on the optical bench.
3. In the presence of teaching assistant turn on the laser power supply.
4. Check if the laser beam is parallel to the optical axis by moving the screen along the optical bench. If not, adjust a position of the laser using a micrometer screw.

Problems for discussion:

What is a light, from the physical point of view?
Principals of operation of laser.

Diffraction:

1. On the optical bench near the laser place a slit and on the opposite end of the bench place the white screen. Try to get a diffraction pattern on the screen by changing the width of the slit.
2. Changing the slit width, observe diffraction pattern when the slit is very narrow and wide in comparison to the wavelength.

Problems for discussion:

What is the phenomenon of diffraction of light waves?
Give examples of deflection other than light waves?
What is the phenomenon of interference - what is the condition for constructive and destructive interference?
Sample sketch running on the edges of the slot bent light rays undergoing interference on the screen.
Indicate where does the wave phase shift relative to each other, in place of the screen.

3. **Discuss** with the Instructor measurement conditions, i.e., the slit width a, the range and the step of the measurement x (usually the range is 25 mm and the step 0.5 mm).
4. Remove the screen and measure the distance between a photodiode and the slit. Use micrometer screw to adjust photodiode horizontal position to the position of the central maximum and write down this position in the header of Table 1. Rotate screw to the beginning of its scale.

Problems for discussion:

How to calculate the sine of the angle of deflected light θ for the position x of the minimum, using the approximation of small angles?
What is the function described by equation (1)? For which α value of function (1) is equal to zero?
From the theoretical equation (1) derive a formula for calculating the width of the slit gap, assuming a position of a given line.

$$I(\theta) = I_0 \left(\frac{\sin(\alpha)}{\alpha}\right)^2 \qquad (1)$$

where: $\alpha = \frac{\pi \cdot a \cdot \sin(\theta)}{\lambda}$,
a - is a slit width.

5. Change a horizontal position of photodiode using a micrometer screw. Record the position x of the photodiode and the corresponding signal of photodiode that is proportional to the light intensity, in Table 1. During the measurement do not change the slit width. At least two first order line maximum and one second order line maximum have to be measured. Note: it is the easiest to move a photodiode in one direction only.
6. Draw a graph of light intensity I as a function of the position of the photodiode x. Remember, that position x = 0 should correspond to the position of the central maximum. Write in Table 2 position $x_1 ... x_n$ observed diffraction minima and their order.
7. Calculate, based on the positions of the diffraction minima, the width of the slit and write it down to Table 2. Discard any values with thick or systematic error, use the

remaining values to calculate the average value of the width of the slit and its standard uncertainty.

8. Use the theory of diffraction of a single slit (Equation 1) and the determined average width of the slit to define a theoretical dependence of $I\ (x)$. Theoretical and experimental data should be put on the same graph.

Polarization:

11. Remove the slit and install the polarizer and analyzer (2A 2P). Place the screen instead of a photodiode and observe the changes in light intensity (on screen) due to the rotation of the analyzer. **Do not point the laser beam directly to the eye!**

14. Set the analyzer at 90 degrees, then rotate the polarizer at an angle so that the light intensity on the screen was the smallest.

Problems for discussion:

How do you define the plane of polarization of the light? Types of polarization.
Give examples of the phenomenon of polarization of light in everyday life.
Malus law.

15. Place a photodiode back instead of the screen. Turn analyzer to an angle of 0 degrees, and then rotate it by a step (discussed with teaching assistant) from 0 to 180 degrees. Measuring the light intensity dependence on the analyzer angle $I(\alpha)$.

16. Theoretical data of the Malus law draw on the same graph with the experimental points.

17. Remove the polarizers from the optical bench.

Literature

1. Halliday, Resnick "Fundamentals of Physics - 8th edition", John Wiley 2007,