Institute of Physics
Centre for Science and Education
Silesian University of Technology

Physics laboratory report

Performed on: 18.11.2024

Exercise 4: Determination of the diffraction grating constant File

Performed by:

Piotr Copek
Zuzanna Micorek
Tymoteusz Kłoska

Introduction

The experiment aimed to measure the wavelength of light emitted by a diode laser. Using an optical setup consisting of a diffraction grating, light source, and screen, the distances between interference maxima and the grating-screen distance were recorded. Calculations were performed to analyze the wavelengths for red and blue laser lights.

Experimental set-up

The experiment involves a measurement setup consisting of an optical bench with a millimeter scale, a light source, and a screen. The diffraction grating is mounted on a movable holder. The light source is a diode laser, which can be red, blue, or green, depending on the configuration. The main objective of this experiment is to measure the wavelength of the light emitted by the laser. The measurement involves determining the distance between the interference maxima and the trace of the primary beam for different distances between the grating and the screen. The grating constant is a known value.

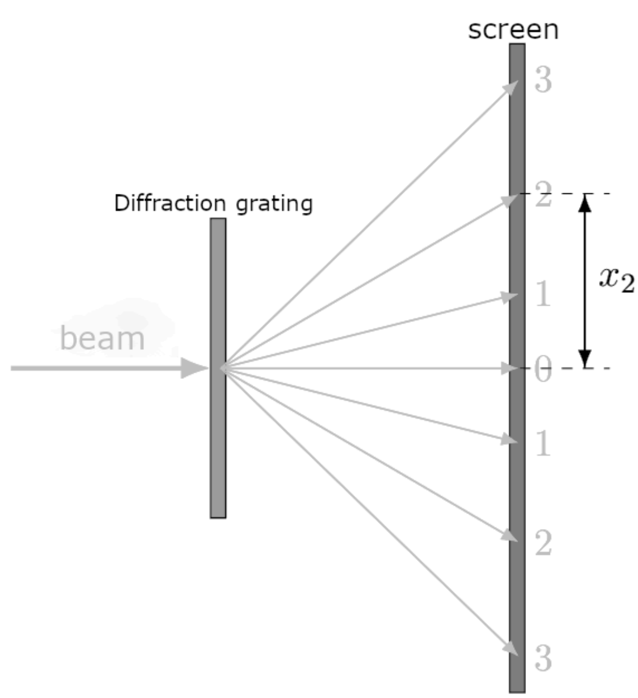

Figure 1 - Experimental set-up diagram

Measurements

Blue light:

d	$-x_3$	$-x_2$	$-x_1$	x_1	x_2	x_3	**Unit**
10	3.8	2.4	1.2	1.2	2.4	3.8	cm
20	7.6	5.0	2.4	2.4	5.0	7.6	cm
30	11.5	7.5	3.6	3.6	7.5	11.5	cm

Table 1 - Measurements obtained during laboratories for blue light laser.

Red light:

d	$-x_3$	$-x_2$	$-x_1$	x_1	x_2	x_3	**Unit**
10	7.2	4.3	2.0	2.0	4.3	7.2	cm
15	10.9	6.5	3.0	3.0	6.5	10.9	cm
20	13.9	8.4	4.0	4.0	8.4	13.9	cm

Table 2 - Measurements obtained during laboratories for red light laser.

Data analysis

Task 1. For each pair of x_L and x_P, calculate the average value x_N, where N is the order of the diffraction fringe.

To calculate the average distance for each pair we used formula:

$$x_N = \frac{x_L + x_P}{2}$$

Blue light:

d	x_3	x_2	x_1	**Unit**
10	3.8	2.4	1.2	cm
20	7.6	5.0	2.4	cm
30	11.5	7.5	3.6	cm

Table 3 - average distances for red light laser.

Red light:

d	x_3	x_2	x_1	**Unit**
10	3.8	2.4	1.2	cm
20	7.6	5.0	2.4	cm
30	11.5	7.5	3.6	cm

Table 4 - average distances for blue light laser.

Task 2. For each average value, calculate the wavelength of the laser light using the formula:

$$\lambda = \frac{d}{N} \frac{x_N}{\sqrt{x_N^2 + L^2}}$$

where:

- d is the diffraction grating constant
- L is the distance between the grating and the screen.

For each distance x_N and distance between the grating and the screen we obtained results:

For blue light:

d	$\lambda(x_3)$	$\lambda(x_2)$	$\lambda(x_1)$	**Unit**
10	402.5176	394.2111	400.0200	nm
20	402.5176	409.6886	400.0200	nm
30	402.5176	409.6886	403.0811	nm

Table 5 - Wavelengths calculated for each each distance x_N and distance between the grating and the screen for blue light.

And red light:

d	$\lambda(x_3)$	$\lambda(x_2)$	$\lambda(x_1)$	**Unit**
10	662.5545	667.2766	658.0008	nm
20	662.5545	671.6342	661.9943	nm
30	662.5545	654.1089	642.6842	nm

Table 6 - Wavelengths calculated for each each distance x_N and distance between the grating and the screen for red light.

Task 3. Average all λ values using the weighted mean.

To calculate average value of all λ values we used formula:

$$\lambda_{avg} = \left(\sum_{i=1}^{n} w_i \lambda_i\right)\left(\sum_{i=1}^{n} w_i\right)^{-1}$$

where:

- w_i is calculated with formula:

$$w_i = u(\lambda) = \sqrt{\left(\frac{\partial\lambda}{\partial x} \cdot u(x_N)\right)^2 + \left(\frac{\partial\lambda}{\partial L} \cdot u(L)\right)^2 + \left(\frac{\partial\lambda}{\partial d} \cdot u(d)\right)^2}$$

where:

- $u(x_N)$ is uncertainty of the measured distance being approximately $0.707\ mm$
- $u(L)$ is uncertainty of the distance between the grating and the screen being approximately $0.5\ mm$

- $u(d)$ is uncertainty of the diffraction grating being approximately 0

After calculations we obtained such results for blue light:

$$\lambda_{avg} \approx 401.8603 \, nm$$

And for red light obtained:

$$\lambda_{avg} \approx 662.4943 \, nm$$

Task 4. Calculate the uncertainty of the weighted mean.

To obtain the uncertainty of the weighted mean we used formula:

$$u(w) = \frac{1}{\sqrt{\sum_{i=1}^{n} \frac{1}{w_i^2}}}$$

After placing numbers into equation for blue light we obtained:

$$u(w) = 1.4501 \, nm$$

And for red light:

$$u(w) = 1.4350 \, nm$$

Summary

Wavelengths for red and blue laser lights were calculated using measured distances and the diffraction grating constant. Weighted mean values of wavelengths were determined, yielding approximately 662.5 nm for red light and 401.9 nm for blue light, with uncertainties of 1.45 nm and 1.43 nm, respectively. Obtained results are matching with theoretical values quite well, which indicates that experimental set-up can be used to obtain reliable results.

Measurement card

Determining the wavelength of laser light using a diffraction grating

Blue light

d	$-x_3$	$-x_2$	$-x_1$	x_1	x_2	x_3 [cm]
10	3.8	2.4	1.2	1.2	2.4	3.8
20	7.6	5.00	2.4	2.4	5.00	7.6
30	11.5	7.5	3.6	3.6	7.5	11.5

Red light

d	$-x_3$	$-x_2$	$-x_1$	x_1	x_2	x_3 [cm]
10	7.2	4.3	2.00	2.00	4.3	7.2
15	10.9	6.5	3.00	3.00	6.5	10.9
20	13.9	8.4	4.00	4.00	8.4	13.9

Section:
Tymoteusz Kosiba
Piotr Capek
Zuzanna Mionek

18.11.2024