NATIONAL RESEARCH UNIVERSITY
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Report

«Diffraction»

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НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ
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Introduction

This report represents an assembly of an installation for observing diffraction on a reflecting diffraction grating. We studied the diffraction pattern for different gratings at different angles of incidence of light on the grating θ_i, determine the positions of the maxima. For each grid, we determined the number of strokes per unit length. Using a photodiode power meter, we measured the light intensity in maxima for the grating with which the greatest number of maxima is observed. After processing the obtained dependence, we determined the angle of the lattice bevel γ

Theoretical information

Single-slit diffraction

Let the edges of the gap be located at $x = \ pmb/2$, where b is the width of the gap. A plane monochromatic wave with a wave vector k at an angle θ_i to the normal vector to the lattice falls on the slit.

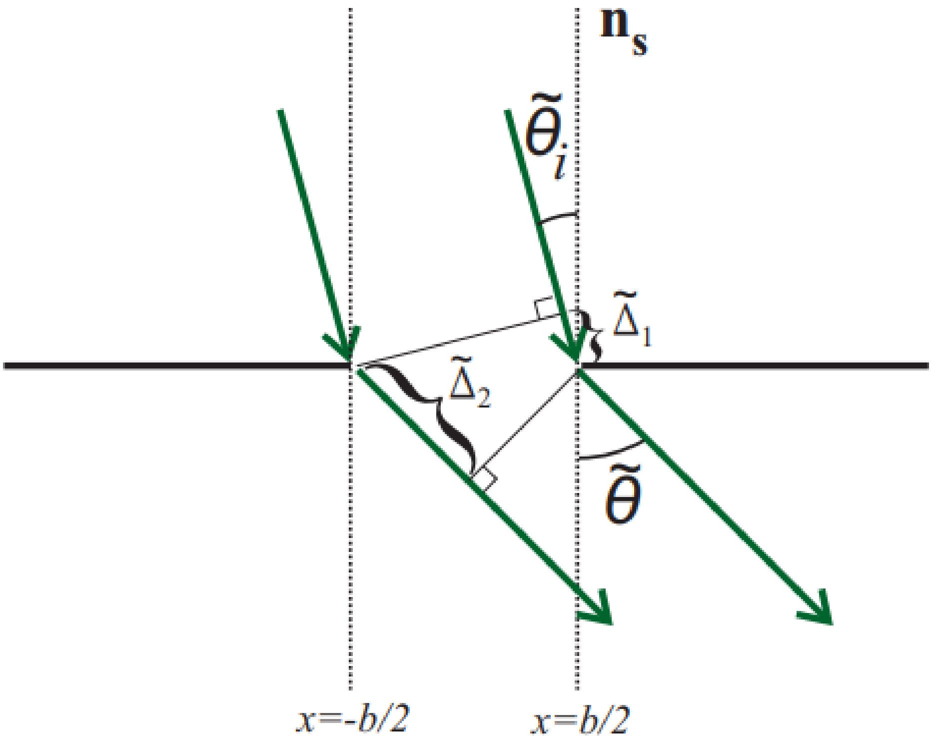

Figure 1. Fraunhofer diffraction on the slit.

The phase difference between the waves emitted from the coordinate $x = 0$ and x is equal to $\delta_1 = -kx(\sin\theta + sin\theta_i)$. We get:

$$E(\theta) \propto \int_{b/2}^{b/2} \exp(-i\delta_1(x))dx \propto \int_{b/2}^{b/2} \exp(-ikx(\sin\theta + \sin\theta_i))dx \tag{1}$$

$$E(\theta) \propto \frac{\sin(kb/2(\sin\theta + \sin\theta_i)}{kb/2(\sin\theta + \sin\theta_i} \tag{2}$$

Diffraction on a lattice with N slits

The path difference between the secondary waves formed by adjacent slits is $delta = dk(\sin\theta + sin\theta_i)$, in addition, the field emitted by the slot with the number n is $E_n = E_1 \exp(-i\delta n)$. Hence the resulting field:

$$E = E_1 * \sum_{0}^{N-1} \exp(-i\delta n) = E_1 \exp(i\delta(N/2-1)) \frac{\sin(N\delta/2)}{\sin(\delta/2)} \tag{3}$$

From here we can get the intensity:

$$I \propto E^2 \propto (\frac{\sin(kb/2(\sin\theta + \sin\theta_i))}{kb/2(\sin\theta + \sin\theta_i)})^2 \cdot (\frac{\sin(Nkd/2(\sin\theta + sin\theta_i))}{\sin(kd/2(\sin\theta + sin\theta_i))})^2 \tag{4}$$

The right multiplier is responsible for the position of the observed maxima, it also gives us the following condition:

$$d(\sin\theta + \sin\theta_i) = m\lambda, \tag{5}$$

where m is an integer called the order of the maximum.

Diffraction on a concentrating reflecting array

Because of the geometry of the concentrating reflecting grid, the multiplier $E_1(\theta)$ will change, and the second multiplier will remain the same.

$$I \propto E^2 \propto [\frac{\sin(kb/2(\sin(\theta-\gamma) + \sin(\theta_i-\gamma)))}{kb/2(\sin(\theta-\gamma) + \sin(\theta_i-\gamma))}]^2 [\frac{\sin(Nkd/2(\sin\theta + sin\theta_i))}{\sin(kd/2(\sin\theta + sin\theta_i))}]^2 \tag{6}$$

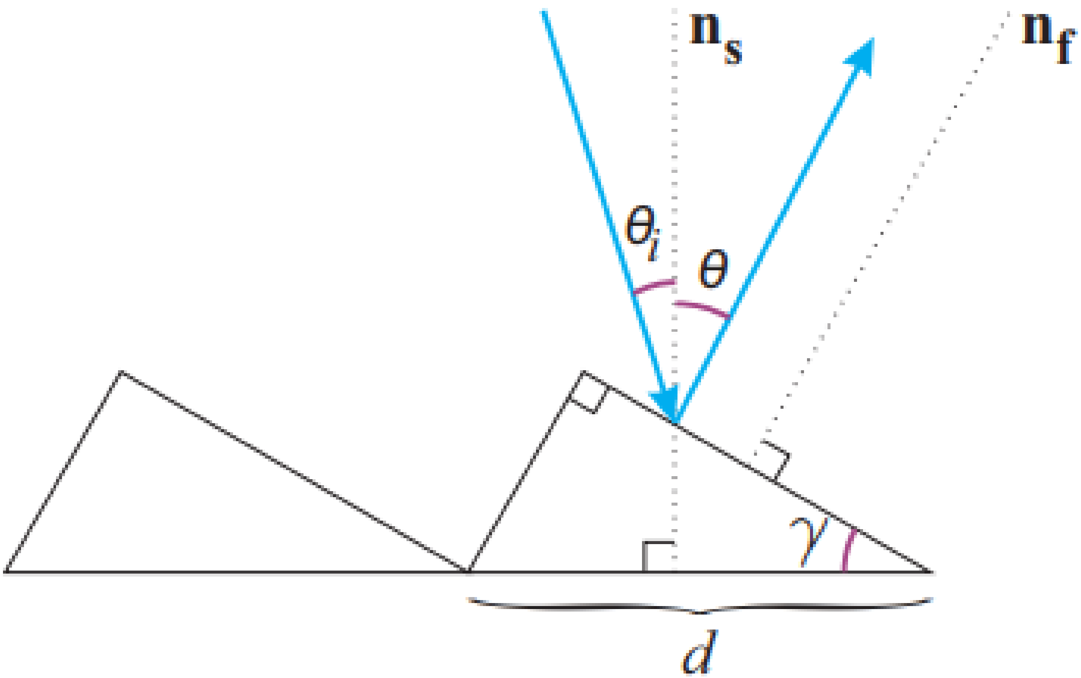

Figure 2. Diffraction on a concentrating reflecting array.

Here we will be interested in the first, changed multiplier, which is the curve that envelopes the intensity.

The angle at which the maximum intensity is observed corresponds to the mirror reflection of the incident light, is called the angle of brightness, and is defined by the following expression:

$$\varphi_B = 2\gamma - \theta_i \tag{7}$$

Equipment and methods

We used a laser with a wavelength of 520 nm, reflecting diffraction gratings with different lattice constants, a tape measure fixed on the wall, a ruler, and a light intensity analyzer.

The results were collected by hand and later processed with Python. Schematic diagram of the installation attached below:

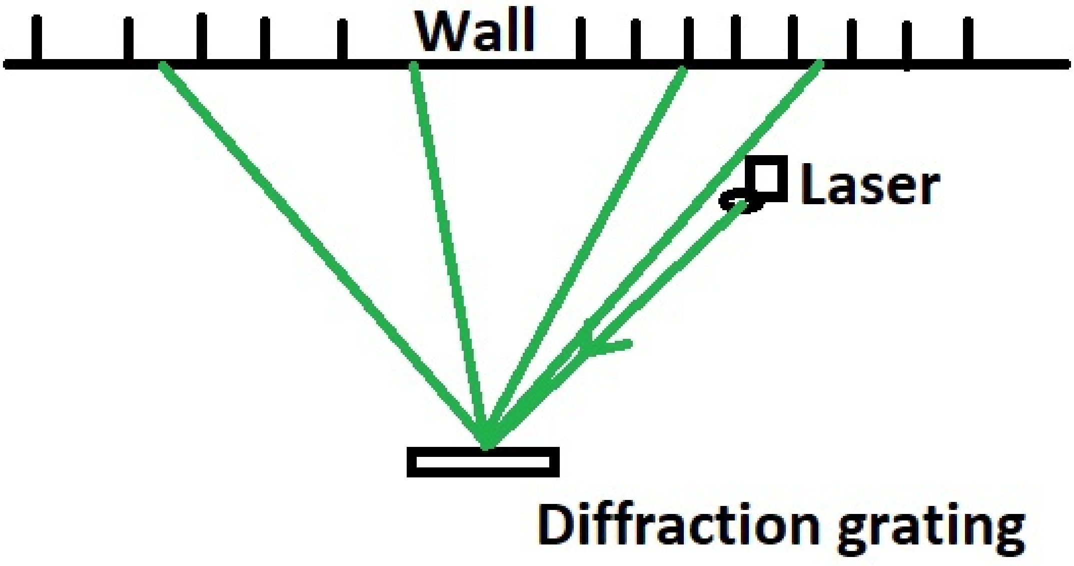

Figure 3.

Source code link: https://github.com/burunduk387/HSE-FF/tree/main/LabOptics/CLC

Experimental results

We fixed the diffraction gratings in front of the screen, which is a wall with a fixed tape measure for measuring the coordinates of the beams on the screen. We moved the laser by changing the angles of incidence of the beam on the grid and recored the results. We repeated this experiment for all three lattices.

The first diffraction grating

The results are represented in a table below.

Table 1. Table with raw data.

Order of the maximum	Coordinate of the maxima, cm
-1	77
0	173.5
1	282.5

After fitting a curve, we get its coeffitiets. Using $N_{slit} = \alpha/(\lambda \cdot 10^{-6})$, we obtain $N_{slit} = 1190 mm^{-1}$

The second diffraction grating

The results are represented in a table below.

Table 2. Table with raw data.

Order of the maximum	Coordinate of the maxima, cm
-2	55
-1	124
0	166
1	207
2	266

After fitting a curve, we get its coeffitiets. Using $N_{slit} = \alpha/(\lambda \cdot 10^{-6})$, we obtain $N_{slit} = 601 mm^{-1}$

The third diffraction grating

The results are represented in a table below.

Table 3. Table with raw data.

Order of the maximum	Coordinate of the maxima, cm
-2	118
-1	141
0	161
1	181
2	202

After fitting a curve, we get its coeffitiets. Using $N_{slit} = \alpha/(\lambda \cdot 10^{-6})$, we obtain $N_{slit} = 294 mm^{-1}$

The second experiment

For the third grating, we attempted to find γ using a light intensity analyzer. The results we got and the theoretical curve that was fitted are shown below.

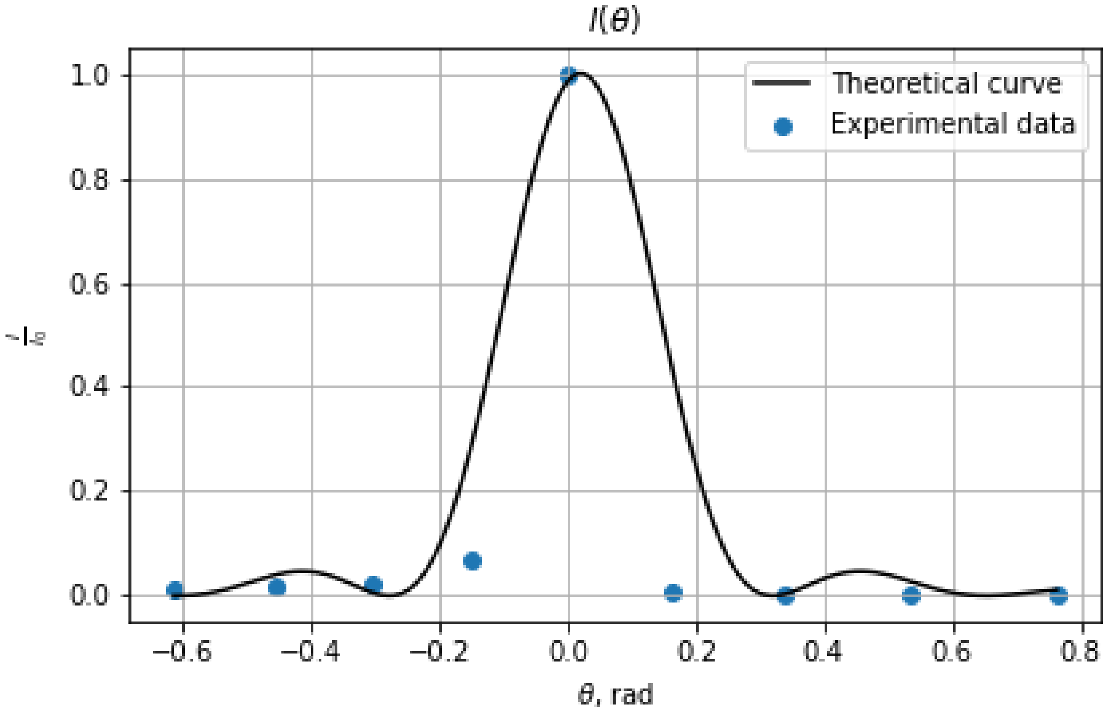

Figure 4.

We got $\gamma = 0.01$ rad.

References

[1] Diffraction. Guidelines for the Optics Workshop, 2021.