

**EXERCISE  
84**

**DETERMINATION OF A WAVELENGTH USING A  
DIFFRACTION GRATING**

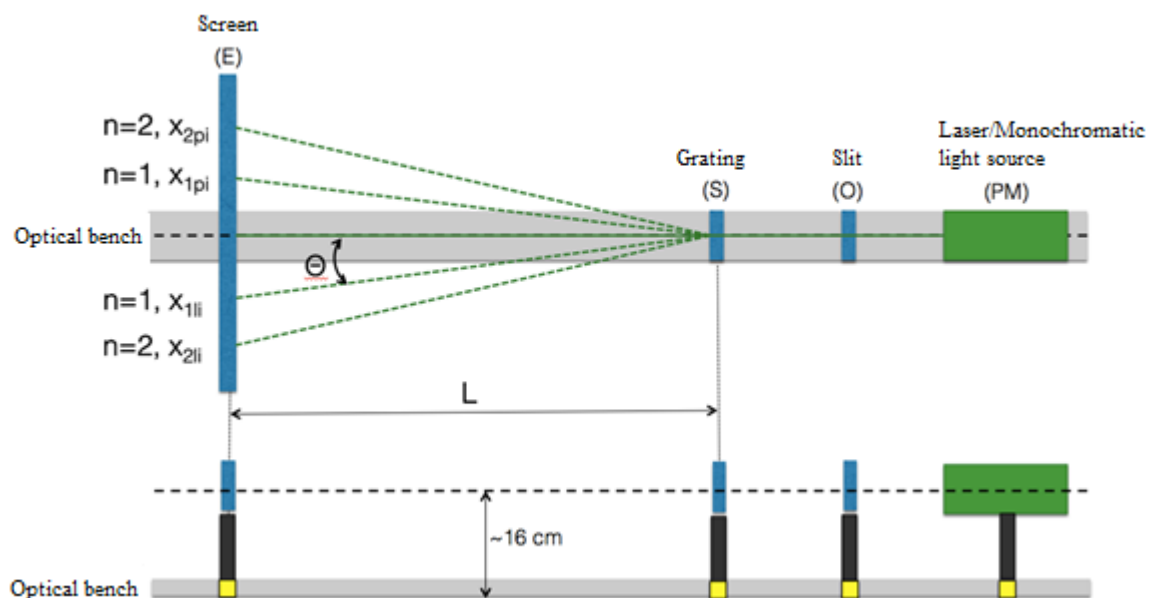
**1. List of equipment**

- Transmission gratings (S): type „A” – contains 50 lines per millimeter and type „B” of unknown number of lines/mm ;
- Laser or other monochromatic light source (PM);
- Screen with a millimeter scale (E);
- Optical bench with a millimeter scale;
- Slit (O);

**2. Aim of the exercise**

- Determination of emission wavelength of a given laser or other monochromatic light source;
- Determination of diffraction grating constant;

**3. Scheme of a measurement setup**



**Fig.1.** A scheme of a measurement setup.

**4. Preparation of the measurement setup:**

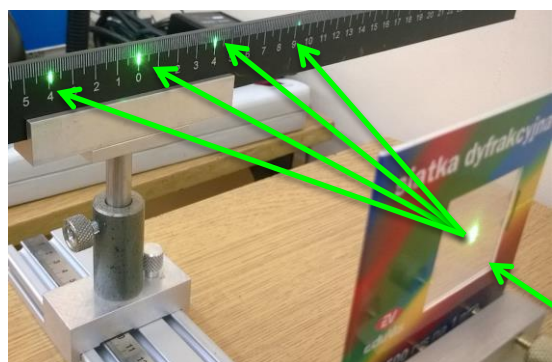
- Put a monochromatic light source/laser (PM) on one side of the optical bench. The output of the laser head should be in a distance of approx. 16 cm above the table top (cf. Fig.1.);
- Put a slit (O) on the optical bench. The center of the slit should be in a distance of approx. 16 cm above the table top;
- Turn on the PM and observe the light emission;

**Note: Never look directly into the laser light and make sure the laser light does not distract the other experimental setups. Keep cautious and protect your eyes.**

- (d) Move the slit (O) on the optical bench starting from the output of the monochromatic light source/laser to the end of the optical bench and back. Fix the position of the PM so that the light could pass through the center of the slit (O) at any change of its position.
- (e) Put a screen on the second part of the optical bench. The light coming from the laser should scatter on the millimeter scale of the screen. **Note**, that the screen should ALWAYS be in a position exactly perpendicular to the axis of the optical bench. Correction of its position during the experiment may introduce significant errors in the measurement.
- (f) Before putting a diffraction grating on the optical bench fix the position of the screen (E) so that the laser light could scatter in the „0” position on its millimeter scale. This position determines the projection of the light source without the effects of diffraction (see photo on the right side).



- (g) Put a diffraction grating (S) into the setup, between the light source and a screen, so that the light beam could pass through the center of the grating. After that, a specific diffraction image (similar to that one, shown in the picture on the right side) should appear on the screen. If the diffraction image is not visible on the screen correct the position of the grating, e.g. by rotating it on angle of 90 degrees relative to the axis defined by the course of the light beam coming from the PM.



- (h) The setup is ready for measurements.

#### **A. Determination of emission wavelength of a given laser or other monochromatic light source that has been used;**

- Make sure, that the setup is correctly set and the light beam coming from the laser or other light source scatter in the „0” position on a millimeter scale of the screen;
- Put a diffraction grating labeled by „A” so that the laser light passes through its center. Observe particular diffraction orders of light on both sides of the "0" position on the screen;
- Set the grating in a distance of  $L_1 \sim 300$  mm from the screen;
- Change the distance of the grating from the screen. Read and note the new distance as  $L_i$ . Determine its uncertainty -  $u(L_i)$ . Read and note the position of diffraction lines on both sides of the „zero” diffraction order. Label the indications for particular diffraction lines in a following way: on the right side of the „zero” diffraction order -  $x_{npi}$ , and left side -  $x_{nli}$ . Name its uncertainties as  $u(x_{npi})$ ,  $u(x_{nli})$ . Perform the measurements for  $n=1,2,3,4,5$  of diffraction order, for the fixed value of  $L_i$ ;
- For five different values of  $L_i$ , taking into account that  $L_i > 300$  mm and the distances between the particular  $L_i$  have to be not less than 20 mm, repeat the tasks from section d.

#### **B. Determination of diffraction grating constant;**

- Make sure, that the setup is correctly set and the light beam coming from the laser or other light source scatter in the „0” position on a millimeter scale of the screen;

- b. Put a diffraction grating labeled by „B” so that the laser light passes through its center. Observe particular diffraction orders of light on both sides of the "0" position on the screen;
- c. Set the grating in a distance of  $L_i \sim 50$  mm from the screen;
- d. Read and note the distance of the grating from the screen ( $L_i$ ) with its uncertainty -  $u(L_i)$ . Read and note the position of diffraction lines on both sides of the „zero” diffraction order. Label the indications for particular diffraction lines in a following way: on the right side of the „zero” diffraction order -  $x_{npi}$ , and left side -  $x_{nli}$ . Name its uncertainties as  $u(x_{npi})$ ,  $u(x_{nli})$ . Perform the measurements for the diffraction order  $n=1$  for different  $L_i$ ;
- e. For 15 different values of  $L_i$ , taking into account that  $L_i > 50$  mm and the distances between the particular  $L_i$  have to be not less than 10 mm, repeat the tasks from the section d.

## 5. Data handling:

A. Determination of emission wavelength of a given laser or other monochromatic light source that has been used in the experiment:

- i. For each diffraction order  $n=1,2,3,4,5$  and distance  $L_i$  calculate the average value of the diffraction line distance from the “zero” position of diffraction order:

$$\bar{x}_{n,i} = \frac{x_{nli} + x_{npi}}{2}$$

Determine the uncertainty  $u(\bar{x}_{n,i})$ .

- ii. Calculate the sine of the deflection angle:

$$\sin \theta_{n,i} = \frac{\bar{x}_{n,i}}{\sqrt{\bar{x}_{n,i}^2 + L_i^2}}$$

- iii. Calculate the uncertainty of the sine of the deflection angle for a given diffraction order  $n$  and distance  $L_i$ :

$$u_c(\sin \theta_{n,i}) = \sqrt{\left( \frac{L_i \bar{x}_{n,i}}{(L_i^2 + \bar{x}_{n,i}^2)^{3/2}} \right)^2 u^2(L) + \left( \frac{L_i^2}{(L_i^2 + \bar{x}_{n,i}^2)^{3/2}} \right)^2 u^2(\bar{x}_{n,i})}$$

- iv. Calculate the emission wavelength of a given laser or other monochromatic light source that has been used in the experiment according to the expression:

$$\lambda_{n,i} = \frac{d \cdot (\sin \theta_{n,i})}{n}$$

where:  $n=1,2,3,\dots$ , are particular diffraction orders,  $i$  – stands for the particular position of  $L_i$ ;

- v. For the obtained values of  $\lambda_{n,i}$  determine its average value  $\bar{\lambda}$  and calculate its standard uncertainty  $u(\bar{\lambda})$ .

B. Determination of diffraction grating constant:

- i. For each distance  $L_i$  and diffraction order  $n=1$  calculate the average value of the diffraction line distance from the “zero” position of diffraction order:

$$\bar{x}_i = \frac{x_{li} + x_{pi}}{2}$$

Determine the uncertainty  $u(\bar{x}_i)$ .

- ii. Calculate the sine of the deflection angle:

$$\sin \theta_i = \frac{\bar{x}_i}{\sqrt{\bar{x}_i^2 + L_i^2}}$$

- iii. Calculate the uncertainty of the sine of the deflection angle for a given diffraction order  $n$  and distance  $L_i$ :

$$u_c(\sin \theta_i) = \sqrt{\left( \frac{L_i \bar{x}_i}{(L_i^2 + \bar{x}_i^2)^{3/2}} \right)^2 u^2(L_i) + \left( \frac{L_i^2}{(L_i^2 + \bar{x}_i^2)^{3/2}} \right)^2 u^2(\bar{x}_i)}$$

- iv. Calculate the average value  $\overline{\sin \theta}$  and its standard uncertainty  $u(\overline{\sin \theta})$ ;
- v. Determine the diffraction grating constant  $d$  according to the formula:

$$d = \frac{n\bar{\lambda}}{\sin \theta} \Big|_{n=1}$$

vi. Calculate the uncertainty  $u_c(d)$  using the equation:

$$u_c(d) = \sqrt{\left(\frac{n}{\sin \theta}\right)^2 u^2(\bar{\lambda}) + \left(\frac{n\bar{\lambda}}{\sin^2 \theta}\right)^2 u^2(\sin \theta)} \Big|_{n=1}$$

**6. The proposed tables which can be used for registration of the results and calculations in a given experiment;**

**Table 1.** The measurement results for section "A" – determination of the emission wavelength of a given laser or other monochromatic light source that has been used in the experiment.

The measurement results for determination of the emission wavelength of a given laser or other monochromatic light source that has been used in the experiment						
$L_i$ (mm)	$u(L_i)$ (mm)	$n$	$X_{lni}$ (mm)	$u(X_{lni})$ (mm)	$X_{lpi}$ (mm)	$u(X_{lpi})$ (mm)
		1				
		2				
		3				
		4				
		5				
		1				
		2				
		3				
		4				
		5				
		1				
		2				
		3				
		4				
		5				
		1				
		2				
		3				
		4				
		5				
		1				
		2				
		3				
		4				
		5				
Grating "A" has 50 lines/mm						
The "A" grating's constant: $d(mm)=$						

**Table 2.** The results of calculations performed within the experimental section "A" – determination of the emission wavelength of a given laser or other monochromatic light source that has been used in the experiment.

The results of calculations performed within the experimental section "A"						
$L_{n,i}$ (mm)	$u(L_{n,i})$ (mm)	$\bar{x}_{n,i}$ (mm)	$u(\bar{x}_{n,i})$ (mm)	$\sin \theta_{n,i}$	$u(\sin \theta_{n,i})$	$\lambda_{n,i}$ (mm)

