Practical No 32

STUDY OF PROPERTIES OF ELECTROMAGNETIC WAVES

Aim

The practical consists of three parts. The aim of the first part is to learn with the polarization of visible light phenomenon, as well as to prepare and analyze the curve representing Malus's law. In the second part of the practical, the Lambert's law will be tested experimentally, and the intensity of the light source will be calculated. Calculating the speed of light in an optical fiber is the aim of the third part of the exercise.

Equipment:

optical bench, luxmeter, light source with red filter, two external polarizers instrument, optical fibers, measuring the speed of light.

Part I. Implementation and analysis of the curve illustrating the Malus law

Aim: Implementation and analysis of the curve illustrating the Malus law

Fig. 1. Scheme of the experimental setup.

1 – optical bench,
2 – light meter’s power on/off,
3 – diaphragm,
4 - external polarizer`s,
5 – light source with filters,
6 – power on/off.

Fig. 2. External polarizer

Course of measurements:

1. Turn on the light source with the button (6) and set it to "A" (white light)
2. Turn the light meter on using the button (2).
3. Set the diaphragm diameter to 10 mm and luxmeter at a distance of 19,5 cm from the light source.
4. Set the external polarizer at a distance of 4 cm from the light source and set the angle of polarizer No. 1 to a value of 90 °.

ATTENTION ! The value of the angle for point 5 read only for the polarizer number 1, for point 7 read only for the polarizer number 2

5. Change the position of the scale indicator every 10^{o} and then read -→ next write down this value into Table 1a in the exercise form.
6. Ask the teacher to set the second polarizer and then set the detector at 17 cm from the light source.
7. Then change the angles on both polarizers synchronously, by value equal to 10° (the illumination values from the luxmeter write down into Table 1b).
8. After completing the measurements, turn off the luxmeter and the light source.
9. Make two graphs on one coordinate system:

a) based on the data from Table 1a,

b) based on the data in Table 1b.

10. Read off from the graph the angular shift of the maxima (from the plot obtained with the external polarizer No. 1 and in the presence of 2 external polarizers)
11. Write down this value into **table 2** of the form.
12. Graphs should be attached to the exercise form.

Part II. Lambert's Law

Aim: Experimental verification of Lambert's law and calculation of the intensity of the light source.

Fig. 3. Scheme of the experimental setup.

1 – optical bench,
2 – light meter's power on/off,
3 – diaphragm,
4 – light source with filters,
5 – power on/off.

Course of measurements:
1. Turn the light source on using the button (2) and set it to the position when white light is emitted.
2. Turn the light meter on using the button (9).
3. Using the button (11) set the light meter at normal range (x1).
4. Set the diameter of the diaphragm to 6 mm and place the detector at the distance of 5 cm from the light source.
5. Find the illuminance of a detector (E) as a function of the distance between the detector and the light source (r). Fill in the table of the report's sheet with the measured values.

Attention: If the measuring range would be exceeded (1 at the left side of the screen would appear) use the range switch (12). This would result in the presence of small black triangle on the screen; now you have to multiply all the readings by 10. When the readings would drop below 2000 you can return to a normal range by pressing the button (11).

6. Change the position of the light source to the position when red light is emitted and repeat the experiment described in point 5.
7. After finishing of the measurements turn off the light meter and the light source.
8. Plot the dependence of illuminance E on $1/r^2$ w in standard conditions and in the presence of red filter.
9. Basing on Lambert's cosine law (7) calculate luminous intensity (I) by finding a slope of $E = f(1/r^2)$ dependence. **All calculated values write down to the table no 4.**

Part III. Measurement of the speed of light in an optical fiber

ATTENTION ! Laser radiation is dangerous for your eyes.
Avoid any contact with the laser light!

The laser light beam (electromagnetic wave of a frequency 2 MHz) generated by the source **L** is splitted into two beams, the first one is approaching the detector $\mathbf{D_1}$ situated near the source, whereas the second one is propagated through a fiber to the detector $\mathbf{D_2}$. The beams are approaching the detectors at different times. The measured time shift is higher than in reality due to some delay generated by the electronic system. In order to compensate for this error the time shift is measured for two different fibers: one with a length of 2 meters and one with a length of 8 meters. The difference of the time shifts between these two fibers is proportional to the speed of light in the fibers.

Device set-up: one semiconductor laser (emission wavelength – 650 nm), phase shift detector.

Course of measurements:
1. ask the tutor for connecting the first fiber
2. turn on the POWER of the measuring device
3. set the F/L switcher in the position F (fiber)

4. check out whether the diode O/K is lighting. If not, press the button RESET
5. leave the device for about 10 minutes to stabilize parameters
6. after this time press the button RESET and, while the button is pressed, check out whether the screen displays the sign +/- and zeroes. If yes, leave the button and read the value of time delay displayed on the screen in nanoseconds. If not, press the button RESET and turn the knob ZERO to adjust the display to +/- and zeroes. Then, leave the button and read the value of time delay displayed on the screen in nanoseconds.
7. write down the value of the time delay displayed on the screen to the table and ask the tutor for connecting another fiber
8. repeat the measurement of the time delay for another fiber and write down the results
9. Calculate the speed of light in the fiber applying the following formula and **write down to the table**

$$\mathbf{V = (L_2 - L_1)/[K(T_2 - T_1)]} \qquad (2)$$

where: V – speed of laser light in the fiber, L_1 – length of the orange fiber (2 m), L_2 – length of the blue fiber (8 m), K – constant equal to 1.4, T_1 – time delay for the orange fiber, T_2 – time delay for the blue fiber.

10. Finally, calculate the refraction index (n) of the fiber according to the definition:

$$\mathbf{n = c/v} \qquad (3)$$

where: c – speed of the light in a vacuum equal to $3x10^8$ m/s, v - speed of laser light in the fiber calculated using the equation (2). **Write down to the table.**

Required theoretical knowledge:

1. Nature of light.
2. Generation of laser's light (population inversion, optical pumping, parameters of semiconductor laser, spontaneous and stimulated emission).
3. Characteristics of laser work
4. Light polarization.
5. Properties of laser's light.
6. Malus's law.
7. Phenomenon of the total internal reflection.
8. Principle of operation of a waveguide.
9. Basic photometric quantities and their units.
10. Lambert's cosine law.

Suggested sources:

1. Wikipedia
2. http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html

Wroclaw Medical University Department of Biophysics and Neuroscience	**Practical No 32** **Study of properties of electromagnetic waves**
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Grade:	Tutor`s signature

Part I. Implementation and analysis of the curve illustrating the Malus law

Table 1

a)

The angle value that was set on the polarizer I[°]	Value that was read off from the luxmeter	The angle value that was set on the polarizer I [°]	Value that was read off from the luxmeter

b)

The angle value that was set on the polarizer II [°]	Value that was read off from the luxmeter

Table 2

angle read from the graph	

Part II. Lambert's Law

Table 3

Distance **r** [cm]	$1/r^2$ [$1/m^2$]	Illuminance E_1 [lx] (diaphragm 6 mm)	Illuminance E_2 [lx] (diaphragm 6 mm,red filter)
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
16			
18			
20			
25			
30			
40			
50			

Table 4

I_1= [cd]	I_2= [cd]

Part III. Measurement of the speed of light in an optical fiber

Table 5

$$V = \frac{L_2 - L_1}{K \cdot (T_2 - T_1)}$$

L_1 [m]	***L_2 [m]***	***K***	***T_1 [s]***	***T_2 [s]***	***V [m/s]***

6. Calculate the refraction index of the optical fiber:

$$n = \frac{C}{V} =$$

where:
c - speed of light in vacuum ($3x10^8$ m/s),
v – speed of light in the optical fiber