Malus' law (Item No.: P2250401)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
Physics	University	Light and Optics	Polarisation	Malus' law

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	10 Minutes	20 Minutes	3 Students

Additional Requirements:

- PC/Laptop with at least Windows XP

Experiment Variations:

Keywords:

Electric theory of light, polarization, polarizer, analyzer, Brewster's law, Malus' law

Introduction

Overview

Linear polarized light passes through a polarization filter. Transmitted light intensity is determined as a function of the angular position of the polarization filter.

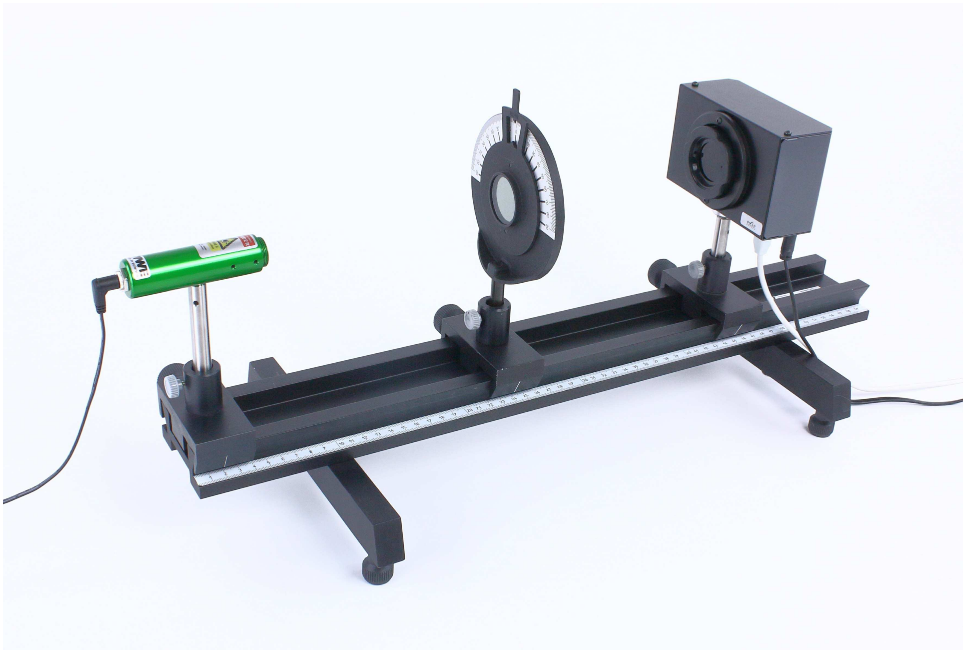

Fig. 1: Experimental set-up: Malus’ law.

Equipment

Position No.	Material	Order No.	Quantity
1	Diodelaser, green, 1 mW, 532 nm	08764-99	1
2	Optical bench expert l = 600 mm	08283-00	1
3	Base for optical bench expert, adjustable	08284-00	2
4	Slide mount for optical bench expert, h = 30 mm	08286-01	3
5	Polarising filter, on stem, for beam height 120 mm	08610-01	1
6	Digital array camera	35612-99	1

Tasks

1. The plane of polarization of a linear polarized laser beam is to be determined.
2. The intensity of the light transmitted by the polarization filter is to be determined as a function of the angular position of the filter.
3. Malus' law must be verified.

Set-up and procedure

The experiment is set up according to Fig. 1. Suggested positions on the optical bench are listed in Table 1, which are subject to variation. With the polarization filter set up, aim to position the incoming laser in the center of the digital array camera sensor. Connect the camera to the USB port of the PC, and the software should install automatically. For further information click the "Help" button in the bottom right. If the experiment is carried out in a non darkened room, the disturbing background current i_0 must be determined with the laser switched off and this must be taken into account during evaluation.

The polarization filter is then rotated in steps of 5° between the filter positions +/− 90°, and the corresponding intensity peak (maximum intensity value) is determined and recorded. Plot all intensity peak values for each measured angle.

Table 1: Positions on the optical bench.

Material	**Position** (cm)
Laser	2
Polarization filter	24
Camera	45

Theory and evaluation

Let AA' be the Polarization planes of the analyzer in Fig. 2. If linearly polarized light, the vibrating plane of which forms an angle φ with the polarization plane of the filter, impinges on the analyzer, only the part

$$E_A = E_0 \cdot cos\varphi \quad (1)$$

will be transmitted.
As the intensity I of the light wave is proportional to the square of electric field intensity vector $\vec{E}$, the following relation (Malus' law) is obtained:

$$I_A = I_0 \cdot \cos^2\varphi. \quad (2)$$

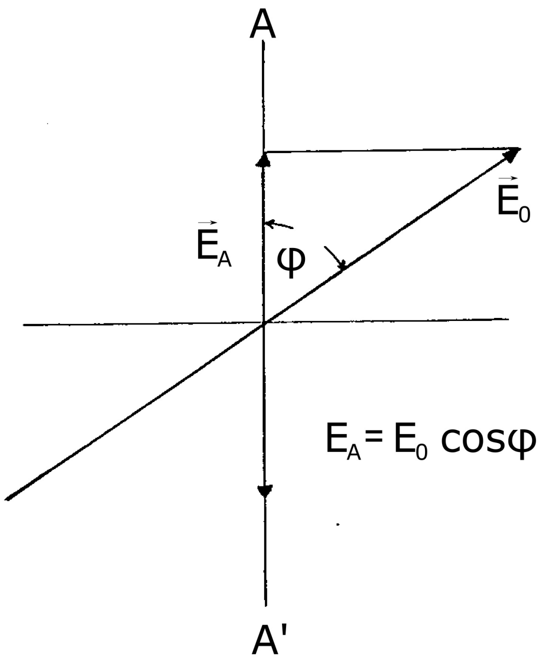

Fig 2: Geometry for the determination of transmitted light intensity.

Fig. 3 shows the transmitted light intensities after background correction (this is a measure for the transmitted light intensity) as a function of the angular position of the polarization plane of the analyzer. The measured results will be more sporatic and the intensity range may vary compared to Fig. 3. The intensity peak for φ = 50° shows that the polarization plane of the emitted laser beam has already been rotated by this angle against the vertical.

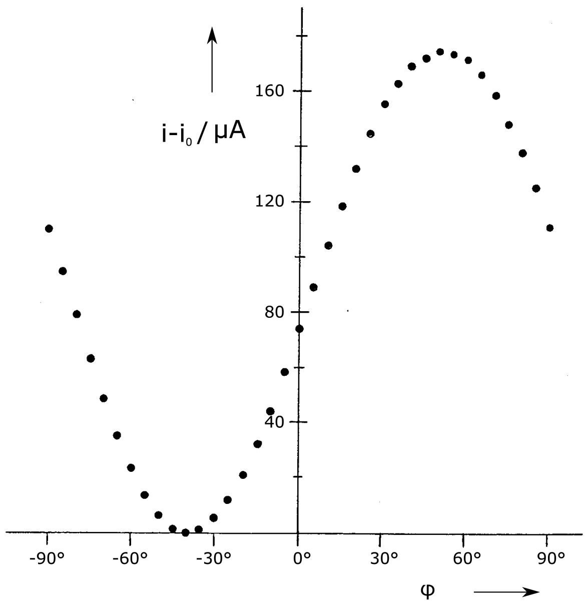

Fig 3: Corrected intensitiy values as a function of the angular position of the polarization plane of the analyzer.

Fig. 4 shows the normalized and corrected intensities as a function of the angular position of the analyzer. Malus's law is verified by the initial line's 45° slope (Note: to determine Malus' line in Fig. 4, an angular setting of 50° of the analyzer must be considered for φ = 0°).

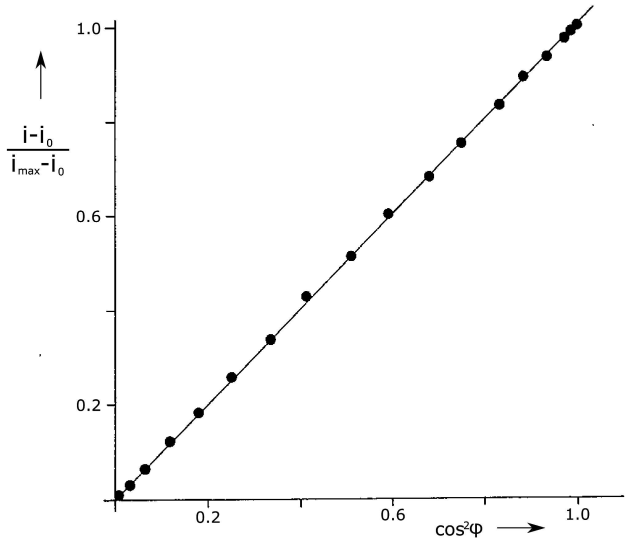

Fig. 4: Normalized intensity values as a function of $\cos^2\varphi$.