Determination of the plane of oscillation of a polarised la-ser beam - Malus' law

If a laser is equipped with a so-called Brewster window, it emits linearly polarised light whose oscillation plane can be determined with a polarisation filter used as an analyser.

Physics	Light & Optics	Wave properties of light
Physics	Light & Optics	Laser optics

Difficulty level	Group size	Preparation time	Execution time
medium	-	10 minutes	20 minutes

This content can also be found online at:

http://localhost:1337/c/6492b66f81696d00027328ed

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

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General information

Application

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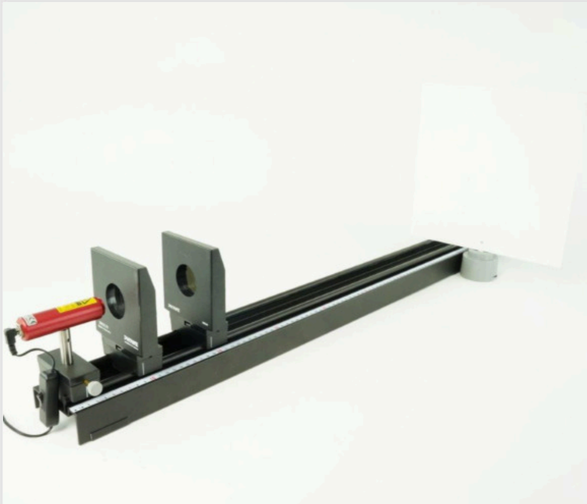

Experimental setup

If a laser is equipped with a so-called Brewster window, it emits linearly polarised light whose oscillation plane can be determined with a polarisation filter used as an analyser.

Polarisation has countless applications in nature and technology. Since light from the sky and reflected light from water surfaces, for example, are also polarised, you can achieve great pictures with polarisation filters for cameras.

There are also many animals that can perceive the plane of polarisation of light. This helps them with orientation and hunting.

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Other information (1/2)

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Prior knowledge

It should already be known that light is an electromagnetic transverse wave, i.e. it has an E-field and a B-field, which oscillate perpendicular to each other and to the direction of propagation and span an oscillation plane.

Principle

Normal light sources emit light waves whose direction of oscillation is randomly determined.

There are materials that, when light falls on them, only transmit light of a certain direction of oscillation. This is how you get linearly polarised light.

Other information (2/2)

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Learning objective

Polarising filters can be used to polarise light linearly. If linearly polarised light falls on a polarising filter used as an acceptor, the intensity of the light behind the acceptor behaves according to Malus' law; it decreases proportionally to the cosine square of the angle between the direction of oscillation and the direction of transmission.

Tasks

- Determining the plane of oscillation of a polarised laser beam
- Answering the questions in the evaluation

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Safety instructions

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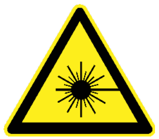

It is essential to ensure that you do not look directly into the laser beam.

The general instructions for safe experimentation in science lessons apply to this experiment.

Theory (1/2)

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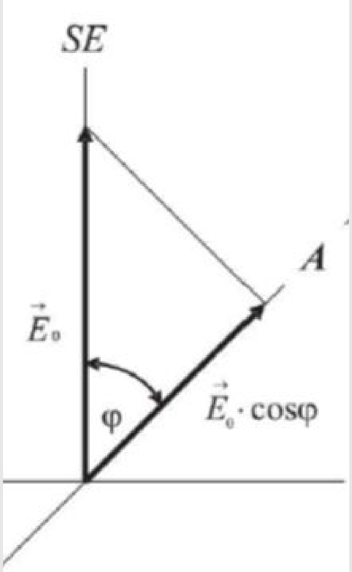
If an unpolarized light beam passes through a polarization filter, only that part of the light whose plane of oscillation corresponds to the polarization direction of the filter is allowed to pass through.

If linearly polarized light with the amplitude E_0 is incident on a second filter (analyzer), whose plane of oscillation A is rotated by the angle φ with respect to the plane of oscillation SE of the light , then only the part

$$\vec{E} = \overrightarrow{E_0} \cos\varphi \qquad (1)$$

is let through. If A and SE are perpendicular to each other, the analyzer is opaque.



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Theory (2/2)

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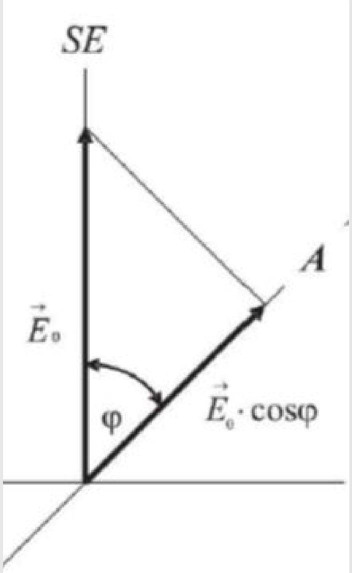
Since the light intensity is proportional to the square of the field strength amplitude of the light, the following applies to the intensity of the light behind the analyzer:

$$\frac{I}{I_0} = \frac{\vec{E}}{\overrightarrow{E_0}} = \cos^2 \varphi \qquad (2)$$

A photo element can be used to determine the light intensity, the photo current of which is directly proportional to the incident light intensity.



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Equipment

Position	Material	Item No.	Quantity
1	Optical profile-bench, l = 1000 mm	08370-00	1
2	Diodelaser 0.2/1 mW; 635 nm	08760-99	1
3	Fixing unit for diode laser	08384-00	1
4	PHYWE Demo Multimeter ADM 3: current, voltage, resistance, temperature	13840-00	1
5	Slide mount for optical bench	09822-00	2
6	Mount with scale on slide mount	09823-00	2
7	Lens on slide mount, f=+100mm	09820-02	1
8	Diaphragm holder, attachable	11604-09	1
9	Polarising filter, 50 mm x 50mm	08613-00	1
10	Photoelement	08734-00	1
11	Screen, translucent, 250x250 mm	08064-00	1

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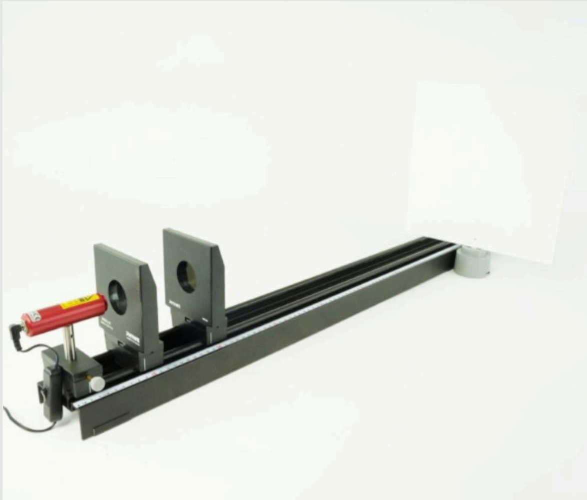
Set-up and Procedure

Setup



Experimental setup

For the first part of the experiment, the diode laser and the transparent screen are fixed in the tabs for the stand bench and placed at each end of the optical bench.

The converging lens mounted in a frame with scale ($f = +10cm$) serves to expand the laser beam.

The aperture holder with the polarising filter is mounted on the second mount with scale. The direction of the polarisation filter is indicated by its perforation. This should be at the top when the line mark of the aperture holder is above the -position of the angle scale. The polarising filter is positioned close behind the lens.

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Procedure (1/2)


First test part

With the room darkened, the polarising filter is slowly rotated and the resulting luminance is observed on the screen.

The filter settings for minimum brightness must be determined, as the eye can recognise differences in brightness better in this case. The laser is operated in 1 mW mode.

Then the transparent shield is exchanged for the silicon diode, which is connected to the current input of the demo multimeter.

The frame with scale and lens is removed.

Procedure (2/2)


Photo element

The distance between the photo element and the diode laser is now approx. 40cm. Both should be aligned so that the active area of the photo element is fully illuminated.

First is the dark current i_0 to register when the laser is switched off.

Subsequently, the polarisation filter is placed in the angular range of $\alpha \pm 100^\circ$ adjusted in 10° steps. The associated current i of the silicon diode is noted.

In the area of the intensity maximum and minimum, the angle change is to be carried out in 5° steps.

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Evaluation

Evaluation (1/3)

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The intensity minimum of the transmitted, linearly polarised laser light found in the first part of the experiment lies at an analyser position of $\alpha = -35^\circ$.

This means that the direction of oscillation of the laser light is rotated by 90° to it.

The diode laser thus emits linearly polarised light whose plane of oscillation is tilted by 55° from the vertical.

What is polarised light?

- Polarised light moves back and forth between two magnetic monopoles.
- Polarised light is filtered according to the direction of oscillation of the electric and magnetic field, so there is only one direction of oscillation.

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Evaluation (2/3)

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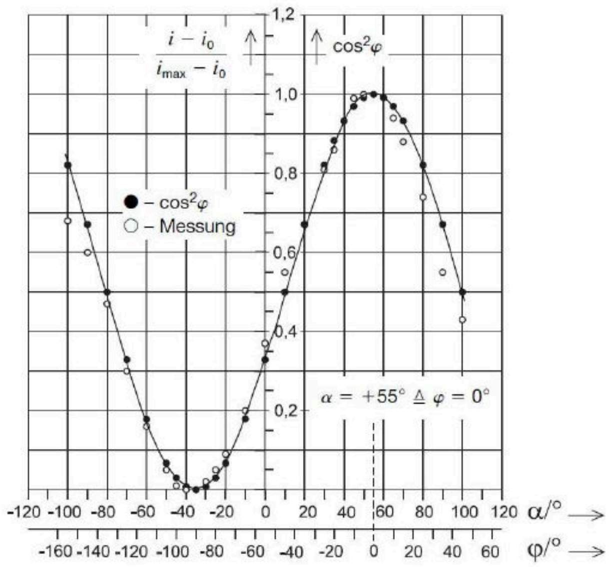
The dark current i_0 is subtracted from the measured current values of the second part of the experiment and the respective ratio $(i - i_0)/(i_{max} - i_0)$ is plotted against the angle in a diagram. The resulting graph corresponds to the curve of a $\cos^2$.

This confirms the law of Malus:

The intensity of a linearly polarized light beam with the initial intensity I_0 after passing through a linear polarizer is still $I = I_0 \cos^2 \varphi$.



Evaluation (3/3)

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To what can Malus' law be applied?

- [ ] Linear polarisation filters.
- [ ] Linearly polarised light.
- [ ] All polarisation filters.
- [ ] Circular Polarised Light.

Check

What are polarising filters used for on cameras?

To filter out reflections from water surfaces or to make the sky appear darker. Both are polarised light.

To enable faster focusing with the help of laser pulses.

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Slide	Score / Total
Slide 14: Polarisation	0/3
Slide 16: Multiple tasks	0/4

Total score 0 / 7

Show solutions Repeat

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