Polarization of light through scattering in an emulsion

Objectives of the Experiment

- Understanding the polarization of light.
- Observation and understanding of light scattering.
- Investigations of the polarization of light by scattering in an emulsion.

Principles

The phenomena of electrodynamics and magnetism were unified by the Maxwell equations for *electromagnetism*. The Maxwell equations in a vacuum can be solved by wave functions and thus describe electromagnetic waves. Such waves are transverse waves, i.e. the propagation direction $\vec{k}$ of the wave is always perpendicular to the electric field $\vec{E}$ and the magnetic flux density $\vec{B}$:

$$\vec{k} \cdot \vec{E} = \vec{k} \cdot \vec{B} = 0. \qquad (1)$$

This property of the electromagnetic waves is instrumental for the phenomenon of polarization. Light is an electromagnetic wave as well. Polarization of light is the direction of the vector $\vec{E}$ or $\vec{B}$ in the plane perpendicular to $\vec{k}$. The unpolarized light is composed of superimposed waves with all possible directions of $\vec{E}$ and $\vec{B}$ combined. If the direction is constant in time, we have *linear polarization*. The E field periodically changes its sign and absolute value. For *circular polarization*, the vector $\vec{E}$ rotates in the plane perpendicular to the direction of propagation $\vec{k}$ and has a constant absolute value.

The thermally generated light (lightbulb) is unpolarized and consists of light waves that are linearly polarized in all directions in the plane perpendicular to $\vec{k}$. Polarization effects occur in particular if light interacts with matter. A light beam is polarized during the passage through certain media. This is called a polarization filter if a certain direction of $\vec{E}$ is removed (filtered) from an unpolarized light beam. Light is also polarized when scattered on molecules or small particles. The scattered particles can be regarded as oscillating dipoles, which are first excited by irradiating light and then emit the electromagnetic waves like small antennas. Figure 1 schematically shows the scattering of light on a dipole. The radiation is polarized depending on the emission direction: The maximum emission is perpendicular to the dipole axis and there is no emission in the direction of the dipole axis.

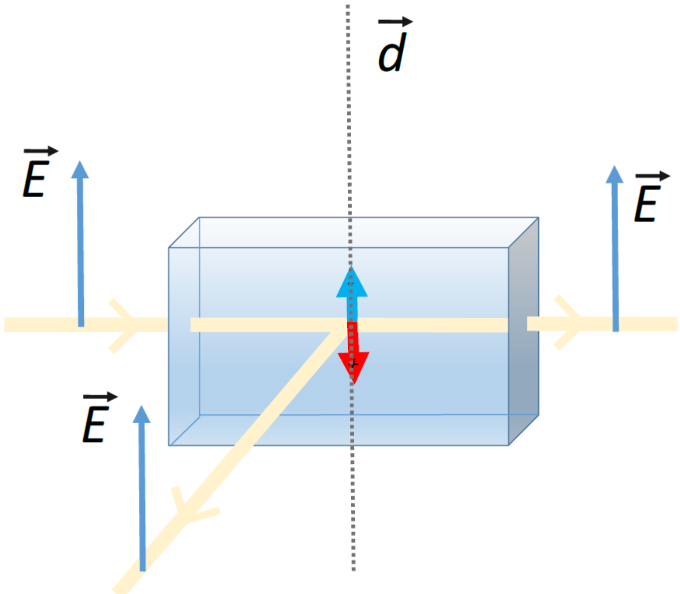

Figure 1: Schematic representation of light scattering on an oscillating dipole.

Consequently, the linearly polarized light is not scattered homogeneously.

A very simple example of a polarizing medium is a mixture of two non-mixing liquids, an emulsion. For example, if there are small droplets in the water, the light is scattered on these droplets and can be examined.

In the present experiment, milk is highly diluted with water until the resulting emulsion is translucent. When viewed through a polarization filter, the polarization of the scattered light can be examined. In addition, the brightness of scattered light that has been linearly polarized before scattering is observed.

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Apparatus

1 Plate glass cell (cuvette), 100 x 100 x 10 mm 477 20
1 Prism table. 460 25
1 Lamp housing with cable........................... 450 60
1 Incandescent lamp 6 V/30 W, E14, set of 2 450 64
1 Condenser with diaphragm holder............. 460 20
1 Transformer, 6/12 V 521 210
1 Iris diaphragm... 460 26
2 Polarization filters 472 401
1 Lens in frame, f=200 mm........................... 460 03

1 Small optical bench 460 43
6 Leybold multiclamp.................................... 301 01
2 Stand base, V-shaped, large..................... 300 01

Figure 2: Experiment set-up, polarization of light by scattering in an emulsion.

Safety Note

Watch for heat development of the lamp housing.

Experiment set-up

The experiment set-up is shown in Figure 2.

(a) Adjustment of the optical devices:

- Attach the small optical bench to the stand base.
- Carefully align the optical bench in a horizontal position.
- Insert the incandescent bulb into the lamp housing and mount the latter to one end of the optical bench. Use Leybold multiclamps for all optical devices.
- Mount the iris diaphragm on the optical bench in front of the halogen lamp so that the distance between the picture slider and the iris diaphragm is approximately 2 - 5 mm.
- Mount the lens at a distance of about 20 cm from the iris diaphragm.
- Connect the lamp housing to the transformer.
- Align the small optical bench so that the image of the iris diaphragm is observed on a wall at a distance of 1 - 2 m.
- Adjust the aperture of the iris diaphragm to a diameter of 2 - 4 cm.
- Move the lens along the optical bench until the image of the iris diaphragm is in focus. Affix the lens at this point.
- Mount the prism table on the optical bench behind the lens.
- Fill the plate glass cell with water, add half a teaspoonful of milk, and mix thoroughly. If necessary, dilute with more water.
- Mount the plate glass cell on the prism table, parallel to the optical bench.

(b) Polarization by scattering:

- For the experiments, the polarizing filter is mounted and removed from between the iris diaphragm and the lens.

Performing the experiment

(a) Polarization of light by scattering:

- Remove the polarizing filter from the optical bench and hold it in your hand.
- Observe the scattered light from all sides through the polarization filter while rotating the polarization filters from 0° to 180°.

(b) Scattering of polarized light:

- Mount the polarization filter between the iris diaphragm and the lens, set it to 0°, and observe the brightness of the scattered light from all sides.
- Set the polarization filter to 90° and observe the brightness of the scattered light from all sides.

Observation

(a) Polarization of light by scattering:

- The light scattered upward is linearly polarized at 90°.
- The light scattered to the right/left is linearly polarized at 0°.
- The light that emerges from the plate glass cell along the optical axis is unpolarized.

(b) Scattering of polarized light:

- With the polarization filter setting at 0°, the scattered light is the brightest on the right/left, and the weakest at the top.
- With the polarization filter setting at 90°, the scattered light is the brightest at the top, and the weakest on the right/left.
- The light emerging from the plate glass cell along the optical axis does not change its brightness.

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