TP n°4

Polarization

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1 Preparation

1.1 Polarization of a wave

An electromagnetic monochromatic and planar wave is characterized by 3 components: the electric field $\vec{E} = \vec{E} \cos\left(\omega t - \vec{k} . \vec{r}\right)$, the magnetic field $\vec{B} = \vec{B} \cos\left(\omega t - \vec{k} . \vec{r}\right)$ and the propagation vector $\vec{k}$. The vectors $\vec{E}$, $\vec{B}$ and $\vec{k}$ form a right handed cartesian system. Light whose electric field oscillates in a particular way is said to be polarized.

- With $\vec{E} = A_1 \cos\left(\omega t\right) \vec{x} + A_2 \cos\left(\omega t - \phi\right) \vec{y}$, show that at any time t, the extremity of $\vec{E}$ describes in general an ellipse.
- From the calculation of $\frac{dE_x}{dt}$ and $\frac{dE_y}{dt}$, show that the ellipse can be traced in a clockwise or counterclockwise sense, as seen from the receiver.

If the major and minor axes of the ellipse are equal, the polarization is said to be circular. If the minor axis of the ellipse is zero, the polarization is said to be linear. Rotation of the electric vector in a clockwise sense is designated right-hand polarization (or negative helicity), and rotation in a counterclockwise sense is designated left-hand polarizetion (or negative helicity).

A polarizer is an optical device that allows only the component of the electric field parallel to its axis to go through. The intensity of an electric field $\vec{E}$ is defined by the product of $\vec{E}$ and $\vec{E}^*$.

- Assuming a wave with a linear polarization, compute the variation of the intensity I as a function of the angle α between the axis of the polarizer and the direction of the incident polarization.
- What happens if the incident wave is polarized circularly ?

1.2 Dispersion law, circular and linear birefringence

Considering an electromagnetic wave with a pulsation ω and a wave vector $\vec{k}$, the modulus of the vector wave k is linked to the pulsation by the dispersion law : $k = \frac{n \omega}{c}$ where n is the index of the medium and c is the velocity of the light in vacuum.

If the medium is anisotropic, the index depends on the propagation direction. Such a medium is characterized by three optical axis associated with three principal indexes n_1, n_2 and n_3.

If $n_1 \neq n_2 \neq n_3$, the medium is biaxial. If $n_1 = n_2 \neq n_3$, the medium is uniaxial or birefringent.

2 Measures

A scheme of the optical setup is depicted of fig. 1

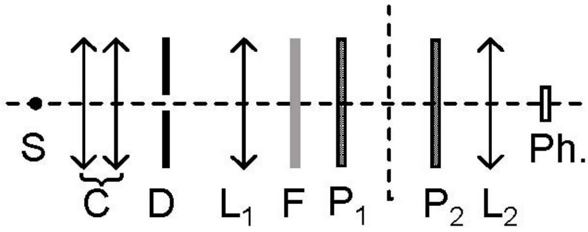


Fig. 1 Setup for the study of the polarization

A light source S, followed by a condenser C, lights up a diaphragm D. L_1 and L_2 are two convergent lenses. F is a monochromatic interferential filter (band pass filter), P_1 and P_2 are two polarizers. Ph is a detector.

Place on the optical bench, the source, the condenser, the diaphragm and the lens L_1. In order to obtain a parallel beam, the diaphragm must be into the focal plan of the lens L_1. Describe and use the auto-collimation method. Measure the residual current given by the detector without any illumination. Open gradually the diaphragm and try to see whether there is a threshold aperture after which there is saturation of the detector. Wright down the maximum current given by the detector.

2.1 Polarization of the source

- Insert an interferential filter and a polarizer on the bench.
- Collect the intensity of the signal and plot it as a function of the orientation of the polarizer.
- What can you say about the polarization state of the incident light ?

2.2 Fixed polarizer and rotating analyzer

Polarizer and analyzer are two identical devices. The first to meet the incident light is called polarizer and the second analyzer.

- Introduce the analyzer and collect the intensity of the signal as a function of the orientation of the analyzer.
- Put the values you have measured in a table and plot the corresponding graph.
- Compare this graph with the curve predicted by the formula established in section 1.
- Give the angular positions where the sensitivity is maximal (a small variation of the angle produces a large variation of the intensity).
- What about the sensitivity around a maximum and minimum in intensity ?

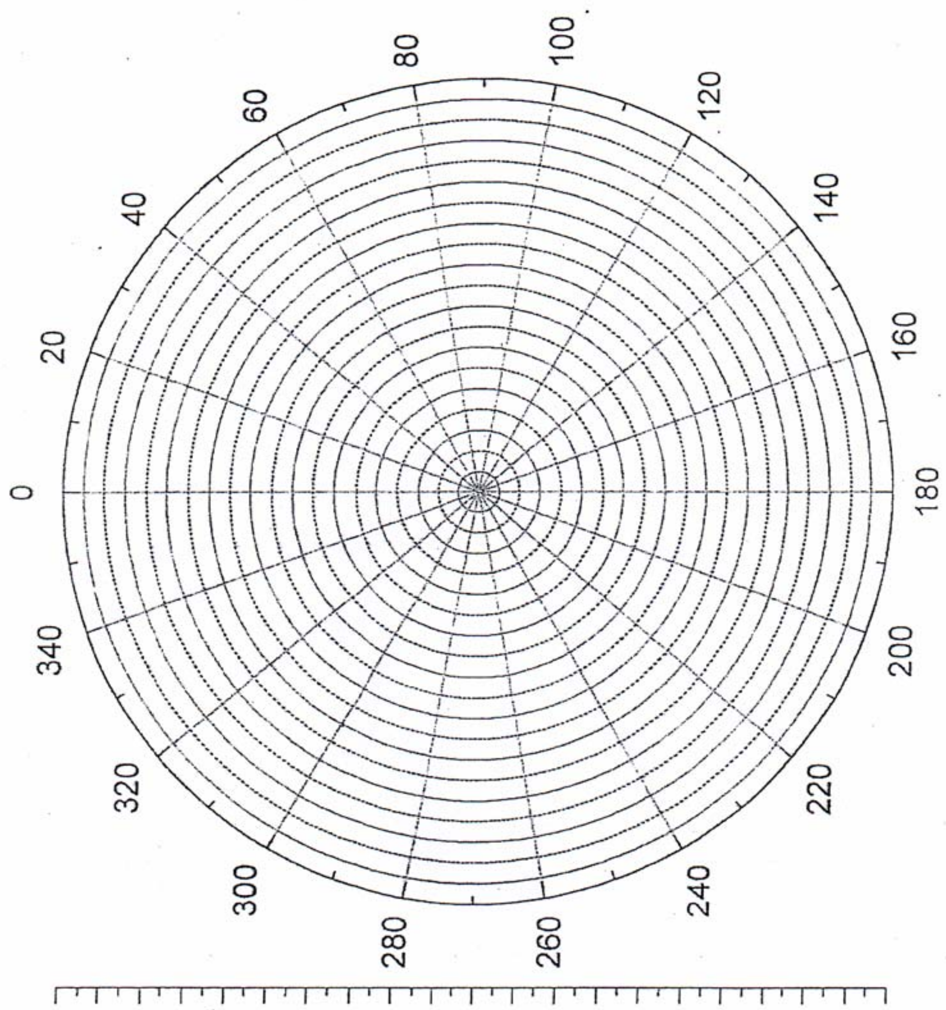
2.3 Circular birefringence and optical rotation

The quartz plate on the table is an example of a uniaxial birefringent material with its optical axis perpendicular to the plan of the plate.

- Introduce the quartz plate between the polarizer and the analyzer.
- Keep the polarizer immobile and turn the analyzer.
- What can you conclude about the polarization of the ray going out the plate ? Is it linear or elliptical ?
- Measure the optical rotation of the plate for several wavelengths using the interferential filters.
- Using the white light source directly, mask the detector with a piece of paper and describe the phenomenon you are looking at.

2.4 Linear birefringence : plate λ/4

- Take out the quartz plate and with a red filter in place, cross the analyzer and the polarizer such as the signal on the detector is minimum.
- Introduce the quarter wave plate between the analyzer and the polarizer.
- Is the current still zero ?
- Turn the plate and note for which angular positions the intensity is maximal and minimal.
- For a position where the current measured is maximal, turn the analyzer and deduce the polarization state of the wave after its passage through the plate. Is it linear, circular or elliptical ?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