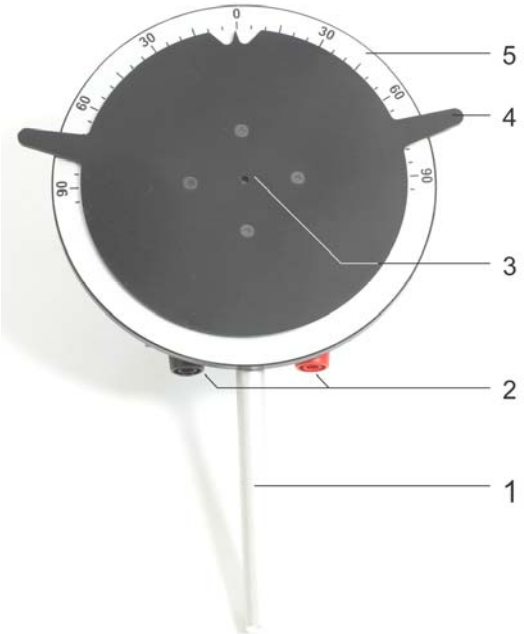
3B SCIENTIFIC® PHYSICS

...going one step further

Pockels Cell 1013393

Instruction manual

09/15 TL/DU



1 Rod, 10 mm
2 Connecting sockets
3 Optical ray opening
4 Rotating disc
5 Scale

1. Safety instructions

- It is dangerous to come into contact with the voltages used here. Take care!
- When applying voltage, make sure that the current does not exceed its limit of 2 mA. Higher values of current may cause damage to the crystal.

2. Description

The Pockels cell is for demonstrating the linear electro-optic effect (Pockels effect).

The Pockels effect covers the emergence of or changes to existing birefringence when an electric field is applied across a crystal. The effect is linearly proportional to the applied field strength. For reasons based on symmetry, the Pockels effect can occur only in crystals which do not exhibit inversion symmetry. In a transverse configuration, the direction of the incident light and the optical axis of the birefringence are perpendicular to one another. The electrical field is applied along the line of the optical axis (Fig. 1).

Lithium niobate crystals ($LiNbO_3$) are most commonly used to make transverse Pockels cells. $LiNbO_3$ crystals are optically uniaxial and exhibit negative birefringence. The refractive index for the “extraordinary” ray is $n_o = 2.29$ while the ordinary refractive index is $n_e = 2.20$ at the wavelength of a neon-helium laser, $\lambda = 632.8$ nm.

An $LiNbO_3$ crystal which can be rotated axially in the light beam has metal foil applied along two sides (to form a plate capacitor). Applying a voltage to the two pieces of foil then creates an electric field across the crystal. The crystal is cut with parallel faces.

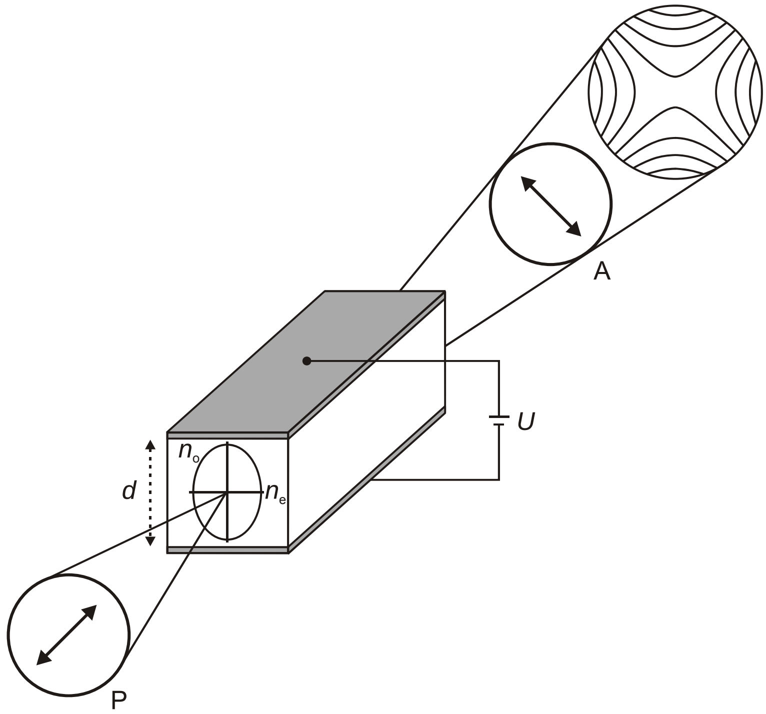


Fig. 1: Ray path schematic.

A divergent linearly polarised beam of light is shone on the crystal and the transmitted light passes through a crossed analyser to be viewed on a screen (Fig. 1).

In the absence of an applied voltage, there is therefore an interference pattern consisting of two sets of hyperbolae at an angle of 90° with respect to one another (Fig. 2).

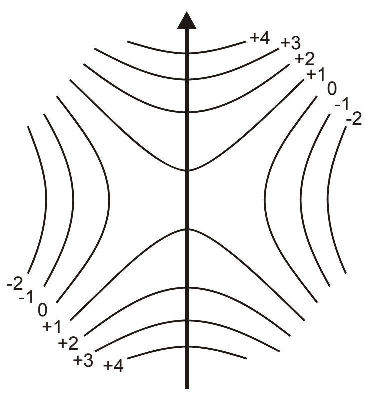


Fig. 2: Interference pattern with the optical axis of the crystal shown by the arrow. The indices of the dark interference lines indicate the path difference between the ordinary and extraordinary rays using the wavelength of the incident light as a unit.

The axis of one of the sets of hyperbolae is parallel to the optical axis while the other is perpendicular to it. The dark interference lines result from destructive interference, i.e. the path difference Δ_m, (the difference in the optical path between the ordinary and extraordinary rays) corresponds to an integer multiple of the wavelength of the light λ:

$$\Delta_m = d \cdot (n_o - n_e) = m \cdot \lambda \text{ where } m \in \mathbb{Z}$$

d: Thickness of crystal in direction of optical axis

When an electric field is applied across the crystal, as long as the sign is correct, the dark interference lines of one set of hyperbolae (parallel to the optical field) move closer to the centre as the voltage is increased (Fig. 3).

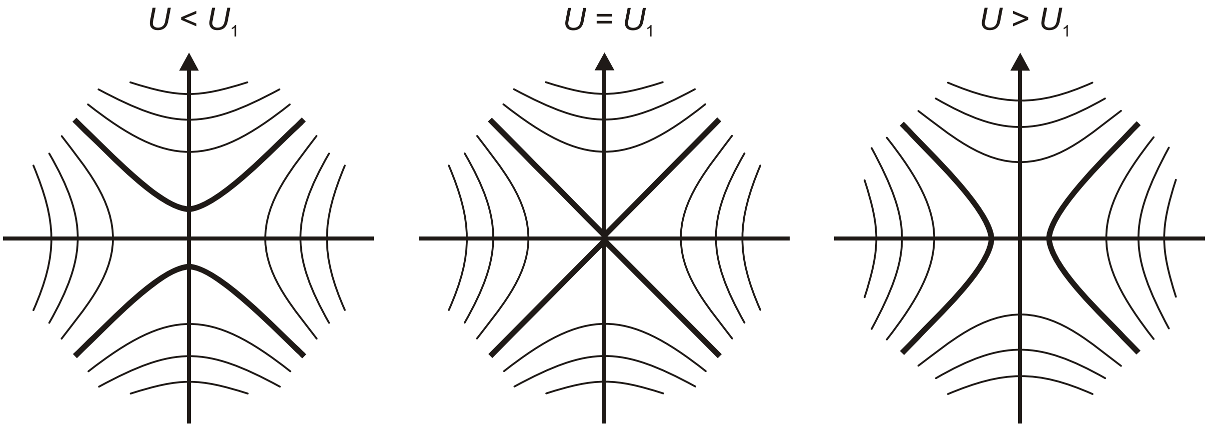


Fig. 3: Change in interference pattern due to Pockels effect. The hyperbolae highlighted bold are those of interference order +1.

Conversely the interference lines for the other set of hyperbolae (perpendicular to the optical axis) move away from the centre as the voltage increases. At voltage U_1, the two hyperbolae with a path difference Δ_{+1} will have moved to the position in the centre, which will now appear dark. As the voltage is increased further, the two hyperbolae swap between the two sets of hyperbolae and move further away from the centre. At voltage U_2 the above will also have occurred to the two hyperbolae with a path difference of Δ_{+2}. The difference in the two voltages, $U_2 - U_1$, therefore corresponds to twice what is called the half-wave voltage U_π:

$$U_2 - U_1 = 2 \cdot U_\pi$$

For each change of one half-wave voltage, the path difference Δ changes by half the wavelength,

$$\Delta\left(U_\pi\right) = \frac{\lambda}{2},$$

i.e. the positions of light and dark lines in the interference pattern are swapped over.

3. Technical data

Maximum voltage:	2000 V
Half-wave voltage	380 V approx.
Crystal:	$LiNbO_3$
Crystal dimensions	2 x 2 x 20 mm
Plate capacitor	2 x 20 mm
Axial angle range	±95°
Contacts	4-mm sockets
Height of crystal above top of stem rod	150 mm

4. Experiment

Additionally recommended:

1 Precision optical bench D	1002628
3 Optical riders D, 90/50	1002635
2 Optical riders D, 90/36	1012401
1 Polarisation filter on stem	1008668
1 Projection screen	1000608
1 He-Ne laser	1003165
1 Achromatic objective, 10x /0.25	1005408
1 Converging lens on stem, f = 50 mm	1003022
1 High-voltage power supply E @230V	1013412
or	
1 High-voltage power supply E @115V	1017725
1 Pair of safety experiment leads	1002849

- Set up the apparatus as in Fig. 4. Adjust the light beam by moving the laser and the convex lens until the beam is focussed on the crystal in the Pockels cell.
- Adjust the position of the crystal to the plane of polarisation by means of the rotating disc.

Note:
The plane of polarisation of the He-Ne laser may change during the course of the experiment

Hyperbola-shaped structures are visible on the screen. These demonstrate the birefringence in light emerging from the crystal.

- Set the polarisation filter for optimum contrast.
- To determine the half-wave voltage across the terminals of the Pockels cell, apply a DC voltage. Start at 0 V and gradually increase it until the current reaches its maximum of 2 mA.

The brightness at the centre of the interference pattern changes between maxima and minima.

The absolute voltage difference between two brightness maxima is the half-wave voltage.

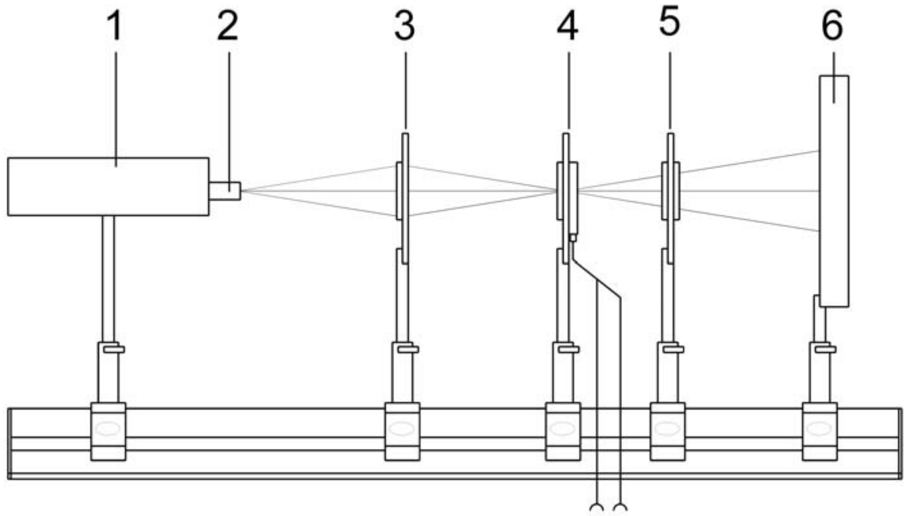


Fig. 4 Set-up for demonstrating birefringence from an $LiNbO_3$ crystal.

1 Laser
2 Achromatic objective
3 Converging lens, +50 mm
4 Pockels cell
5 Polarisation filter
6 Screen