Polarization by stress birefringence (Photoelasticity)

Task and equipment

Information for teachers

Additional Information

During the manufacturing process, by subsequent treatment or the exertion of external forces it is possible to induce tension in transparent materials, which bring about optical anisotropy of those materials. This means that a light wave train is split up into two parts with different oscillation planes when it passes through these materials. The propagation velocity of the light and hence the diffraction index are dependent on the direction of travel. This phenomenon is known as stress birefringence or photoelasticity.
In this experiment the students should realize that when polarized white light passes through optically anisotropic materials, coloured bright areas appear behind the crossed analyzer, and these are apparently brought about because the oscillation planes of parts of the emerged light are altered.

Suggestions for Set-up and Performance

Working in groups, one to each photoelastic model, the students should be allowed to reach the stage of focusing their model on the screen before blacking out the lab completely.
The students can use their own spectacles for investigating the anisotropic properties of spectacle lenses. They will also notice interesting colour phenomena occuring when polarized light passes through plastic spectacle frames.

Remark

We can produce our own optically anisotropic lenses as follows: heat a thin glass plate over the flame of a bunsen burner until it is about to melt, then cool it rapidly by waving it briskly in the air.
It is possible to use safety glass in this experiment. This is manufactured with areas of different tension and breaks into small fragments when damaged. Its best-known application is for car windowscreens.

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Task

What happens to polarized light when it passes through lenses with inner tension?

Direct polarized light through given photoelastic models, exerting on these at the same time various pressures which bring about inner tensions, and analyze the emergent light. Then investigate whether spectacle lenses display inner tensions.

Equipment

Position No.	Material	Order No.	Quantity
1	Light box, halogen 12V/20 W	09801-00	1
2	Bottom with stem for light box	09802-10	1
3	Support base, variable	02001-00	1
4	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	2
5	Meter scale for optical bench	09800-00	1
6	Lens on slide mount, f=+50mm	09820-01	1
7	Lens on slide mount, f=+100mm	09820-02	1
8	Mount with scale on slide mount	09823-00	1
9	Screen, white, 150x150mm	09826-00	1
10	Photoelastic model	09829-00	1
11	Polarising filter, 50 mm x 50mm	08613-00	2
12	Diaphragm holder, attachable	11604-09	2
13	PHYWE power supply DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
Additional material			
	Spectacle with glass and plastic lenses		

Set-up and procedure

- Set up the optic bench with the two support rods and the support base and place the scale in position (Fig. 1 and Fig. 2).


Fig. 1


Fig. 2

- Assemble the light box according to Figures 3 and 4 and clamp it into the left part of the support base with the lens end pointing away from the optic bench (Fig. 5). Insert a light-tight diaphragm into the well in front of the lens (Fig. 6).


Fig. 3


Fig. 4


Fig. 5


Fig. 6

- Clamp the screen into the right part of the support base (Fig. 7).

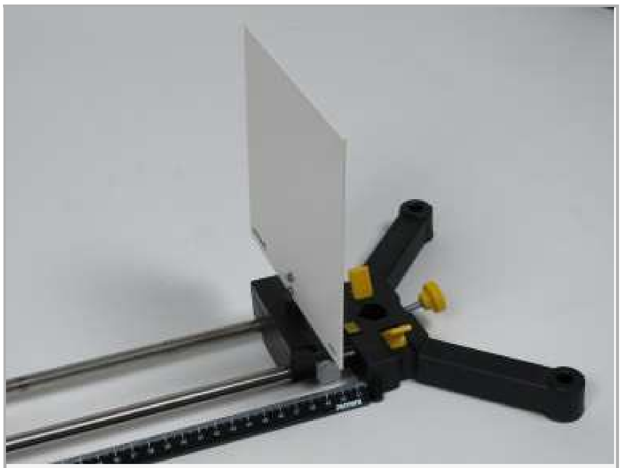

Fig. 7

- Position a lens with *f* = +50 mm at approx. 3.5 cm and a lens with *f* = +100 mm at approx. 25 cm on the optic bench (Fig. 8).

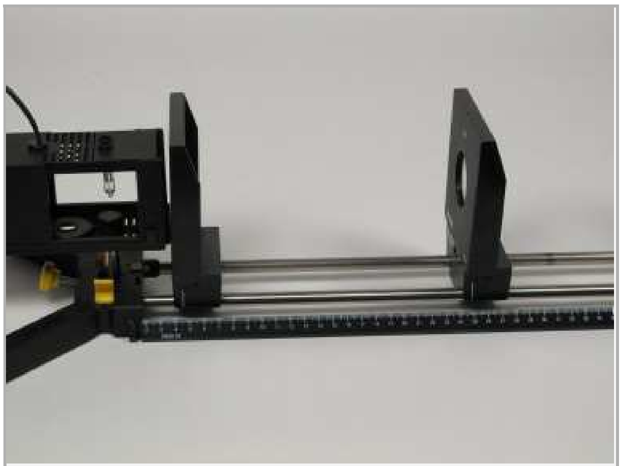

Fig. 8

- Connect the light to the power supply (12 V~) and swith on the power supply (Fig. 9).

Fig. 9

- Hold a photoelastic model at approx. 8 cm in the light path and adjust its position until you have a sharp image on the screen; note this position (Fig. 10).

Fig. 10

- Attach one diaphragm holder with filter (polarizer) to the lens with *f* = +50 mm (Fig. 11) and the other diaphragm holder with filter (analyzer) to the scale mount. Place the latter at approx. 20 cm on the optic bench (Fig. 12).

Fig. 11

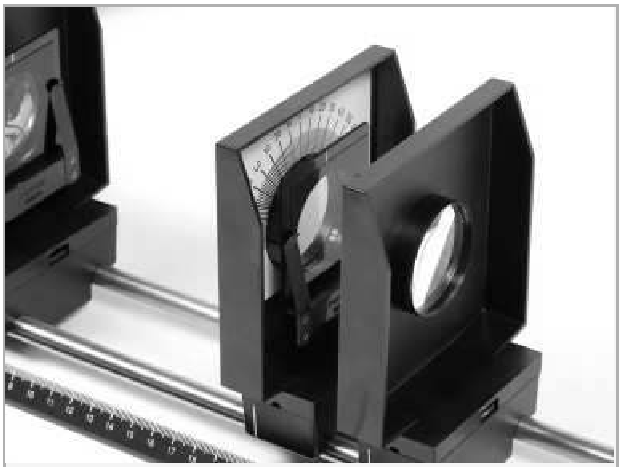

Fig. 12

- Adjust the analyzer so that the two filters are crossed (α = 90°).
- Hold the photoelastic models one after another in the light path at the previously established position, press the narrow edges together exerting different pressures with your fingers, and observe the images on the screen. Note down your observations in the report (Result - Observations 1).
- Now hold the spectacle lenses in the light path instead of the photoelastic models. Note your observations in the report (Result - Observations 2).
- Finally, hold the photoelastic models in the ray path exerting pressure on them, and alter the angle by rotating the analyzer. Note what you observe in the report (Result - Observations 3).
- Switch off the power supply.

Report: Polarization by stress birefringence (Photoelasticity)

Result – Observations 1

Describe the images on the screen:

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Result – Observations 2

Describe the effect of spectacle lenses on the images:

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Result – Observations 3

Describe the effect of the rotation of the analyzer with the photoelastic model in the ray path:

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Evaluation – Question 1

Can you explain the coloured brighter areas on the screen?

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Evaluation – Question 2

What can we conclude from this about the nature of the colours?

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Evaluation – Question 3

Which technical application could you envisage for the observed phenomena?

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