Coloured plastic

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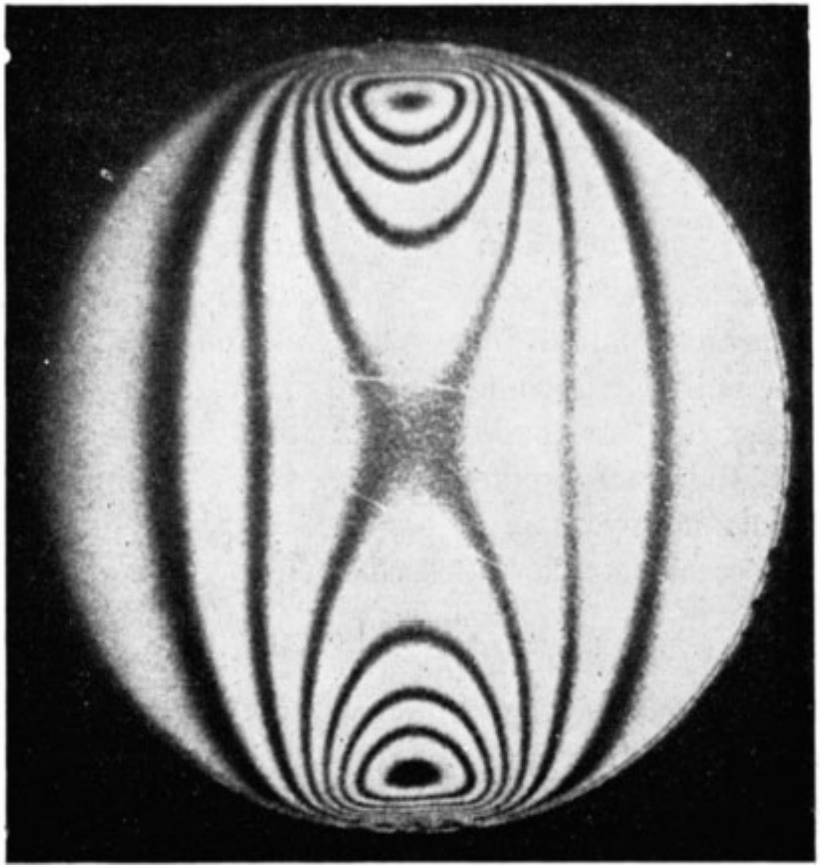
The problem

In bright light a transparent plastic plate (e.g. package for CD-disc) sometimes can shine in different colours. Explore and explain this phenomenon. Find out is it possible to obtain this phenomenon using different light sources.

Previous investigations

Figure 1 Frozen stress fringes in a CR 39 disc compressed along a diameter



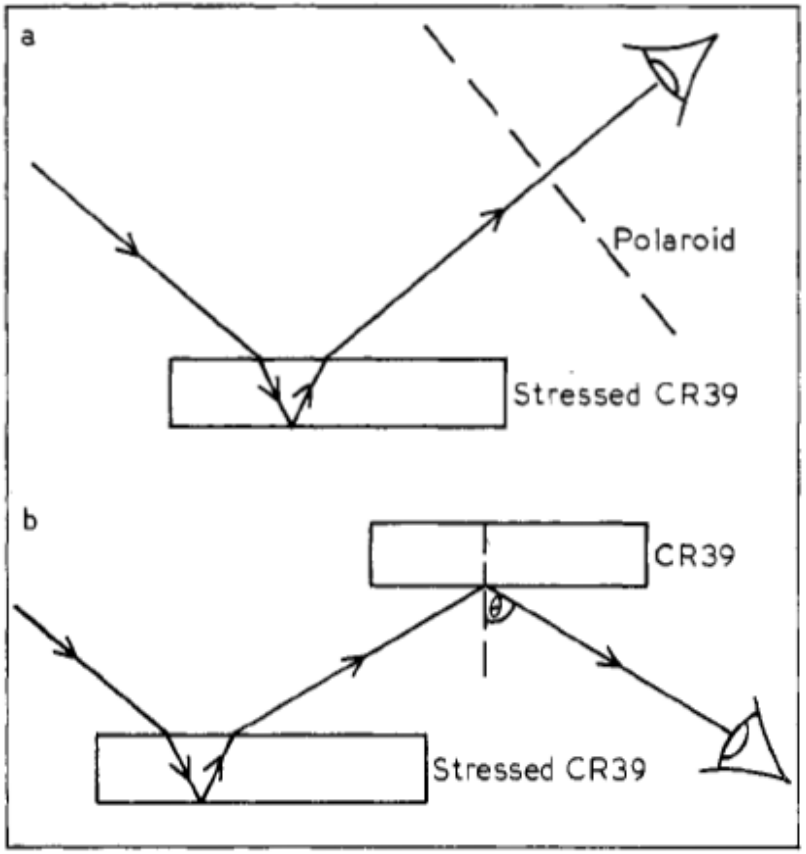
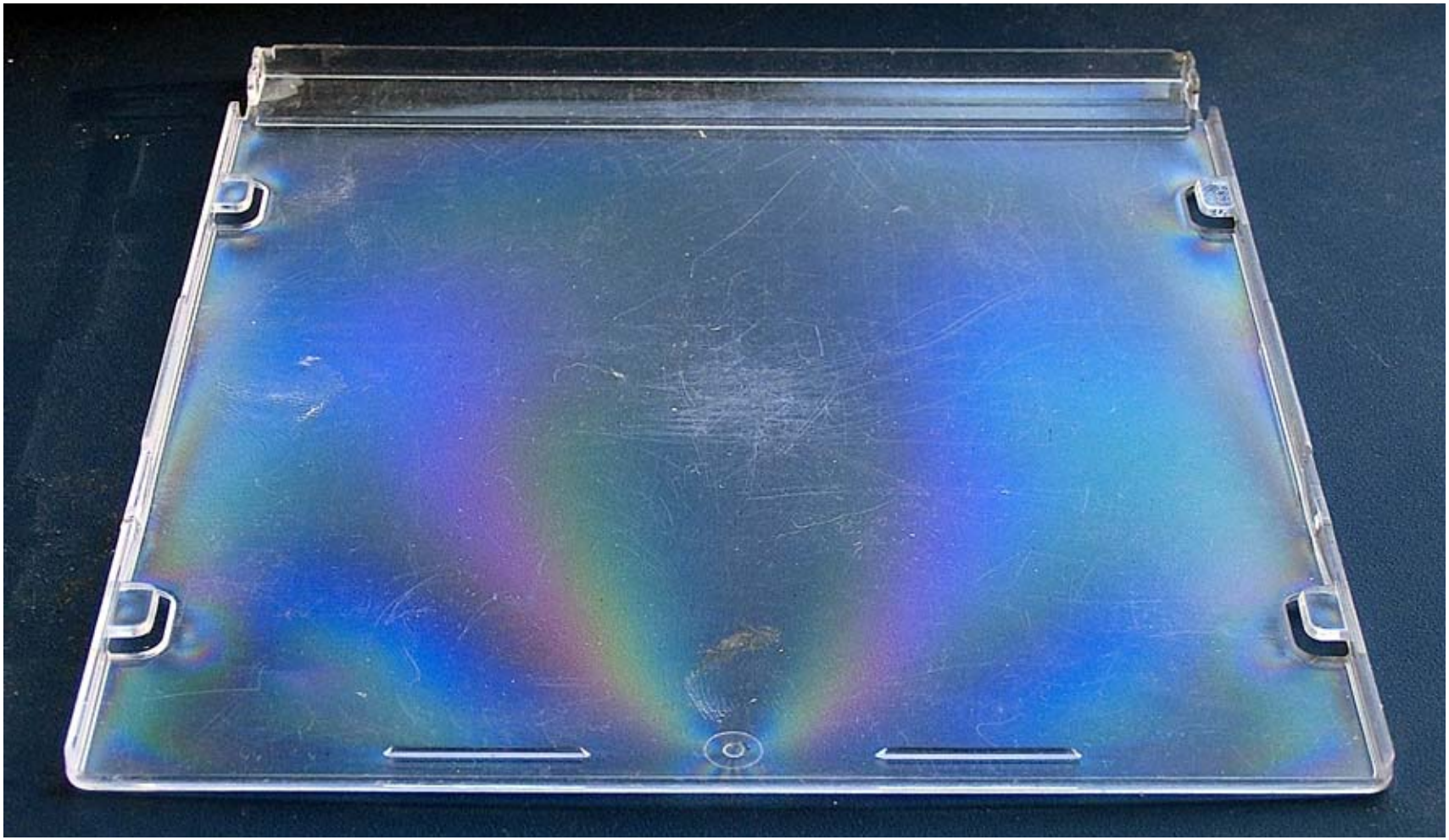


Figure 5 Observation of photoelastic interference fringes: (a) directly; (b) by reflection at the Brewster angle

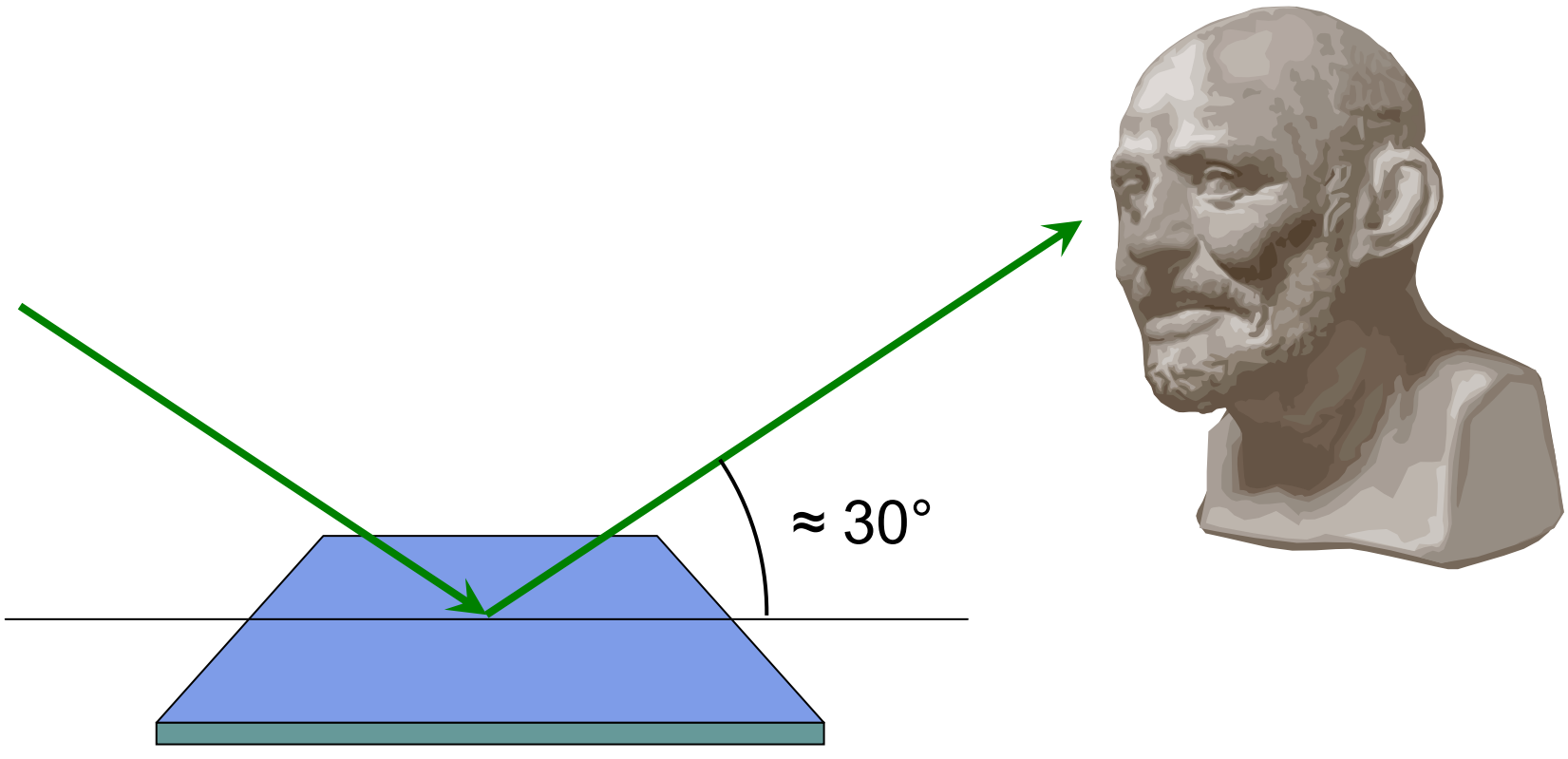
Bond M.M., Hadley D.W. (**1974**) “Photoelasticity without polaroids”. *Phys. Educ*. **9**, 411–413.

First observations

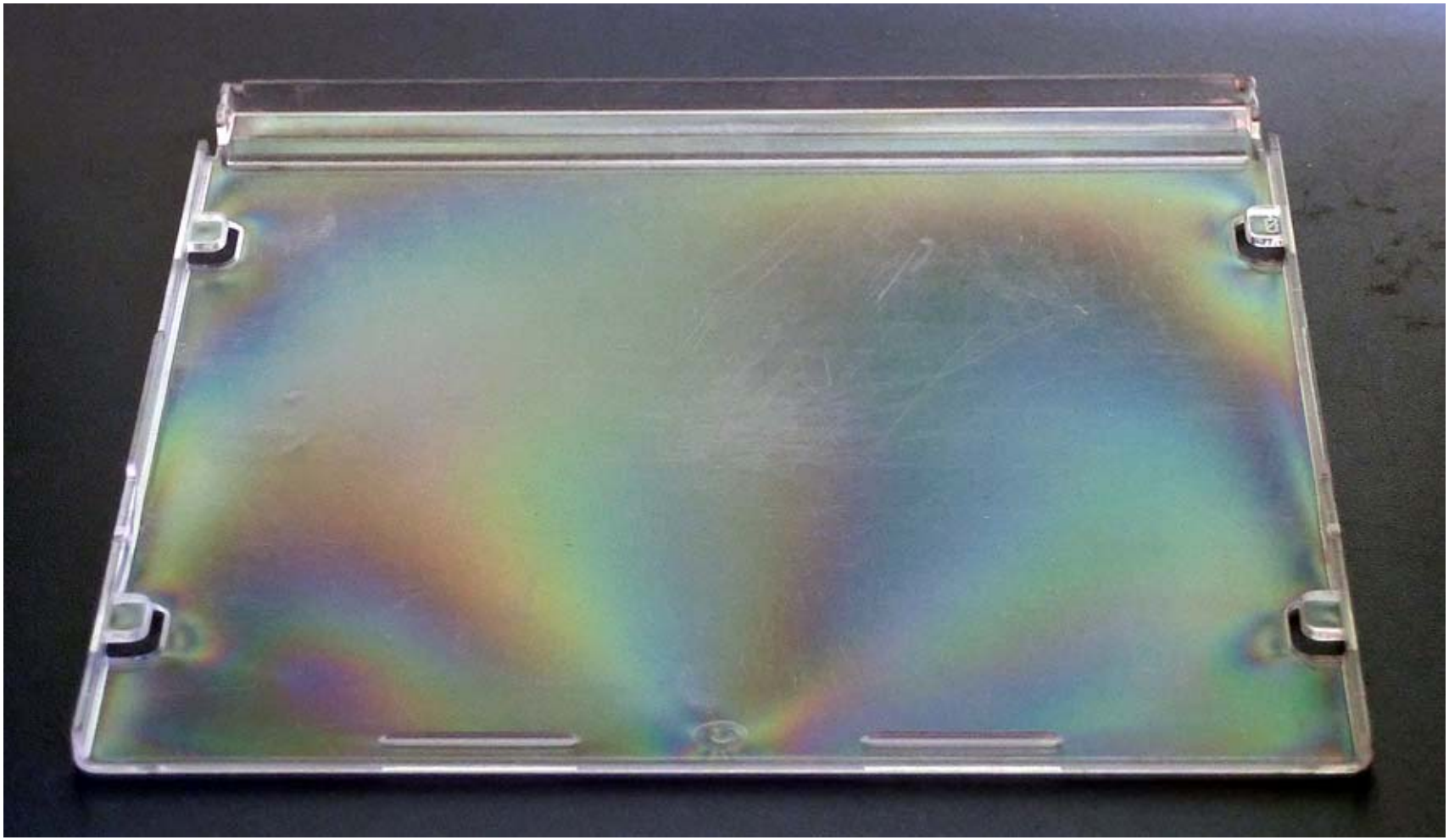
Reflected skylight



Condition for good observation

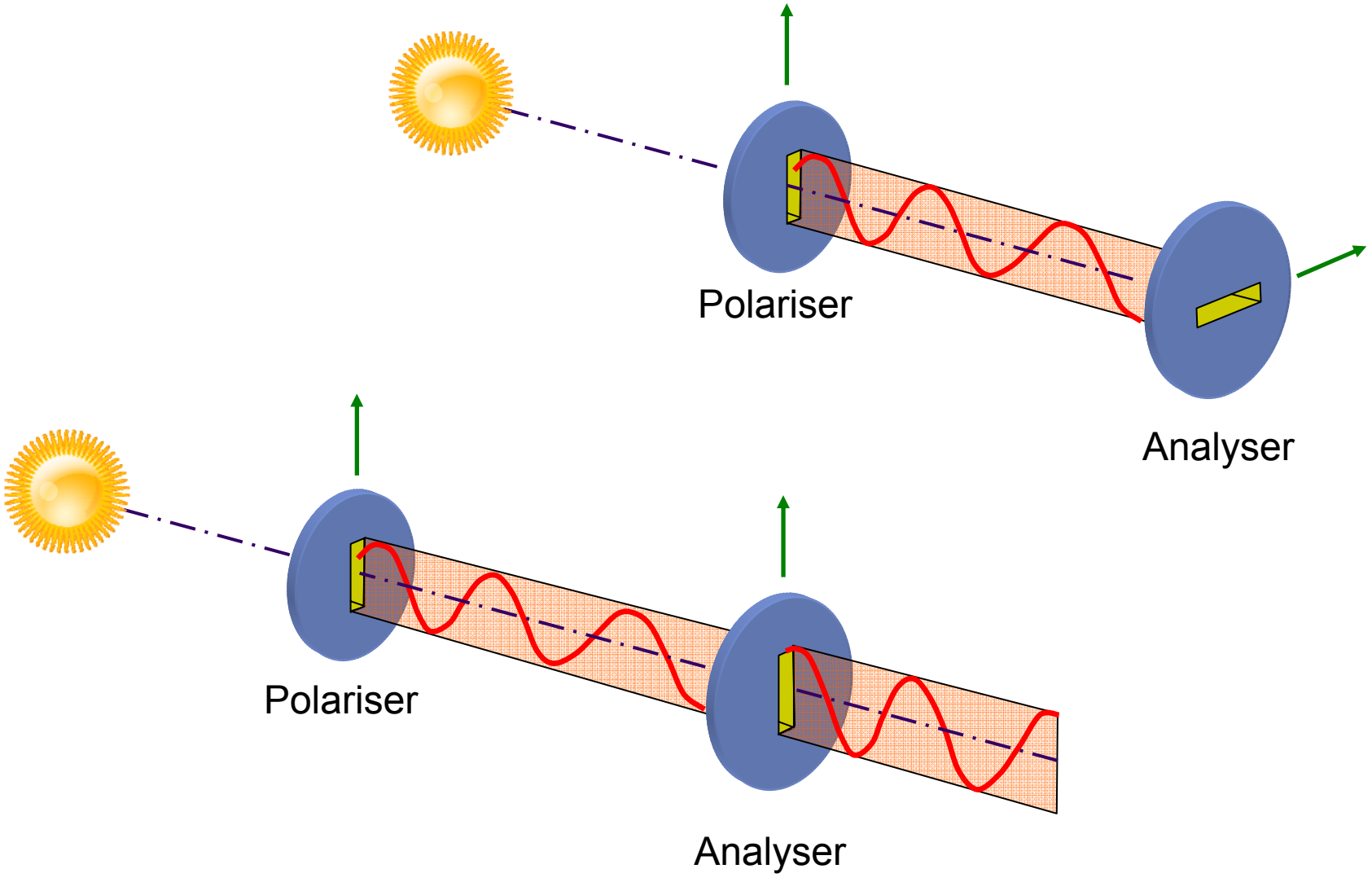


Reflected light from a LCD screen

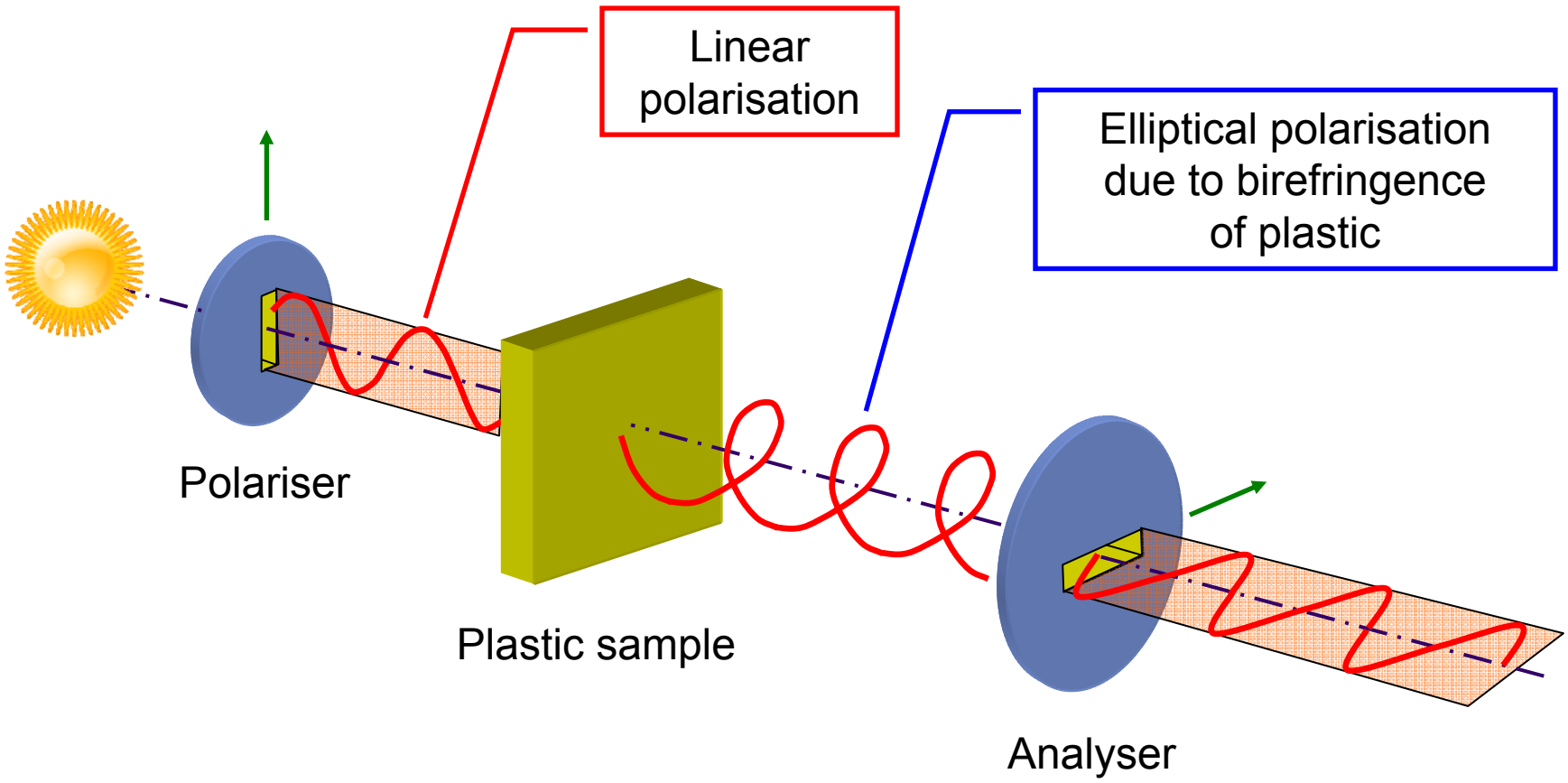


Observations with a polariscope

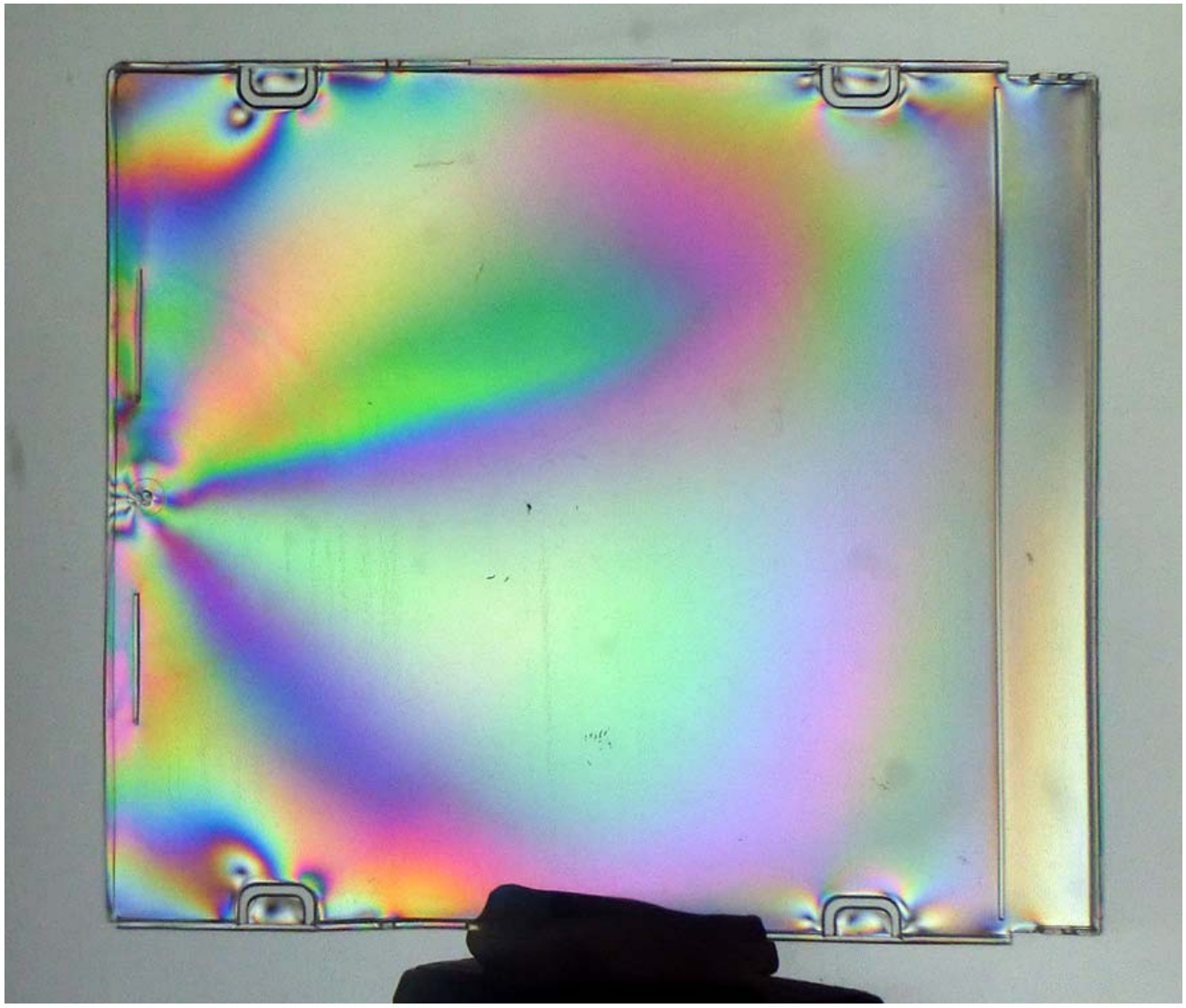
Plane polarised light



Plane polariscope



Colour fringes on a plastic plate

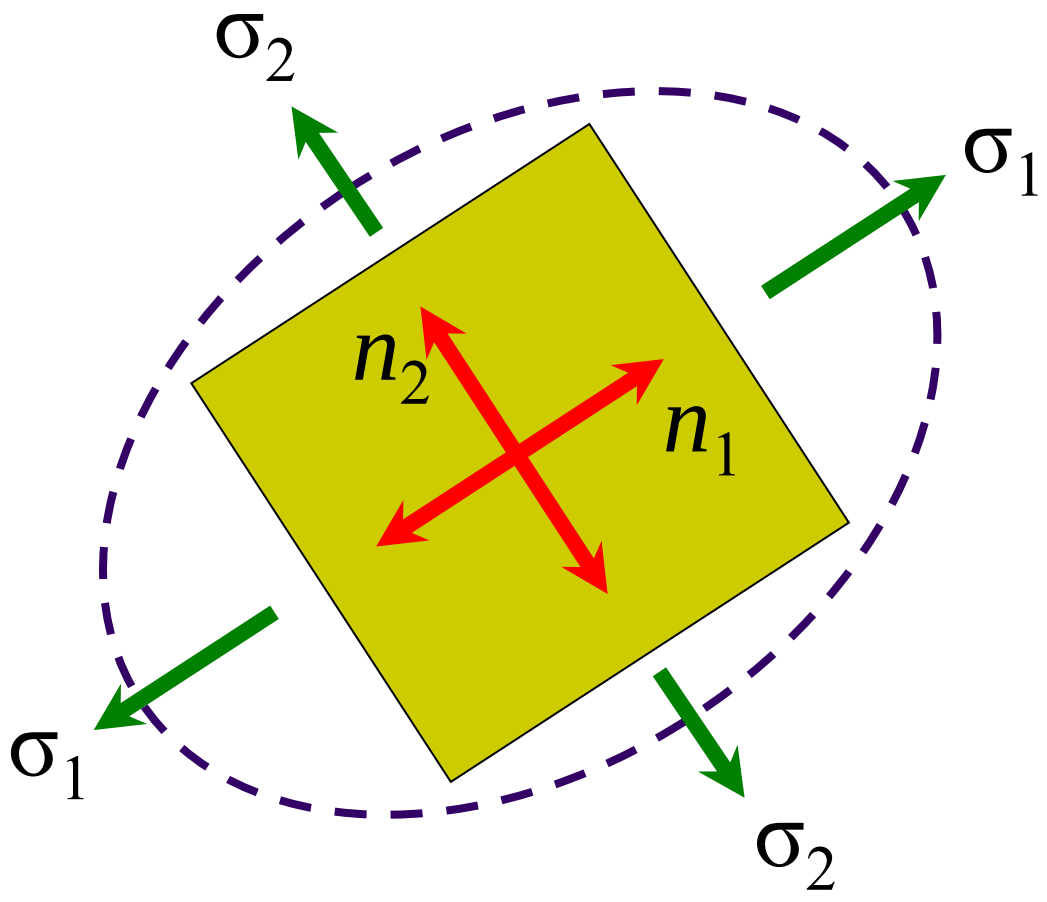


Birefringence and photoelasticity

Optical anisotropy in plastics

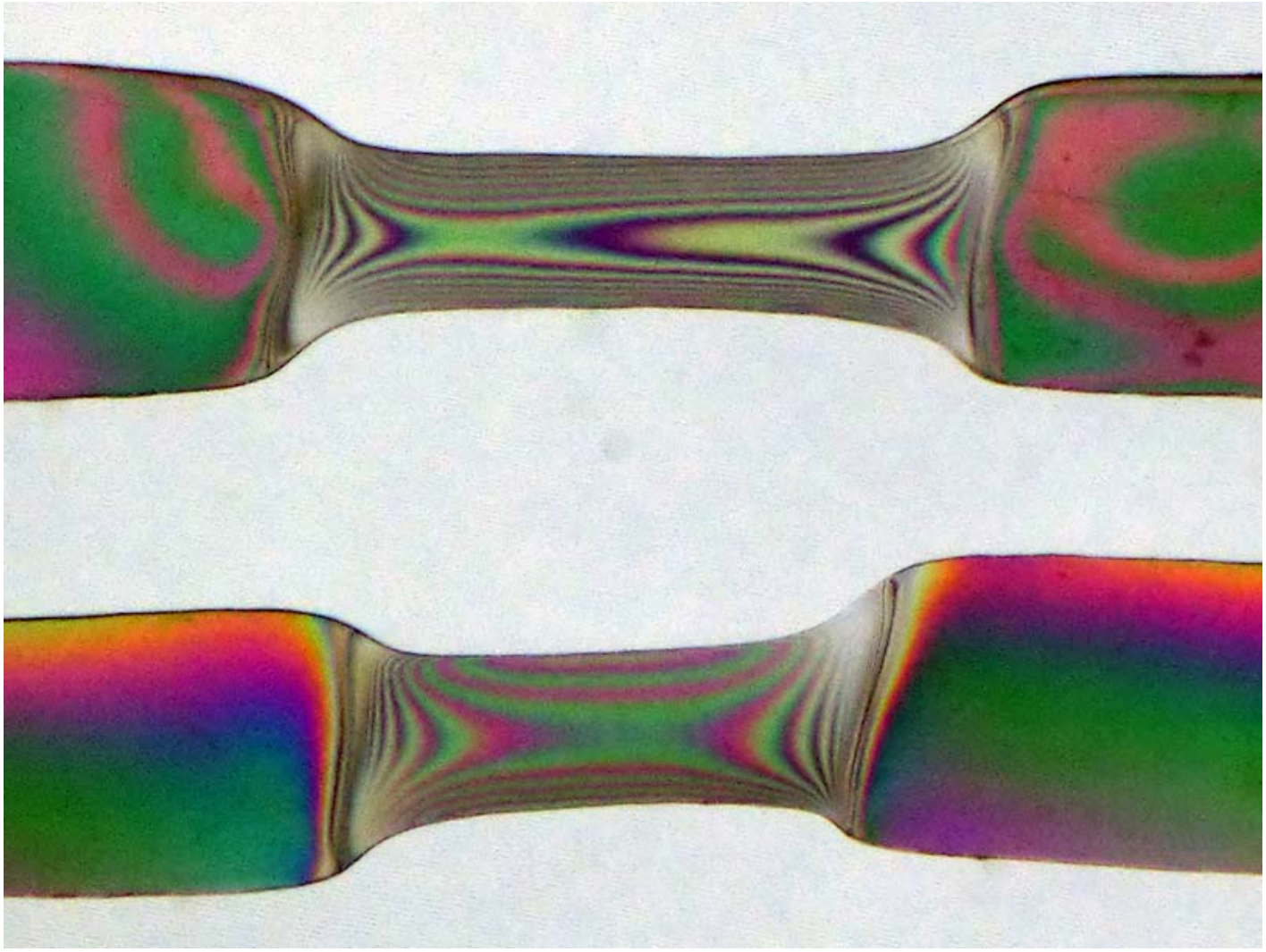
- When the temperature of plastic is above its softening point, some part of molecules creates a rigid skeleton, and the other part is situated in the liquid state.
- When the load is applied, molecules in liquid state are aligned to an extent depending on the applied stress.
- After cooling, this chosen orientation of molecules still remains.
- The chosen orientation of molecules makes the plastic be **optically anisotropic.**

Stress optic law

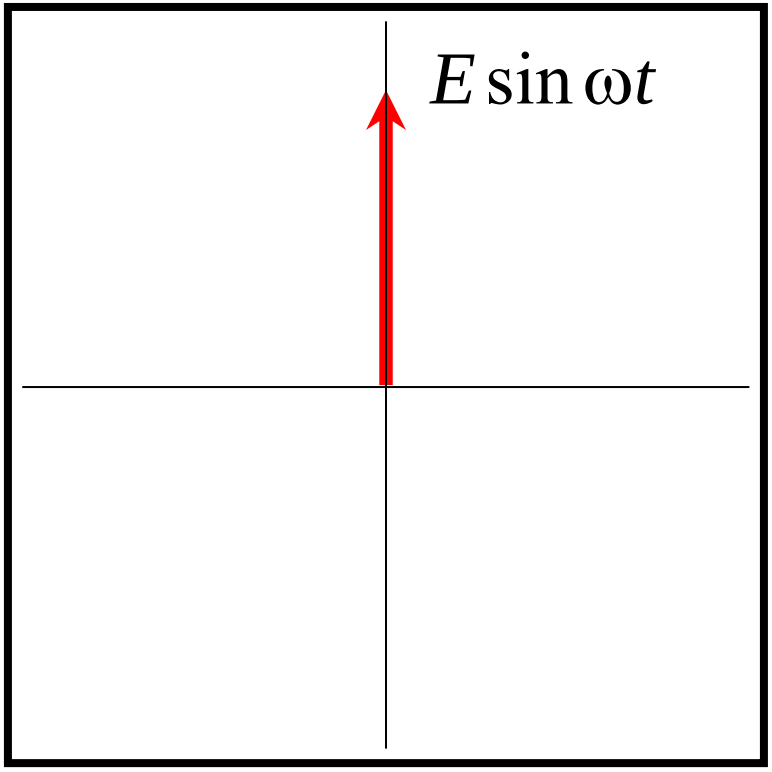


$$(n_1 - n_2) = F \cdot (\sigma_1 - \sigma_2)$$

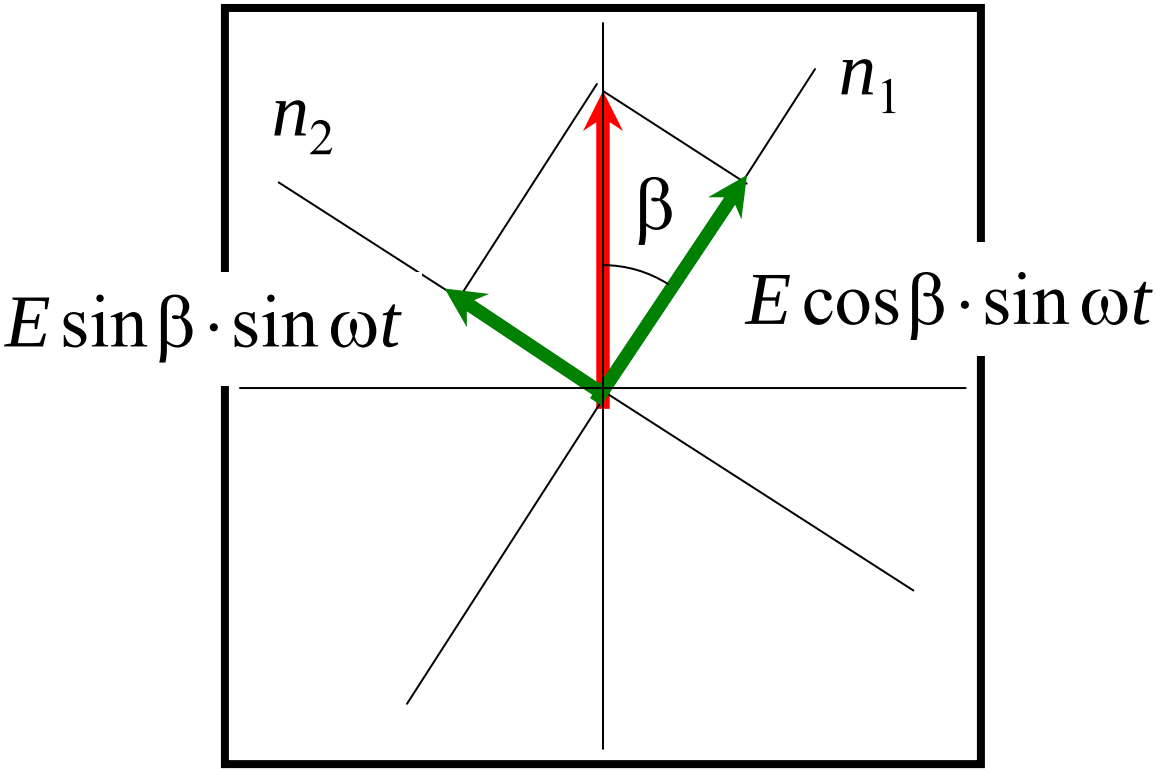
Colour fringes on polyethylene samples



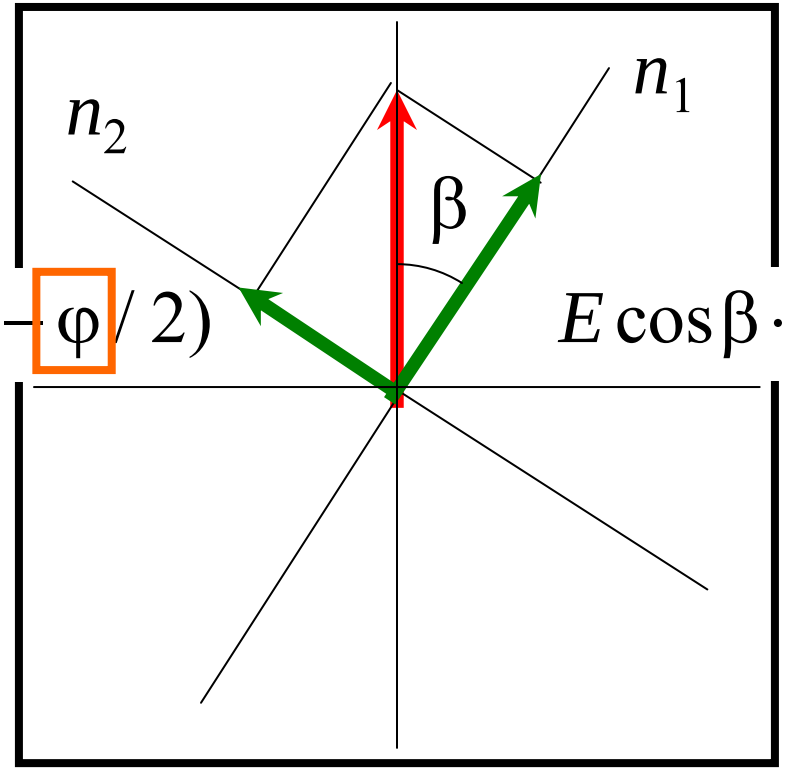
Polariser output



Plastic sample input



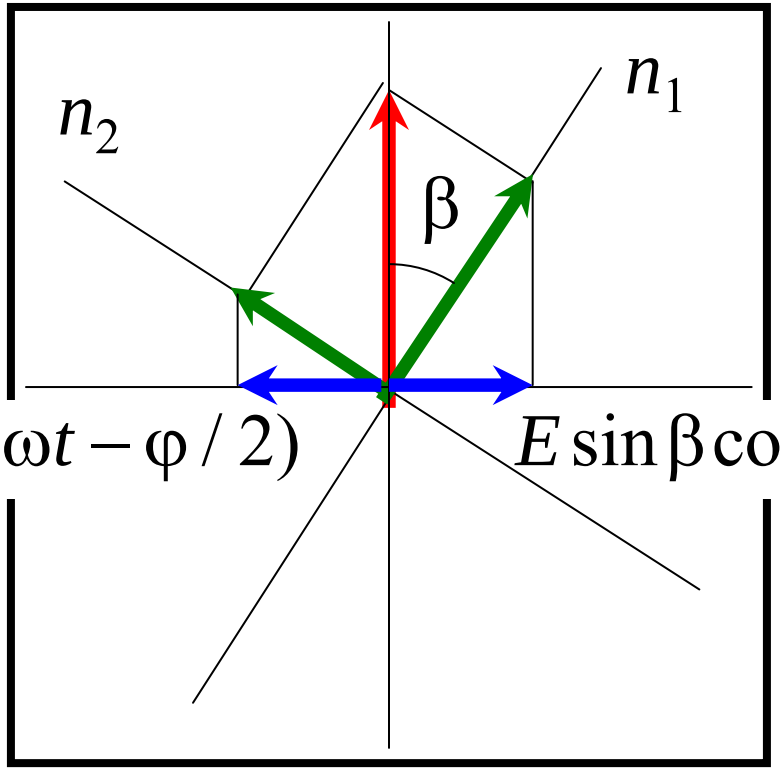
Plastic sample output



$$E\sin\beta\cdot\sin(\omega t-\varphi/2) \qquad E\cos\beta\cdot\sin(\omega t+\varphi/2)$$

Phase difference $$\varphi=\frac{2\pi\delta}{\lambda_0}(n_1-n_2)$$

Analyser output



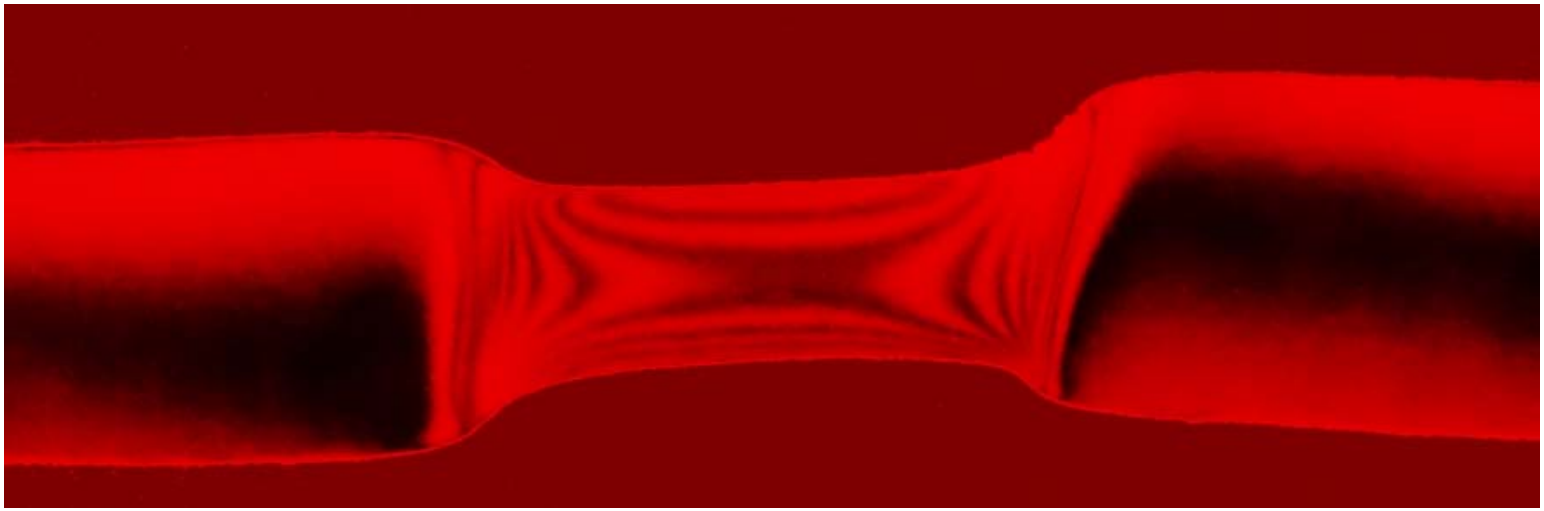
$E \sin\beta\cos\beta \cdot \sin(\omega t - \varphi/2)$ $E \sin\beta\cos\beta \cdot \sin(\omega t + \varphi/2)$

$$E_{out} = E \sin 2\beta \cdot \sin(\varphi/2) \cdot \cos\omega t$$

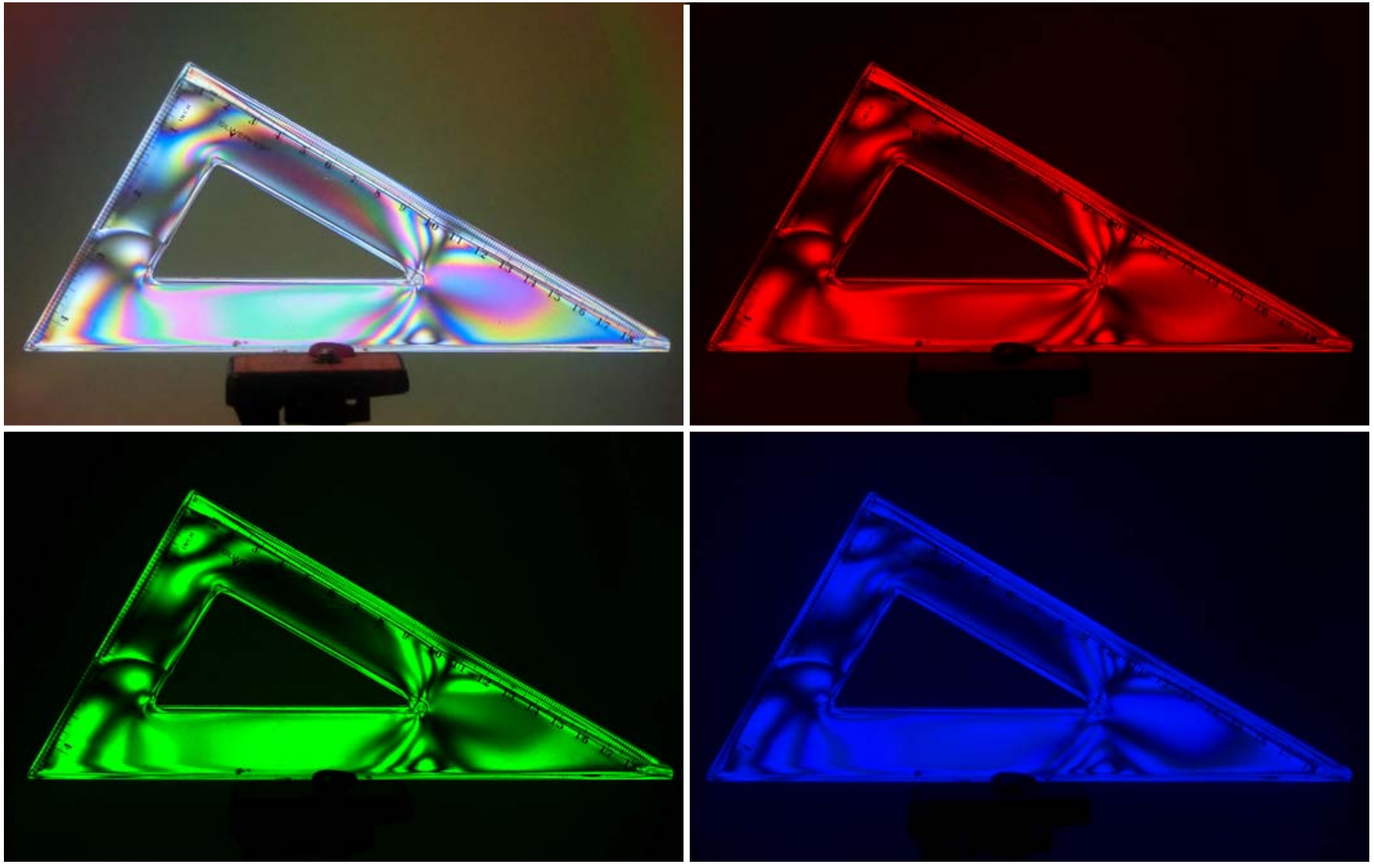
Monochromatic light

$$I_{out} = I_{in} \cdot \sin^2 2\beta \cdot \sin^2\left(\frac{\pi(n_1 - n_2)\delta}{\lambda_0}\right)$$

if $\frac{(n_1 - n_2)\delta}{\lambda_0} = N,$ then $I_{out} = 0$

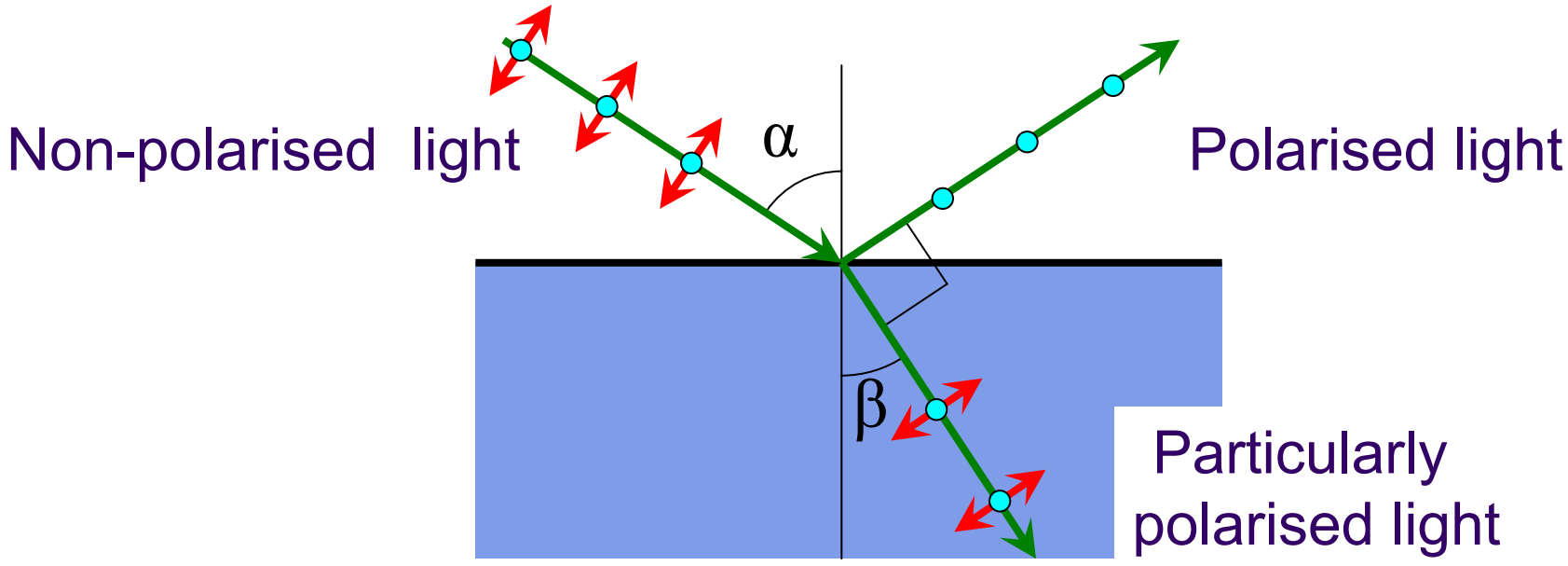


Polychromatic light



Polarization of reflected and refracted light

Brewster angle



$$\sin\alpha = n\sin\beta$$

$$\beta = \pi/2 - \alpha$$

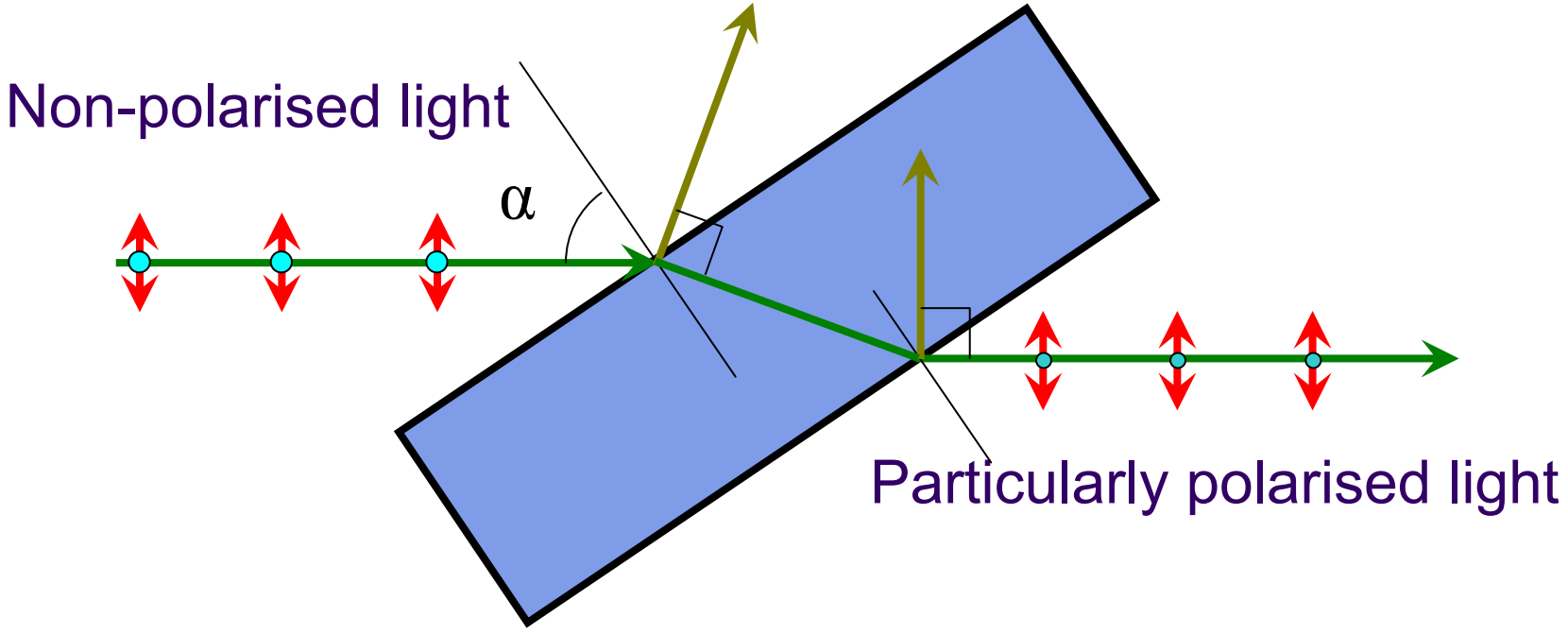
$$\mathrm{tg}\,\alpha = n$$

For glass

$$n = 1{,}5$$

$$\alpha = 56°$$

Brewster window



Degree of polarisation

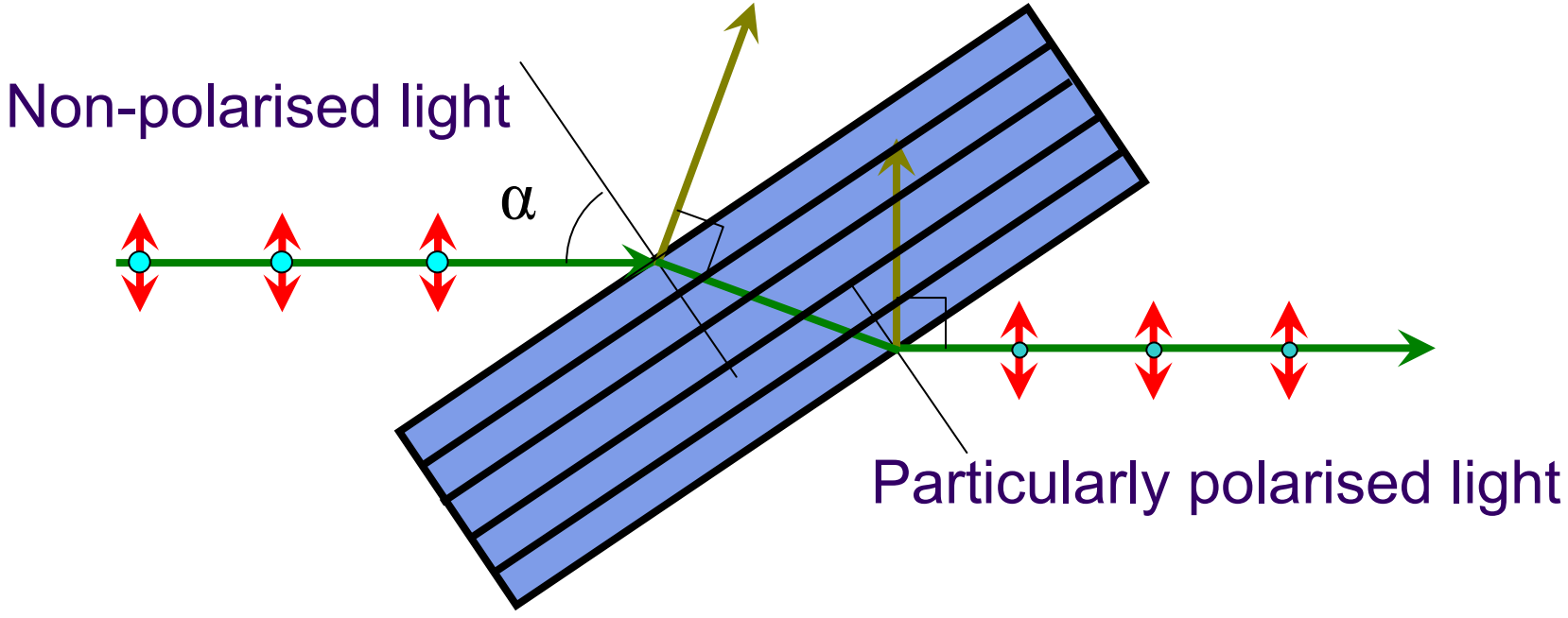
$$\Delta = \frac{I_{\perp} - I_{\parallel}}{I_{\perp} + I_{\parallel}}$$

For a glass plate

$$\Delta = 0{,}16$$

Г. С. Ландсберг, *Оптика*, § 136

Stoletov pile

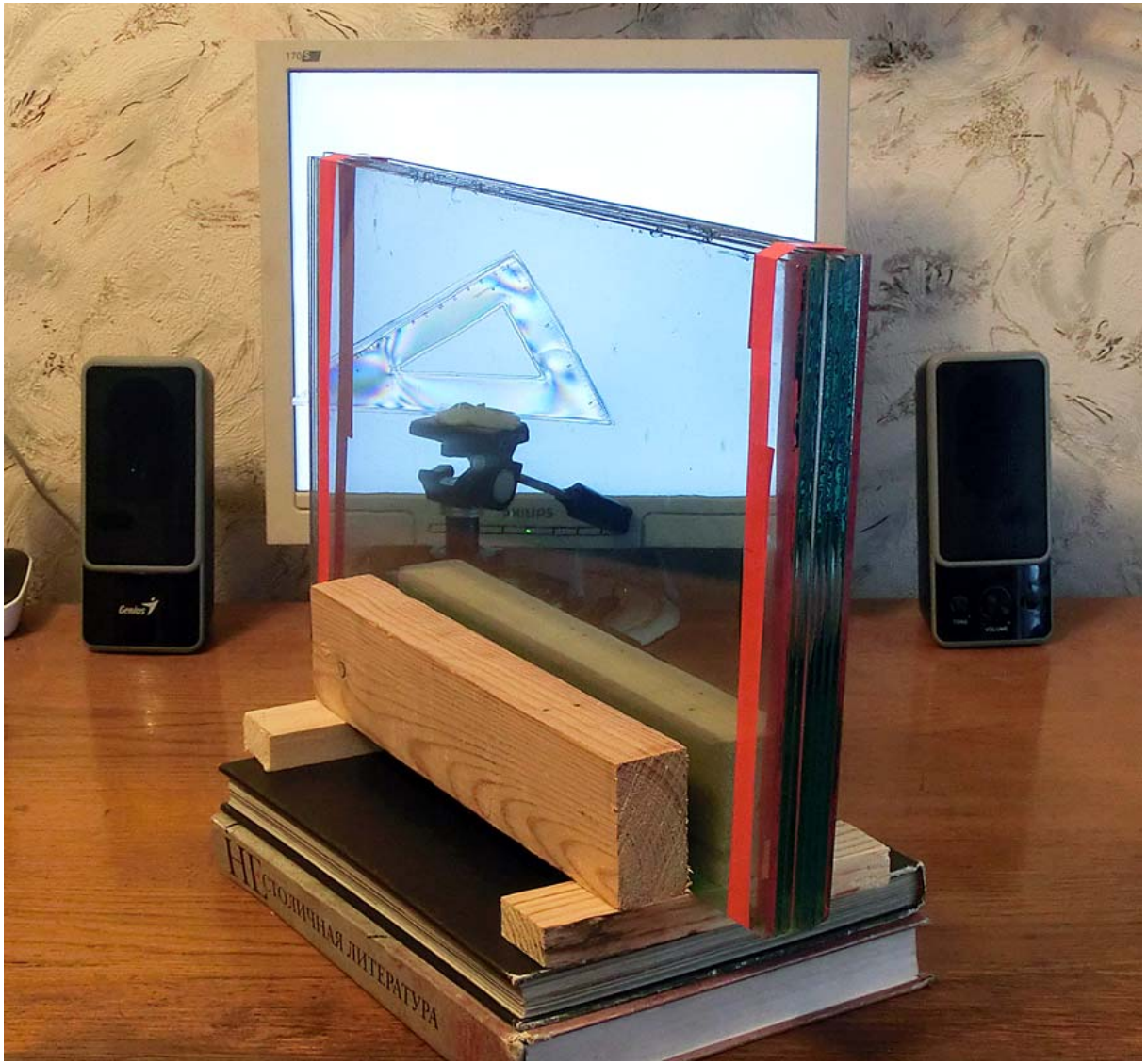


$$\Delta_n = 1 - (1 - \Delta_1)^n$$

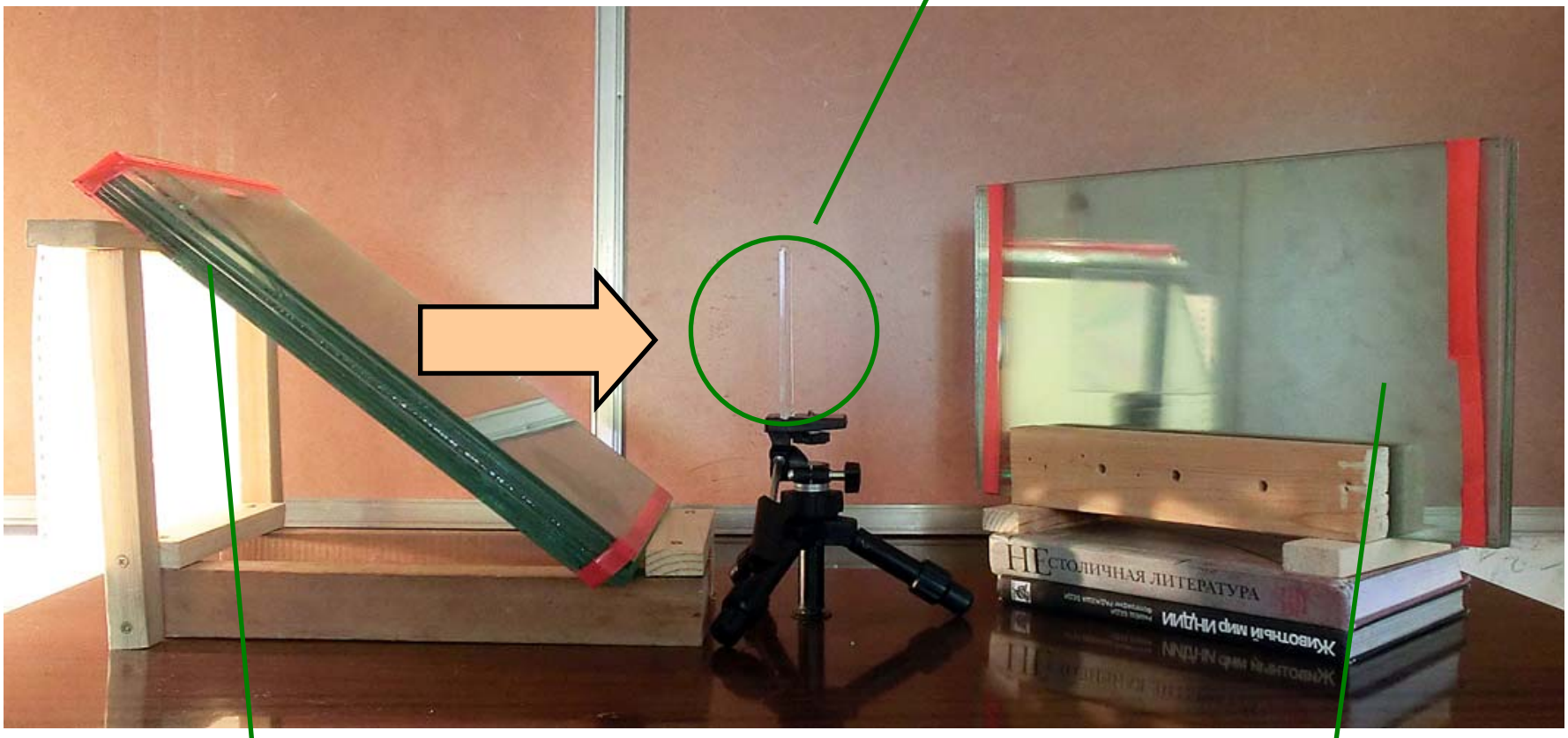
if $\Delta_1 = 0{,}16$ and $n = 8,$

then $\Delta_n = 1 - 0{,}84^8 = 0{,}75$

Observation with a Stoletov pile

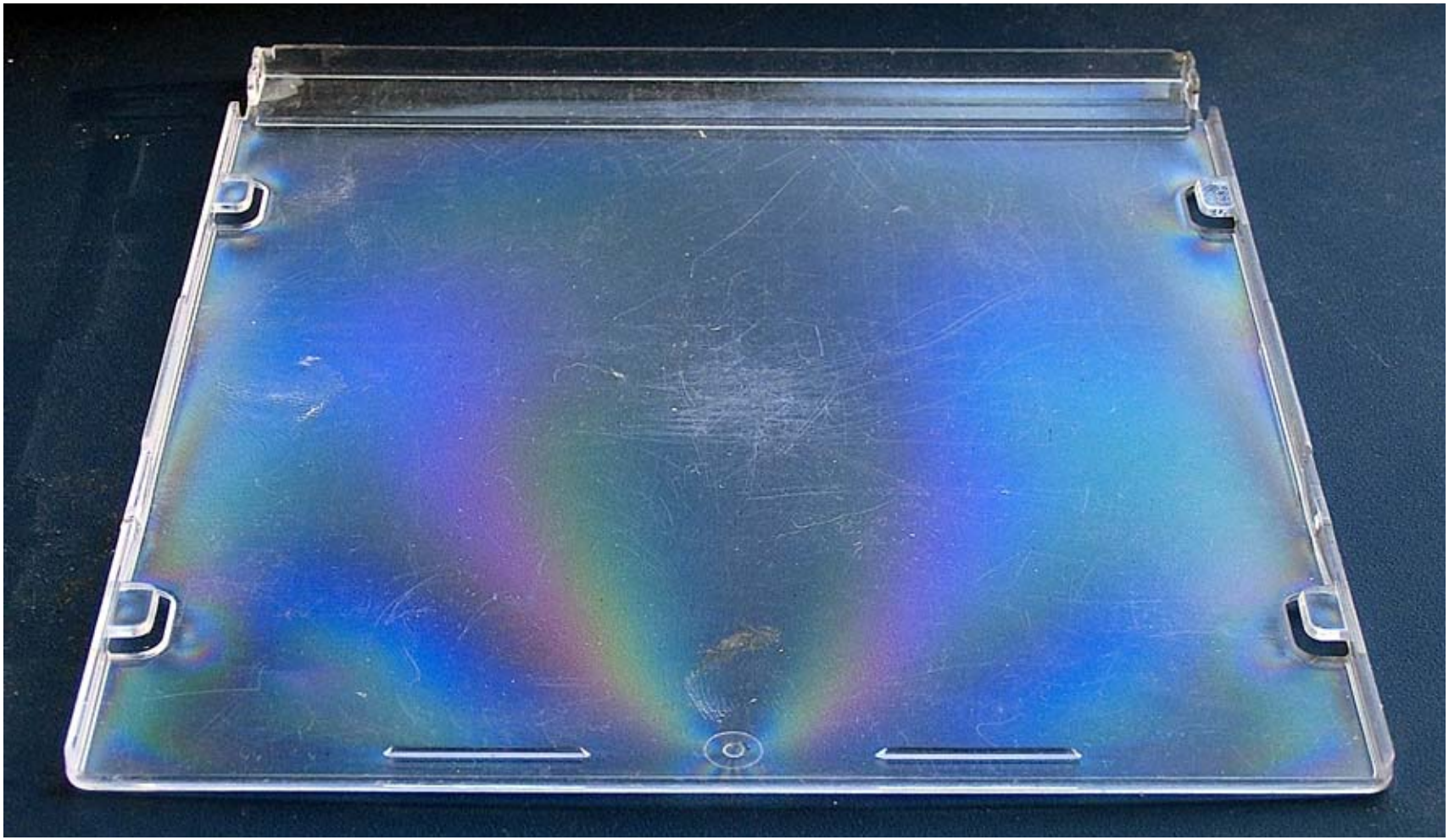


Polariscope

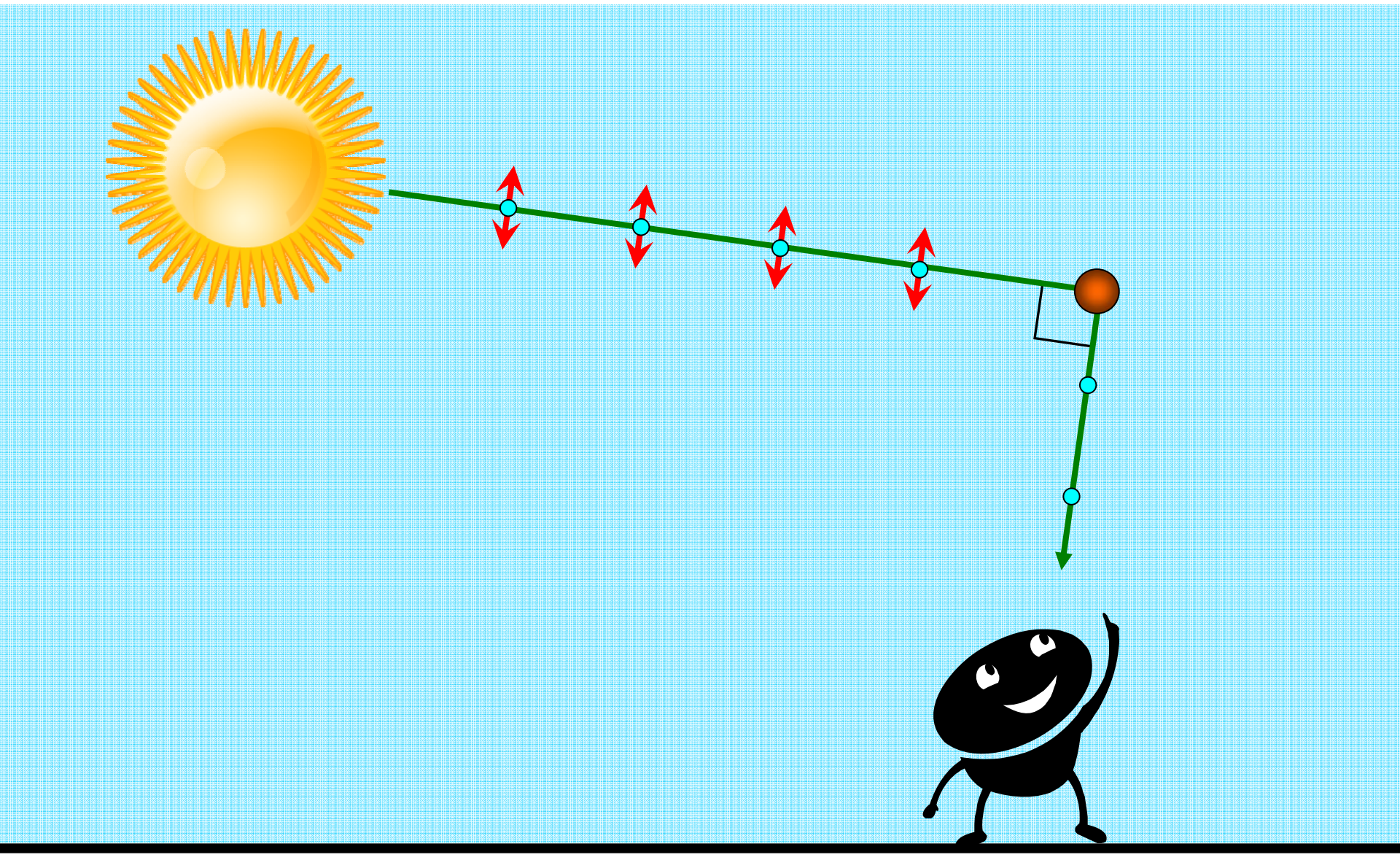


Photoelasticity without polaroids

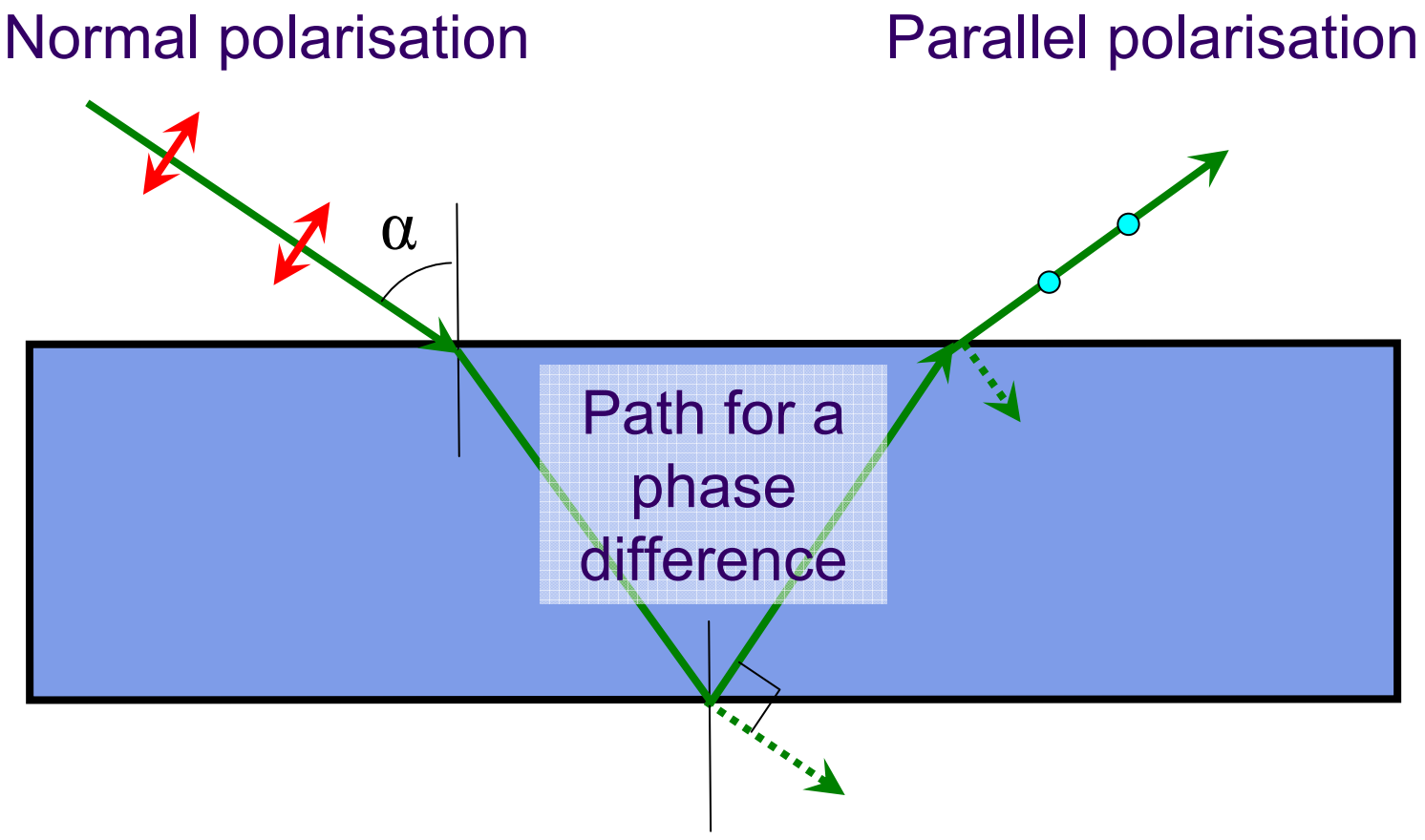
Reflection of a skylight



Polarisation of a blue skylight



Explanation



Reflection of a reflected light

Colour fringes in non-polarised light

Summary

Conclusions

- Frozen stresses appear in plastic during its casting. That leads to its **optical anisotropy**.
- If one illuminates such a material by polarised light and looks at it through another polaroid, colour **interference fringes** are visible.
- Skylight is particularly polarised. Reflection or refraction also can cause particular or perfect polarization of light. Because of this we can observe the phenomenon of **photoelasticity without polaroids**.

References

- Frocht M.M. (1948) *Photoelasticity.*
- Bond M.M., Hadley D.W. (1974) “Photoelasticity without polaroids”. *Phys. Educ*. **9**, 411–413.

Thank you for your attention!