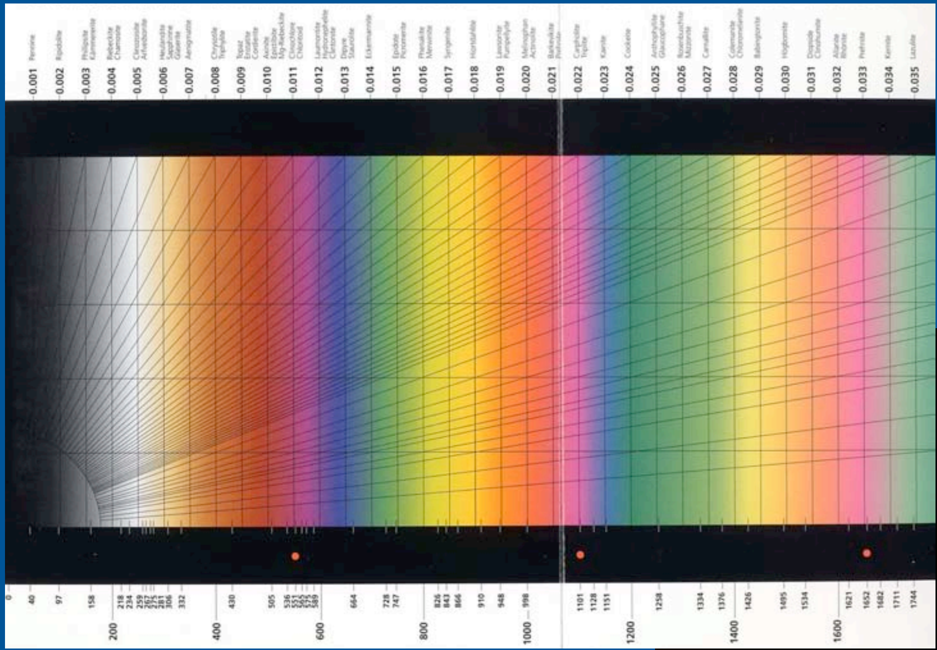
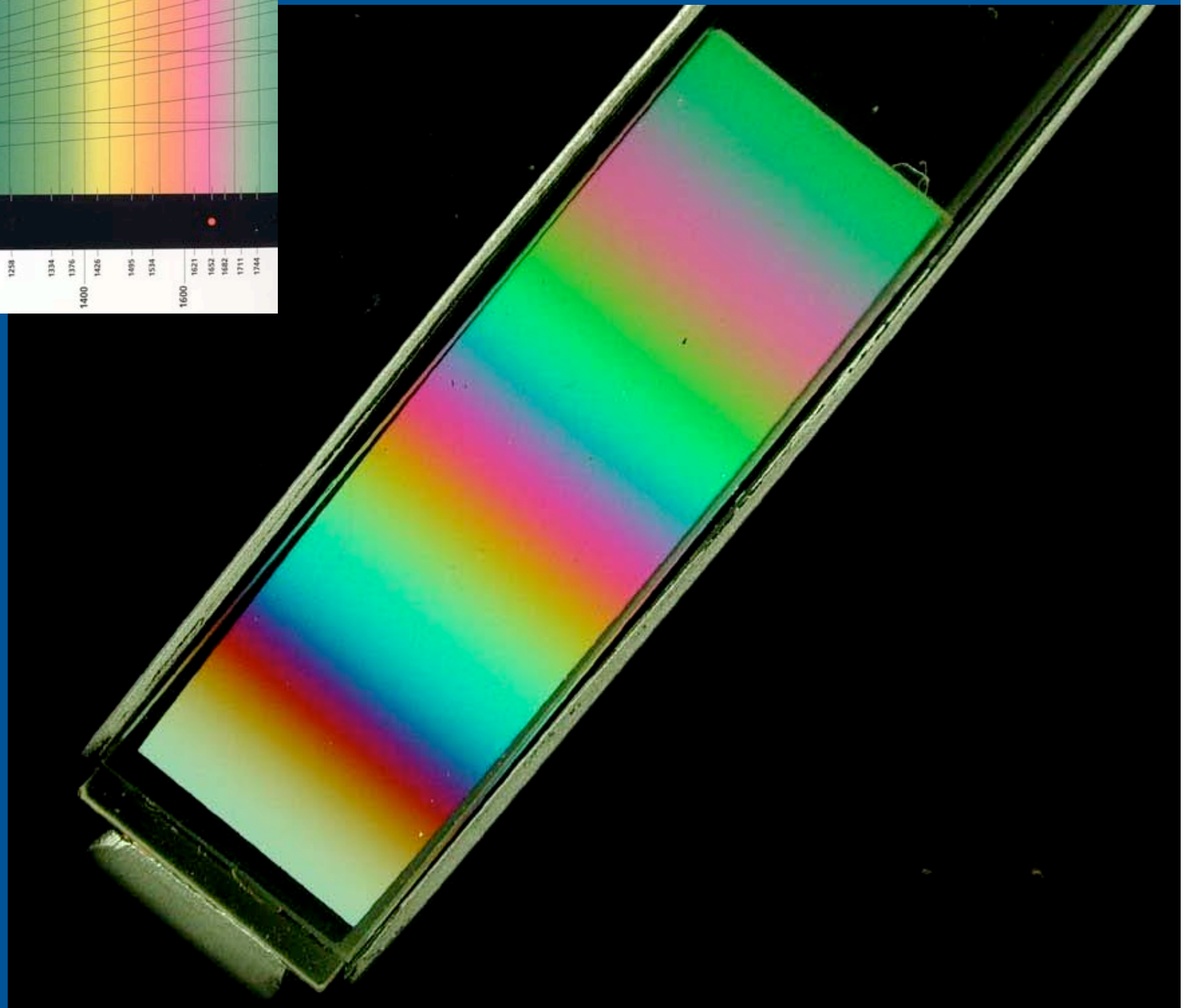
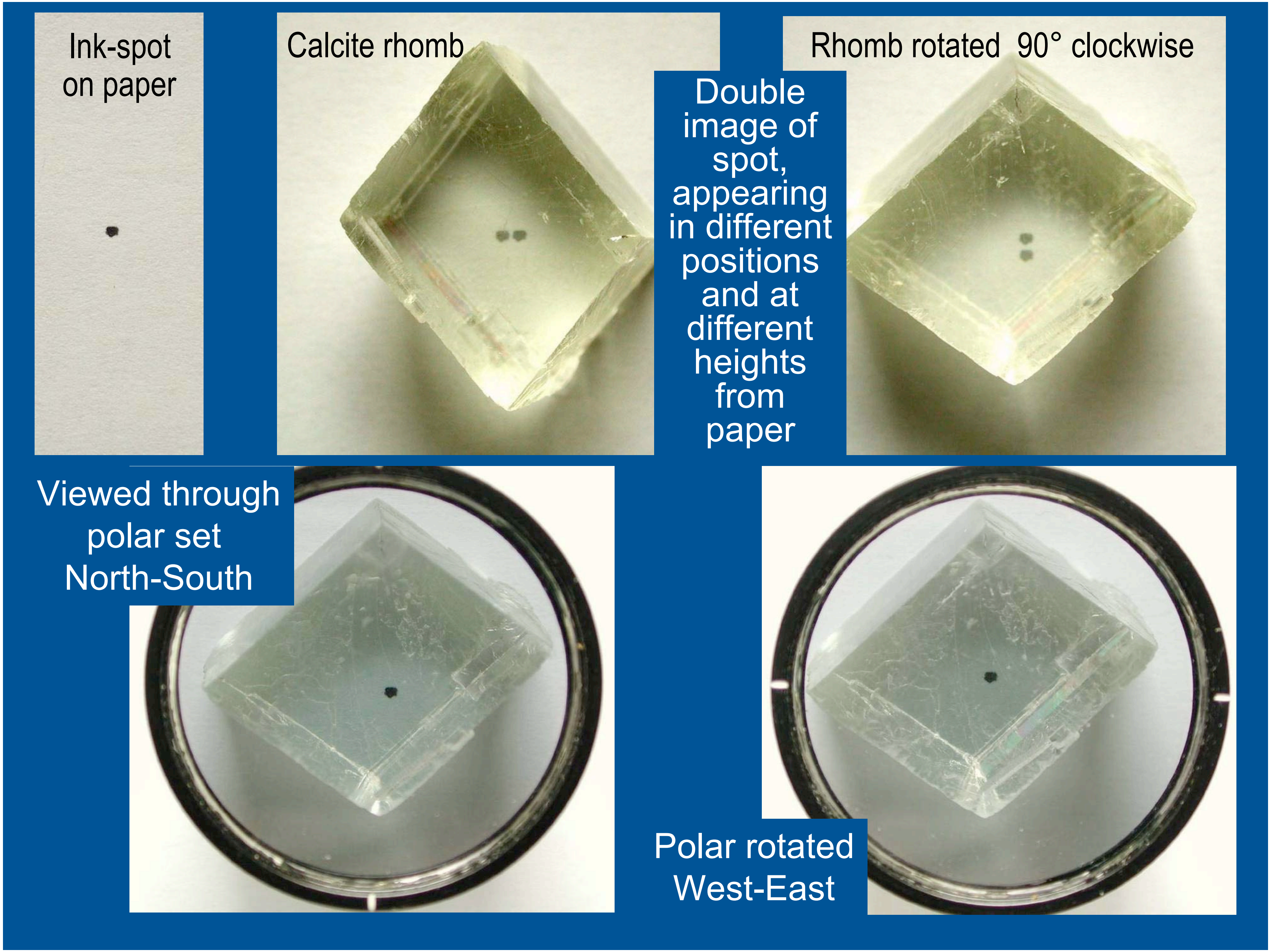


Polarised Light Microscopy



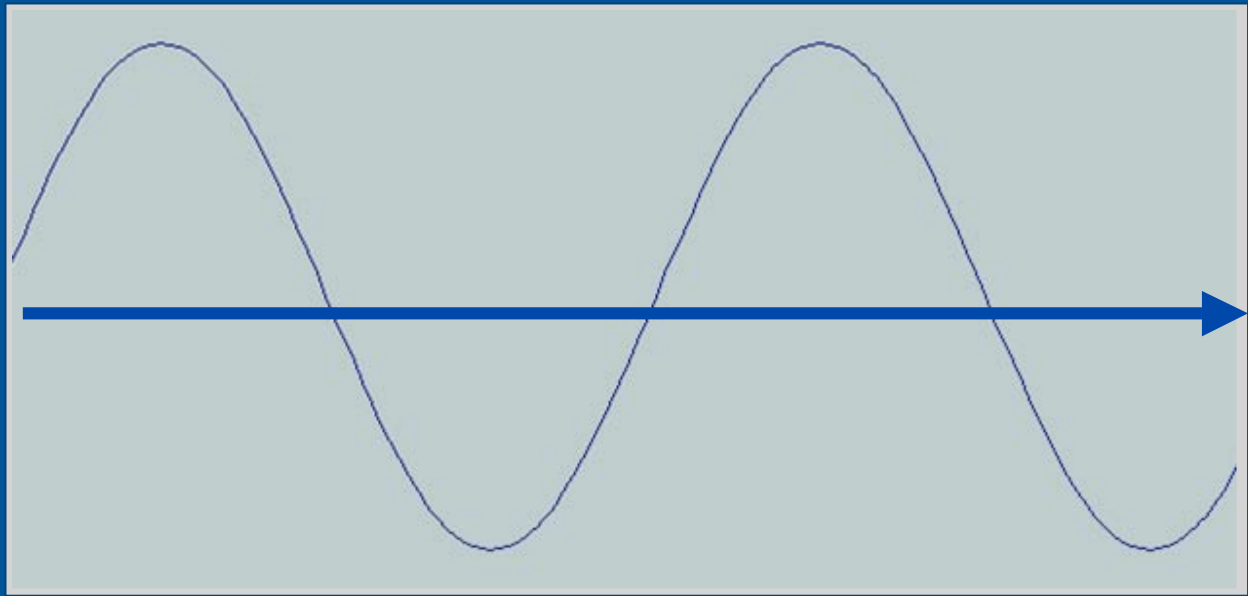
Peter Evennett


Ink-spot on paper
Calcite rhomb
Rhomb rotated 90° clockwise
Double image of spot, appearing in different positions and at different heights from paper
Viewed through polar set North-South
Polar rotated West-East

Polarised light phenomena depend upon:

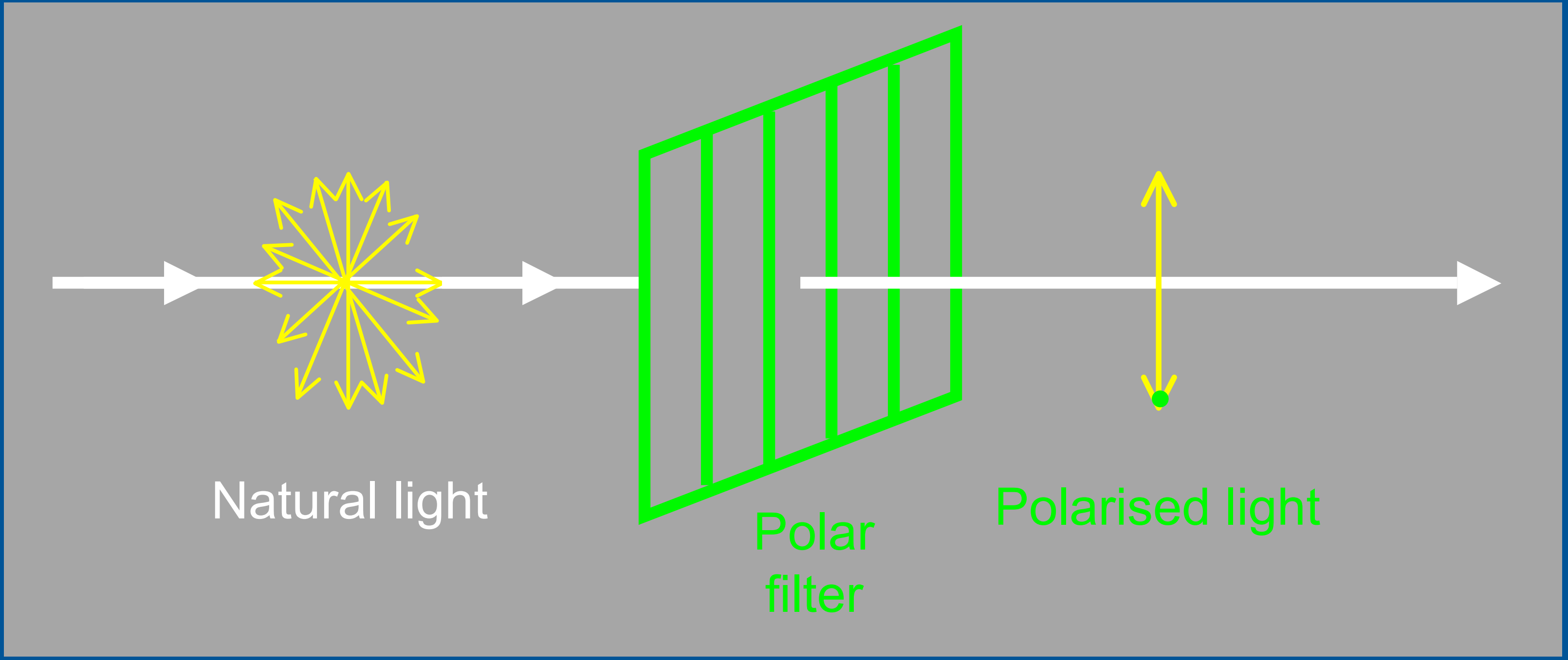
- The wave nature of light
- Interference between waves
- ‘Slowing’ of light waves as they pass through objects (refraction)
- Differences in refraction for different wavelengths
- Many objects exhibiting differences in refraction for waves vibrating in different directions

Light waves



Light can be considered to be a wave motion with its planes of vibration transverse to the direction of propagation.

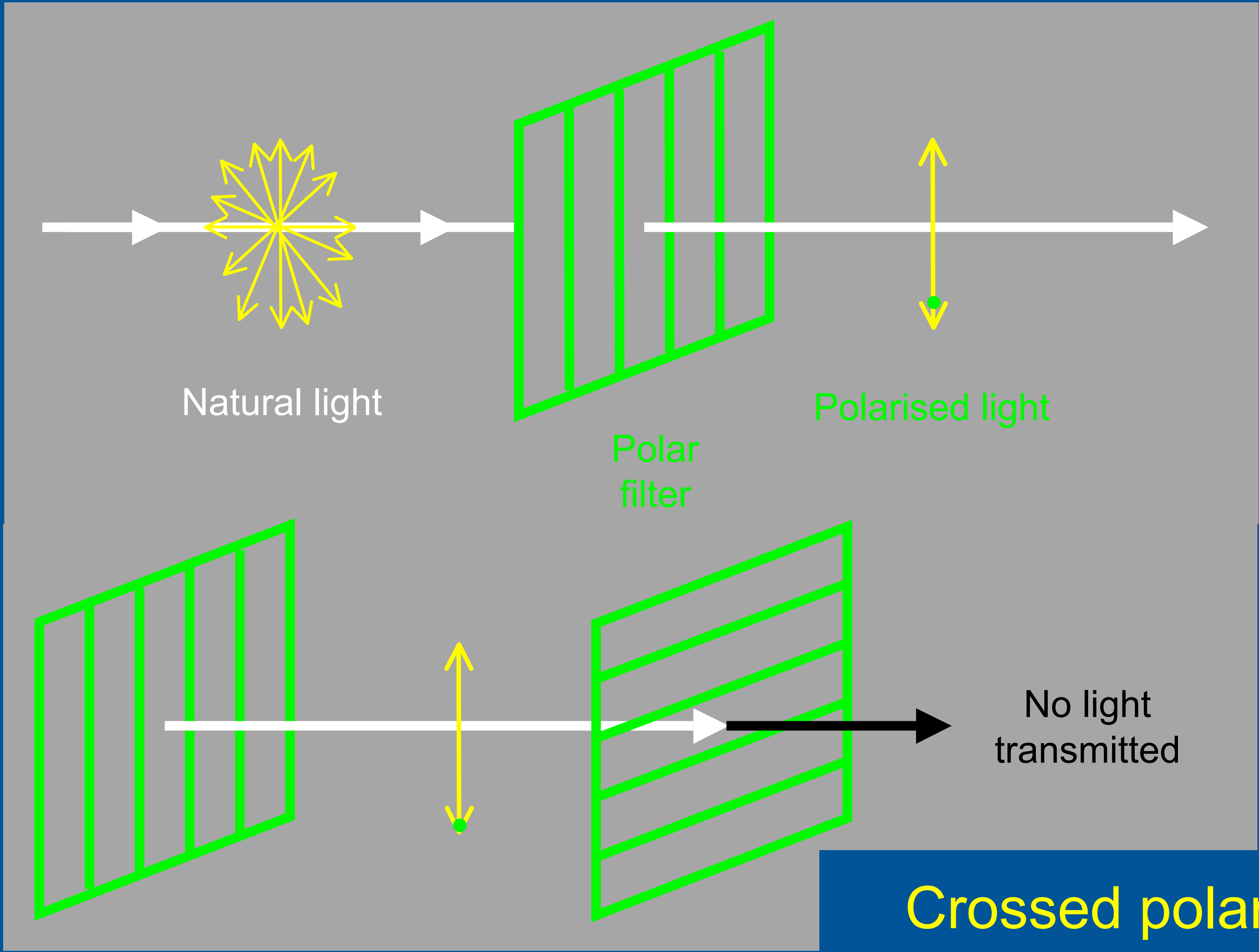
Light waves



Light can be considered to be a wave motion with its planes of vibration transverse to the direction of propagation.

In ‘natural light’ these vibrations occur in all directions.

In Polarised Light all but one of these directions have been ‘filtered out’.



Crossed polars

Refraction

The speed of light in a vacuum is constant,

But light is slowed down when it passes through a transparent medium.

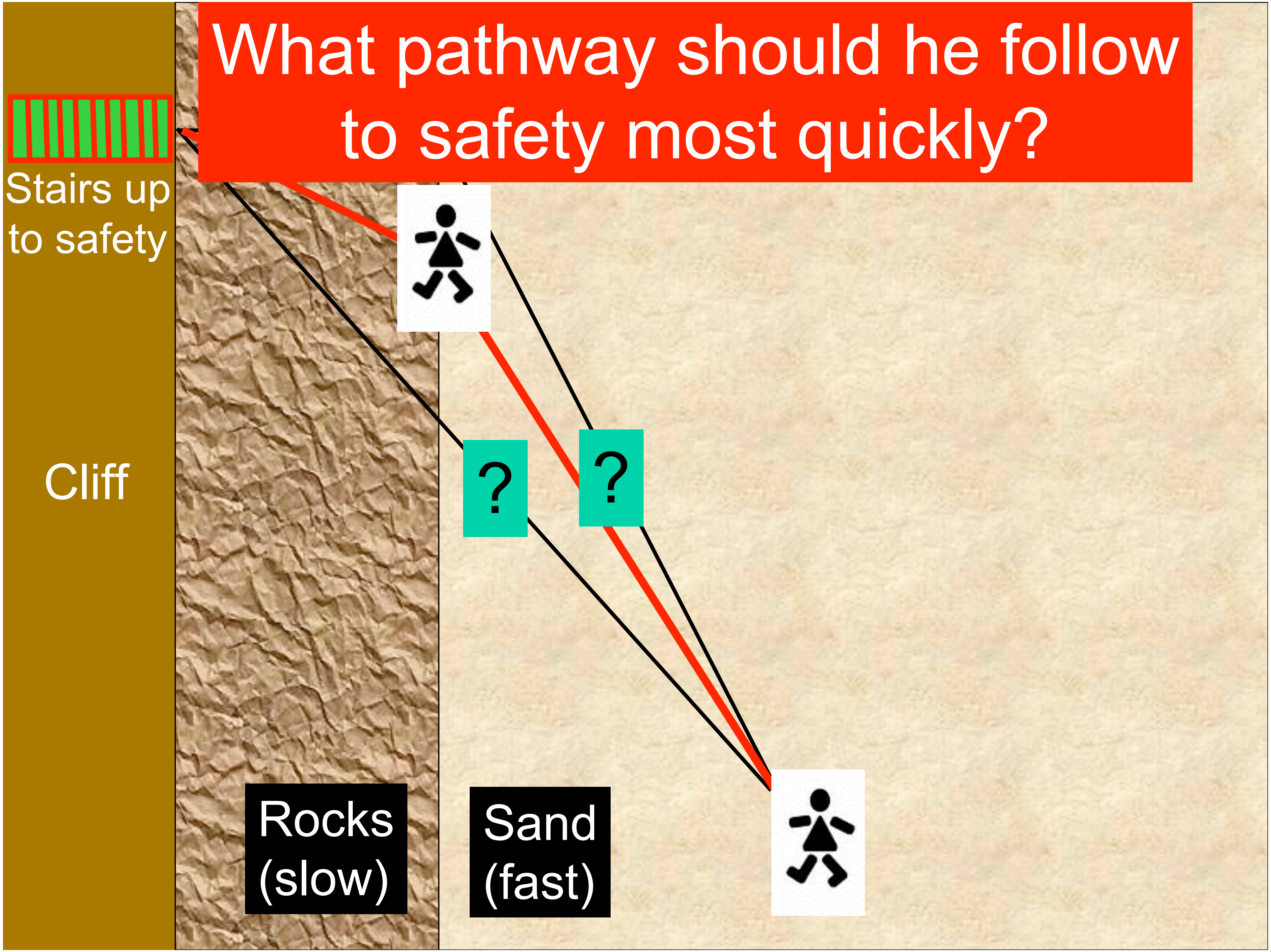
The amount by which it is slowed down is called the Refractive Index n

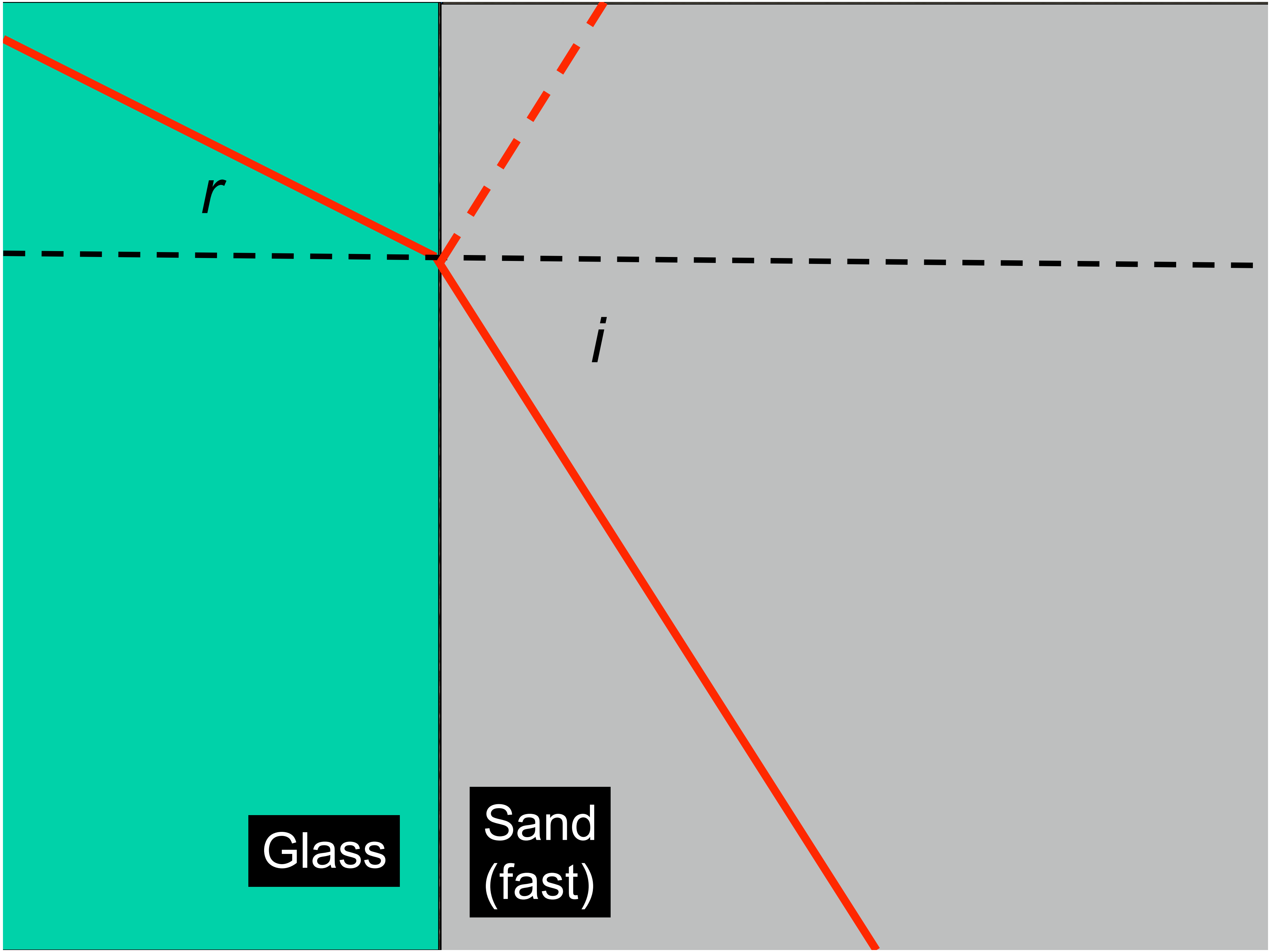
$$n = \frac{\text{speed of light in vacuum}}{\text{speed of light in medium}}$$

Refraction

The slowing down of light has a very important consequence:

The direction of a light beam is changed when it passes from one medium to another


What pathway should he follow to safety most quickly?
Stairs up to safety
Cliff
?
?
Rocks (slow)
Sand (fast)


r
i
Glass
Sand
(fast)

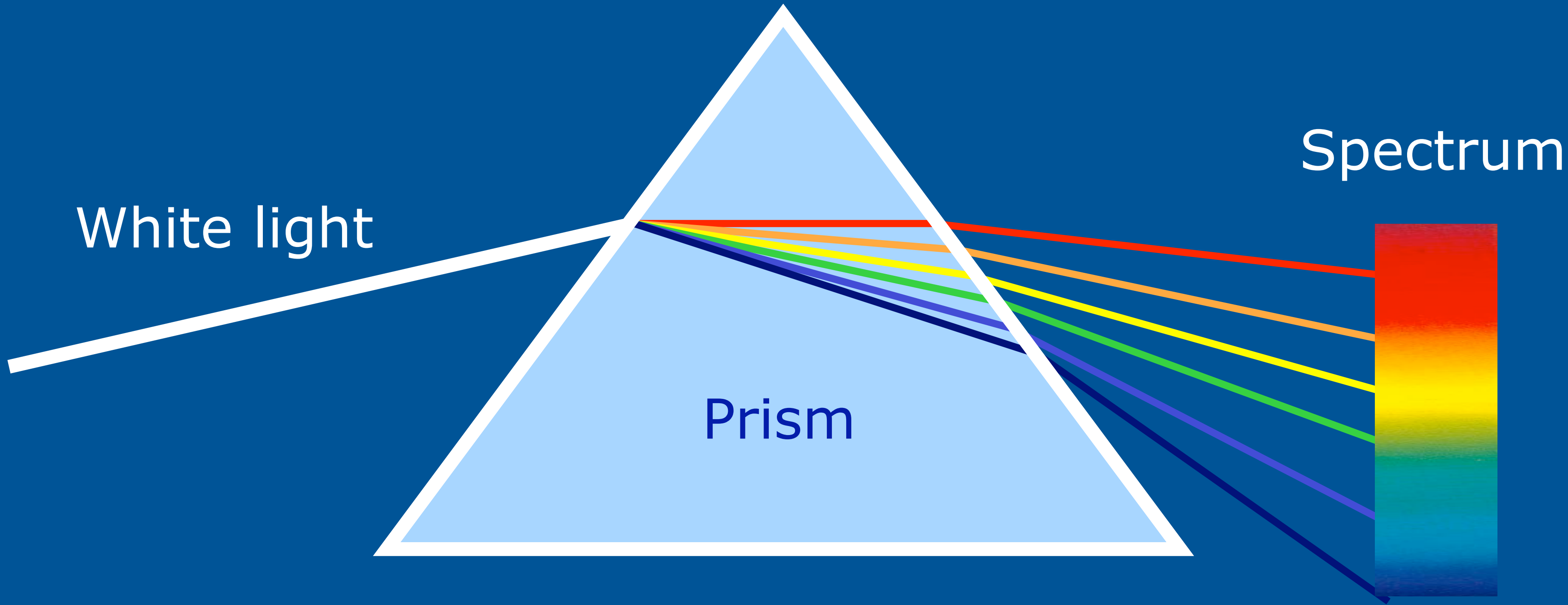
Snell's Law:

$$n = {}^{\sin i}/_{\sin r}$$

n is the refractive index of the glass;
Refractive index of air = 1

Refraction

Refractive index varies with wavelength:
short wavelength blue light is refracted more than longer wavelength red light



Refraction

- Refractive index *may* also vary with the plane of polarisation of the light.
- Materials in which this occurs are said to be *birefringent.*
- Birefringence is due to some directional or *anisotropic* arrangement of atoms or molecules which constitute the material structure.

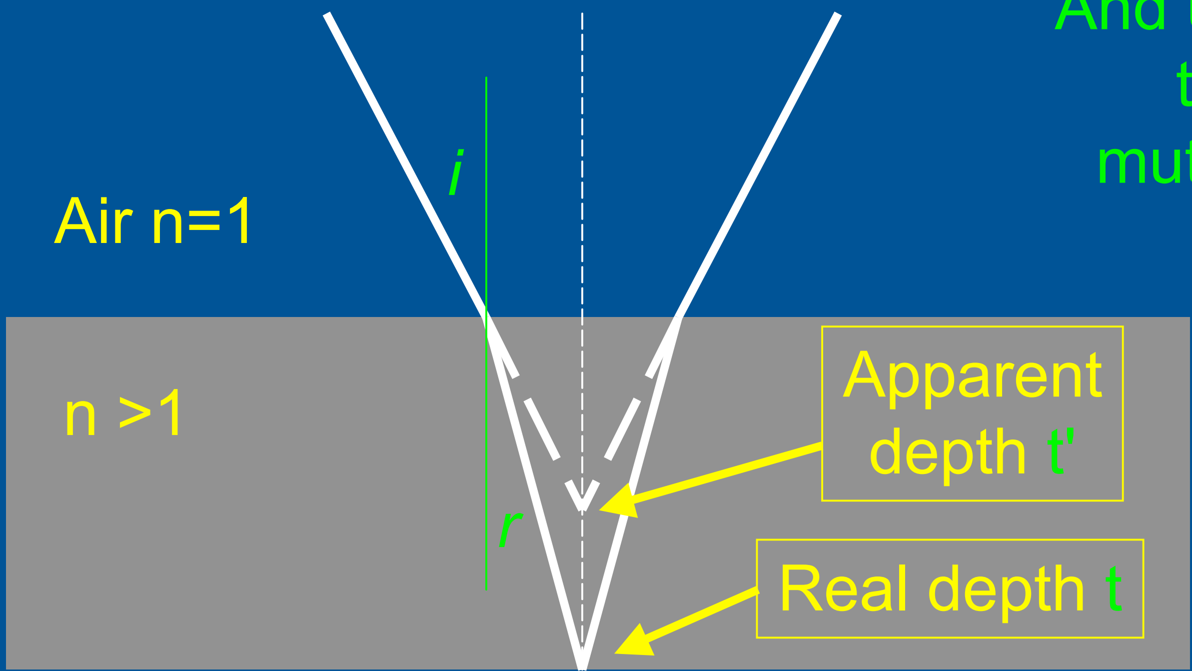
Refraction

Snell's Law:

$$n = {}^{\sin i}/_{\sin r} = {}^{t}/_{t'}$$

Calcite gives a double image at two apparent depths because it has two refractive indices.

And use of the polar shows that these relate to mutually perpendicularly polarised beams.



Interference

Light waves from the same source, and vibrating in the same plane can interfere, the effect depending upon their phase relationships

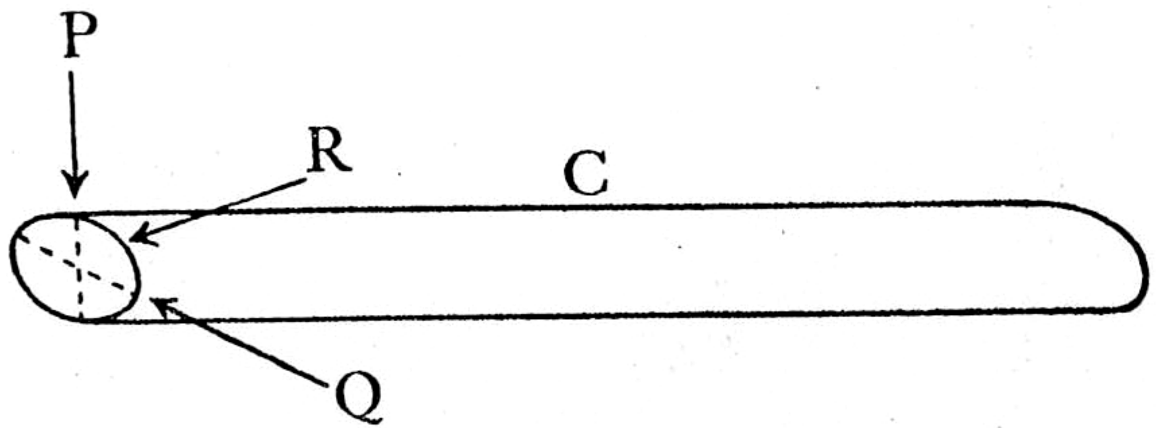
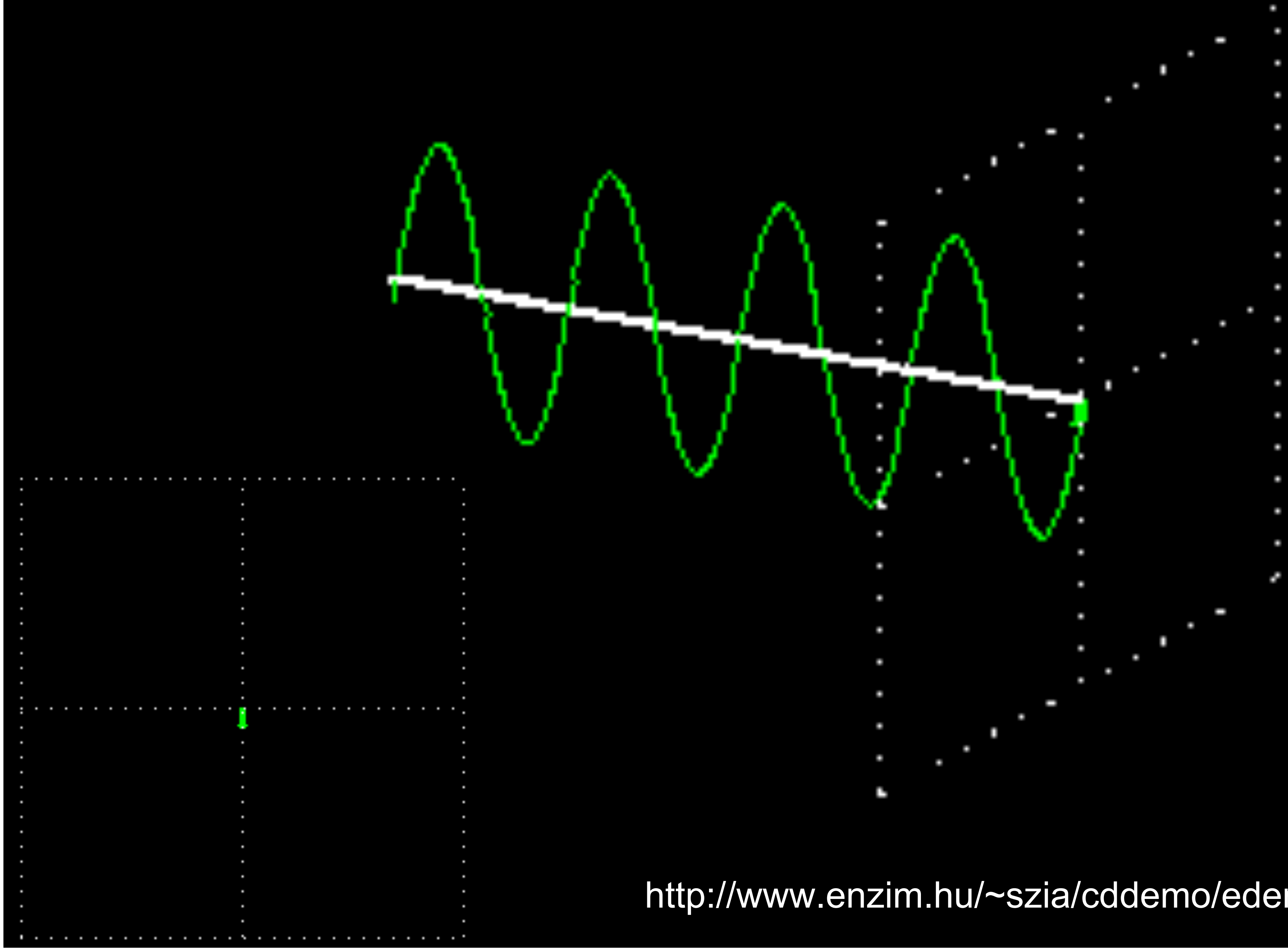


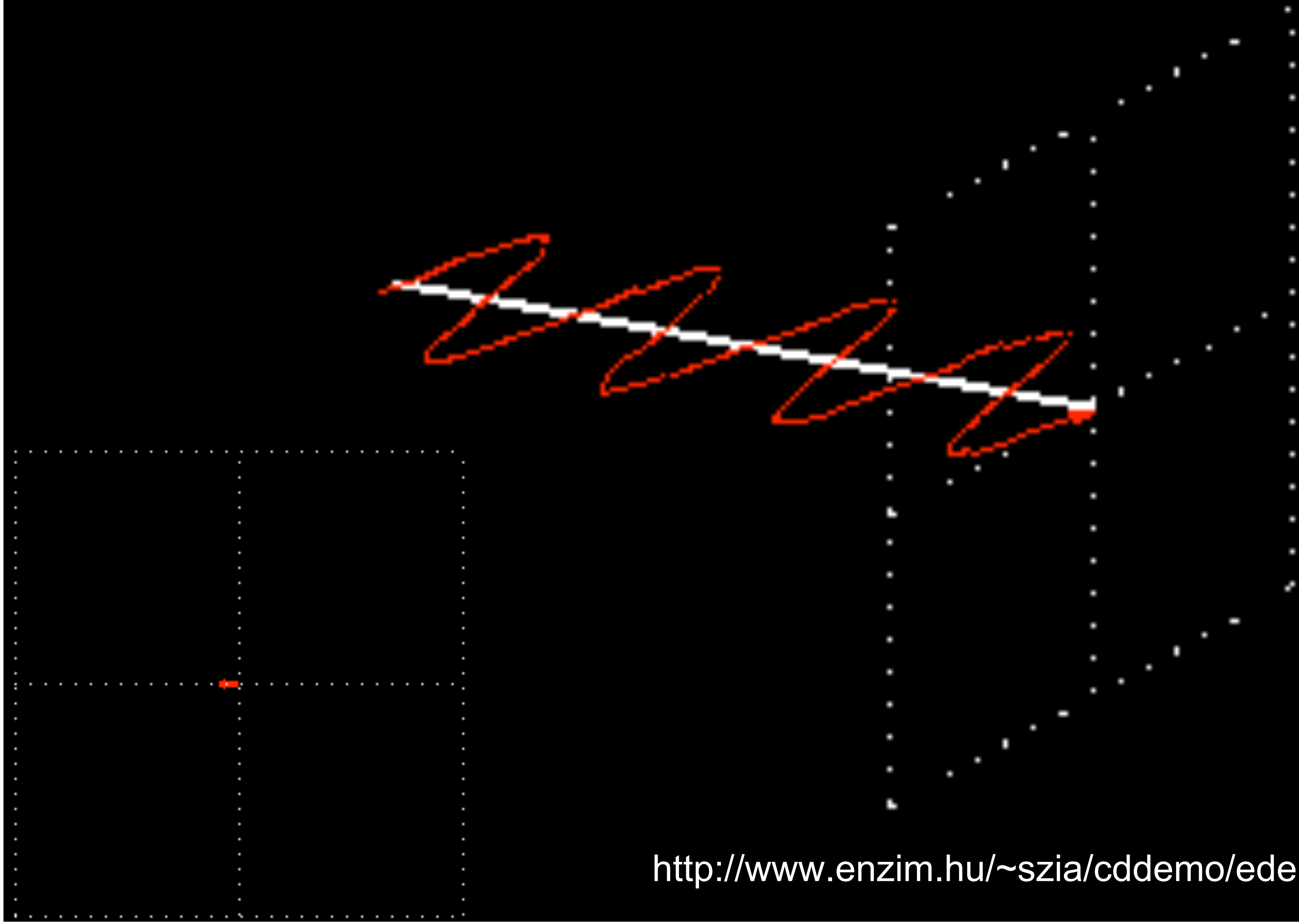
Fig. 84. A steel rod of elliptical section sounds a higher note when struck at Q than at P, the latter being on the flatter side. When struck at R, it emits both the high note of Q and the low note of P, but not a note of intermediate pitch.

Light vibrating vertically



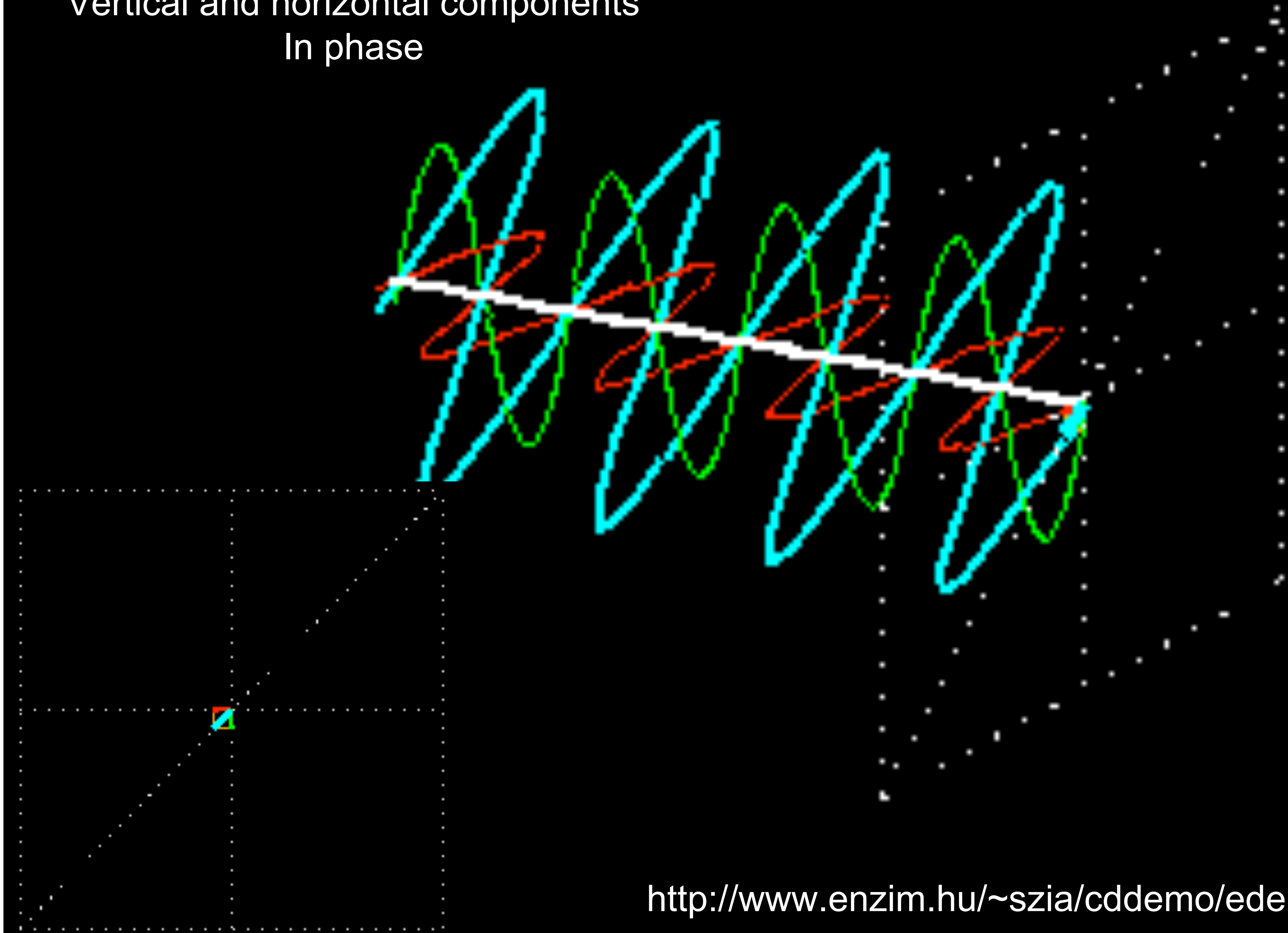
http://www.enzim.hu/~szia/cddemo/edemo2.htm

Light vibrating horizontally

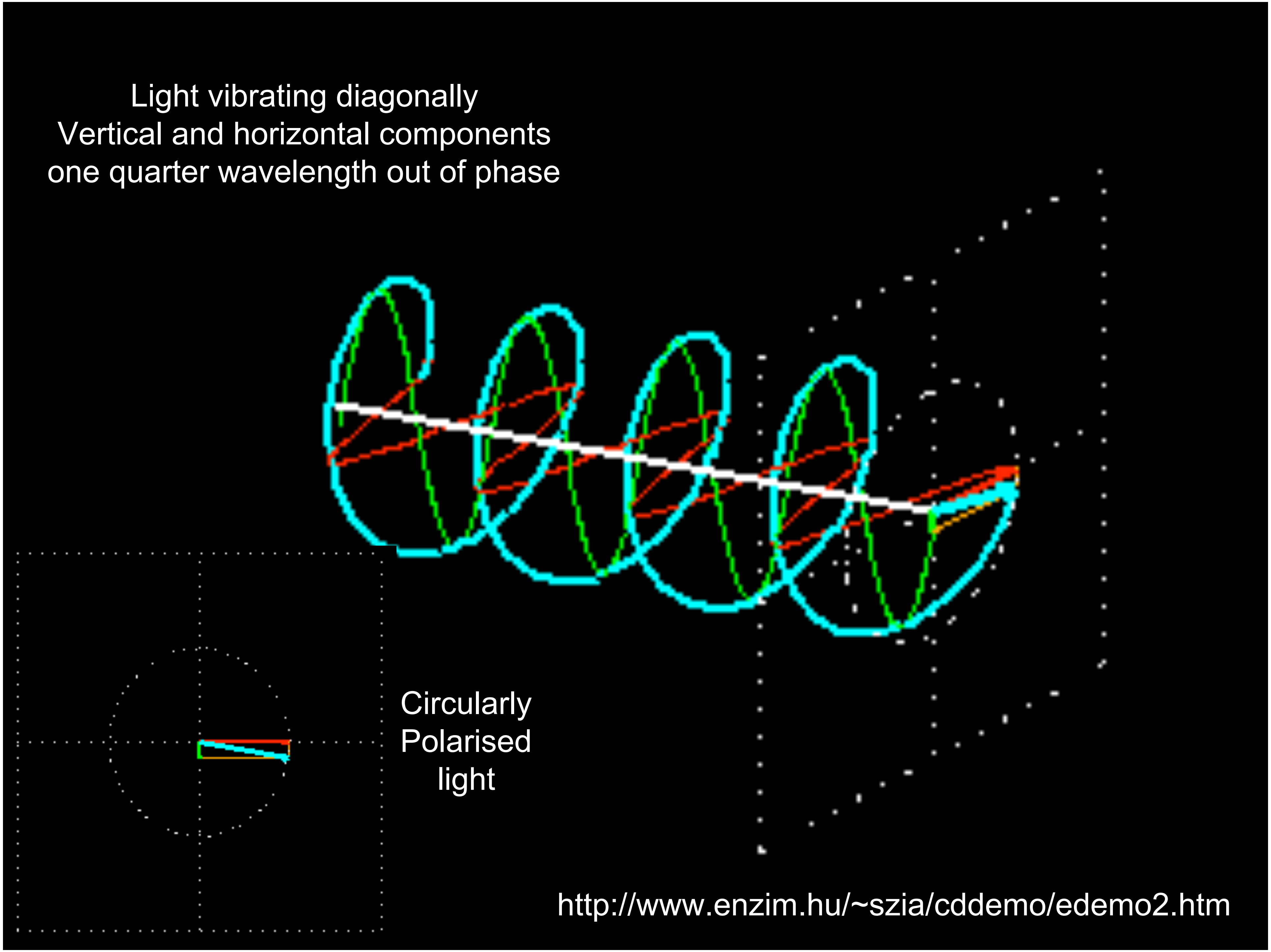


http://www.enzim.hu/~szia/cddemo/edemo2.htm

Light vibrating diagonally
Vertical and horizontal components
In phase



http://www.enzim.hu/~szia/cddemo/edemo2.htm


Light vibrating diagonally
Vertical and horizontal components
one quarter wavelength out of phase
Circularly
Polarised
light
http://www.enzim.hu/~szia/cddemo/edemo2.htm

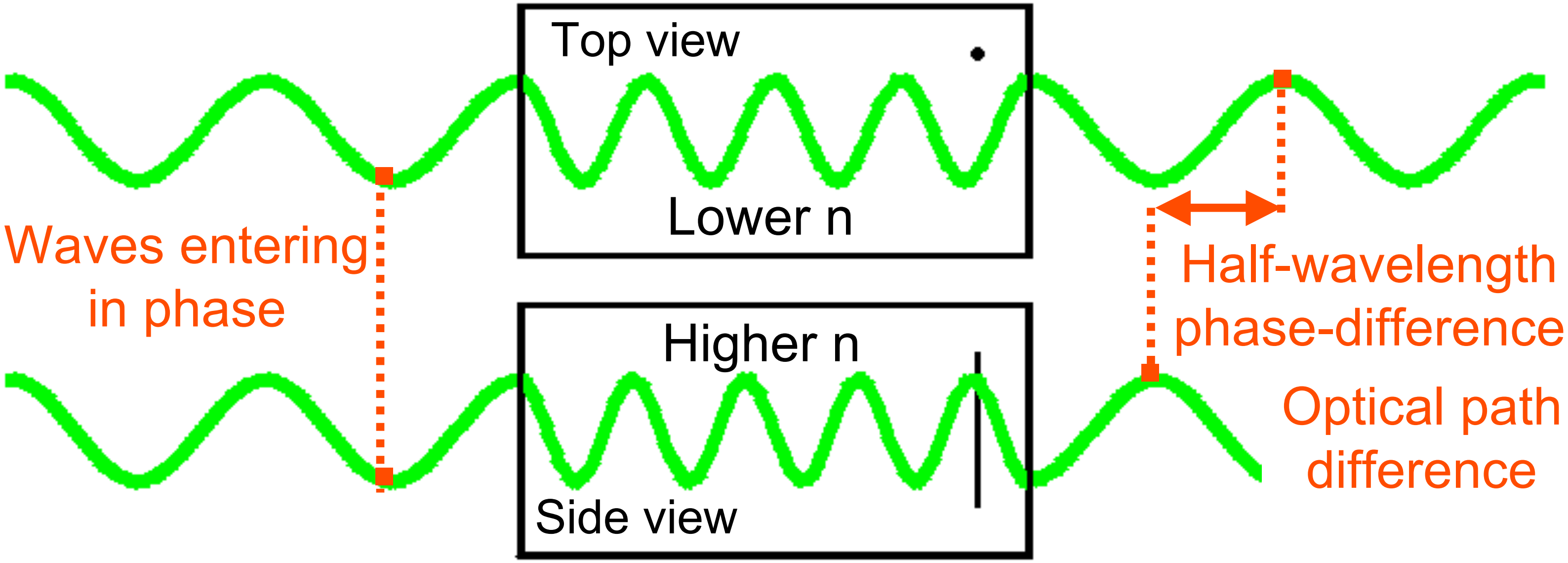
Refraction is a due to the interaction between light waves and the molecules of the material through which they pass

Light is slowed down in direct proportion to the refractive index…

…but the component vibrating along the *slow* axis is slowed down more.

Here the emerging waves are out of phase by $\lambda/2$ so the

Optical Path Difference = 273 nm ($\lambda/2$ for green light).

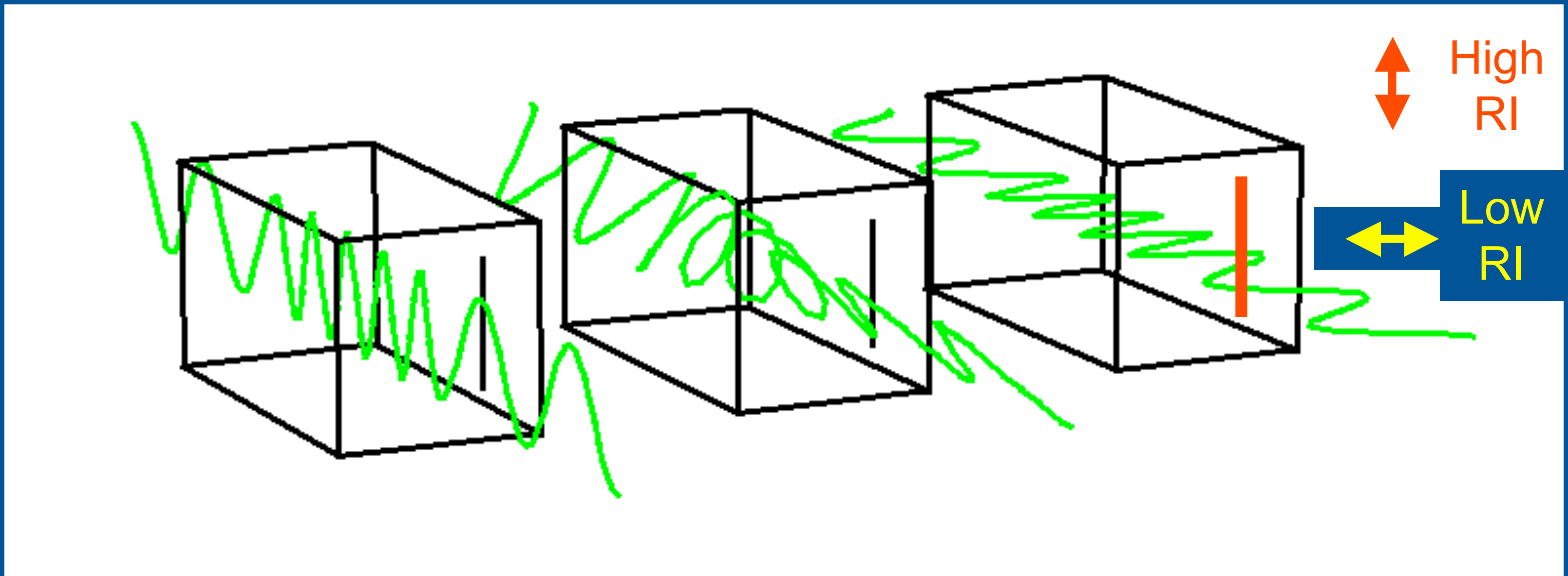


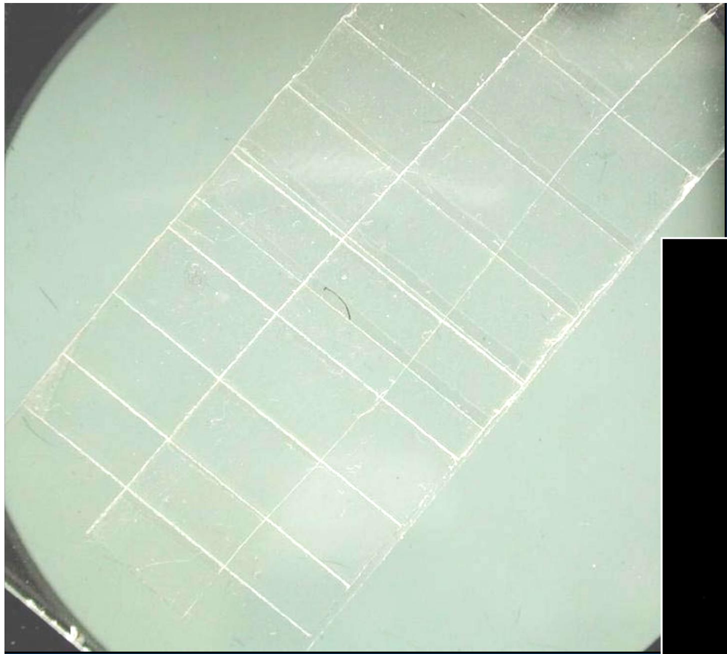
Birefringent object

In a birefringent object, different axes have different refractive indices.

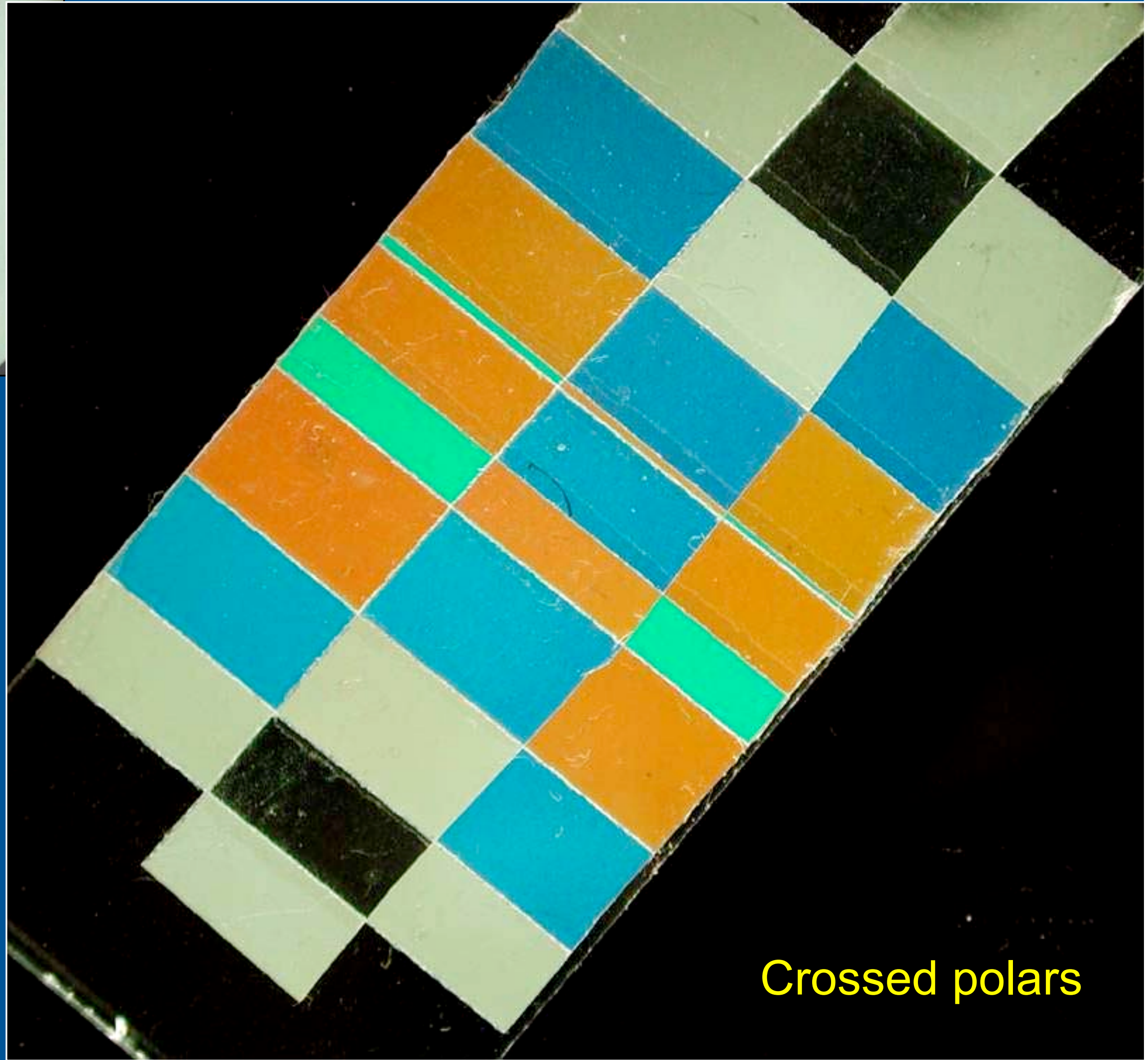
Here the axis with the **highest** refractive index is marked with a **line**; the axis with **lowest** index is **perpendicular** to this.

When light enters the object vibrating in a plane not parallel to one of these axes, the light ceases to vibrate in a plane while passing through the object.

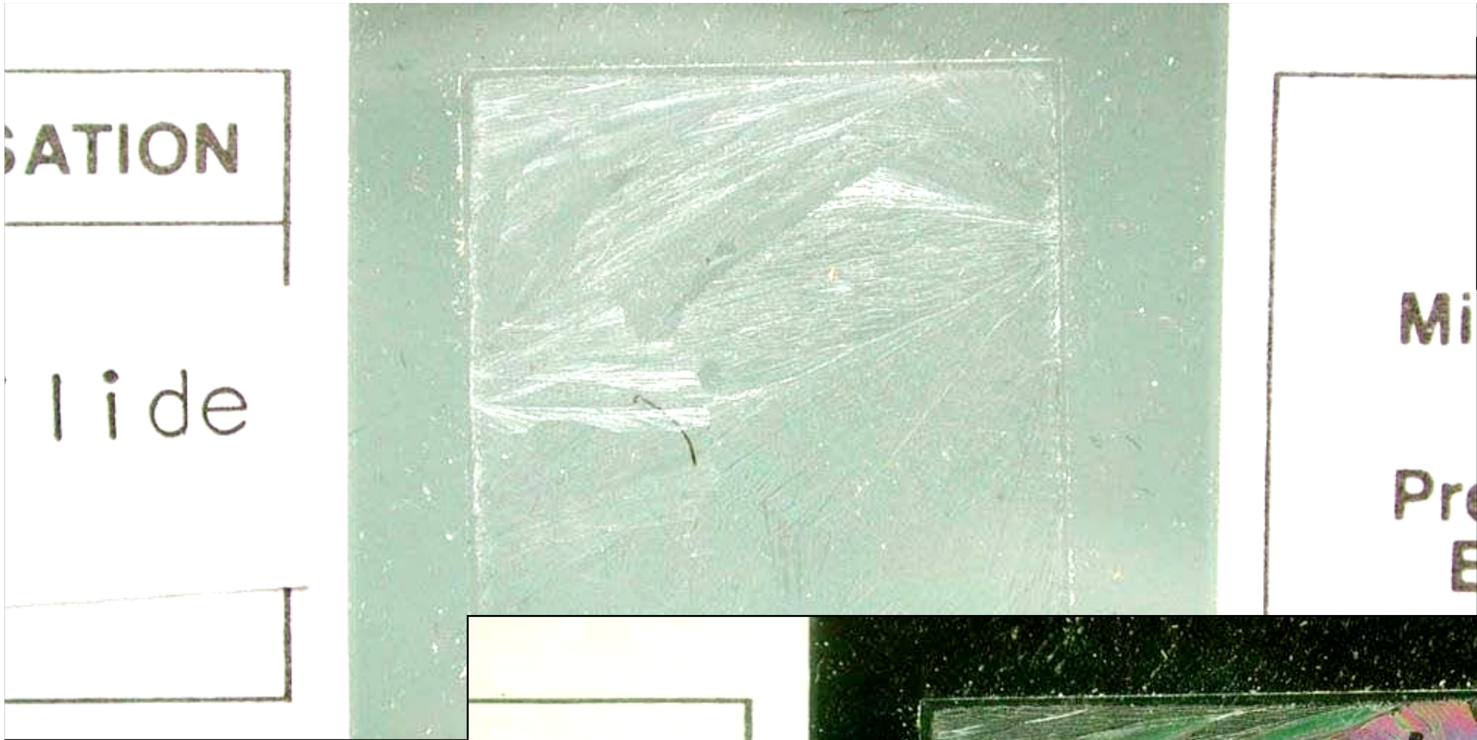




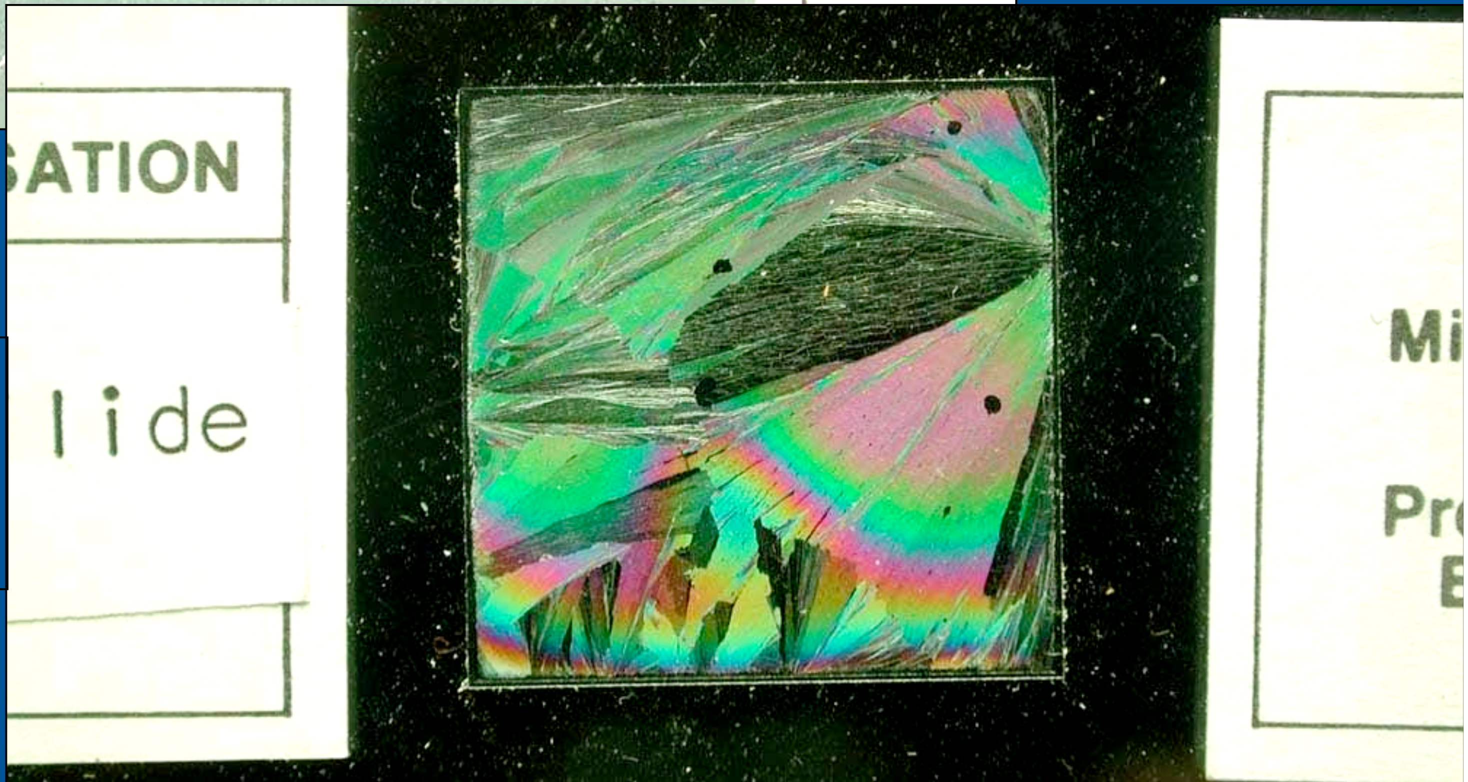
Overlapping pieces of Sellotape

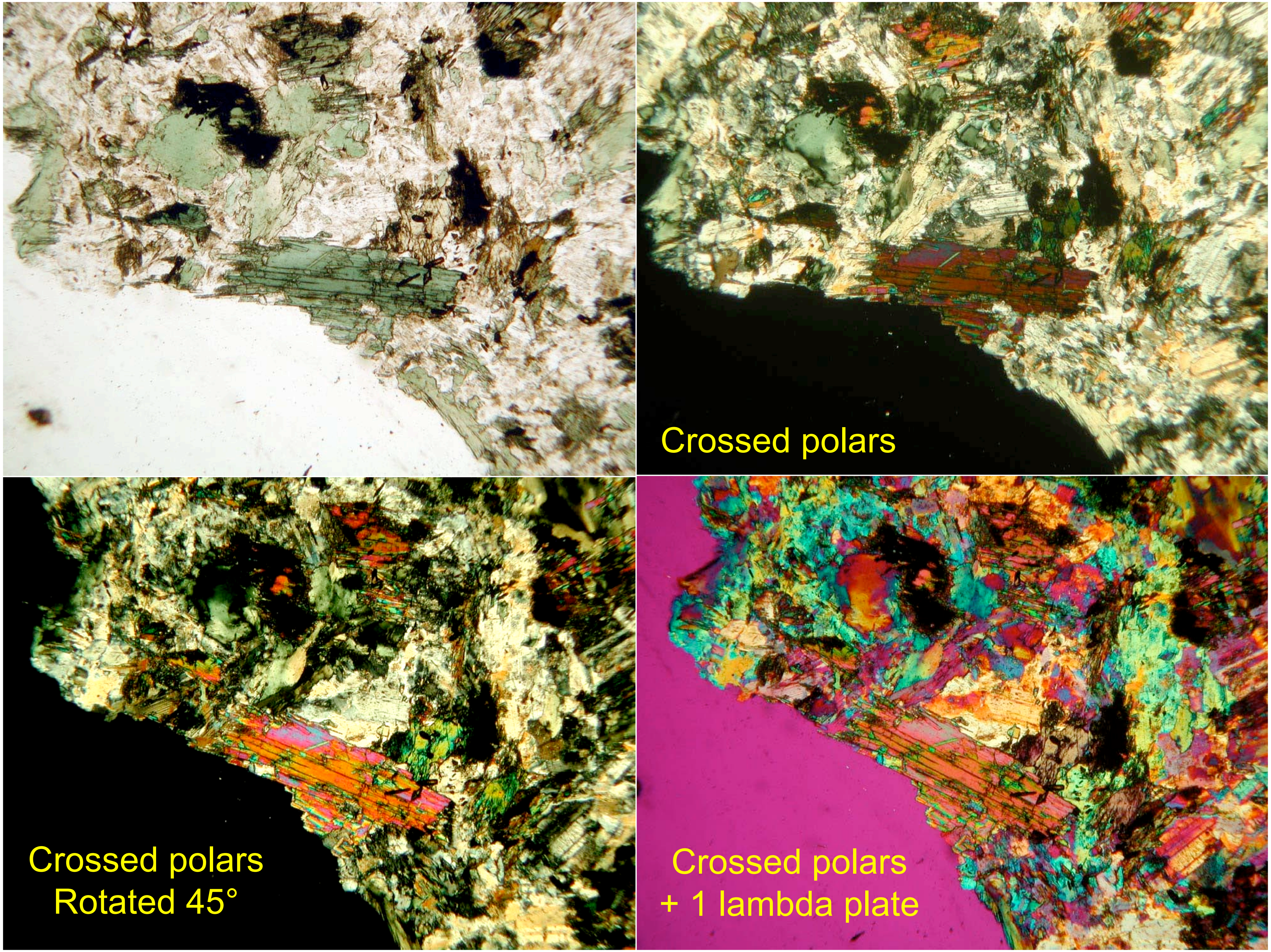


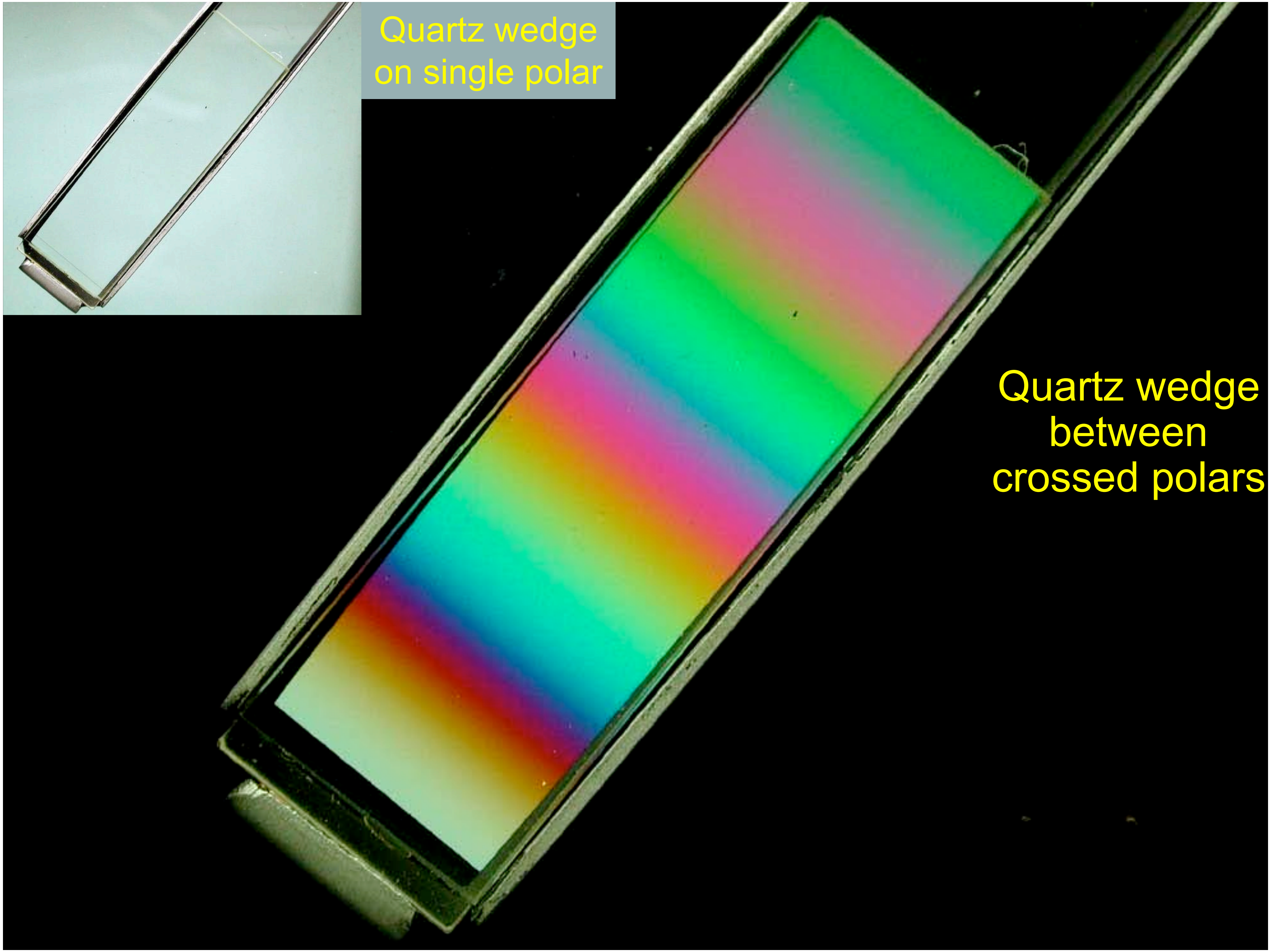
Crystals of Acetanilide. Natural light

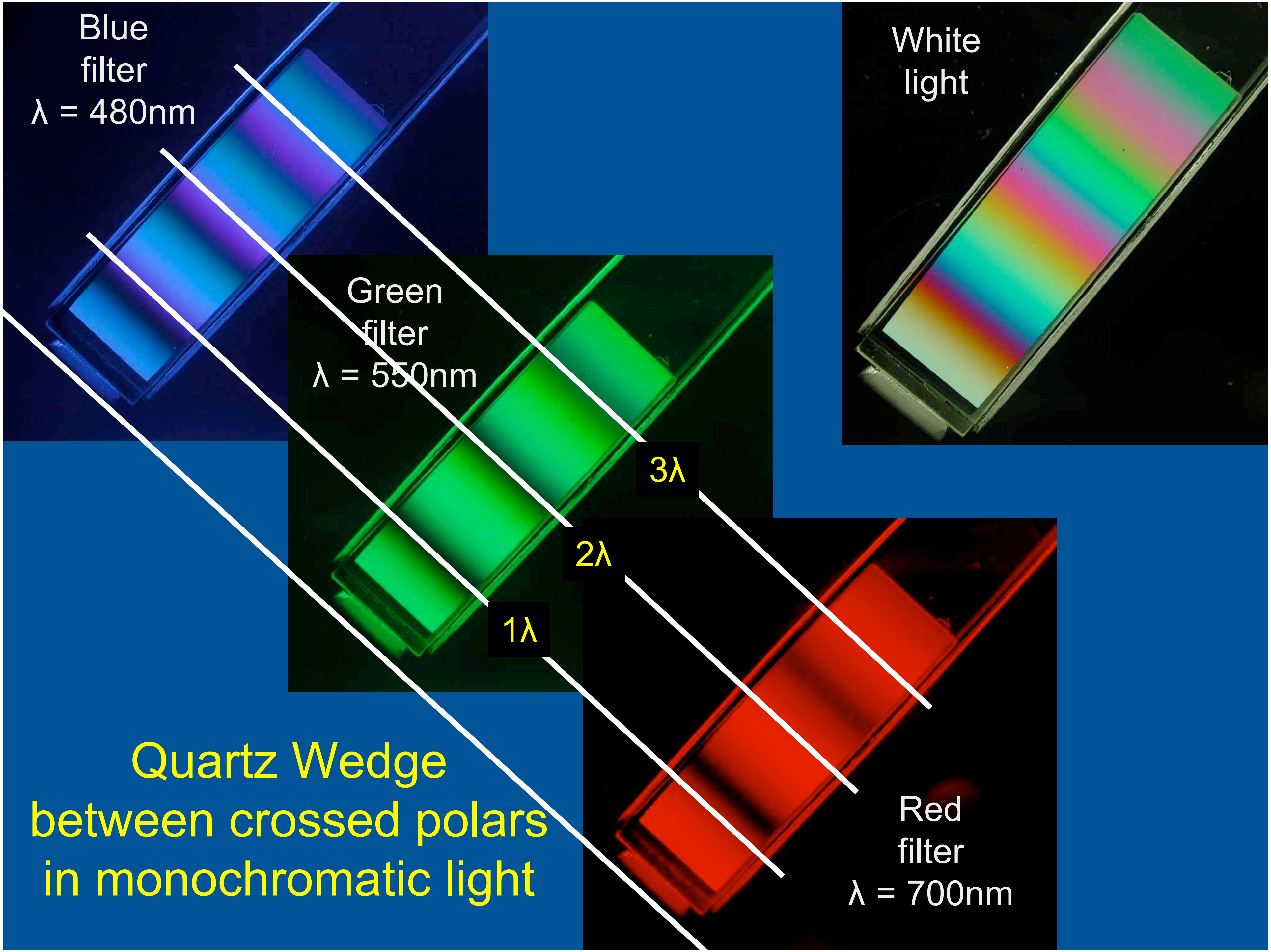


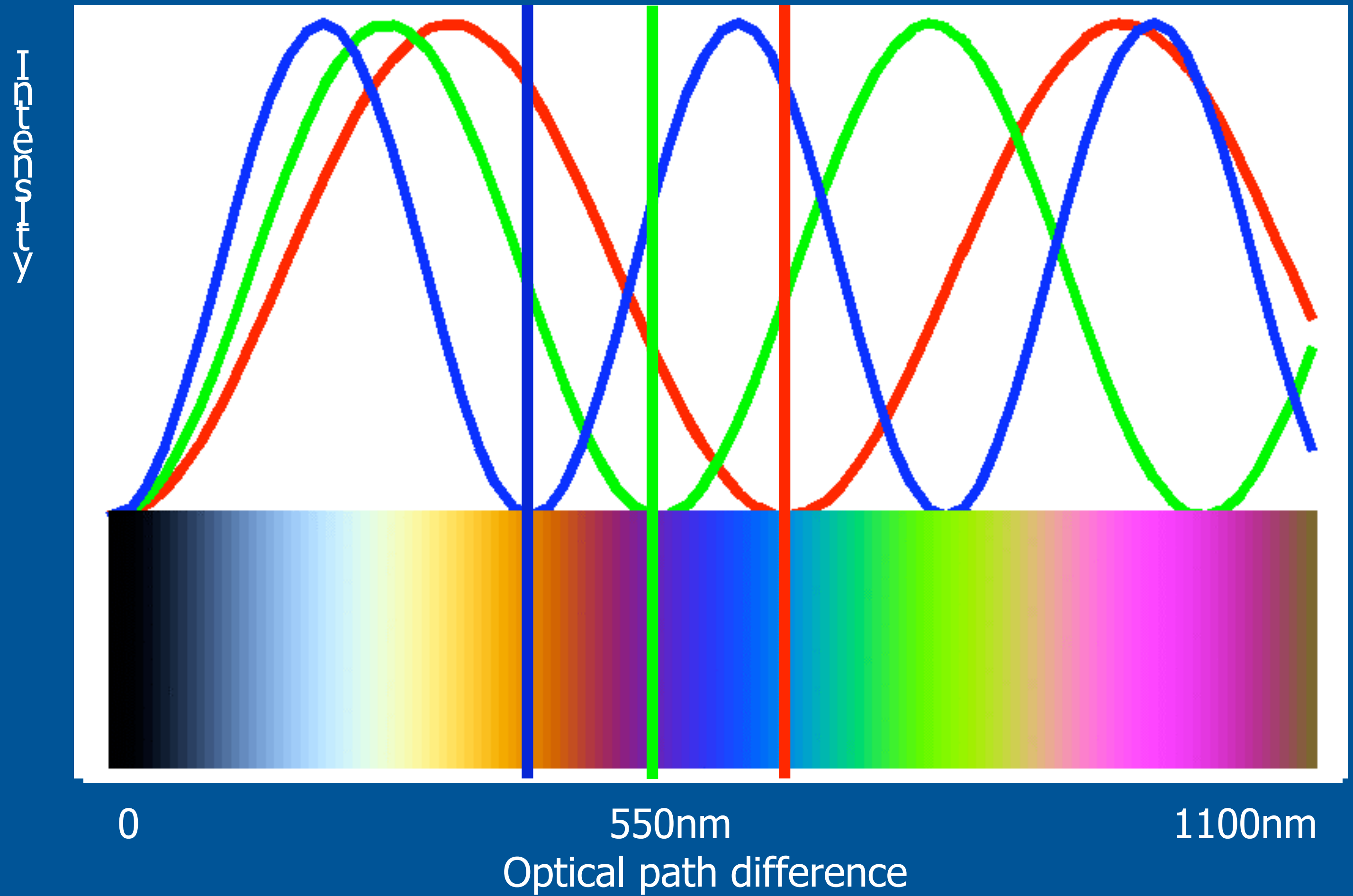
Between crossed polars




Crossed polars
Crossed polars
Rotated 45°
Crossed polars
+ 1 lambda plate

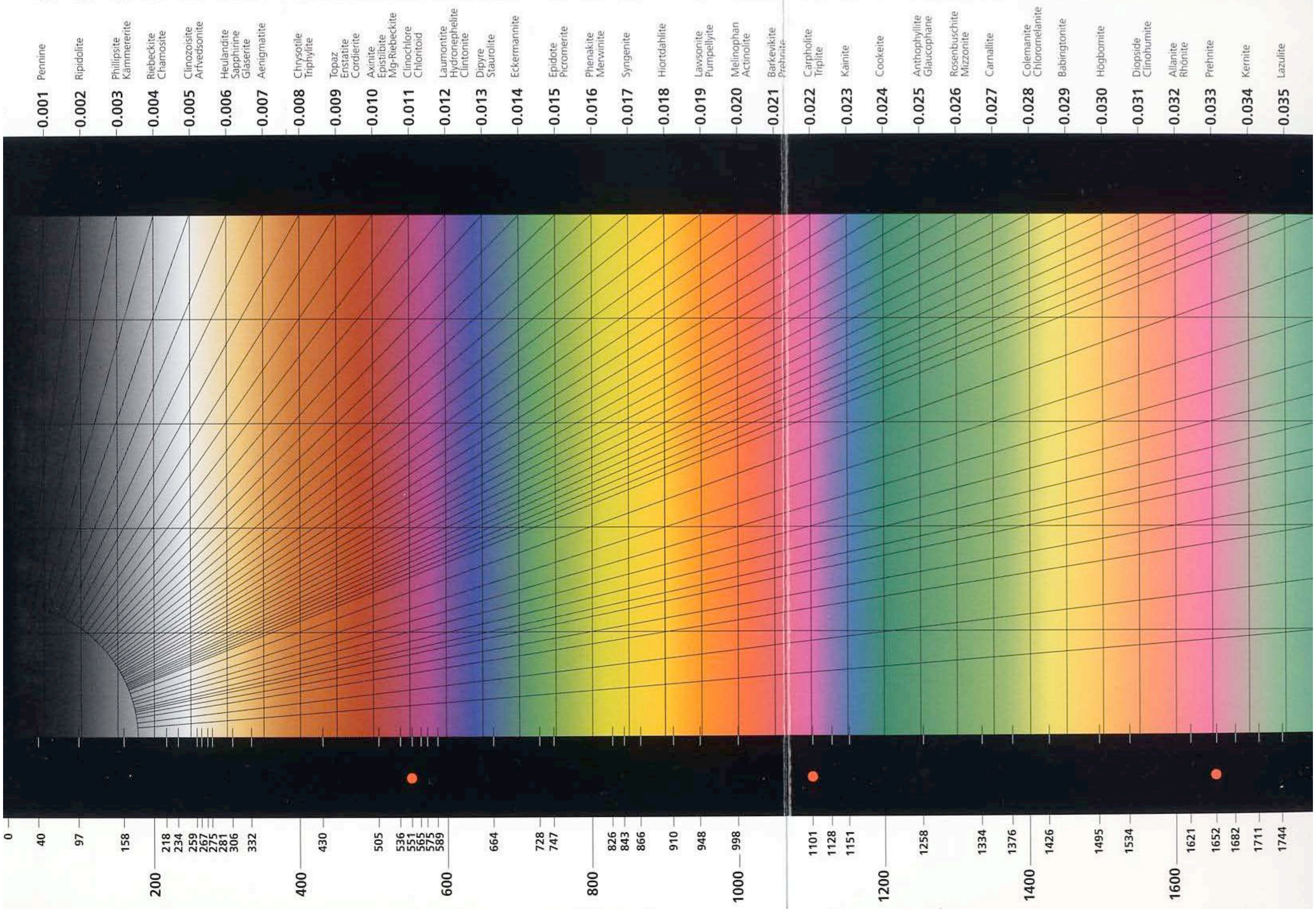

Quartz wedge
on single polar
Quartz wedge
between
crossed polars


Blue
filter
λ = 480nm
White
light
Green
filter
λ = 550nm
3λ
2λ
1λ
Red
filter
λ = 700nm
Quartz Wedge
between crossed polars
in monochromatic light



It is possible to guess the OPD from the interference colour using the Michel Lévy chart. If the thickness of the object is known, the birefringence can be calculated.

The Michel-Lévy Interference Colour Chart



Polarised Light Microscopy