DEPARTMENT OF PHYSICS
york.ac.uk/physics

UNIVERSITY of York

Polarisation of Light

Safety hazards and precautions:

- This practical uses a class 2 laser. Do not look directly into the beam, or at any reflections. You should not alter the beam path, or remove any optics during this practical. It is good practice to remove any reflective jewellery such as watches or rings as these can cause accidental reflections of the beam when you are adjusting the optics.

Experimental Objectives:

- This practical will teach you about the polarisation of light and how it can be manipulated by using polarisers.

Learning Outcomes:

- Describe what polarisation is.
- Explain how light is affected when passing through a polariser.
- Understand how polarisers can be combined to alter the intensity of a beam.

1. Theory

You will remember from GCSE that light is a transverse electromagnetic wave, with electric and magnetic fields perpendicular to the direction of travel of the wave. You will also remember that polarisation refers to the direction in which the electric field points. Light from most sources is unpolarised, which means that the electric field does not point in any specific direction. We can polarise the light, i.e. restrict the electric field to lie along a specific direction, by using a polariser. As we rotate the polariser, we rotate the direction of the electric field of the transmitted light.

In this practical we will take this a step further, and look at what happens when light passes through more than one polariser with their axes rotated from one another. The full theory can be found at the end of this script.

2. The Experiment

You will be working at an optical bench. You will not need to alter the setup of any of the components except for rotating the orientation of the three polarisers (see above). This is done by moving the yellow tabs, and a scale on one side of each polariser will allow you to precisely choose your rotation angle.
The components of the experiment, all mounted to an optical rail, are as follows –

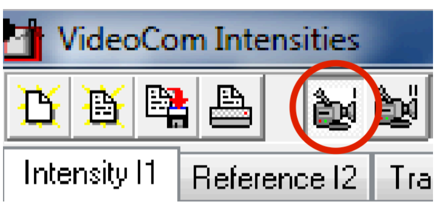
1. A laser – the light source for this experiment. Make sure you have read the safety box above with regards to this.
2. Three polarisers (P1, P2 and P3), numbered from left to right.
3. A detector, which displays the intensity of light on the attached PC.

You will be adjusting the angle of all three polarisers during this experiment, and will see the intensity hitting the detector on your PC.

2.1 Setting the laser intensity

The laser we are using is too bright for the detector to handle, so we will start by using the first two polarisers (P1 and P2) to dim the beam.

1. Set all polarisers to 0° (the yellow tabs should all be pointed directly upwards). All our polarisers are now aligned, so we are letting the maximum amount of light through the to the detector that we can.
2. Make sure the left hand camera button at the top of the "Videocom Intensities" software has been pressed (see below). You will want this to be on at all times!



3. Adjust P1 until a peak appears on your PC's software. Rotate P1 so that the peak height is roughly 75% (100% just means the brightest beam the detector can handle). You will probably need to be very close to 90° on P1 to achieve this.
4. The table at the left of the window shows the intensity recorded by each pixel of the detector. Scroll down the table at the left of the window until you reach a pixel with a value close to 75% and make a note of which one it is. You will only use this one pixel value in this practical, so make sure you remember which one you are using.
5. You should not touch P1 or P2 again until part 3 of the practical.

2.2 The effect of two polarisers

You have already seen that we can alter the intensity of a beam by setting two polarisers at different angles. In this section you will look at this more carefully.

1. Take a look at the spreadsheet provided. It contains a table into which you can put your data, and it will automatically graph your results. It also shows the theoretical result (the derivation for this is at the end of this lab script in case you want to find out where it comes from after the practical!).
2. Rotate P3 to the angles given in the spreadsheet. Start with 0° as the spreadsheet will use this value to normalise your data (i.e. scale it such that the maximum intensity is 1.) You may not have time to do them all, so start by doing every other one. You can always fill in your gaps later.
3. Once set, record the value recorded by your chosen pixel. You will see that it jumps around, so you can get the software to take an average by clicking the button labelled Σ_1. **Click it again to turn off averaging before you adjust P3 and take your next measurement.**
4. Repeat these steps until you have a graph. It may not match theory precisely. Have a chat with a demonstrator to find out why.

2.3 One more thing…

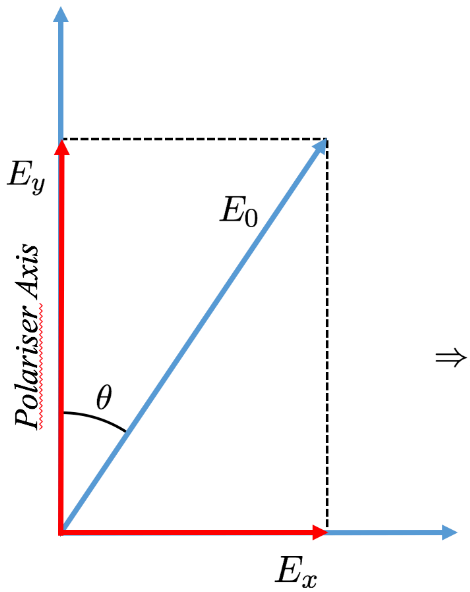
You should have seen that polarisers let through (almost) no light when they are at 90° to one another. So take a guess what will happen if you do the following, and then give it a go…

1. Set P1 and P2 to 0°, and then adjust P3 to reduce the beam intensity down to zero (this will of course be close to 90°). So now, the first two polarisers only let through vertically polarised light, and the third only horizontal. Since plane polarised light can't be both vertically and horizontally polarised at the same time, nothing makes it through all three polarisers.
2. Now try rotating P2 slightly. P1 is still only letting through vertical polarisation, and P3 is still only letting through horizontal, so will rotating P2 have any effect on what reaches the detector?

Were you right?

3. More theory

Electric field is a vector quantity, meaning that it has magnitude and direction. As we will see, the magnitude is related to the intensity of the light. Let us assume that our light is already polarised, and then sent through a second polariser. The electric field of the light will form some angle, θ, to the polariser axis. For simplicity, let us assume that the polariser axis is vertical (which we will call the y axis). Below is a diagram of this situation –



$$\cos\theta = \frac{E_y}{E_0}$$
$$\Rightarrow E_y = E_0 \cos\theta$$

Since the electric field, E_0, is a vector we can split it into two components, one along the polariser axis (E_y), and one perpendicular to it (E_x). In other words, $E_0 = E_x + E_y$, where this is a vector sum. What polarisers do is let through the component of the field along the polarisation axis, and absorb the component perpendicular. As shown in the diagram we can use trigonometry to find that the E_y component which is transmitted is equal to $E_0\cos(\theta)$. This has two effects. Firstly, the beam's polarisation has been rotated to lie along y, regardless of its initial orientation. Secondly, the E field has been reduced in magnitude. The final step is to realise that the electric field is the amplitude of the wave, whereas our detector measures the intensity of the wave (you will learn more about the amplitude and intensity of waves, and how they are related, during your A-Level). This means we must square our result for E_y to get a formula for I, the transmitted intensity.

$$I = I_0 \cos^2(\theta)$$

This is known as Malus's law, and is the theory plotted in the Excel spreadsheet.
Think about what it tells us when θ=0° and θ=90°. Does this make sense?