University of Glasgow

QUANTUM TECHNOLOGY SCHOOL 2021

ACADEMIC PACK

PART 2: POLARIZATION: TEACHERS PACK

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Task 1.1: Introducing polarization

1. When looking out the window and rotating the polarizer, there should not be much change, as ambient light outside is mostly unpolarized. Light from an LCD screen is polarized, and when looking at this through a polarizer, pupils should see the screen go from bright to dark and back again when it is rotated.
2. Any light passing the first polarizer is now polarized, so when looking through a second polarizer, pupils should be able to see that the amount of light passing through depends on the angle between the polarizers, going from bright to dark and back again as the second polarizer is rotated.
3. To achieve minimum transmission of light from the window the polarizers should be crossed (at right angles)
    a. When placing a third polarizer between the other two, pupils should see that some light is able to pass through the sequence of polarizers.
    b. When placing the protractor provided in the pack, or the plastic wrapping from the protractor it should be possible to see colours, which change as the polarizer is rotated, as shown below:

Now can you explain what happened when you placed a third polarizer in between two crossed polarizers?

The first polarizer produces light polarized in one direction (say horizontally); when the second polarizer is at right angles, it completely blocks this polarization, and no light can pass. When a third is placed in between the two, as long as it is not at right angles to the first polarizer, some light can pass through it. If this polarizer is at 45 degrees to the horizontal, then any light which passes through is now diagonally polarized. The final polarizer blocks all horizontally polarized light, but as the light is now diagonally polarized (at 45 degrees), some of it can still pass, so we can see light pass through again.

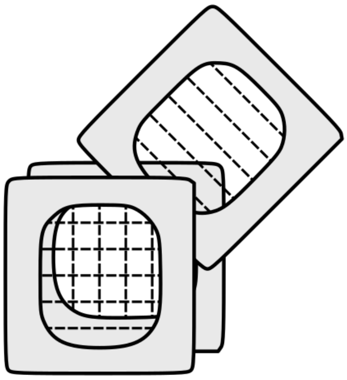

Figure 1: Polarizer between crossed polarizers.[Image: CC BY-SA 4.0 via Wikimedia Commons]

Task 1.2: Malus' law

Graphs won't be perfect, but should show plausible agreement with Malus' law. It should be clear from data obtained that the intensity reduces as the angle between the polarizers is increased.

Task 1.3: Photons, probabilities, communication

The probability that a single photon with polarization oriented in the horizontal direction passes a polarizing filter at an angle of 45 degrees to the horizontal is $\cos^2 45° = ½$.

To use the polarization of a photon to send two different signals, a sender could use horizontal polarization for "0" and vertical polarization for "1". Thus the sender sends light through a polarizer oriented horizontally to send "0" and switches the orientation of the polarizer to vertical to send "1". Assuming a receiver knows when to look for a signal, they can use a fixed polarization filter oriented horizontally: if light is detected at a given time slot then the signal was "0", if none is detected the signal was "1".

[In practice a polarizing beamsplitter (shown to the right) is used instead of a filter: horizontal light is transmitted and vertical light is reflected; if light is detected in the transmitted output port it is a "0", light detected in the reflected port represents a "1".]

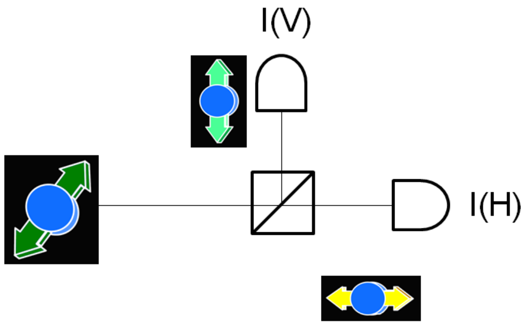

Figure 2: Polarizing beam splitter. Horizontally polarized light is transmitted, and vertically polarized light reflected. A detector in each arm measures the intensity of horizontally polarized light I(H), and of vertically polarized light I(V).

The last part of this worksheet is intended to prompt pupils to recognize that all that is needed is any two orthogonal directions: horizontal and vertical is one possibility, but there are many others: polarizations at +45 and -45 to the horizontal also work. Once the "0" is set, by any chosen orientation of a polarizer, "1" is just the polarization at right angles to this.