Hands-on Workshop: Interference and the Quantum Eraser.

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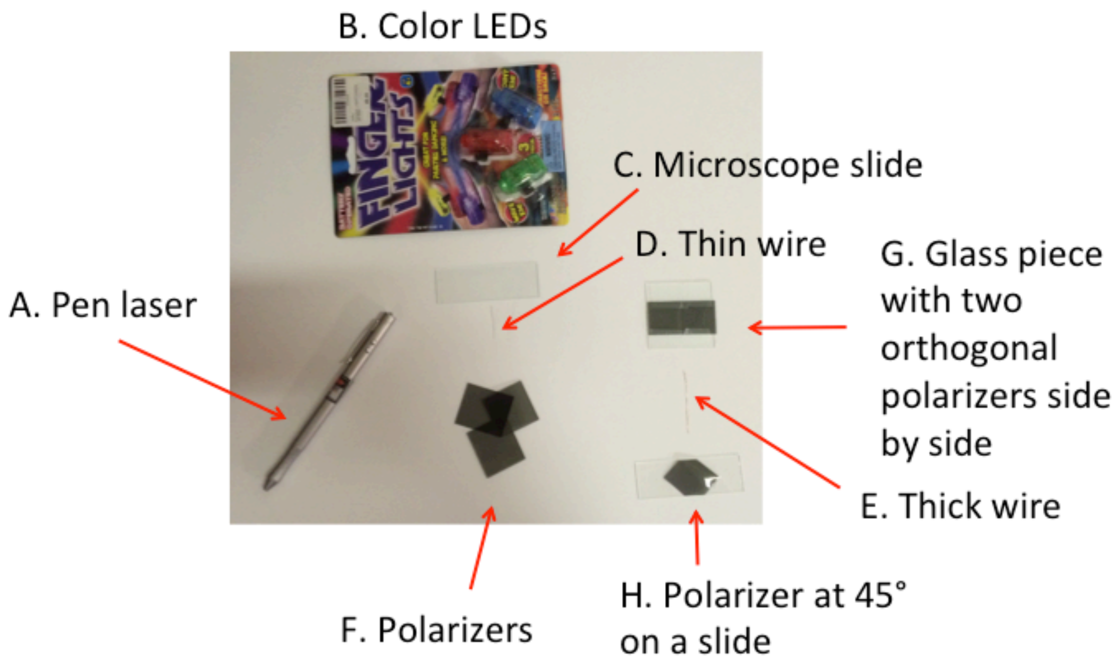
Parts per participant:

A. Pen laser
B. Color LEDs
C. Microscope slide
D. Thin speaker wire strand(~160 μm)
E. Thick power wire strand (~270 μm)
F. 3 polarizers
G. Glass slide with two cross polarizers side by side
H. Polarizer at 45° on a glass slide



Parts per group

I. Screen + stands for laser and diffractive element.
J. Holder for diffractive element
K. Lens
L. Ruler
M. Tape

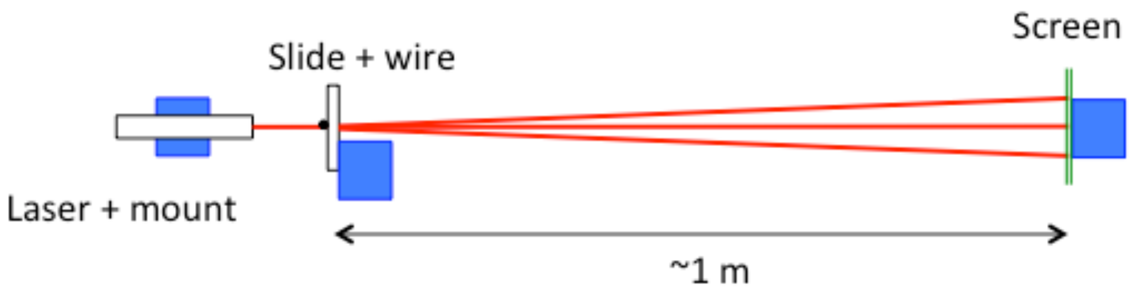
For the class:

N. Two sets of needle-nose pliers
O. Hot glue
P. Measuring tape/ meter stick

Activity 1: Wire diffraction

1. Tape thin wire strand (C) on a microscope slide (D). Take the cover off the color LEDs (B). Observe the diffraction from an LED by placing the slide (C+D) up against your eye. Do you see the difference in the patterns of different colors? Can you explain it?

2. Set the pen laser (A) up to see the wire diffraction, taping the wire+slide (C+D) on a stand. (You have to tape the "on" button so it stays on.)



Using $d\sin\theta = n\lambda$ find the diameter d of the wire. The (small) angle θ is between incident direction (central maximum and n-th minimum).

3. Let us think in terms of photons: which path do the photons take?

Activity 2: Polarization projection

1. Put two polarizers (F) back to back, with the second one forming an angle of about 30° with the first one. If you place the third polarizer after the first two, at what angle should you place the third polarizer so that it blocks the light? Predict then verify.

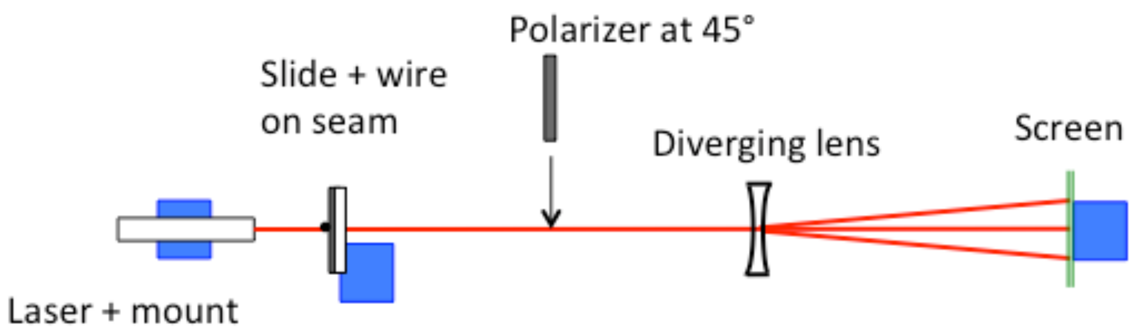
2. Place the two polarizers 90° to each other, so you do not observe any light coming through. Place a third polarizer in between so that you get a maximum light through.
   a. Can you explain why light goes through? In terms of photons?

b. How much light goes through? (For a polarizer $I_T = I_i \cos^2 \alpha$, where I_i and I_t are the incident and transmitted intensities, proportional to the number of photons), and α is the angle between the incident polarization and the transmission axis of the polarizer.

c. If you rotate the third polarizer by 90°, how much light would go through? Verify qualitaatively, comparing it with the previous case (a).

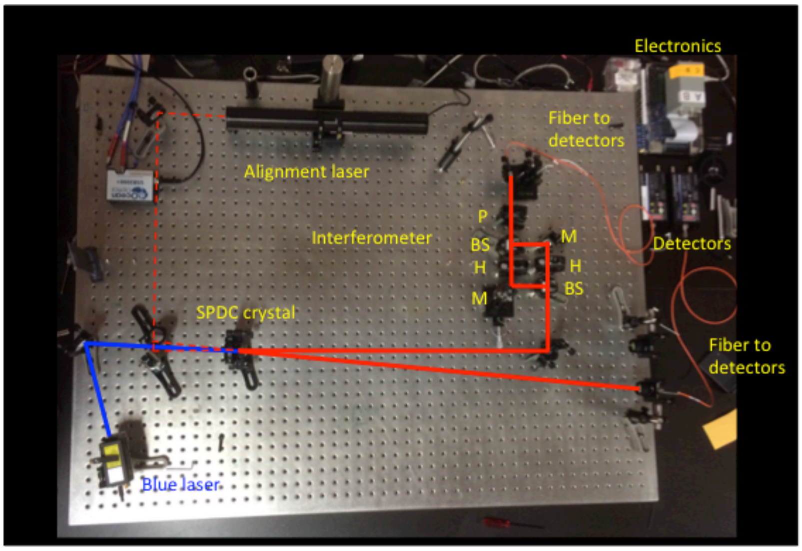
Activity 3: The quantum eraser

1. Assembly procedure:
   a. Straighten the thick wire (E), if needed, with needle-nose pliers (pull the wire to stretch it).
   b. Place it exactly along the seam of the two polarizers mounted side by side (G). Affix it with tape and mount it.
   c. Set up the laser and rotate it in place so the light going through a polarizer at 45 degrees is a minimum.
   d. Set up the apparatus below:



   e. Make sure that the beam illuminates the wire. Lens must 50 cm down-stream.
   f. Place the polarizer at 45° (H) in and out to observe the difference. Explain what you observe in terms of the principles of quantum superposition.

Demonstration with Single Photons (Groups take turns)



The apparatus is shown in the figure. The blue laser is incident on the SPDC crystal, generating photon pairs. One photon goes straight to a detector, heralding the other photon going through the interferometer. The interferometer has parts: beam splitters (BS), mirrors (M), half-wave plates (H), and polarizer (P). Photons go to detectors through fibers. The detectors produce electronic pulses that go to counters and a coincidence circuit. The length of one of the arms of the interferometer is scanned with a piezoelectric.

The experiment has the following steps:

1. Polarizer is out. Half wave plates are set to zero so they do not change the polarization of the photons. We scan the length of the interferometer and we see interference. The paths are indistinguishable.
2. We rotate one of the half-wave plates so that the polarization of one of the arms is rotated by 90 degrees. Then the paths are distinguishable by the polarization of the photons (each arm has a different polarization: one horizontal and the other vertical.
3. We add a polarizer with axis forming 45 degrees with the horizontal (diagonal). It projects the state of the photons to be diagonal. This erases the path information. Interference reappears.