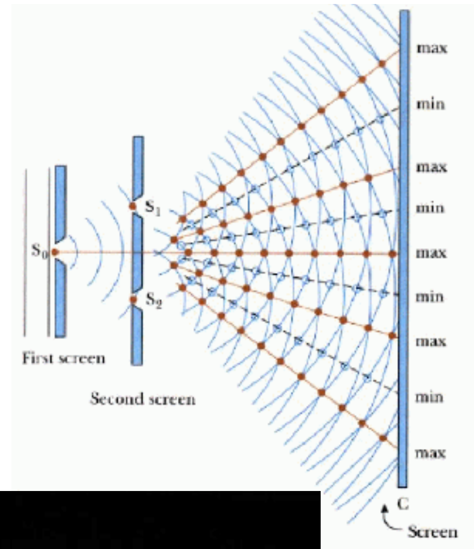
PHYS 105

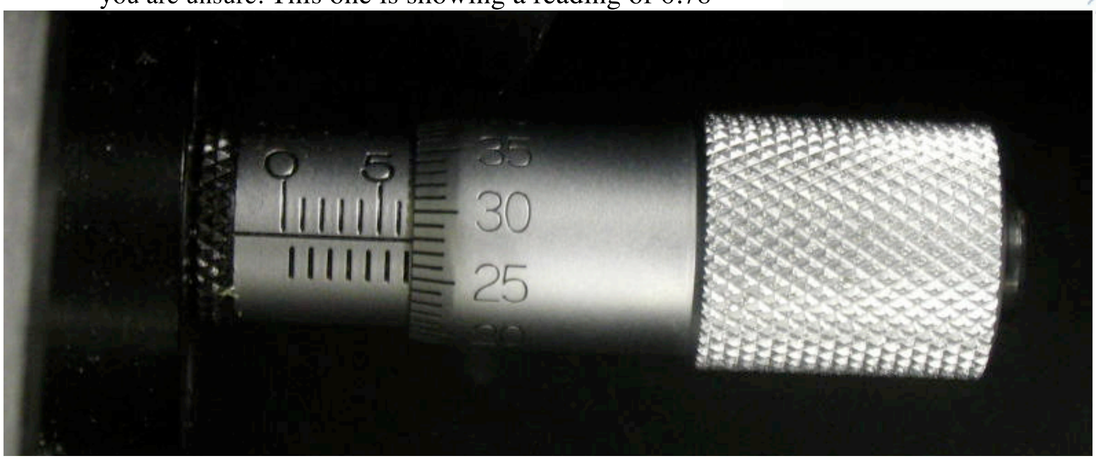
Double-Slit experiment: One photon at a time

In this experiment you should see a double slit interference patter from a (red) laser, schematically pictured at the right. So if you do, we can conclude that light is a wave, **right?!**

You will explore both the wave nature as well as the particle nature of light…



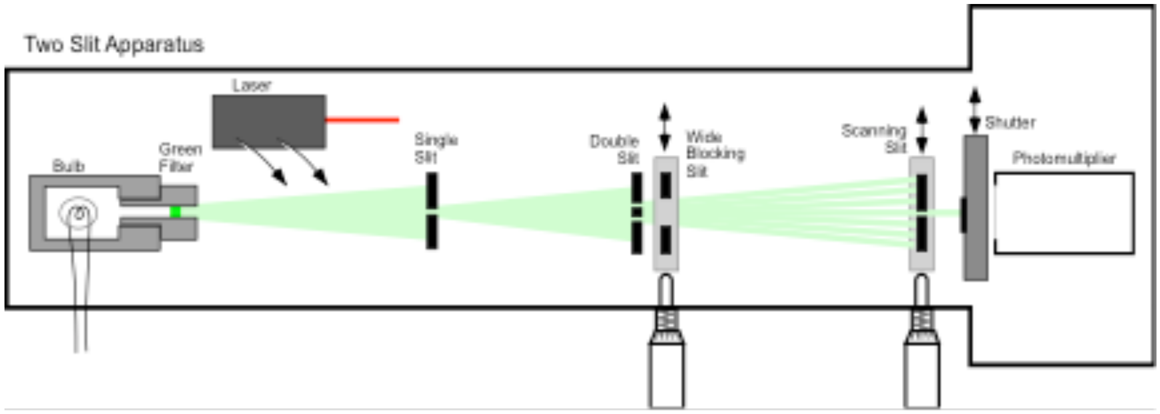
Most of you will not have had practice reading/working with micrometers before. Ask your instructor to show you how if you are unsure. This one is showing a reading of 6.78



Set-Up

- Turn on the Spectech Counter (*behind*) the photon apparatus.
- Keep high voltage off for now. Even with the HV off, worry about the PM tube:

- The photomultiplier (PM) tube is extraordinarily sensitive and should never be exposed to ambient light. **Be sure the shutter is closed**. (Shutter rod is pushed DOWN) **If you don't know what this means don't proceed, GET HELP.**
- **When you are absolutely, positively sure the shutter is closed**, open the cover.



See the light path:

- Put the laser into position in the beam path.
- Put the T-paper at B (just after the first slit)
- Turn the switch at the left end of the apparatus to "laser".
- Adjust (aim) the laser by hand to get a bright spot on the T-paper.
- Put the T-paper at C (just after the double slit)
- Turn the 'Wide Blocking Slit' micrometer to move the blocking slit back and forth. You should find 5 different position ranges as you move the blocking slit across the beam.
- Record micrometer readings for the *approximate middle* of regions 2,3, and 4:

  1. Totally blocked
  2. One slit blocked (dim) _ ________________________
  3. Both slits open (bright) ___ ______________________
  4. Other slit blocked (dim)
  5. Totally blocked

  1.
- Dim the lights and move the T-paper to D (near the right end)
- Watch the pattern change as you move among positions 2, 3, and 4. You should see a set of very fine vertical lines that only appear in the middle position. These are interference fringes due to the light waves from the two slits interfering destructively. With only one slit open there is no interference.

Look at the very fine fringes when both slits are open. You could do an experiment here to relate the spacing of these fringes to the wavelength and the slit separation.

$\lambda = 2d \sin\theta$

Since the wavelength λ is extremely small for light (red = 0.7μm) and d is moderately small then θ is also small and so the fringes are close together.

Now:

- Put the blocking slit into the middle position where both slits are open.
- Slide the laser to the side position out of the way
- Turn the switch at the left from ‘laser’ to ‘bulb’ (see that it is set to about 5)
- You should see a very dim green glow emanating from the snout on the bulb box.
- Replace the cover and be sure it is on and clamped down.
- Make sure the high voltage dial (black knob on detector) is turned to zero (Counter-clockwise)
- Switch on the high voltage.
- Turn the high voltage dial slowly up to 4.5 turns.

Now, try counting with the Spectech counter. Set it to a one second preset count time by

1. Turning ‘display select’ until the indicator for ‘time’is lit
2. Press ‘up’ and ‘down’ as necessary to set the time to 1.
3. Turn ‘display select’ until the indicator is back to ‘counts’

Now pressing the count button does a one second count. Do this repeatedly and see the resulting counts. You should get a variable number anywhere from 0 – 10. this is the *dark count rate* for this detector.

Continuing…

- Confirm that the switch is on “bulb”,
- Put the cover on tight, fastening it with the spring-loaded “L” clamps.
- Open the shutter by pulling up on it. (this is on top of the detector unit on the right)
- Now you should see a much higher count rate of 30 – 500 depending on where the final slit is positioned. Try translating it and do repeated counts to see the change. You can do a crude fast scan this way to see the peaks and valleys of the fringes.

Hey wait a second, are you counting “waves”? No, you’re counting “pulses” from the photomultipliers. The more light there is, the more pulses the photomultiplier detects. It seems like light is arriving at the photomultiplier in **particle-like chunks**--?!

Collect data on the interference pattern.

Do two complete scans of the scanning slit. One with just one slit open and the other with both slits open. For each scan, cover the full range from 0 to 10 mm taking a one second count at each increment of 5 hundredths of a millimeter.

Put these into an Excel spreadsheet and plot both datasets on the same graph. You may want to have one person moving, measuring the micrometer and counting with the Spectech, and then yelling out to another partner running the spreadsheet, what the counts at each position are.

Turn things off properly:

1. Close the shutter by pushing it down.
2. Dial the high voltage down to zero
3. Turn off the high voltage switch
4. Turn the switch on the left end to the off position (neither laser nor bulb)
5. Turn off the Spectech counter

One last calculation to do and a question to answer: Measure the approximate distance from the light bulb to the photomultiplier tube. Figure out how long it takes for one, erm, photon of light moving at 3×10^8 m/sec to traverse this distance. Call this Δt.

Take the highest count rate that you had (counts/ 1 sec) and figure out from that the average time between photons (1 sec / counts). (You might pause to worry here about this: How many of the incoming photons does the photomultiplier detect? Typical detection efficiencies are above 90%...). Call this time between photons T.

During the time Δt that one photon is in the apparatus, the probability that a second photon will be anywhere in the apparatus in that same time interval is approximately…

$T/ \Delta t$ = _______

So, is the interference pattern that you measure when both slits are open more likely to be due to two photons interfering with each other, or one photon interfering *with itself*?

Write up this calculation in your spreadsheet as well as a sentence or two of conclusion to your spreadsheet.