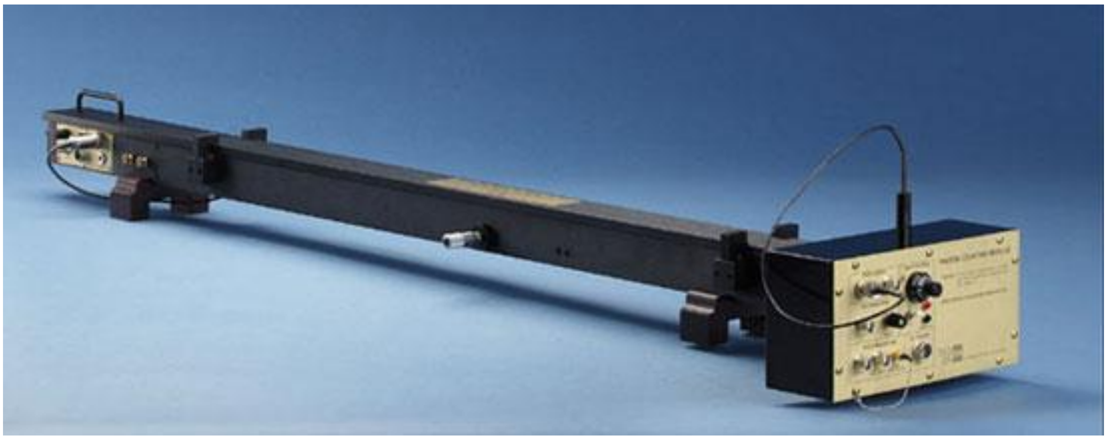
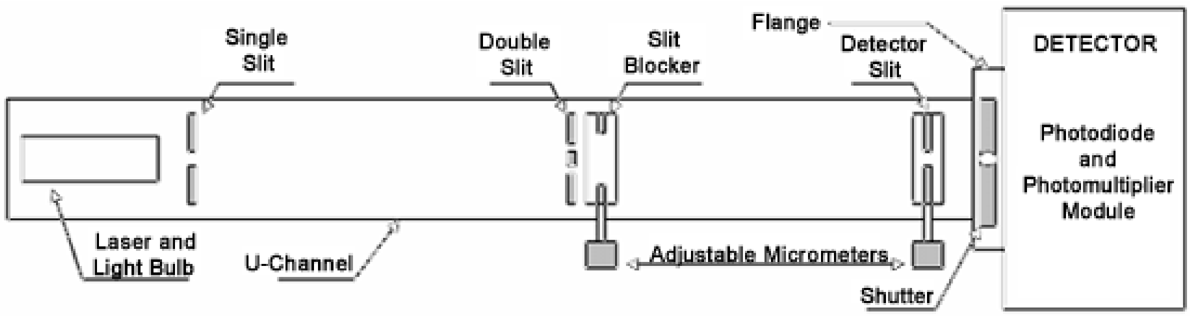
Two Slit Interference, One Photon at a Time

Before this experiment, you need to know the wave-particle duality. 'Modern Physics' textbook (Serway, Moses, Moyer) can be a good reference, which explains this phenomenon in Section 5.7.



(a)



(b)

Figure 1 (a) Experimental setup containing the black box and photon counting module. (b) Schematic of the experimental setup

The instrument consists of a black anodized aluminum U-channel, a little over a meter long, with a removable light-tight cover (Fig. 1). Students select one of the two light sources: a 670 nm, 1mW laser or a flashlight bulb. The detection system is either a photodiode, or a complete photon counting module. In front of the two light sources is a single entrance slit. With either the laser or the light bulb illuminating this slit, the central maximum of the slit's diffraction pattern is aligned to cover a double slit assembly about 40 cm down the U-channel. Just past the double slit, a movable slit-blocker can be actuated manually via a micrometer mounted on the outside of the U-channel. Using this slit-blocker, students can compare the light pattern created by the double slit with the patterns created by either of the single slits. Three double slit assemblies, each of distinct slit spacing, are included. At the far end of the U-channel is a movable single slit, the detector slit. It too is attached to a translational stage actuated by a micrometer. Students move this slit across the interference pattern, in front of either the photodiode or the cathode of a photomultiplier, to make quantitative measurements of either the light intensity or the photons' arrival rate, as a function of position. The black box with the brass front panel contains a complete photon counting module, as well as a photodiode detector connected to a current-to-voltage converter. The front panel is shown in Fig. 2. The box is supplied with a special flange and a light shutter. The photodiode is mounted on the outside of the shutter so that it is in the light path when the shutter is closed, and removed from the light path when the shutter is opened to let the light pass to the photomultiplier. The photomultiplier's high-voltage supply and pulse-height discriminator level are both controlled and monitored from the front panel. It is also possible to inject a test pulse to calibrate the charge-sensitive preamplifier.

The entire photon-counting module can be detached from the U-channel and operated independently (requiring only a 15 volt regulated dc supply). This unit is thus available for other applications in the teaching or research laboratory, such as low intensity spectroscopy or photon correlation experiments.

Figure 2 Photon counting module

The single-photon light source (Fig. 3) consists of a #47 flashlight bulb connected to a variable voltageregulated power supply. The bulb is housed in a black plastic tube with a removable narrow-band green interference filter at its output end. Although such bulbs generate about 10^{16} photons per second in ordinary use, operation at reduced power not only lowers the total production rate of photons, it also shifts their distribution toward longer wavelengths, thereby markedly reducing the production rate of "green" photons. The result is a thermal source of randomly produced photons, capable of giving a photon event rate at the detector in the range of 10^1 - 10^5 per second. Thus, it is easy to take data in the "one photon at a time" regime in which the average waiting time for the next photon event vastly exceeds the time-of-flight for a photon through the apparatus.

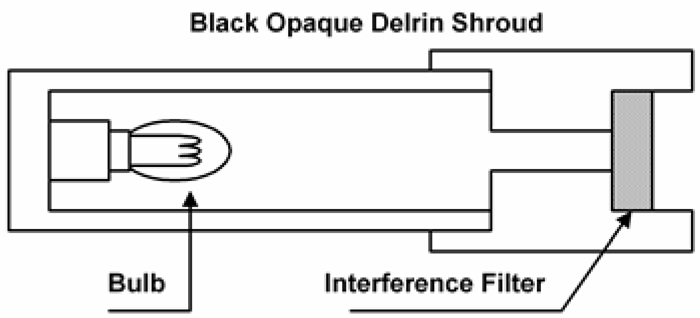


Figure 3 Light Bulb

Experiments

Part 1

1- Open the cover of the “black-box”.
2- Use the laser as the light source.
3- Use the white cards to observe two slit interference patterns.
4- Repeat the same procedure to see the single slit interference patterns.
5- You can take the photos of the interference patterns to show and explain in your reports.

Part 2

1- Close the cover.
2- Use the laser as the light source.
3- Read the above instructions carefully to understand how the shutter works. In this part, photodiode must be in the optical path; therefore, shutter will be closed.
4- Record the output voltage as a function of the position of the detector slit.

Part 3

1- Use photon counting module
2- Cover has to be closed.
3- Use the light bulb as the light source.
4- Shutter is on in order to use the photomultiplier.
5- Observe the interference pattern as a function of the detector slit.