Lab 3a Alignment for Single-Photon Interference Experiment- Week 5

Phys434L Quantum Mechanics Lab
2018

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1 Introduction

This setup adds to the setup of Experiment 1. The added components are those that constitute an interferometer. The alignment is delicate but feasible,[1] so instructions must be followed closely. We need to set up an interferometer, and its arms have to be equal to within 10 μm.

Down-conversion photons have a wide bandwidth set up by the filters before the fibers. The quantum mechanical way of understanding this is that the input photons have an energy uncertainty given by $\delta\lambda$. In our case $\delta\lambda = 40$ nm. This is an energy superposition, or wavepacket. For photons we have that $E = hc/\lambda$, where h is Planck's constant and c is the speed of light. The uncertainty is then

$$\Delta E = \frac{hc\Delta\lambda}{\lambda^2} \tag{1}$$

From the time-energy uncertainty relation we have

$$\Delta t \sim \frac{h}{\Delta E}, \tag{2}$$

which we can interpret as the temporal width of the wavepacket. Thus, a large energy uncertainty implies a short temporal width, and conversely, a small energy uncertainty implies a long temporal width of the wavepacket. We can translate the temporal width to an actual distance

$$\ell_c = c\Delta t = \frac{\lambda^2}{\Delta\lambda}. \tag{3}$$

This distance is also known as the coherence length of the light.

To see interference we must align the interferometer so that the difference in path lengths ΔL satisfies

$$\Delta L < \ell_c. \tag{4}$$

[1] E.J. Galvez et al. *American Journal of Physics* **73** 127-140 (2005)

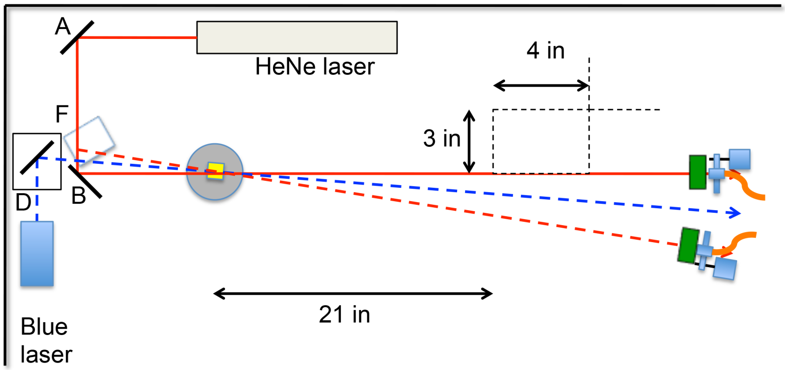


Figure 1: Approximate layout of the interferometer.

That is, the difference in the lengths of the arms of the interferometer have to be less than $\ell_c = 16\ \mu$m (!), but no worries: we have a systematic way to do this.

2 Parts

Qty	Part	Description/Comments
2	Non-polarizing beam splitters on pedestal mounts	(G) They must be identical; purchased together.
1	Mirror with pedestal mount	(I) Pedestals are very stable.
1	Mirror on a translation stage	(J) Identical to the previous mirror.
1	Piezo-electric	To be used as spacer between the translation stage and its micrometer.
1	Fiber-coupled spectrometer	One that displays the spectrum on a screen.
1	Small incandescent bulb	6-V bulb will suffice.
1	Diverging lens and mount	(L) To inspect the interference pattern produced by the interferometer.

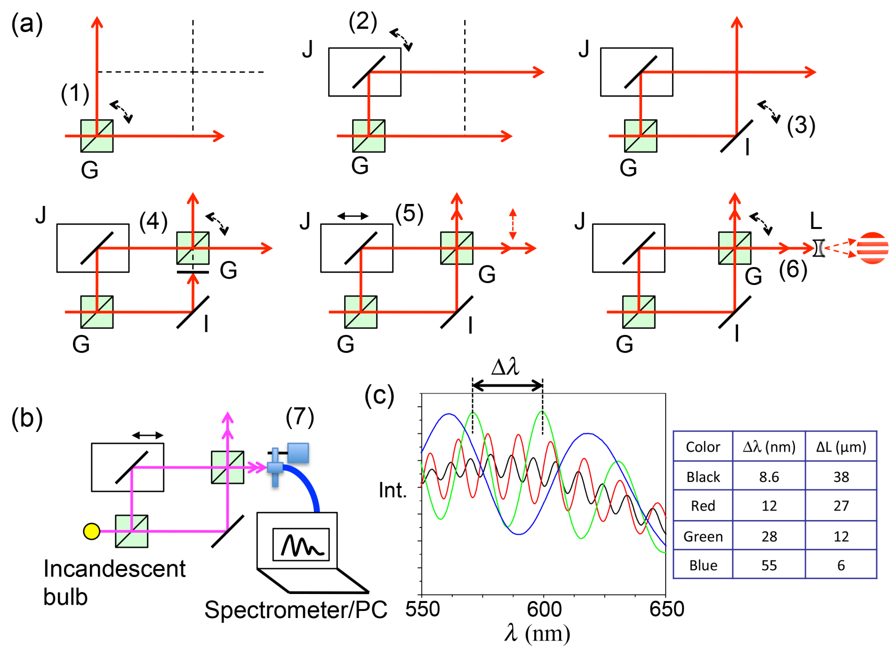
3 Procedure

The first steps in the set up involve decide where the interferometer parts are going to go. Follow the approximate layout shown in Fig. 1.

The interferometer must be as small as possible, making room only for a waveplate in each arm.

1. Insert first beam splitter (G) as shown in Fig. 2(a). Align the 90° reflection of the HeNe alignment beam. Here you have to be compulsive: we need *perfect* alignment.

2. Insert mirror on the linear stage (J) and align the 90° reflection. This step might be a bit cumbersome because the translation stage has to be screwed to the breadboard. Patience takes you far...



Color	Δλ (nm)	ΔL (µm)
Black	8.6	38
Red	12	27
Green	28	12
Blue	55	6

Figure 2: (a) Step by step schematic of the set up and alignment of the interferometer. (b) Schematic of the final adjustment of the interferometer using a spectrometer. Numbers within parenthesis refer to steps in the procedure. (c) Modulated spectrum of continuous light passing through the interferometer with different path lengths ΔL.

3. Insert mirror on mount (I) and align the 90° reflection.

4. Insert 2nd beam splitter (G) and align the 90° reflection. After this alignment the beam coming from the two arms are at least parallel to each other but at the same height.

5. Adjust the micrometer of the translation stage, which displaces one of the beams, so that the two beams overlap.

6. Add a diverging lens (L) after the interferometer to expand the beam. Fringes should be seen. Adjust the tilt of the second beam splitter for broadest fringes. Destructive interference should be a *completely dark* output. A bulls-eye indicates that the alignment is not good enough and has to be redone. We could be satisfied with this by day 1.

7. Place the fiber that sends light into the spectrometer so that it is looking into the output of the interferometer, as shown in Fig. 2(b). Place a small incandescent bulb at the input of the interferometer. Observe the fringes modulating the continuous the spectrum of the incandescent light, as shown in Fig. 2(c). This is the Alford-Gold effect. The fringes reveal the difference in path length: $\Delta L = \lambda^2/\Delta\lambda$, where $\Delta\lambda$ is the difference in wavelength between adjacent maxima in the spectrum. Broaden

the fringes by translating the stage via the micrometer. Remove the bulb and spectrometer and allow HeNe beam to go through the interferometer. Check that the interferometer is still aligned, adjusting the second BS if not. If you do not see fringes, you may have to realign.