Notes about Equipment for Quantum Mechanics Labs

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The parts list includes essentially all of the equipment you'll need to do the experiments described in the textbook. Most of the items are self-explanatory, but below are some comments and some information on assembling the equipment.

Please don't get sticker shock when you see the final price for all the equipment. You don't NEED everything here to get started. You can start with just one experiment. You can use equipment (such as optical mounts and laser current supplies) that you've already got on hand. You can skip the optical filter assemblies to save money (just use the RG780 filters). Most people will be able to put together these experiments for much cheaper than the final cost shown in the parts list.

I've done my best to research the equipment I recommend, but I have not personally tried every piece of equipment listed. You should consider this list to consist of the equipment that I would buy now if I were starting over from scratch.

Downconversion Crystals

There are three different downconversion crystals listed. One is a 3 mm long single crystal, the second is a 0.5 mm long single crystal, and the last is a pair of 0.5 mm long crystals used to create a polarization entangled pairs. The 3 mm long crystal gives LOTS of counts for experiments not requiring polarization entanglement. However, if you have a laser of 50mW or more powerful, you'll probably get sufficient counts with just the 0.5mm long crystal, and save the cost of the 3mm crystal. The 0.5 mm crystal is nice because you can use it to do dispersion compensation for the polarization entangled source, which increases the amount of entanglement. A discussion of this can be found on my "Updates" webpage (http://people.whitman.edu/~beckmk/QM/updates/updates.html , scroll down to 6/25/09).

TAC

In the optional equipment I've included one time-to-amplitude converter (TAC). I do this because it is a useful device to show students that the photon pairs emitted in downconversion are produced at the same time. You can see this by histogramming the amplitudes of the output pulses from the TAC. You can do this either using a LabView vi that I wrote (included with the other LabView files available for download), or using a multichannel analyzer (MCA). recommend my vi, since it uses an A/D converter to acquire the data, making it a lot cheaper than purchasing an MCA. Note also that I have not used the specific A/D converter listed in this parts list, but I believe that it is currently the best unit for this task.

Polarizing Beamsplitters

Also on the optional list are Rochon polarizing beamsplitters. The thin-film cube beamsplitters are fine for the other experiments, but when doing local realism experiments with entangled beams the Rochon polarizers work much better because they have better polarization quality. The problem with the cubes is that they work fine in transmission (purity of about 1000:1), but 4-10% of the transmitted polarization is reflected, meaning that the reflected beam is quite poorly polarized. Glan polarizers have the same problem, as Fresnel reflections off the inner surface give the reflected beam poor polarization properties. Rochon polarizers allow one polarization to go straight through, while the other comes out at an angle. (Wollaston polarizers are similar, but Wollastons deviate both beams, which makes them harder to align.) Since there are no reflections in a Rochon, both beams are very well polarized. We have gotten MUCH better results on local realism tests with Rochon polarizers (in Bell tests we get S>2.7 with the Rochons, while the best we've ever done with cube splitters is S=2.6, and more typically get S=2.5). The Rochons are harder to align since the deviated beam comes out at 15 deg, not at a right angle. For this reason I suggest using the cubes for the other experiments.

Filter Assemblies, Optical Fibers, Fiber Microscope

The "Optical Filters (4-channel)" are really optional, but highly recommended. You can get most of the benefits by simply placing the RG780 filters directly in front of the collection optics (you could insert them into the SM1 beam tubes for this). The disadvantage of this cheaper solution is that the RG780 filters are not blocking the SPCMs at all times (i.e., when you're shining alignment laser light backwards in order to align things). I feel it's worth the money to have the full filter assemblies to protect the SPCMs at all times.

Also, since aligning the optics means shining a laser backwards onto the down conversion crystal, this means frequent screwing and unscrewing of fibers and moving them around. Fiber tips get damaged in this process, and the fibers need to be replaced. The opaque jacket fibers are expensive – literally 10x as much as the patch cords – so you don't want to replace them. In the set up with the optional 4-channel filters these opaque jacket fibers get installed between the filters and the detectors and are never touched again.

Originally I used fiber-coupling lenses that were pre-aligned to the fiber. However, I found that since this pre-alignment is done at 633nm, the focusing is not very good for 810nm downconversion. Now I'm recommending a separate lens that can be mounted in a lens tube with an FC-connectorized fiber; the focusing of this lens can be adjusted by screwing it in and out of the tube (see details below). I achieve approximately a factor of two increase in singles count rate (factor of four coincidence count rate) by doing this if the lens is properly focused. I'm recommending this same trick be used in the optical filters as well, but I have not specifically tried doing that (I already have the pre-aligned lenses, and it's expensive to replace everything). It's likely that another factor of two increase in singles count rates will be achieved by doing this.

On a related note, the optional equipment also includes a video fiber inspection microscope and a fiber cleaner. The fibers can very easily get dirty, and when this happens your count rates will drop. After you've gone around in circles for an afternoon trying to figure out why your count

rates are down, you'll appreciate having something which allows you to inspect and clean your fibers. Note that the monitor that comes with this microscope can be used to display the image from the CCD camera.

The Alignment Laser

Note the I have NOT tried the alignment laser I have listed. I have listed it because it's cheap, espeicially since it doesn't need an expensive current source, and it should fit into a Thorlabs mount.

The assembled alignment laser is shown in Fig. 1 (again note that a different laser is shown in this figure, but your setup should look similar). The laser module goes into the adapter (AD12F), which then screws into the threaded faceplate of the KC1-T. Adjust the focus of the lens to collimate the laser output--use the SPW301 spanner wrench for this purpose.
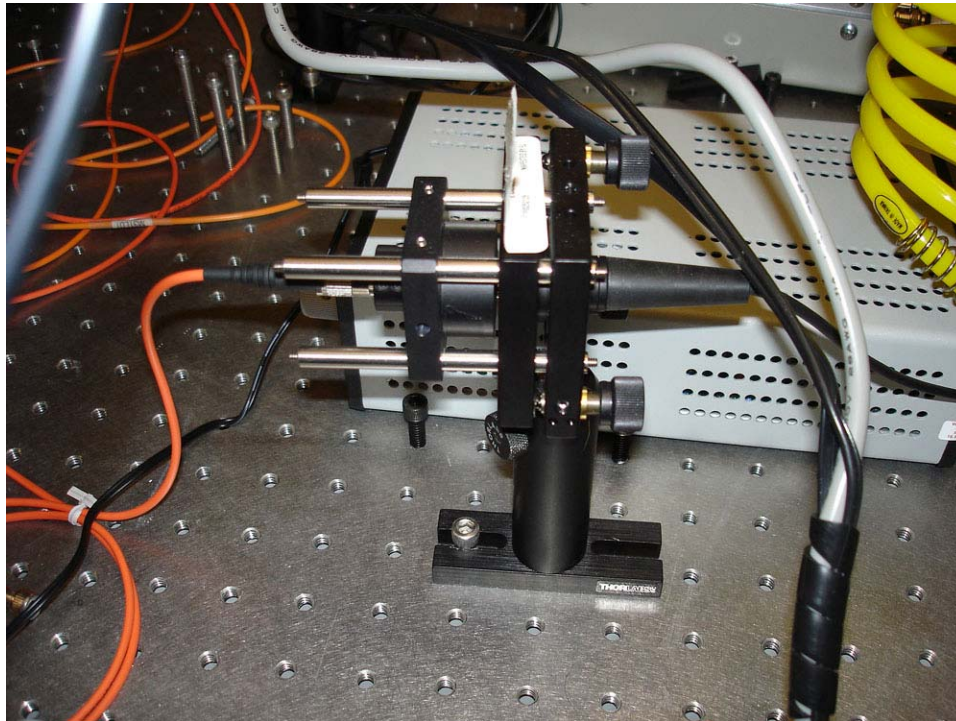

Figure 1: The alignment laser assembly.

The fiber coupling lens (F220FC-780) goes in the adapter (AD11F), which screws into once side of the cage plate (CP02), while the SM1L05 lens tube screws into the other side. The only purpose of the lens tube is to cut down on scattered light in the lab. Position the lens tube close to the tilting face plate, and adjust the tilt to maximize the laser coupling into the fiber.

Fiber Coupling Optics

See Fig. 2. The SM1FC adapter screws all the way down to the bottom of the lens tube. Secure it with a retaining ring, so it won't unscrew when you screw in the fiber. The lens gets mounted in

its adapter, and also screwed into the lens tube (make sure it's oriented properly to focus onto the fiber (flat side of lens toward fiber). To focus the lens, use the alignment laser to shine light backward through the fiber and the coupling optics (put the fiber from the alignment laser and the fiber from the coupling optics together at a fiber-fiber coupler). Place the assembly on the table, approximately the same distance from the downconversion crystal as it will be used in the experiments. Use the spanner wrench SPW909 to adjust the focus of the lens; try and minimize the spot size of the alignment laser on the downconversion crystal.
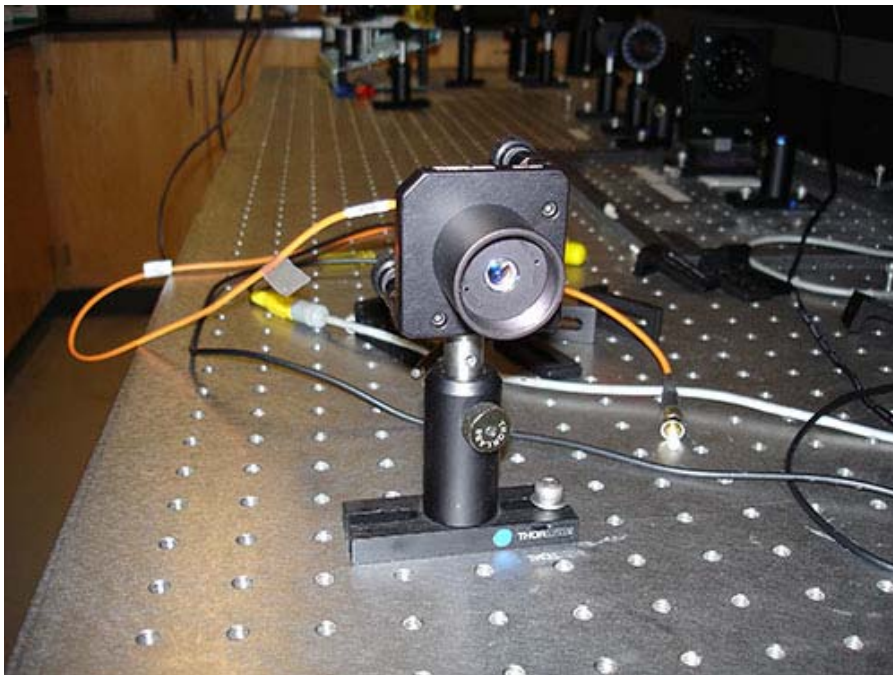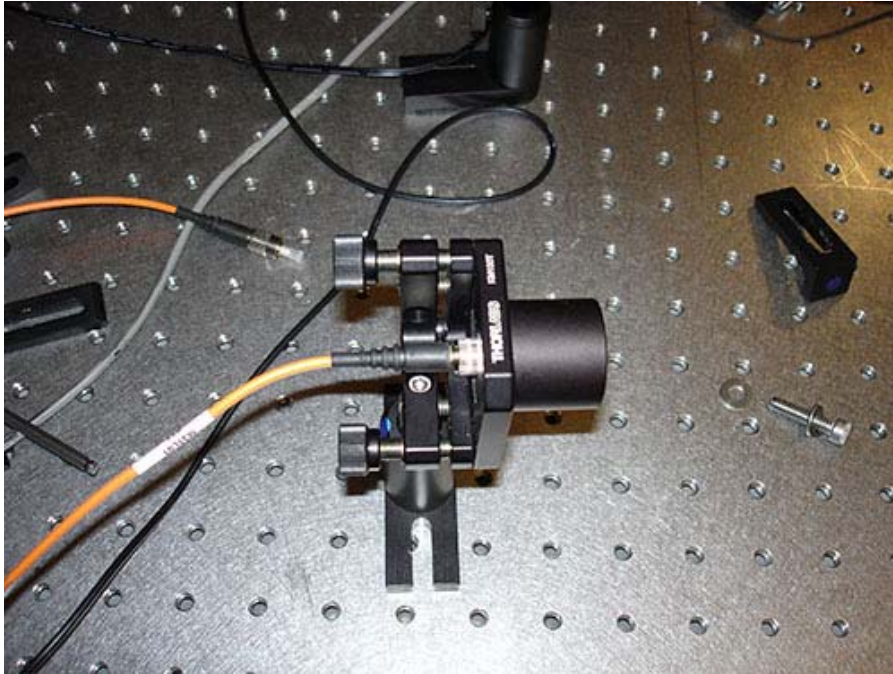

Figure 2: Top and front views of the fiber collection optics.

Thorlabs has introduced the F220FC-780, which is a pre-aligned fiber-coupling lens that is aligned at 780 nm. This should work fairly well (much better than the old lenses that were aligned at 630 nm that I no longer recommend), but I haven't tried them.

Filter Assemblies

See Fig. 3 for a photo of the filter assembly, and Fig. 4 for a photo of the entire light-collection assembly (from the fiber-coupling optics to the SPCM). To align the filter assembly, start by aligning two lenses to optical fibers using the technique described above under "Fiber Coupling Optics", except collimate the alignment laser light emerging from the lens as best you can, instead of focusing it. To collimate the beam, minimize the spot size at a point a few meters away from the lens. One of the lens tubes screws into the face plate of the KC1-T, and the other screws into the cage plate (CP02). Place the RG780 filter in the lens tube which will be closest to the SPCM; the opaque jacket fiber should be screwed into this lens tube. Place the two lens tubes close together (you can seal the gap with electrical tape, or something similar, to keep light from getting in).
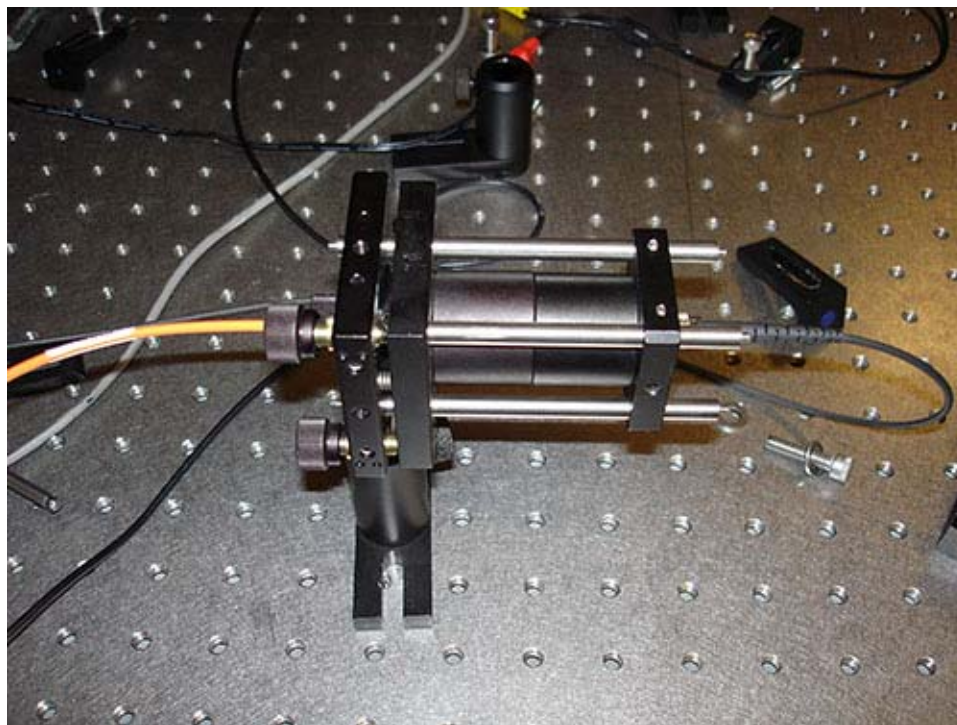

Figure 3: The filter assembly.

Again, the F220FC-780 might work here in place of aligning your own lenses.

A few notes on the opaque fibers. 1) They are not listed on the Pacer website. You must call and ask about them. 2) I don't know any other supplier. 3) You might try simply wrapping electrical tape around a standard fiber to achieve the same effect. If you don't use the opaque fibers, your backgrounds will be higher (by how much depends, but I've seen a factor of 2).
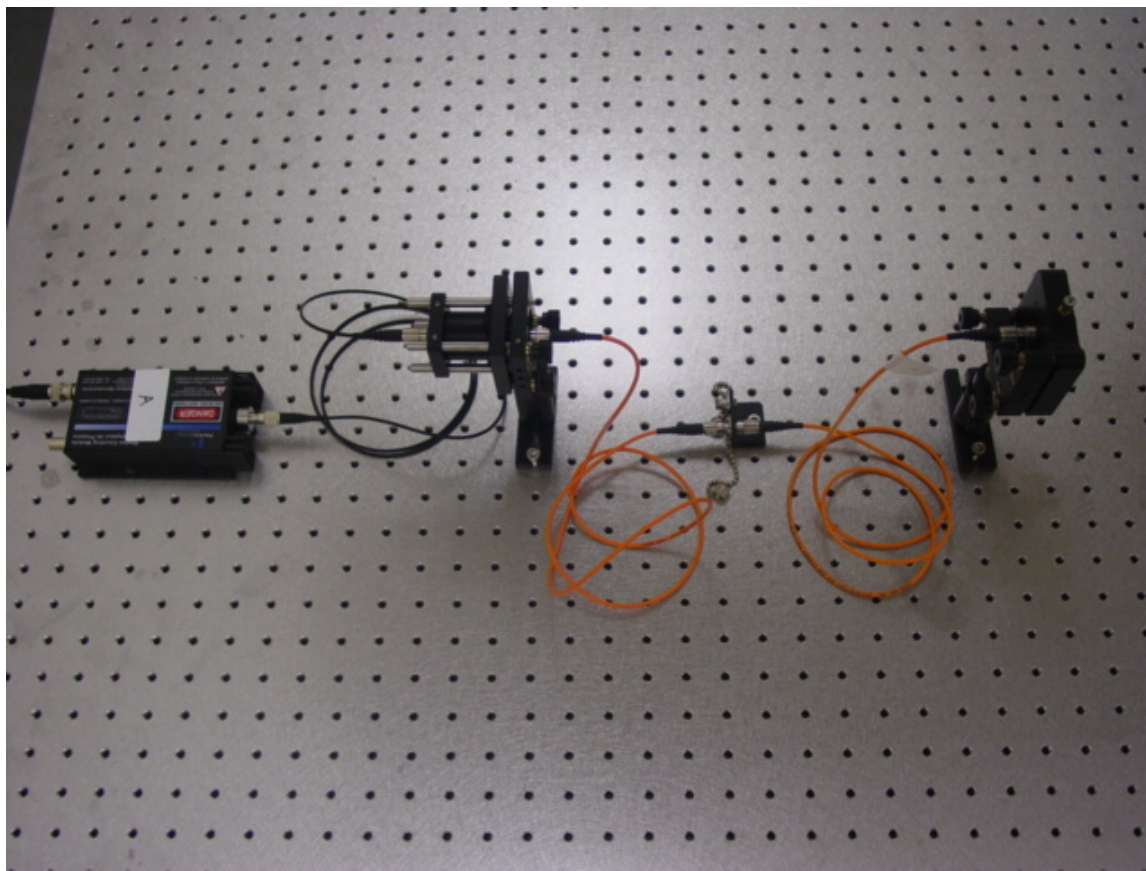
Figure 4: The entire light collection and detection system.

Align things so that you get some photons passing through the filter assembly to the SPCMs. (It doesn't matter from where--could be blue pump laser light scattering off a card. But DON'T use the alignment laser, as it's too bright at wavelengths that pass through the filter.) Monitor the photon count rate, and adjust the tilt of the mount to maximize the count rate.

Pump Laser

I don't have extensive experience with the pump laser I've listed, but I have tried it and it seems to work well. At $63 for 150mW of collimated 405 nm, including current supply, you can't beat it.

Switch for SPCMs

The SPCMs are internally wired so that the gate is held at TTL high. This enables the SPCM, so if you connect nothing to the Gate the SPCM is ON, and will count photons. To turn the counting off (e.g., to protect the SPCMs from the room lights), you can short the Gate to ground with a simple switch, like that shown in Fig. 5(a). To switch all four SPCMs with a single switch, you can connect the four gates to the switch using an arrangement like that shown in Fig. 5(b).
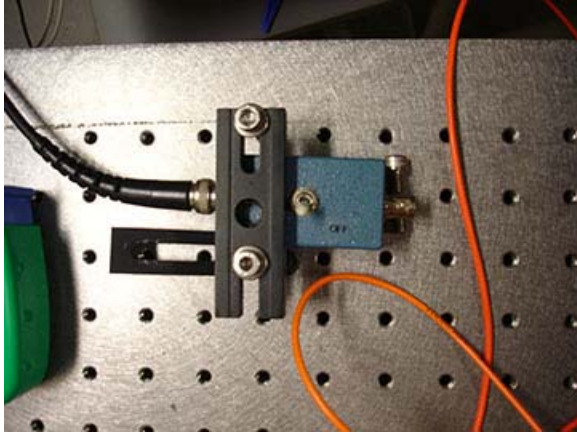
Figure 5: (a) A switch to gate the SPCMs off. It is attached to the optical table so that it is easy to find. (b) Cable arrangement to switch 4 SPCMs at once.