Notes about Equipment for Quantum Mechanics Labs

Mark Beck, Dept. of Physics, Reed College
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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.reed.edu/~beckm/QM/updates/updates.html , scroll down to 6/25/09).

TDC

I no longer recommend a time-to-amplitude converter as an option. I recommend a time-to-digital converter (TDC) instead. You don't NEED this instrument, but it is nice to show that the photons are produced at the same time. The TDC listed is the least expensive one that I'm aware of. It has a time resolution of 2ns, which is plenty for this purpose (and note that I haven't actually bought and tested it). In principle you could also use this TDC to do all your coincidence counting, but you'd have to write your own software.

Polarizing Beam Splitters

Also on the optional list are Rochon polarizing beam splitters. The thin-film cube beam splitters 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.

The Alignment Laser

An assembled alignment laser is shown in Fig. 1 (note that different alignment laser modules might need to be mounted differently). 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.

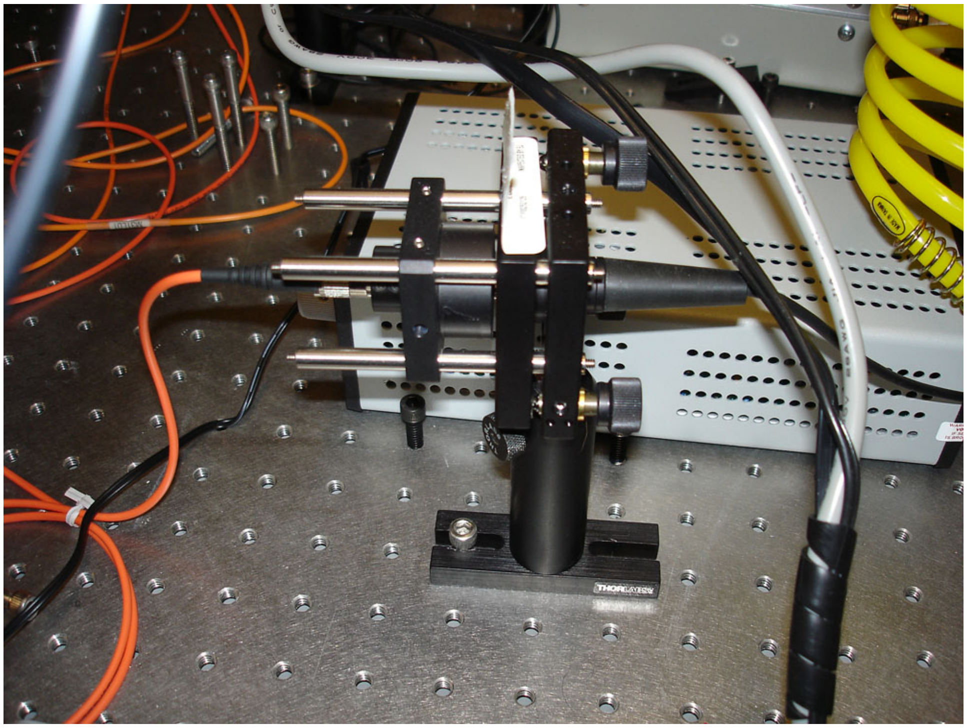

Figure 1: The alignment laser assembly.

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.

Filter Assemblies

See Fig. 2 for a photo of the filter assembly, and Fig. 3 for a photo of the entire light-collection assembly (from the fiber-coupling optics to the SPCM). One fiber coupling lens goes in the AD11F and then in the KC1-T, and the other coupling lens goes in the AD11F and then the CP02. The lens tube screws into the cage plate (CP02). Place the RG780 filter in the lens tube. Light from this side (the CP02) will go to the SPCM; the opaque jacket fiber should be screwed into this lens tube. Place the lens tube close to the face plate of the KC1-T (you can seal the gap with weather stripping, or something similar, to keep light from getting in).

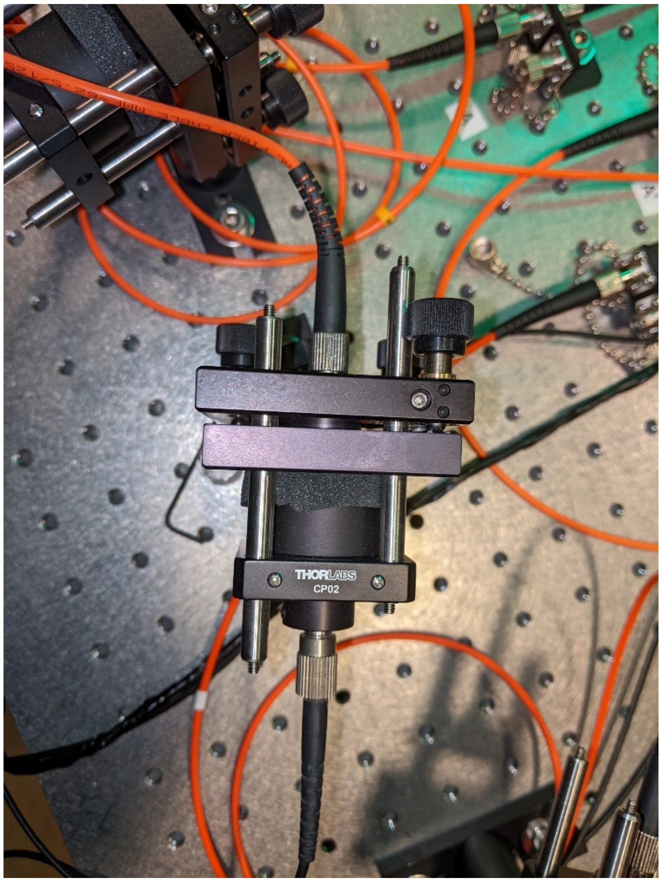

Figure 2: Top view of the filter assembly.

You might simply wrap electrical tape around a standard fiber to block stray light from getting into the last fiber before the SPCM.

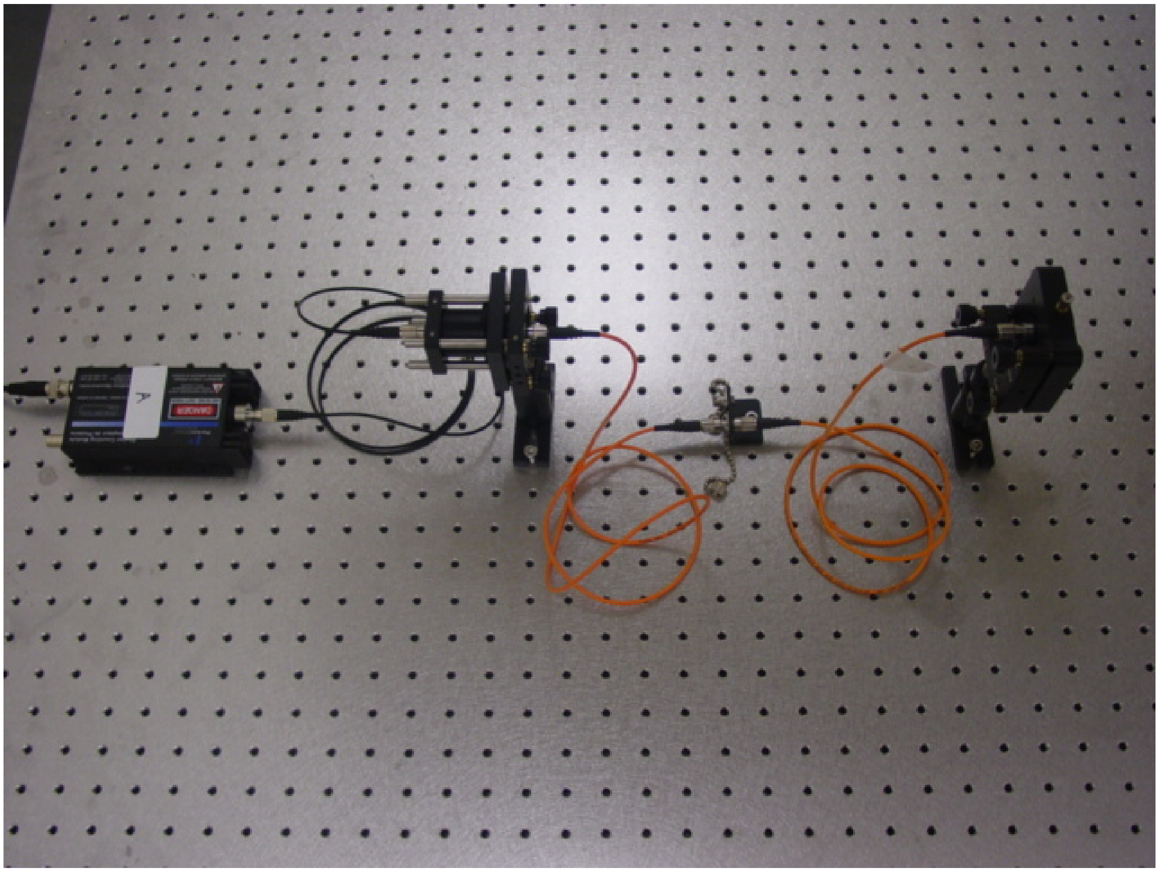
Figure 3: The entire light collection and detection system.

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

Lots of 405nm laser module options out there (they come and go rapidly, so there's no point in recommending a particular one). Nowadays may of them are 500mW and up, which is REALLY a lot of power. If they have a separate poser supply, you can often turn the power down to 100 mW or so. That will increase the life of the laser, and also make things a bit safer.

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).

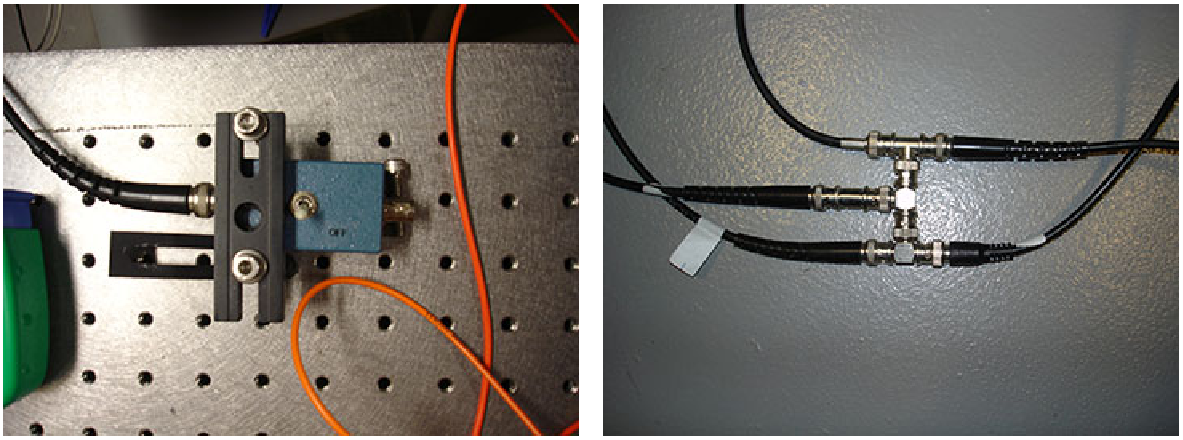

Figure 5: (a) A switch to gate the SPCMs off. It is attached to the optical table so that it is easy to find. (b) Cable arrangement to switch 4 SPCMs at once.