Relevant Procedures for Optical Tweezer Experiment

**General safety.**

1. Wear green safety goggles (rated for 1064nm light) whenever the IR laser is on and open. Let Igal (who shares the same optical table) and others around the lab know if the laser is operating at high powers (above a few mW).
2. To turn on IR laser:
   1. Turn key.
   2. Press green button.
   3. Turn up injection current to desired level.
3. Never let more than 100mW of light be incident on the detection photodiodes. This will damage them. Put a few punch cards in front of the detector to block the beam if the laser is ever higher than the damage threshold (this usually occurs around 1.4A of injection current).
4. Turn off lasers, TV, and AOM controller at the end of the day.
   1. To turn off IR laser:
      1. Turn down injection current to zero.
      2. Press red button.
      3. Turn key.

**Beam collimation.**

1. Install a mirror to divert the relevant beam, after its telescope but before the trap.
2. Send the beam to the far field (i.e. across the table or aisle), then feed it to the beam profiler.
3. Translate one of the lenses until the spot size is minimized at the beam profiler (thereby focusing it at infinity).
4. Remove any added mirrors and proceed to alignment.

**Pinhole alignment.**

1. Coarsely align beams with mirrors, make sure that the beams (in both directions) are making it (almost—expect maybe 10% loss) fully through the trap.
2. Suspend 5um-diameter pinhole between objective lenses, mounted on 3-axis translation stage with differential actuators.
   1. Piezo actuators would provide increased precision, use them if available.
3. Visually align the pinhole and the focus as close as possible, then carefully sweep the pinhole through the space surrounding the focus until a small signal is transmitted from left to right.
   1. There will not be a huge jump, simply a small increase above the background noise. This step may require a great deal of patience.
4. Maximize power output from left to right by moving the pinhole only, then fix the pinhole.
5. Maximize power output from right to left by moving the right objective lens and a mirror on the right side of the experiment.
6. Go back to left side, and now use two mirrors to maximize power output from left to right.
7. Repeat this back-and-forth process until ~70% of beam makes it through the pinhole.
8. Align the red laser by maximizing its power output through the pinhole via moving the two mirrors it reflects off before the trap. This may require a different power meter.
9. All three beams are now aligned within 5 microns at the focus. (The red beam will, of course, be relatively unfocused.) This should be good enough for trapping, but if it still fails, a 1um pinhole may be used, although it is ~25x as difficult to align, unfortunately.
10. Carefully remove pinhole from trap and proceed.

**Alignment of photodetector.**

1. Once the beams are aligned, it is imperative that the balanced photodetector also be aligned to maximize signal to noise.
2. First, coarsely align the beams (i.e., ensure that they seem to be incident on the photodiodes) with the FIND-R-SCOPE and the three mirrors in the detection area.
3. Balance the powers of the split beams by moving the D-shaped mirror in or out of the way of the beam.
4. Connect the detector to a multimeter.
5. Adjust mirrors until the detector output is sensitive to all FOUR of its adjustment knobs. There should be an optimal position for each (i.e. output behaving like a local extrema)
6. Then, leave mirrors fixed and maximize the output with each adjustment knob on the detector.
   1. Be careful, one of the PDs yields a negative voltage (hence the “balanced”). So, for one of the diodes, you will want to minimize the output (to as large of a negative number as possible), rather than maximize it.
7. Check that the amplitude of the noise is small compared to the signal (by collecting data with the computer). If it is not small compared to the signal, restart the detector alignment process, and check, either with indicator cards or the FIND-R-SCOPE, that the laser is not hitting the edge of a mirror or any other sort of unusual/unexpected behavior.
8. Proceed with trapping and data collection.

**CCD camera focusing.**

1. If the image on the television of a trapped bead is out of focus, you can translate the lens that is mounted on a stage in front of the camera. This will also require fine horizontal adjustments of the mirror right in front of the trap, as the lens’ path is not perfectly parallel to the path of the beam.
2. If the camera is saturated, place ND filters, found in a lightly-stained wooden box in the slower area, between the camera and the objective lens.
3. If the camera is completely out of focus or pointing in the wrong direction, you may wish to suspend a needle (likely from a translation stage) near the focus and then align the camera system to the needle.

**Trapping.**

1. Clean coverslip with methanol if it has been a while since it was last cleaned—this will make it easier to shake microspheres into the trap.
2. Make sure the amplifier (electronics in small cardboard box) is **UN-PLUGGED** from the power source. The on/off switch does not work, so you must unplug it to ensure you will not be zapped. Then, install piezo shaker in chamber and connect wiring to amplifier.
3. Make sure that CCD camera is focused, and television monitor is on.
4. Make sure that the intensities of the trapping beams are matched at the focus. This is difficult to measure exactly because of lens aberrations, but it has been found that the left beam should be about 1.15-1.25 times more powerful than the right beam before entering the trap. 78mW and 72mW (at injection current of 1.2A) for the left and right beams, respectively, has been found to be very effective for trapping. The distribution of power between the two beams can be manipulated by rotating the waveplate directly in front of the IR laser.
   1. If the beam coming from right to left looks weak or distorted, check that the AOM is on and functioning properly. If you check the rear beam with a detector card, there should be two dots to the left of the aperture in the back of the experiment and only one to the right, as the aperture blocks the zeroth order diffraction beam.
5. Select desired size of microspheres and carefully insert clean Q-tip into vial, covering one side of Q-tip with spheres. Remove Q-tip and put cap back on vial.
6. Rub the Q-tip against the coverslip and ensure that the coverslip is coated.
   1. Some microspheres will fall during this step and may even become trapped. Very convenient.
7. Plug amplifier into power source, and crank voltage until the shaker makes an audible buzzing sound.
   1. Various techniques have been employed at this stage, but generally short bursts of power are more effective than long periods of high voltage supply. The goal is always to produce a good-looking plume of spheres that pass through the trap. Clumps are undesirable.
   2. The amplifier will output no current to the shaker below a certain input voltage (around 60V). So, you can twist the knob slightly past this threshold to shake, and then quickly turn it back to create a “pulse” that generally works well.
   3. Turn off immediately when a particle is trapped—additional particles may dislodge the one you have trapped.
   4. Use CCD to confirm the trapping of a single bead. If it is multiple (unusually bright, large, or pulsating background), you can drop it by blocking the IR beam anywhere along its path with a punch card.
   5. If you continue trapping multiple beads, turn laser injection current down, as a double-well may have formed. We have trapped at as low as 1.0A.
      1. If this does not work, you may need to realign with a pinhole.

**Data collection.**

1. Data collection is done on the computer next to the setup. It does require a password.
2. Open up GageAcquire.
3. The only relevant parameters on the collection software are sampling rate and segment size. The current values (10MHz and 4000128) work perfectly fine, but it may become relevant to explore different values.
4. Save the .txt file that appears on the desktop as YYYY\_MM\_DD\_#.txt where # is the run number from the day, then move it into the Brownian motion folder (also on the desktop) and update Note.txt with the parameters used in the sample.

**Data analysis.**

1. It is easiest to get the data onto your computer via TeamViewer.
2. If possible, clone the GitHub repository, located at https://github.com/gabealvarez11/BrownianMassMeasurement.git.
3. All crucial Python analysis files are either located in \Gabe\polished or \Julia. Raw data should be put into \Data\rawdata.
4. Once the raw data is in obtained, it should be noise filtered with filter.py. It will be saved to \Data\filtered.
5. If a major change in the optical setup has occurred, calibration.py should be used to determine an appropriate calibration factor. Be sure to use data samples from different sizes of beads.
6. The filtered data can then be averaged, differentiated, and fit to the Maxwell-Boltzmann distribution in dataToMass.py, and the dependence on the length of sample can be explored in graphFittings.py.
7. If there is any concern with the averaging length, use graphPosAndVel.py to see actual position and velocity plots.
8. Contact me if there are any questions! There is also a README file in \Gabe\polished.