ALIGNMENT OF CONVENTIONAL ROATING ARM INSTRUMENT

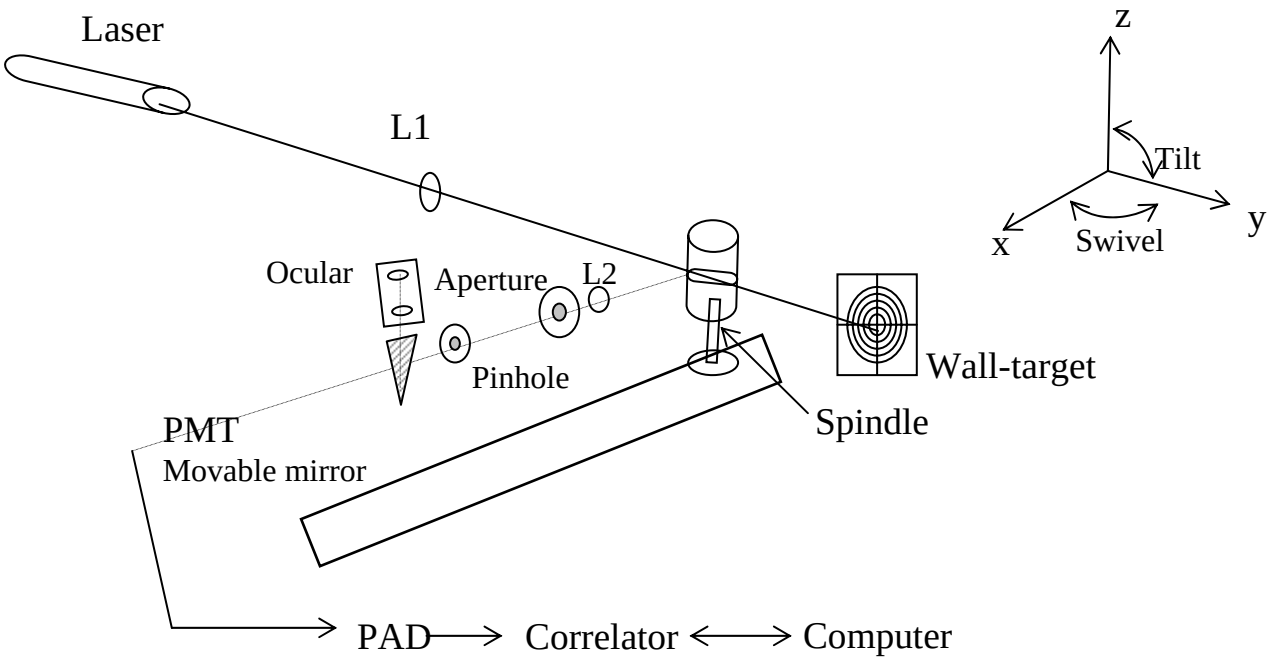
GENERAL PRINCIPLES

The most important thing in aligning the instrument is ensuring that the beam GOES OVER THE CENTER OF THE TABLE. The particular direction it's going in when it goes over the center is unimportant, as adjusting the zero indicator and wall target internally compensates this. Another feature of our instrument would be considered a nuisance by some. This is the relative inattention paid to VERTICAL alignment (beam height and upward/downward tilt). The use of a lens in the detection optics makes alignment a snap; bur easy alignment requires that AT EACH AND EVERY ANGLE, the lens on the detector arm undergo a SLIGHT vertical adjustment. This is simply a design choice. (In fact, vertical tracking is relatively stable in this system, even without special care).

INTRODUCTION TO ELEMENTS OF THE SYSTEM

PARTS

The diagram shows the major parts and tools used in alignment. The diagram also gives the coordinate system. The laser beam travels in the +y direction. Hence, +x axis corresponds to detector at 90 degrees scattering angle. +z is the "up " direction. "Tilt" is a vertical rotation in the yz plane, about x-axis. Swivel is a horizontal rotation in the xy plane about z-axis.

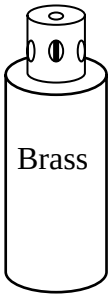


Source: Laser, with x, y, z, tilt and swivel adjustments.

Lens L1: Input condensing lens, with x, y, z, tilt and swivel adjustments.

Spindle: This is where we attach cell holders, insulators, etc. It is important in our apparatus that the distance from the spindle center to the edge of the table (where angle is read) is the same in all directions. This has been checked by the machine shop and, barring catastrophe, should remain stable.

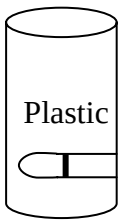
Primary Alignment Tool (Brass): When the cell holder assembly is changed, disassembled or whenever you are in doubt about alignment, the primary alignment tool should be placed on the Spindle. The laser beam should be placed on the spindle. The laser beam should be adjusted until exactly the thin pin in the primary alignment tool bisects it. The primary alignment tool is pretty well made by our shop. However, you will detect a very slight difference if you rotate the tool by 90°. This can be considered the absolute limit of our alignment.



1° Alignment Tool

Cell holder: We have (or plan) two so far. The original small holder for square cells and 1" vat and the 3.5" Hellma vat holder. Alignment of these will be slightly different.

Secondary Alignment Tool: Fits in the cell holder/insulator assembly. In the small cell holder, the copper block is movable and the goal is to center the copper block AFTER the beam is made to cross the center of the table using the primary alignment tool. For this purpose, the cell holder/insulator assembly can be rotated by 90°. The secondary alignment tool should bisect the beam at either position of the cell holder/insulator assembly. Barring disaster or disassembly, the secondary alignment tool is sufficient for testing laser position and routine alignment from the primary pin has been successfully "transferred".



2° Alignment Tool

Lens L2: Receiving lens, with x, y, z, adjustments. The lens is pretty common in other systems, but is not universally used, and one could design a system without it. Its purposes are:

1. To produce an image of the pinhole (see below),thus defining the scattering volume, which depends on scattering angle as sin(ϑ)
2. To adjust for minor vertical misalignments
3. To provide for magnification of the beam, at the same time demagnifying the image of the pinhole to provide a very small viewing volume without using so very small pinholes. This also minimizes the effects of vibration of the detection arm
4. To focus all light not coming from the center of the cell (e.g., room lights) to a point in the plane of the aperture (see below), which does not hit the aperture center, and hence is prevented from being detected. This is how we can operate (pretty well) with lights on, without using a laser line filter, as in some systems.

Aperture: Rotating choice of 8 sizes. Located one focal length (approximately) behind lens L2, this element has several functions.

1. Together with pinhole, it determines the number of coherence areas for quasielastic scattering.
2. It also sets the angular resolution of the instrument
3. As described under "L2" it limits the entrance of off-axis light.
4. It plays a minor role in determining the scattering angle.

Pinhole: Rotating choice of 8 sizes. The distance from the pinhole to the center of the cell is about 400nm, and was selected to be about $4*f_{max}$, where f_{max} = 100nm is the largest focal length for L2 which will produce focused image. For our usual choice of L2 (80nm), the distance between L2 and cell center is smaller than L2 and pinhole, in order to produce a magnification of about something like 4 at the pinhole. The pinhole is primarily responsible for volume selection, which varies as sin (ϑ). Note: without lens L2, the sin (ϑ) dependence would degenerate at low angles. The pinhole also serves a role in determining the number of coherence areas, together with the aperture.

Movable Mirror: When lever is in "up" position, this will send the scattered light to the microscope, which will magnify it by about 25x overall, for a total of near 100x. In this position, theoretically the phototube will not see any light. However, it is not wise to aim the detector arm directly at a bright source with phototube on, because some light may leak through or, worse, the mirror lever could move down, exposing phototube.

Phototube: Obvious

Wall target: Used as a visual aid to tell if something has gone wrong with alignment, and also to transfer unfocussed zero to zero when lens L1 is inserted. See step 12 below.

PAD: Pre-amplifier / Discriminator. This device serves two functions. Photons detected at the photocathode of the PMT will produce charge pulses can also appear at the anode, which are NOT related to photons. These are "discriminated" against by the PAD. The PAD also "standardizes" all acceptable pulses. It works like this: charges are amplified

and covered into (I think) a voltage level big enough to make discrimination easy. Those amplified to a level larger than the threshold level (which can been, and has been, set to match the tube and voltage level) are retained and turned into "standard" ECL pulses (like TTL, but different voltages). These are passed on to the correlator and/or ratemeter on the photometer. The distance from phototube to PAD must be kept short, but distance from PAD to photometer can be long.

Photometer: We have (or will have) at least two systems. The common one is the PPI 126, which combines a ratemeter with high voltage (for phototube) and TTL outputs corresponding to the ECL inputs, which are fed to the correlator. A second system will arrive eventually, which will be all ECL, not that is matters much.

Correlator: Obvious.

STEP-BY-STEP ALIGNMENT PROCEDURE

1) Remove lenses L1 and L2, cell holder, and turn off high voltage phototube.
2) Set the beam height and levelness. The nominal height is 3.5 inches above the rails on the detector arm (note input rail is 4.1 inches above the optical table. You can see whether the beam is level using a simple ruler. You can get it to the right height by making it hit the center of one of the pinhole mounts. Easy.
3) Transfer the alignment. A rare first step in this is to adjust the ocular of microscope to focus on the crosshairs. This might need to be done about once a decade. After this, remove the spring-loaded tube joining the pinhole and apertures. Look into the microscope and focus on one of the pinholes. If necessary, loosen the four socket head cap screws connecting the microscope plate to the pinhole assembly block. Move the microscope around until the crosshairs center on one of the smaller pinholes. It isn't generally possible to get ALL the pinholes to the center exactly. However, they can be pretty close: i.e., to within about 0.001 or 0.002 inches, I think. The pinholes have been mounted so as to optimize the centering of the vertical crosshair (i.e., optimized for horizontal-angular-alignment). Worry less about making the horizontal crosshair bisect the pinhole image. I recommend setting it to center on the 100μ pinhole, which is a commonly used one. When aligned, retighten the four socket head capscrews, which usually messes up the alignment some. It requires gradual tightening and iteration to get it right.

Note: THE ABOVE STEPS SHOULD ONLY BE REQUIRED AFTER DISASSEMBLY OR OTHER DISASTER. ROUTINE ALIGNMENT IS DONE BY THE STEPS BELOW.

4) If not done already, remove L1 and L2.
5) Turn off photometer high-voltage power supply, if on.
6) Set mirror to up position, in which case phototube is protected and your eyes ARE NOT! Whenever the lever is up, there is potential danger to your eyes

7) Remove the spring-loaded tube, which connects aperture rotator and pinhole rotator. Note that the tube has a definite front and rear. It is labeled on the inside, should you forget.
8) Rotate the detector arm until the beam hits the exact center of one of the pinhole mounts. For this step, the aperture should be all the way open. For greater accuracy, you can move the aperture / pinhole/ phototube sliding apparatus all the way back on the phototube arm. DO NOT LOOK IN MICROSCOPE DURING THIS STEP> YOU COULD GO BLIND.
9) In the previous step, you DEFINED where zero is. Now you FORCE the scale to read zero by moving the scale marker.
10) Move the detector arm away from zero until the laser beam strikes the wall. Center the target on the wall to the beam. You see, the alignment is internal to the instrument. The target moves according to the instrument's alignment, not vice versa. However, the target is used in the next step to align lens L1.
11) Remount lens L1. Use gimbal adjustments to set tilt and swivel until beam is reflected off L1 back into laser, ALMOST. For optimum laser performance, you don't really want reflections to go exactly back into the laser cavity. Now use x-z controllers to make the expanded laser beam image strike the center of the target. Be careful about this step.

[Alternate step 11) Put the secondary alignment pin in and move the x controller so as to make the focused beam pass first just to the left and then just to the right of the pin. Then move x controller back to middle of these settings. This method is totally internal to machine and does not rely on target on the wall at all. It's more difficult, however, and to do effectively, you really have to install a micrometer drive on the L2 holder. We have one, but I've never installed it, since the target method works well enough].

12) Move detector arm to exactly zero again. Put in lens L2. Use x and z controllers to bring beam through smallest pinhole. It may be helpful to aim for larger pinholes first. DO NOT LOOK INTO MICROSCOPE AT THIS STEP. If you did step 4 right and alignment of microscope hasn't changed, a '+' diffraction pattern from the crosshairs should be visible by laying a piece of paper over the microscope at this point.
13) There may be other alignments specific to the particular cell holder in use.

TESTING

- A first test, which should always be performed, is to mount a water sample in a cylindrical cell. The beam should still hit the target.
- A γ vs. q^2 plot should be generated for one of the standard latex sphere or silica sphere samples. The intercept should be near zero.
- Intensity vs. angle scan can be made for toluene or water. Water is the tougher one to do, so makes a better test of system performance. The quantity $I*\sin(\theta)/\sin(\theta=90)$ should remain unity plus or minus about 1 or 2 percent from 20 to 135 degrees. Remember to subtract phototube dark count first.