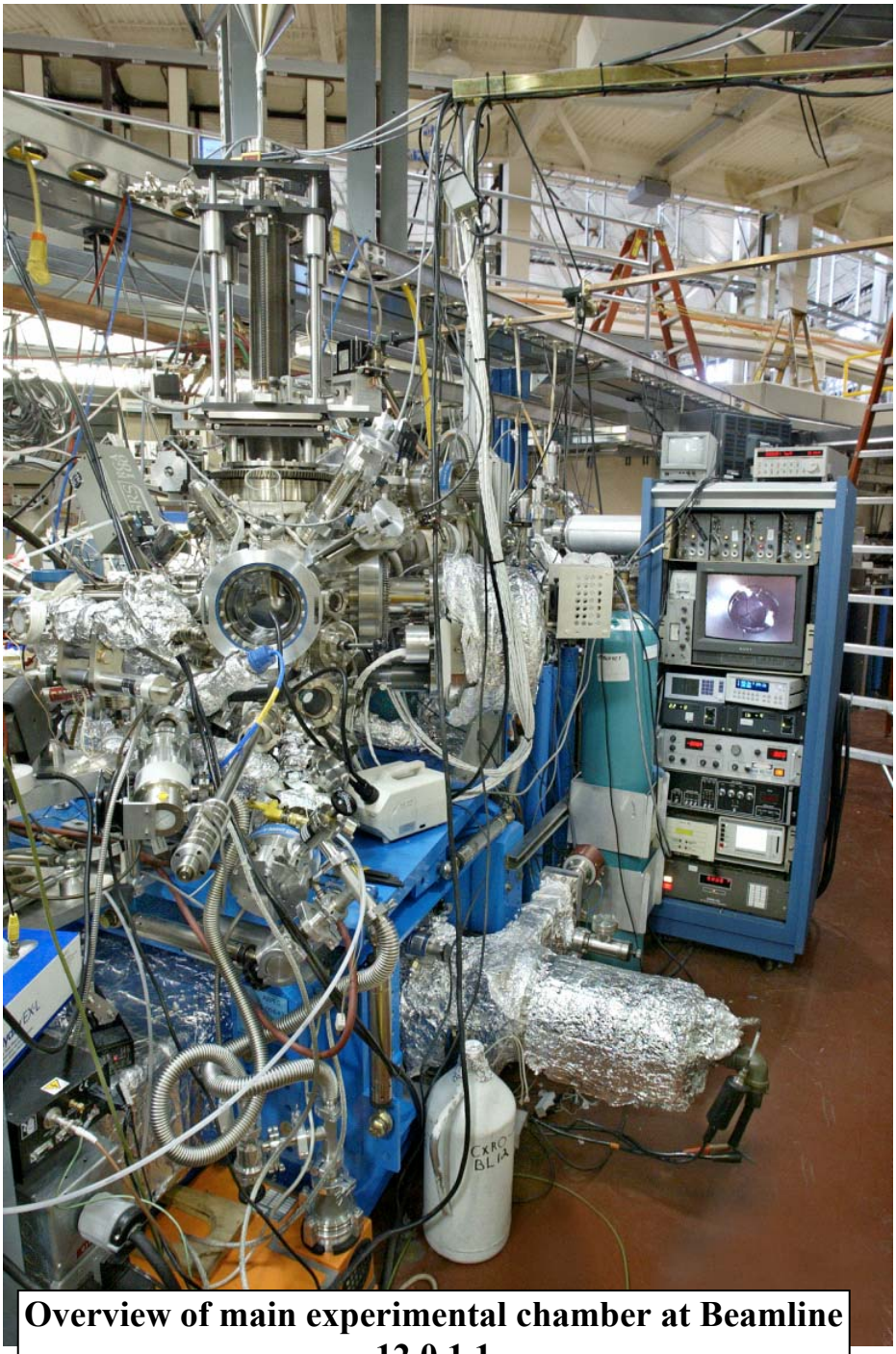
Beamline 12.0.1.1 Manual



Overview of main experimental chamber at Beamline 12.0.1.1

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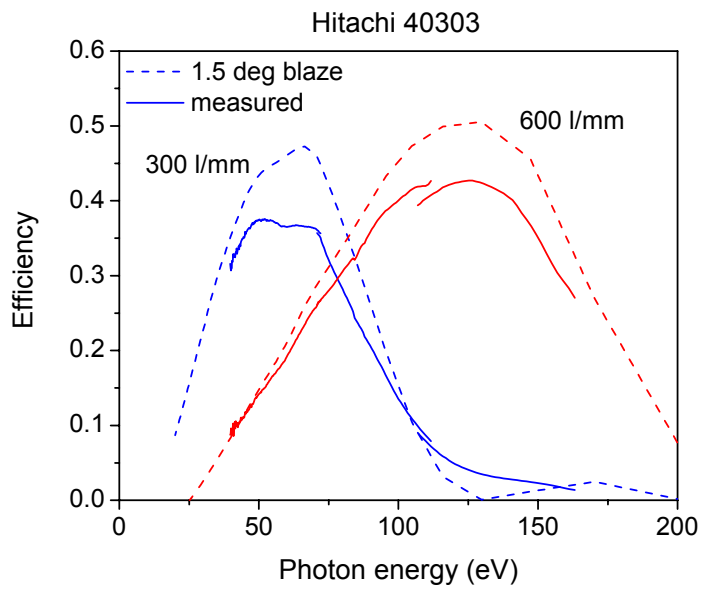
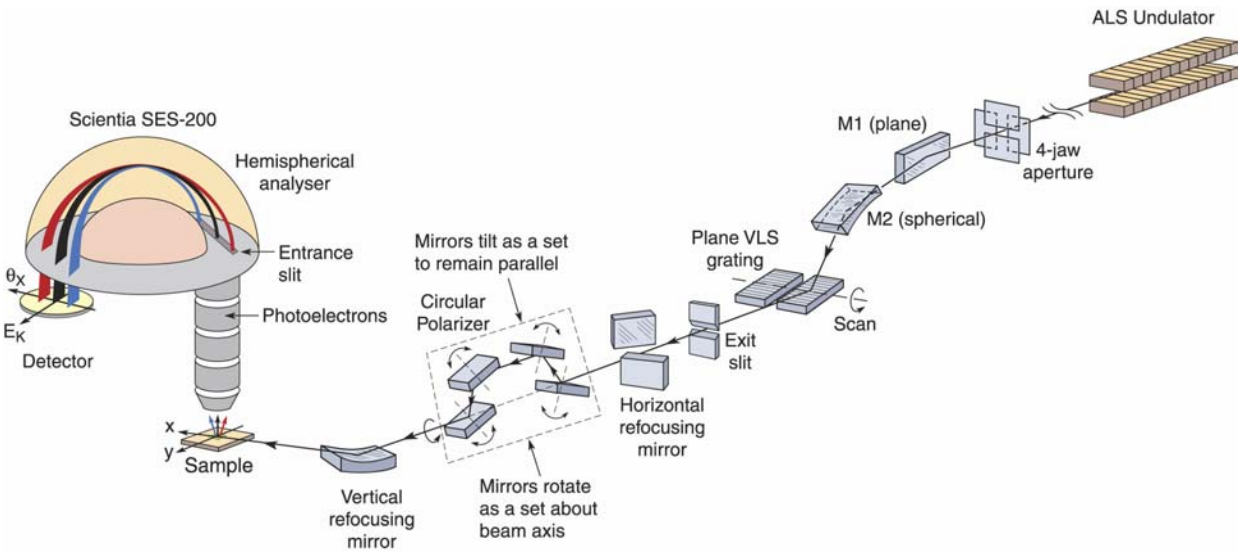
Overview of the Beamline:

Beamline 12.0.1.1 is the ARPES (Angle Resolved Photoemission Spectroscopy) branch of beamline 12 at the ALS. Below is a simplified diagram of the optical design of the beamline (See the end of this document for an enlarged version of this diagram). Light leaves the U8 undulator, after which it is collimated by the 4-jaw aperture before moving on to the first horizontal plane mirror (M1). It is then deflected slightly down by a spherical mirror (M2) to the monochromator. The monochromator contains three plane VLS gratings- one has 200 lines per mm, one is blank, and the third has two areas with different ruling densities- a 300 line/mm area, and a 600 line/mm area. The 200 line grating is optimized for ~60 eV and provides a resolving power of ~1200. The efficiency curves for the 300/600 grating may be viewed below. The 300 line grating is optimized for ~50-75 eV with a resolving power of ~. The 600 line grating is optimized for ~125 eV with a max resolving power of ~10,000.



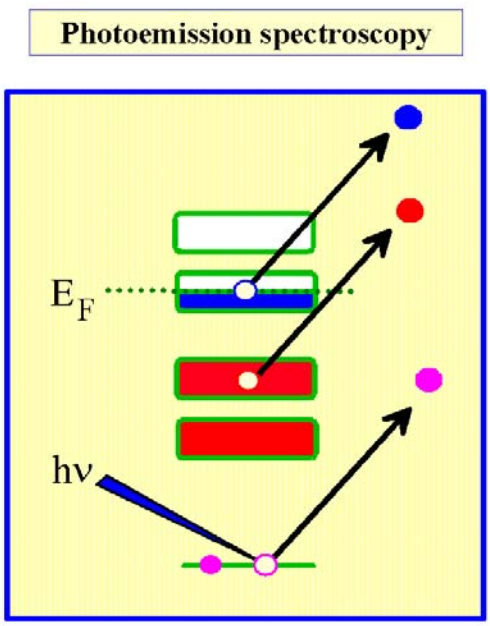
The overall range of energies for this beamline is from about 20-320 eV. The beamline is quite bright- the 200 l/mm grating can deliver about 10^{13} photons/s at 134 eV. This brightness made it possible to install the low energy circular polarizer which uses reflection off of four plane polarizing mirrors to turn the linearly polarized light from the undulator into left or right hand circularly polarized light. With this polarizer it is possible to achieve nearly 100% circularly polarized light for energies up to 80 eV. Just downstream from the monochromator grating is the exit slit, which can close down with precision to a few microns. Down from the exit slit is the M3 horizontal mirror, which deflects the beam to any of the three endstations at beamline 12, and controls the horizontal focus of the beam in the main chamber. Just downstream from the M3 mirror is where the circular polarizer is located- when not in use, it allows the beam to simply pass through to the vertical focusing mirror. Tweaking the vertical and horizontal mirrors should rarely be necessary- the beam has been aligned to maximize flux and resolution to all three endstations on Beamline 12.



Optical Design of Beamline 12.0.1.1

Photoemission Spectroscopy:

Photoemission Spectroscopy relies is a combination of two techniques of great importance in physics. The first is photoemission, whereby one may strike a surface with a photon and expel an electron with a characteristic energy, and the second is spectroscopy, where one studies the distribution of energies emitted from a sample, surface, or object. An excellent description of how the two work together is given by Laurent Alvarez on his personal website (http://www.geocities.com/ CollegePark/3972/index.html):
"Photoemission is widely used in the study of the electronic structure of solids. It utilizes the photoelectric effect in which an electron is ejected from the occupied electronic levels of the sample. In a photoemission experiment, the kinetic energy of the photoelectrons usually varies from a few electron volts up to a few hundred electron volts, depending on the photon energy used. This results in the surface sensitivity of the technique, as the inelastic mean free path of a typical photoelectron in the solid is in the range of 5-30 Å. This means that UHV (ultra-high vacuum) is necessary to maintain a surface of adsorbates during the time scale of measurement, and that the surface effect should be borne in mind during the interpretation of the resulting spectra."



$$E_B = \hbar\omega - E_{kin}$$

ΔE: 350 meV Al:Kα; 80 meV He I

The figure to the left shows "excitation of an electron from an electronic state below the Fermi level by X or UV rays (occupied states)"

Using the formula to the left, we may analyze the kinetic energy of the emitted electrons to get the binding energy of the state, telling us where the electron was excited from, or what materials may be present in the sample. The resulting spectra will give us insight into the density of the electronic state(s) that are present in the sample.

A more accurate and representative idea of what is going on with electrons within a solid and the angle-resolved aspect of ARPES is well described by the UK Surface Analysis Forum web site (www.uksaf.org/tech/arups.html):

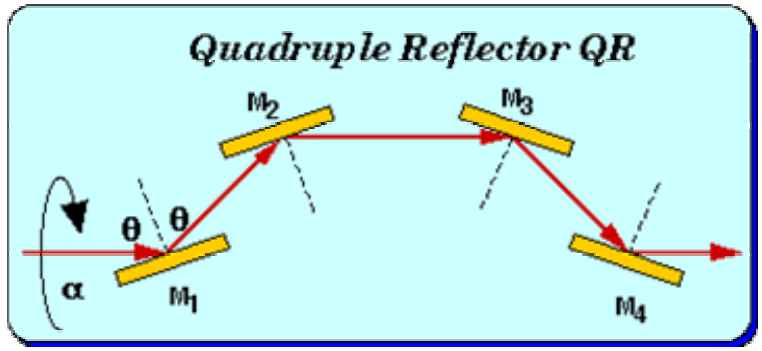
"In an isolated atom, the electrons occupy certain energy levels. In a solid, the levels involved in bonding 'the valence states' become blurred, and electrons can occupy a range of energies bands. The energy of an electron in the solid depends on its momentum. Hence, by detecting photoelectrons emitted from a surface at different emission angles, the energy of the electrons as a function of the momentum vector may be determined. This process is

known as 'band mapping' and is a powerful probe of the electronic structure of crystalline materials. The measurements can usually be compared with theoretical predictions."

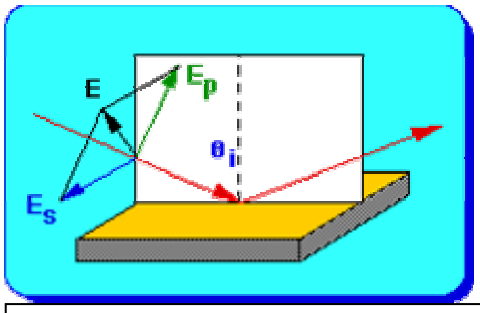
For information on how the SES-100 Analyzer works, please refer to its manual, located at the beamline.

The Circular Polarizer:

The Circular Polarizer (or CP) at BL 12 was installed in September of 2002, and has opened up a broad range of experimental possibilities at the beamline. The CP can transform the linearly polarized light produced by the U12 undulator into elliptically polarized light of any orientation. More specifically and importantly, it can transform the light into left or right-hand circularly polarized light. It does this using the simple concept of plane reflection in a precisely aligned system of 4 mirrors.



Optical Design of the Circular Polarizer



When light reflects off of a metallic surface, it is reflected into two resulting components, called the s- and p-polarized components. This is true for incoming light of any polarization. Reflection off of a metallic surface also introduces a partial phase change between the periods of the s- and p-polarized components. For each successive reflection off of a mirror, the phase difference between the s- and p- components changes.

Reflection of an EM wave off of a metallic surface

This phase difference changes as a function of the angle of incidence of the light onto the reflecting surface (mirror). Since the CP has been designed so the beam reflects off of each mirror at the exact same angle, we produce 4 consecutive equal phase shifts. If we align our angle of incidence such that the total phase shift introduced over the four reflections is 90 degrees, we have perpendicular components of light with equal maximum amplitudes and a phase difference of 90 degrees- this is the definition of circularly polarized light.

Criteria for circularly polarized Light :

a) match Amplitudes

$$\tan \alpha = R^*_p / R^*_s$$

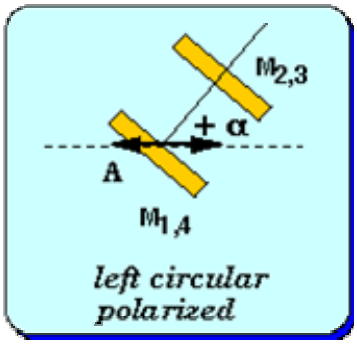
b) match total Phase Shift

$$\Delta = 4^*\delta = \pi / 2$$

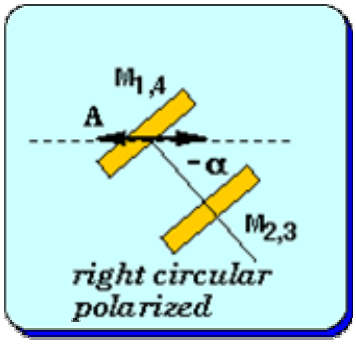
CP Light Criteria

Since the CP is designed to send light out on the same axis as [illegible] linearly polarized light into circularly polarized light by adjusting the [illegible] introduce a 90 degree phase difference. We adjust the alpha angle of the polarizer to choose either left or right circular polarization. For any given alpha angle, one can change theta in order to get CP light. Depending on whether the phase difference is + or – 90 degrees, we will have

light that is either left or right circularly polarized- rotating alpha once we find either left or right CP will allow us to switch to the other.



Left CP Mirror Alignment

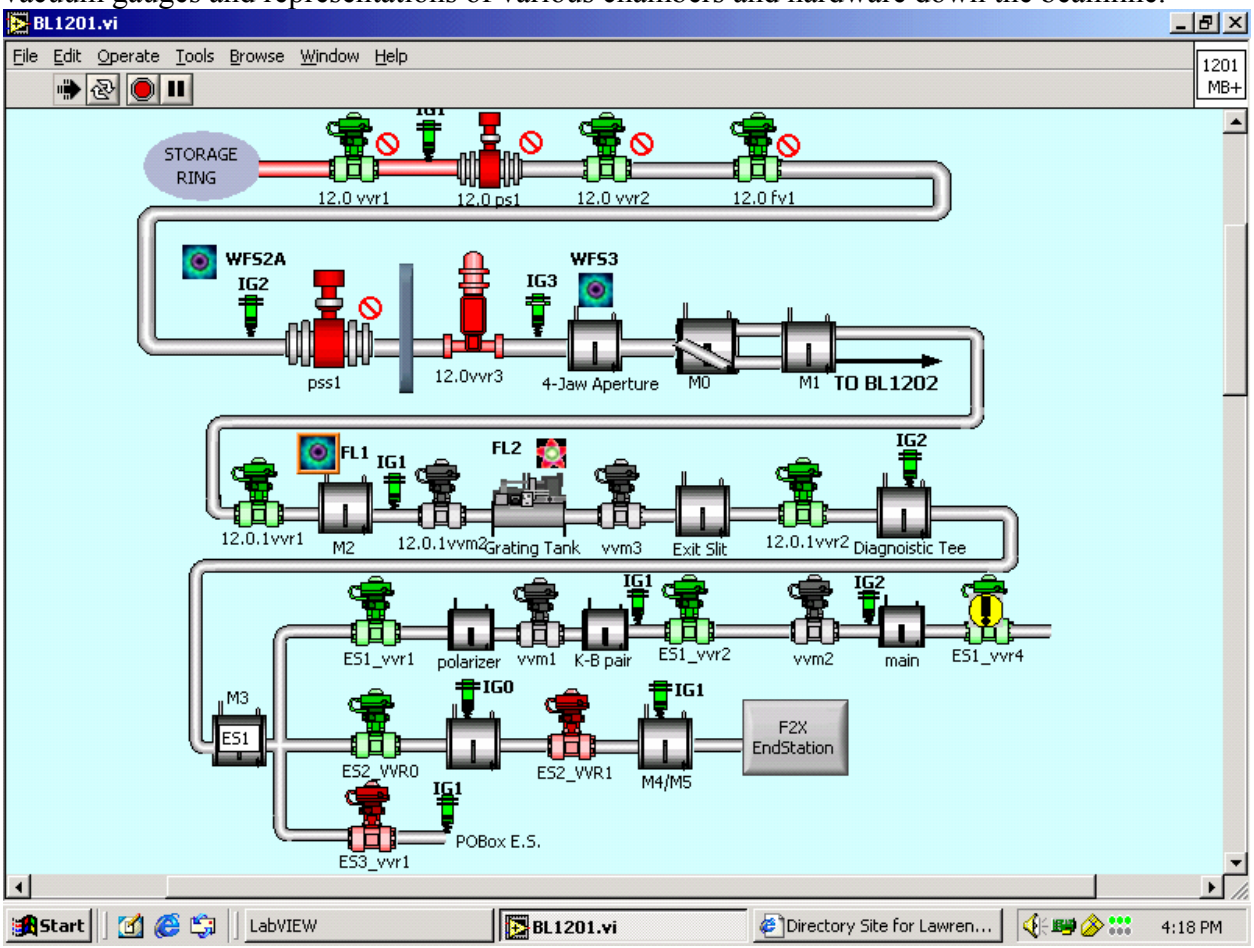


Right CP Mirror Alignment

A polarizer which works like this is referred to as a λ/4 phase shifter or retarder. An excellent reference site for this circular polarizer is the page of Hartmut Höchst from University of Wisconsin-Madison, where the CP was built (http://hhochst.src.wisc.edu/HHH.html).

Vacuum Safety Interlock System

This beamline (like all beamlines at the ALS) has a set of interlock systems to ensure the safety of users as well as prevent damage to the beamline and storage ring in case of accidents. The main safety interlocks are controlled by a LabView VI shown on the screen in the rack labeled BL1223 next to beamline 12.0.1.2. This program allows you to control all of the valves upstream from the endstation, as well as most of the valves on all of the three BL 12 endstations. The panel will show you a schematic drawing all of these vacuum valves, plus the various vacuum gauges and representations of various chambers and hardware down the beamline.



The LabView VI to control the valves at Beamline 12

During operation, open valves are colored green, while closed valves are colored red. All of the gauges, labeled IG1, IG2, etc. should be green. The schematic will also indicate how far the beam is passing through the tube by showing sections of the pipe which are open to the beam as red. Gray pipe indicates empty pipe. (Note: Pipe coloring on the schematic is solely a function of which gauges are opened, the schematic does not actually know if beam is passing through tubing). In order to get beam to the 12.0.1.1 endstation, for safety first make sure all valves downstream from and including the one labeled 12.0.1vvr2 are closed. If the beam is going to BL 12.0.2, first click of the figure in the schematic labeled M0, and switch the mirror to setting

12.0.1. Next, click on the figure in the schematic labeled M3, and switch the mirror setting to M1. The schematic will display three periods (...) while the mirror moves into place. Once the label M1 comes up on the figure, the mirror is in place, and you may open up the valves from 12.0.1vvr2 down. When beam is not available, you will not be able to open the main valve. If light is available to users, and the valves do not open, there is a problem or a lockout by EH&S, in which case you should call Alexei Fedorov (x7521), Rudy Kimmerling (x7519), or the control room (x4969). There is one upstream shutter and 2 manual valves NOT controlled by the VI. The shutter is located just upstream of M3, and is controlled by a small switch in the beamline equipment control rack labeled BL1225. There is a switching panel near this shutter switch that controls the monochromator gratings as well- in order to move the gratings into place, it is necessary to click these switches a few times- please talk to a Beamline Scientist for assistance with this.

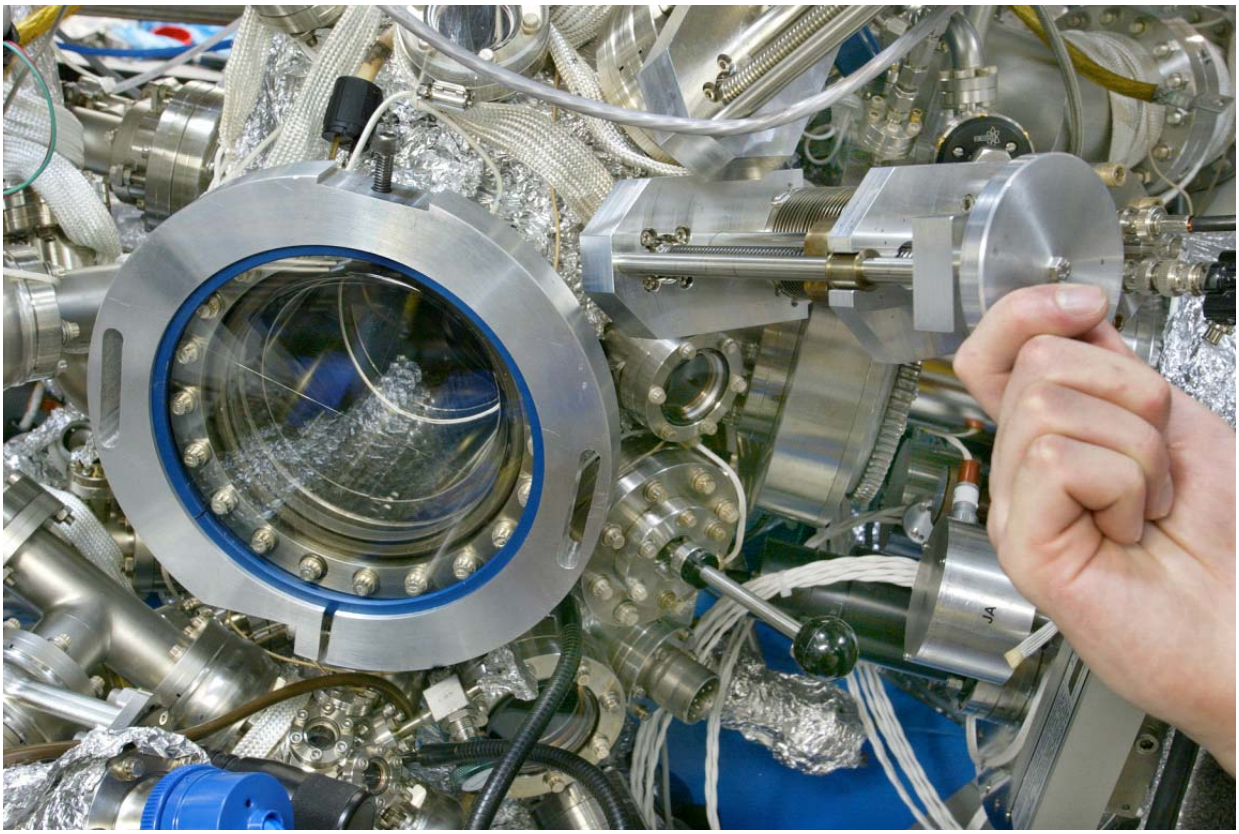
Shutter Switch at BL 12 (left of green BNC cable, below round knob)

The switch for the shutter itself is labeled, and the shutter is open when the switch is in the down position. The first manual valve is just downstream of the circular polarizer, while the second one is just upstream from the main chamber, under the He lamp (these valves are usually left open). If all valves are open, and the VI shows red pipe all the way to the end, then beam should be available in the main chamber.

Beam Detection

Beam should be easily detectable in two different ways. To check for beam, first raise the manipulator out of the way using the positions for "Withdraw Manipulator" in the motor control software (discussed below), removing the cryostat from the path of the beam. A phosphor-coated window at the end of the chamber should show the presence of beam. Also, a YAG crystal that will illuminate can be moved into the beam path by rotating the handle located just to the right of the main viewport and above the handle used for cleaving the sample (see picture, next page). If you insert the handle with the YAG crystal further into the chamber, a photodiode

will move into the beam path, which can be used to indirectly measure the photon flux (the resulting current will be directly proportional to the photon flux). A switch was added to this feedthrough for extra safety- when activated, it is not possible to move the manipulator. In order to move the manipulator, it is necessary to back this feedthrough out and off of the switch- motion will not occur in any direction unless this feedthrough is withdrawn. Still, despite this safety measure, always watch the inserted YAG and feedthrough as it goes in to prevent running into the cryostat.



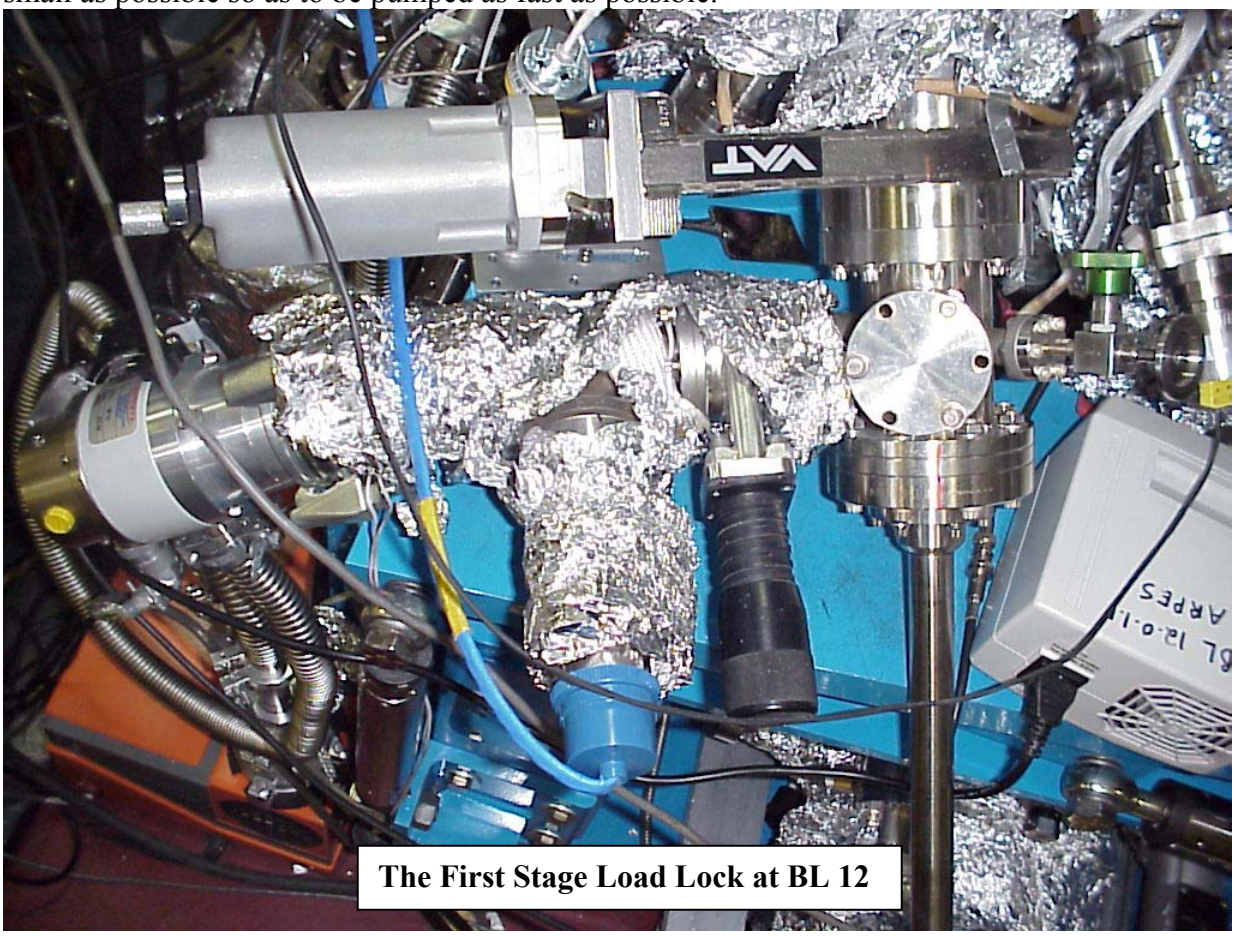
The YAG crystal/photodiode insertion device

Sample Transfer and the Load Lock System

Inserting a sample into the chamber is a fairly straightforward, but delicate task. There are two stages of load locks in order to prevent excess gas from entering the chamber. Always make sure your sample is as clean as possible before you put it in the chamber- dirty samples may contaminate the chamber, cause delays, and take longer to pump down.

The Load Lock- 1st stage

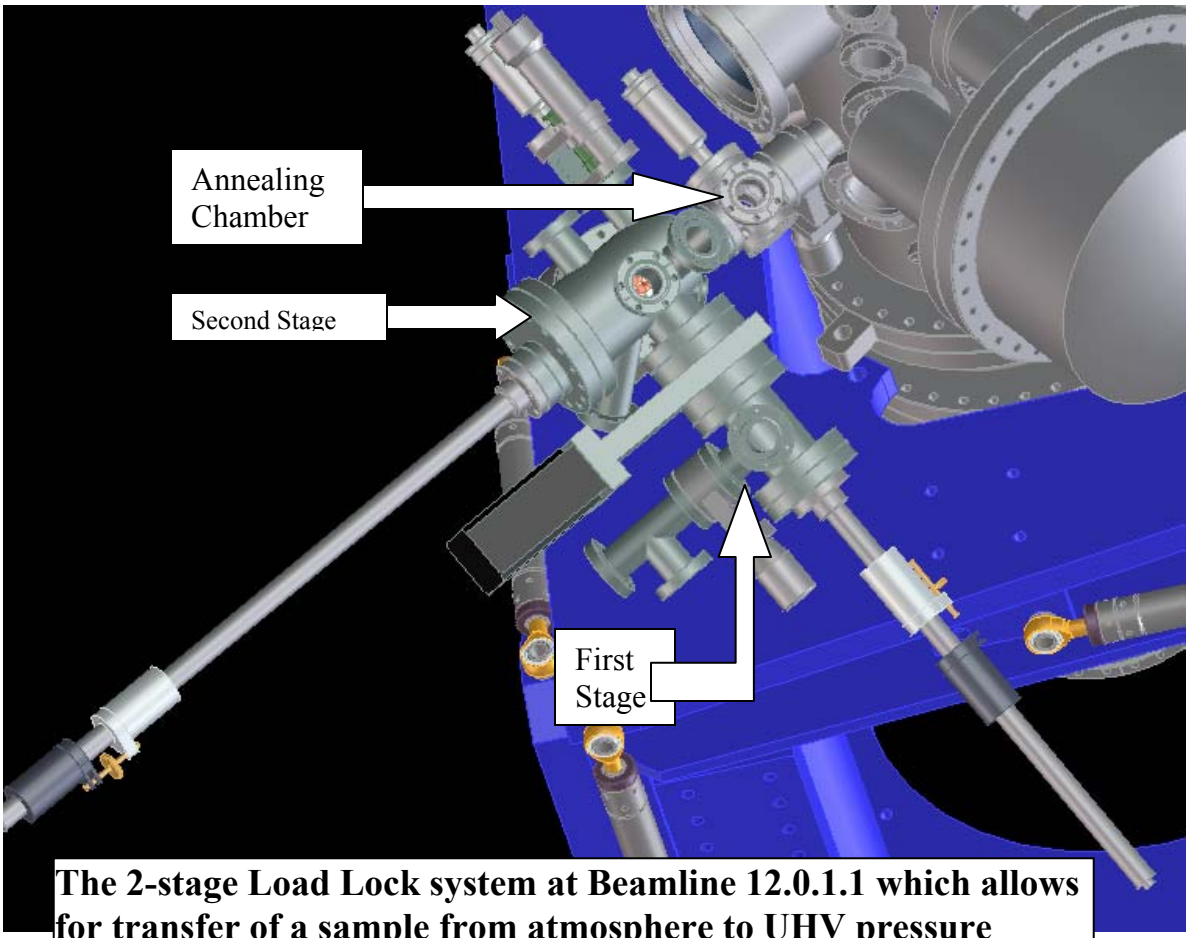
The first stage of the load lock simply consists of a short 2.5" diameter tube with several smaller flanges branching off of it. It is connected to a transfer arm, a small turbo pump, and a larger valve that leads to the second stage of the load lock. The first stage is designed to be large enough to house the sample garage. The sample garage can hold up to 6 samples at once. The front most 2.75" flange is sealed with a viton gasket, for quick access. It is through this flange that the sample is loaded, using the handheld transfer piece. The first stage is designed to be as small as possible so as to be pumped as fast as possible.



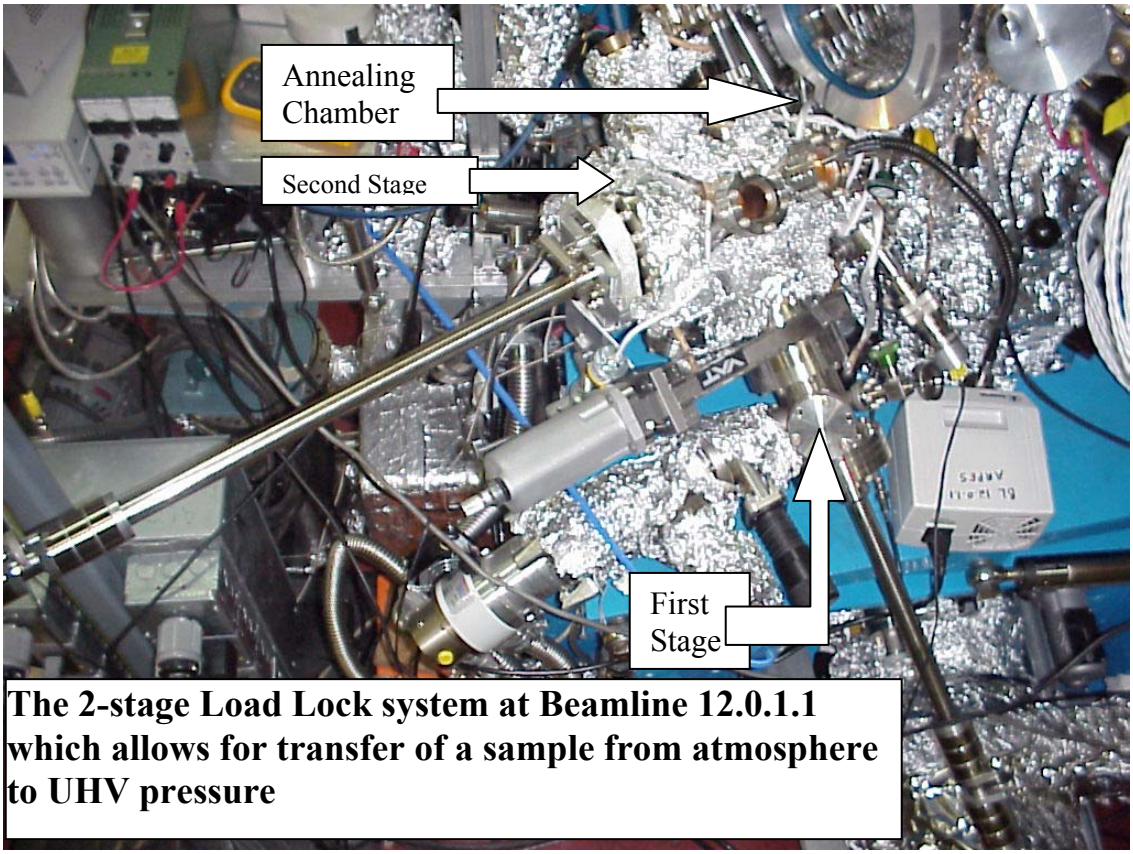
The First Stage Load Lock at BL 12

The Load Lock- 2nd stage

The second stage of the load lock is a bit more complex, but has the basic function of housing samples for study. It has the basic shape of a 4 inch tube elbow, with many smaller flanges branching off for various purposes. The heart of the load lock is the combined linear/rotary compact feedthrough. This feedthrough, located on top of the load lock, is connected to a rigid plate inside the load lock. In turn, the parking garage locks down into this plate, and all sample manipulation hinges on it operation Moving the feedthrough linearly allows for sample garage transfer, individual sample transfer (by the second stage transfer arm) and general positioning of samples for other purposes. The large rotary feedthrough functions in the same way. Mounted on the face of the load lock is a flange containing the main transfer arm, and a small wobble stick. This wobble stick is used to flip the rotating stage on the new rotating sample holder, please ask for assistance in using this for the first time. There is also a small window on the front flange used as an entry port for light. The rest of the 2nd stage nipples contain windows for easier viewing of the samples for transfer.



The 2-stage Load Lock system at Beamline 12.0.1.1 which allows for transfer of a sample from atmosphere to UHV pressure



The 2-stage Load Lock system at Beamline 12.0.1.1 which allows for transfer of a sample from atmosphere to UHV pressure

The Annealing Chamber

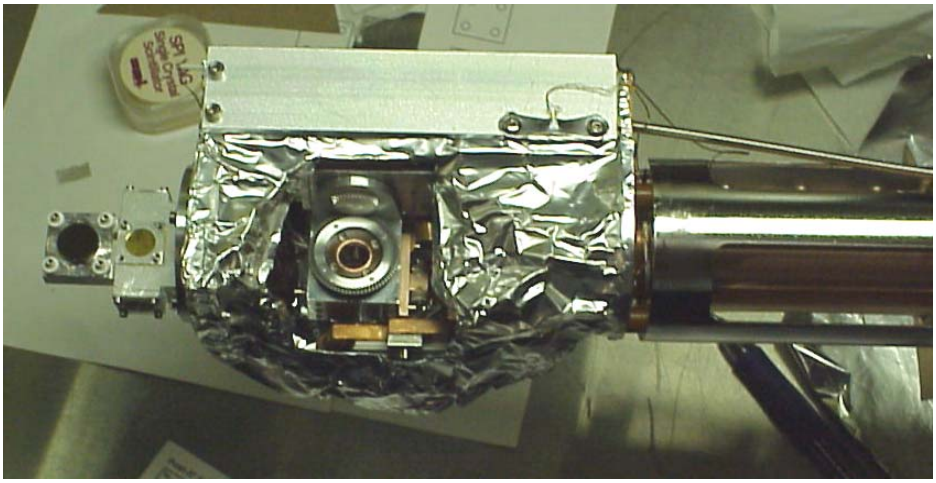
In between the main chamber and the 2nd stage of the load lock is the compact annealing chamber. There are several parts to this chamber. On the bottom flange is a linear translator with a portaliner that is mounted to the annealing chamber garage. This single slot garage has a stainless steel plate in front that is wired to the feedthrough on the flange. Use this translator to move the garage into the center of the chamber for annealing, and down out of the way for access to the main chamber. On the right side of the chamber is the thermocouple feedthrough, mounted to a linear feedthrough which provides about an inch of travel, and a small bellow that can be aligned by positioning its three small struts. This thermocouple can be moved to touch the face of the sample plate during annealing, and out of the way for transfer to and from the main chamber. On the left side of the chamber, the filament is mounted on a linear feedthrough. This filament can also be moved either out of the way for transfer, or into the chamber right up to the back of the sample plate for annealing. Some words of caution when using the annealing chamber:

a) When moving the filament in, ensure that the sheath protecting the filament does not make contact with the sample or sample garage. The sample garage and sample are held at high voltage during annealing, and this sheath is connected to ground and the chamber itself. You can ensure that these pieces are not making contact by measuring resistance

between the connector feedthrough on the sample garage flange, and the chamber itself. If you see any finite resistance, you are making contact.

b) When using the thermocouple to measure temperature of the sample when it is annealing, the thermocouple wire must be touching the sample holder. Because the sample holder is at high voltage, this means that the thermocouple leads will also be at high voltage. Do not touch the thermocouple leads during annealing, and take all precautions to shield yourself and other users from this danger.

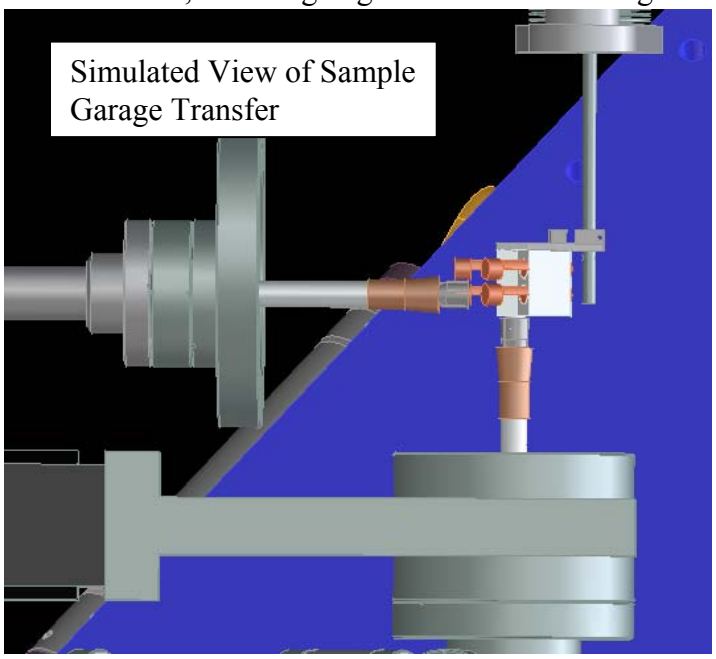
c) The annealing chamber is pumped by the same turbo as the second stage load lock, whose ion gauge controller and pump controller are located in the rack furthest from the chamber. Keep an eye on pressure and pump conditions as you slowly raise the current to the filament.



The Goniometer and Cryostat

Sample Transfer

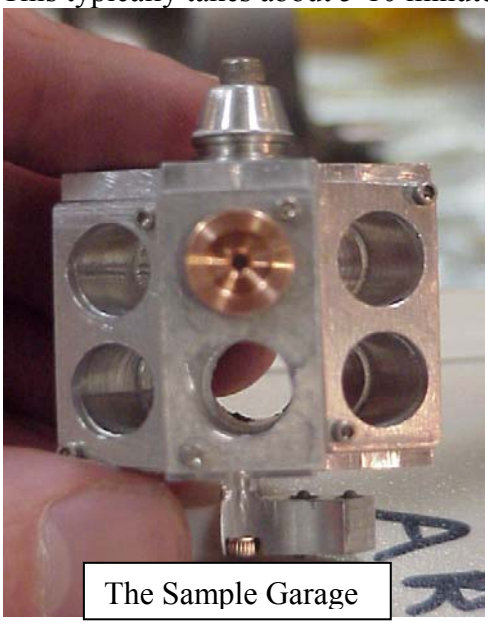
There are two garages for transferring samples into the main chamber- the first is the large 6 slot garage that is the predominant means of swapping in and out samples. There is also a small 2 slot garage- this garage is used when only one or two samples need transferring- it allows the large garage to stay in the 2nd stage load lock and speeds up pumping time. We will first discuss transferring with the large garage. Here are the steps for sample transfer assuming the system is under vacuum, and the garage is in the second stage.



1. Adjust the rotary feedthrough on the second stage so that it lines up with the marks at about 30 degrees. This should put the garage in the middle position, with the two middle slots on axis with the 2nd transfer arm. Move the linear stage into the chamber far enough that the plate attached to the feed through is visible.
2. Making sure that pressures are reasonable, open the valve between the first and second stage of the load lock
3. Extend the first stage transfer arm all the way up into the chamber, and around the sample head on the top of the garage.
4. Tighten down the collet onto the head, very tightly.
5. Rotate the transfer head counterclockwise until the garage unclips from the plate- **always do this while holding the 2nd stage rotary feedthrough firmly**. You should be able to feel/see the garage unclipping. If you encounter difficulties, try tightening the first stage transfer arm on the head- sometimes it takes a good deal of torque to rotate the garage, and the collet may slip or rotate without engaging the head.
6. When you see the clip is undone and fits through the slot, pull the whole garage down all the way into the first stage.
7. Close the valve between the first and second stages, and close the valve between the first stage and its pump.
8. Use flowing nitrogen gas to vent the 1st stage through the swagelock valve and quick fitting located on top of the first stage. Don't forget to attach an overflow valve to this setup for safety.

Side View of Transfer Plate

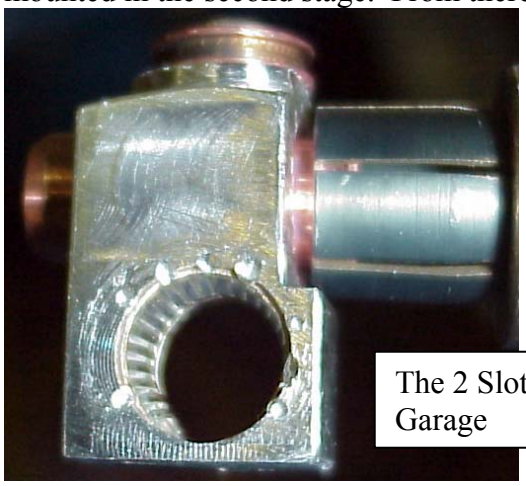
9. When the first stage is vented, open the blank flange in the front of the load lock for transfer.
10. Using the hand operated collet, transfer in 1-6 samples to the garage. Leave nitrogen flowing while the chamber is open.
11. When samples are parked, close up the loading nipple, and turn off nitrogen flow.
12. Use the roughing pump located at the base of the chamber to rough down the first stage. This typically takes about 5-10 minutes.


The Sample Garage

13. When the first stage has been roughed to satisfaction, close the swagelock valve tightly, and close the valve between the second stage turbo and its backing pump. This will prevent a pressure increase in the second stage. Also, switch off the ion gauge for the first stage.
14. Open the valve between the first stage and its turbo. After a few seconds, turn on the ion gauge once again, and observe pressure drop.
15. When the pressure in the first stage drops down to the order of 10^-6 torr, open the valve between the 2nd stage turbo and its backing pump.
16. When the pressure in the first stage drops below 5x10^-7, it is low enough to transfer the samples to the next stage. Open the valve between the 1st and second stages.
17. Following the same protocol as above (make sure angle of plate is aligned, plate is inserted a bit deeper into chamber) move the garage into position on the plate. Two pegs must line up- one circular peg on the axis of rotation of the transfer arm should line up with the round hole in the plate regardless of transfer arm rotation. The clip should also slide through the slot in the plate.
18. When you line these pegs up, insert the garage in carefully until you feel the round peg slide in and the clip go through its slot, and rotate the transfer arm clockwise until you feel the garage click into place. Again, it may be necessary to tighten the transfer arm to turn the whole garage.
19. When the garage is locked down onto the plate, release it from the transfer arm, pull the transfer arm down into the first stage, and close the valve between the two stages.
20. It will now be necessary to wait for the samples to pump down to a low pressure before opening up the load lock to the main chamber. In order to maintain an excellent pressure in the main chamber, it is necessary to not open the load lock to the main chamber unless the load lock pressure is in the mid to low range of 10^-10 Torr.
21. While you wait for the samples to pump down, you may want to go ahead and grab one to be ready from transfer. Using the liner/rotary feedthrough, position the garage so that the sample lines up with the transfer arm. For reference, there are lines drawn on these feedthroughs designating where transfer points are. The angle between faces in the three columns is 25 degrees- therefore, transfer points are close to demarcations at 30 degrees, 5 degrees, and 55 degrees.

22. When the pressure in the load lock gets down into the 10^-10 torr range, you may transfer it to the main chamber. First, move the sample garage out of the way of the transfer arm by moving it up and rotating it out of the way.
23. As stated before, in order to access the main chamber, you must go through the annealing chamber. Make sure that all the annealing chamber apparatus (garage, filament, and thermocouple) are withdrawn out of the way before putting the sample through.
24. You are now ready to load the sample into the main chamber. Use the BL 12 software to move the manipulator into transferring position. The BL 12 software is discussed later in the manual, and is one of the most vital and potentially hazardous parts of the beamline. BE SURE TO UNDERSTAND ITS OPERATION BEFORE PROCEEDING!
25. Once you have moved the manipulator into place, open the hand operated valve between the main chamber and load lock, and carefully place your sample into the goniometer. It is important that the sample be pushed all the way back into the goniometer to not only make good contact but more importantly place the sample at the center of rotation.
26. Withdraw the transfer arm, and shut the valve between the main chamber and the load lock. Your sample is now loaded, and the remaining samples are ready for quick exchange into the main chamber.

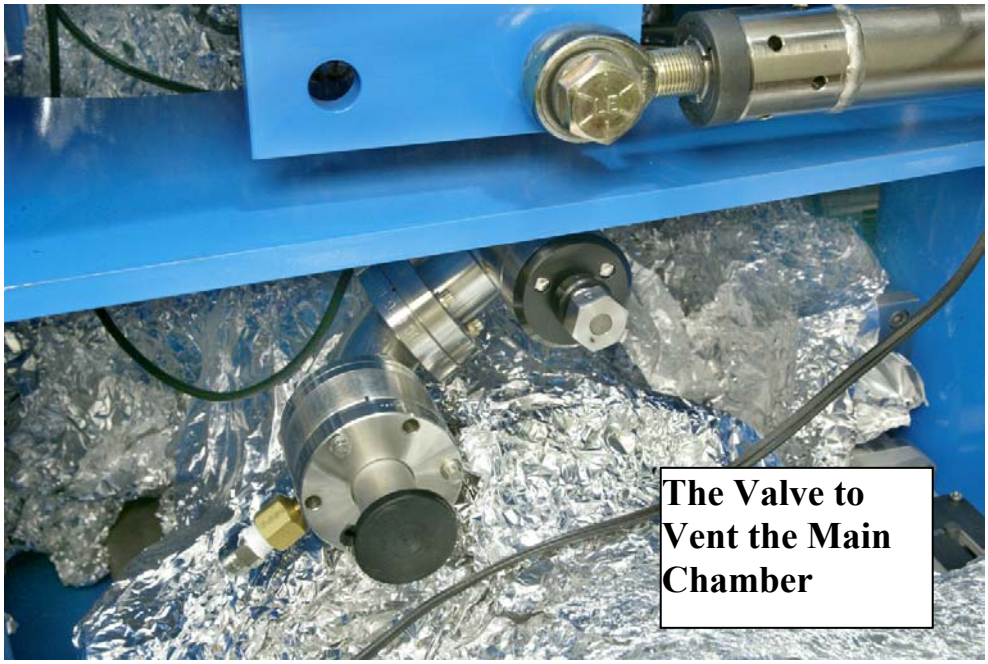
For the small 2 slot garage, the process is a bit easier. First off, the large garage stays mounted in the second stage. From there the steps are virtually the same



1. Go through the venting procedure for the first stage load lock, with the valve to the second stage closed.
2. Load one or two samples into the small garage using the hand held collet. With both samples in, the package will still be rather light. Use the hand held collet, while gripping a sample, to insert the whole package through the transfer nipple. With your other hand, have the transfer arm grab the small garage by the transfer head on top.
3. When the first stage transfer arm has a good hold, release the sample, and close up the nipple. Proceed with pump down routine.
4. When you are ready to open the first stage to the second stage, move the large garage up and out of the way to the side.
5. Open the valve, and move the first stage transfer arm into the 2nd stage. Use the 2nd stage arm to grab samples out of the small garage, and place them one by one into the larger garage.
6. When both samples have been unloaded into the 2nd stage large garage, withdraw the small garage and transfer arm to the first stage and close the valve. This is the quicker way to pump down a sample or two.

Venting the Main Chamber

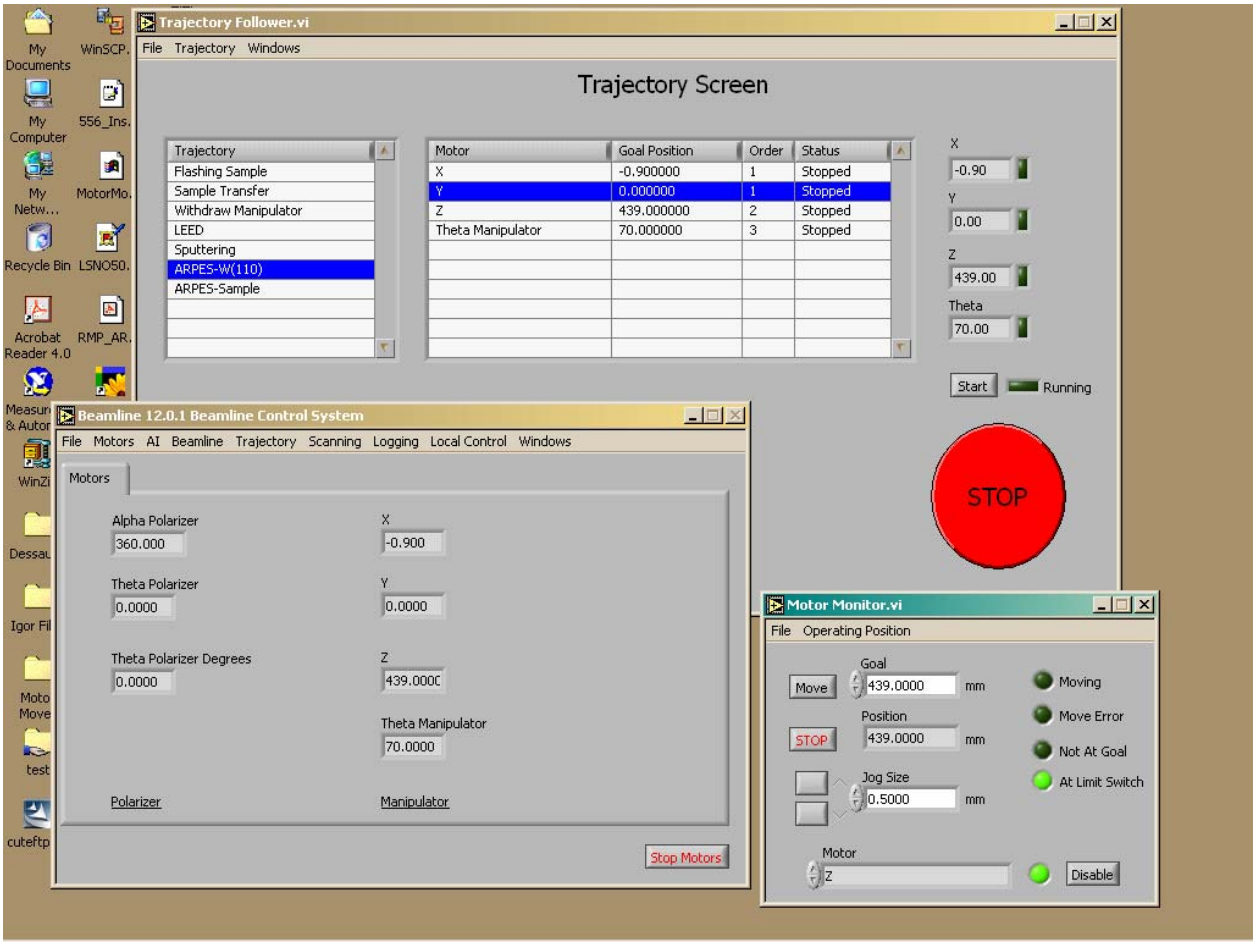
The main chamber is best kept under high vacuum at all times; however, sometimes it is necessary to vent it and open it so that items my be placed inside or on the chamber. Always contact Alexei Fedorov (x7521) or Rudy Kimmerling (x7519) before venting the chamber, or if you think you have accidentally vented the chamber, as doing so will cause a delay of at least two days for bake-out before the main chamber can be opened back up to the beam. There are safety mechanisms on the chamber in the case of an accidental vent- each pump on the main chamber is protected by a pneumatic valve which will close if the pressure rises above 10^-7 torr. If you hear and see all of these valves close at once, you are either overpressure, or have cut power to the rack. In the event that you must vent the chamber on purpose, the first step is to make sure you close every valve surrounding the chamber. First, use the computer program on the panel (see Vacuum Safety Interlock System) to close all valves surrounding the main chamber. To minimize the amount of apparatus that needs to be baked, and to avoid damaging the high-vacuum pumps, you must also valve off all of the pumps and hand valves connected to the chamber. Make sure to close the following valves: Directly upstream from the chamber, there is a hand controlled valve, it is directly under the Helium lamp, and a little hard to reach. Also, make sure that the hand valve between the chamber and load lock is closed. Close the hand valve directly beneath the He lamp, if it is not already shut. Most valves that isolate pumps are controlled by buttons located on the top shelf of the portable blue rack of controllers to the left of the chamber (see picture, next page). Make sure all four valves (main turbo, ion pump, cryo pump, He monochromator) are closed. There are three more button controlled valves on the box in the rack above the workbench numbered BL 1231. Make sure that these three valves, VVR2 Main/KB, VVR4 LL/Prep and VVR4A Vent LL, are closed. All valves should now be sealed, and the main chamber should be isolated from the rest of the apparatus. Near the foot of the blue rack is one last gray box that controls the valve for the Gd pump to its left, close it as well. Approximately 1 meter below the Scienta analyzer is another large hand operated valve which isolates the second turbo located underneath the chamber, turn this handle clockwise all the way until it is in the closed position. Just to the left and above this pump is the vent that is attached to the main chamber.



If the scroll pump is attached, make sure that the valve just to the right of the vent is all the way closed. Remove the scroll pump and attach the nitrogen hose to the vent with a quick flange. Start the flow of nitrogen using the regulator located above the KB chamber of BL 12.0.1.2. There is a relief valve on the vent; when you feel the nitrogen flowing, turn off the ion gauge controller for the main chamber, and open the valve just to the right of the vent. You may need a wrench to do so. The flow of air from the relief valve should stop for a few minutes; when you feel it once again, the chamber is vented, and is safe to open.

Controlling the Manipulator, Goniometer head, and Polarizer Motors

There are 6 degrees of freedom in the motion of the manipulator: X, Y, Z, Theta manipulator, Tilt, and Azimuth. The best way to control the motors, and to monitor their positions, is using the software on the white Vectra computer at the beamline. There is a shortcut to the LabView VI that performs this operation on the desktop labeled "BL Control Main." When you open this program, you will see two columns of indicators, which list all of the values for both the manipulator and polarizer motors. To run the VI, press the little white arrow in the top left corner (though this program is usually left running). A second window will pop up with a small box to send the motor to a given position or to jog it. When you do this, a smaller window will also open displaying three indicators and a few buttons and controls. This window, labeled "Motor Monitor.vi" has a small control on the bottom with each motor's name in it. You can scroll through to control any of the 8 motors at the beamline. This VI is fairly self explanatory; you simply enter your requested position, and press the Move button. The new goniometer/manipulator setup is quite large, and takes up a sizable amount of space in the chamber. For this reason, manipulation can be a dangerous process. The most useful tool to avoid running the goniometer into the wall or other feedthroughs is the camera placed under the chamber. This will give you a good view of the X-Y plane of the manipulator. Always watch this screen when moving the manipulator. Homing switches have recently been mounted to the manipulator- these are set up to find a zero which places the sample at the X-Y center of the chamber. If you fear you have lost position coordinates, it is always a good idea to renormalize by homing the X and Y motors- but be careful to watch the monitor when moving nevertheless, the make sure there are no collisions. **In order to home the manipulator, make sure that you start with X and Y positions on the positive side, above the home switches**. It is important to start in these positions before making the home move, otherwise the motors will run to the reverse hard limit. In the “Debug Motor” window, you will see the Home command. Before you home, make sure you know where you are. Bear in mind that when you home, the computer will reinitialize the values of X and Y to zero where they sense the home switch- and any previous numbers used before the home move will be slightly different. Also remember to be careful when jogging or setting target distances, and always be ready to hit the “stop” button in Labview in case you see a collision nearing. Do not continuously press the jog button, this tends to jam the program. Instead, wait for the motor to finish jogging before hitting the jog button again. The newest addition to this program is the trajectory window. This window, when configured correctly allows for one-click motion to your destination. At this time, it contains the correct coordinates for several key positions. Use these positions as a guide and move manually towards them motor by motor in a safe fashion. Do not run one touch motion unless you are positive that in going from the origin to destination positions, you will not crash the manipulator.



The Beamline 12.0.1.1 "Beamline Control System" Software

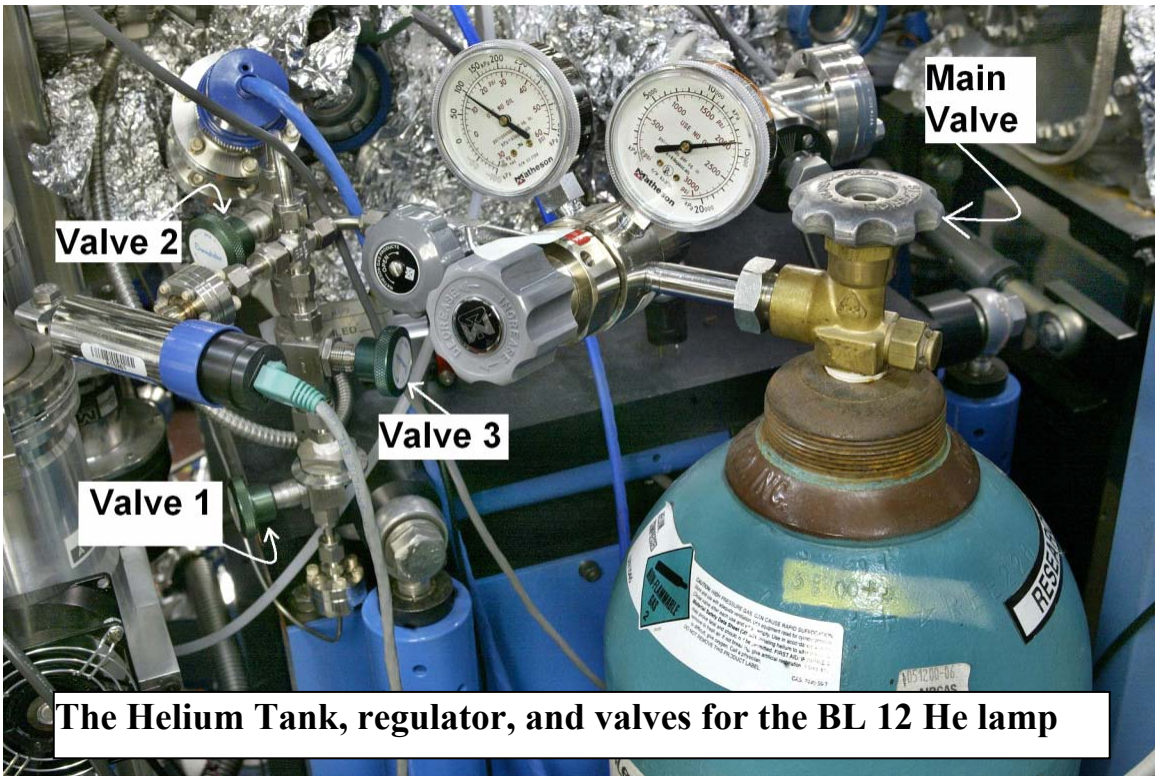
Several standard positions, such as sample transfer, LEED, etc. are programmed into this window, and you can find virtually every important position at the click of a button. Please do not edit the trajectories yourself- if you find the positions to be off, use the jog buttons in the program to move to the correct spot, and make a note of the new position for the beamline scientists (Alexei Fedorov and/or Rudy Kimmerling). The program should be run continuously so you can monitor the position- but position will stay recorded if you shut down the program. The program only needs to be reset if the controllers themselves lose power. The angles represented on the program are calculated from the number of steps sent- there are no encoders- so it is always best to physically observe where the manipulator is if you can. In order to stop this VI (which should not be necessary unless the program seems to be malfunctioning) simply go to File-> Stop Beamline Controls. If you would like to change the parameters of the motor motion, please speak with Alexei or Rudy first, such elements as speed, acceleration, backlash, and gear ratio have been optimized given the needs and limitations of the system. The tilt and azimuth motors are limit switch linked (there are limit switches on all movable stages but theta manipulator) and operate through a separate set of controllers, even though the software is the same. If you would like to change their basic parameters, you must talk to Rudy or Alexei- changing one or both parameters could drastically affect the ability of the goniometer to hold an azimuthal rotation angle steady. The tilt of the goniometer has a range of about 60 degrees, and

zero degrees is defined as just a few degrees below perpendicular. The azimuthal range is about 220 degrees, and in general the zero point is defined as the midpoint, so inserting your sample at zero degrees means you will have 110 degrees of rotation in either direction. **The most important concept when using the manipulator is safety- watching the monitor and goniometer as it moves within the chamber can save days of delays and months of hard work. Please keep our goniometer safe!**

On the polarizer, there are 2 parameters you can control. The first is the tilt of the 4 mirrors, which is represented in the polarizer controls as theta, or theta degrees. The second is the rotational angle of the mirrors about the beam's axis. This parameter is designated as Alpha. Press on the control in the Motor Monitor window and scroll to either Theta Polarizer Polynomial to control theta, or Alpha Polarizer to control alpha. DO NOT USE THE "THETA POLARIZER" SETTING UNLESS YOU WISH TO JOG THE MOTOR A FEW STEPS. When you have chosen your motor, simply type in your destination value in the top "Goal" control, and click the move button. The position indicator will show you the current position of the motor. Although there are many features to this VI, you should not need to go any further than the Motor Mover window. To stop the VI, go back to the first window called Beamline 12.0.1 Beamline Control System, and click on File-> Stop Beamline Controls, which should automatically close the Motor Mover window and stop the VI.

Using the Helium Lamp

The Helium Lamp on BL 12.0.1.1 allows for data taking even when ALS beam time is not available.



The Helium Tank, regulator, and valves for the BL 12 He lamp

There are many steps to follow in order to ensure proper usage of the He lamp, as it is a delicate instrument. The first step is to remove the old helium from the system and flush it with fresh helium before use.

The He Lamp and He Leak Valve

- First, ensure that the valve on top of the green helium tank is tightly closed. Attach the scroll pump which is at the base of the endstation to the vent at the helium tubing with a quick flange.

- Start the pump, and open green valves one, two and three, in that order. Wait a few seconds for the He to pump out.

- Close valve 3, and open the main valve atop the green tank, putting fresh Helium into the system.

- After a few seconds, close the main valve on top of the green tank, and open green valve number 3 again. Let it pump for a few seconds, then close green valve 3 again tightly, and turn off and remove the scroll pump from the vent.

- Open the valve on top of the green tank, and adjust the valves until the pressure in the left side of the regulator is at about 10-13 psi. You now have fresh He in the system.

The next stage of the process involves getting the right He pressure inside the lamp.

There is a gauge to measure the He pressure which sits in the blue rack and is labeled "He Lamp." Normally, this pressure should be in the 10^{-8} range. Check the pressure, and make sure that the two hand valves attached by the lamp are closed- one separates the small turbo pump from the lamp, the other separates the lamp from the monochromator.

Open the small leak valve slowly while watching the pressure, and adjust it to the point that the pressure goes to about 2 to 3 $\times 10^{-4}$ Torr. Make sure that the pressure is not above 6×10^{-4} Torr, or else the lamp could be damaged when the microwave generator is on. If the pressure is below 2×10^{-4}, it will be harder to start the lamp.

It is now time to turn on the lamp with the Gammadata microwave generator located in the rack labeled BL1124, which is directly across from the chamber.

- First, walk around and make sure that the door behind the Gammadata is open; the Gammadata has a fan which vents out the back. You should not run the Gammadata with the door closed. When it is open, come back to the front and switch on the orange power button.

- Next, press the black UHV ON button. The two green lights, Filament On and Filament OK will go on, which means everything is normal, and the microwave generator is starting up.

In about 2 minutes, the voltage meter on the Gammadata will bounce up, as will the discharge current and reflected power. The discharge current should be between 250 and 275 mA, the voltage should be about 4.5 kV, and the reflected power should be below 10%.

The Gammadata Microwave Generator

- You want to minimize the reflected power, so if it is not zero, adjust the pressure once again with the leak valve, watching the reflected power meter to get the lowest possible reflected power. Check to see that everything is within these given okay ranges.
- When they are, first close the valve to the Cryo pump- He exposure may damage the Cryo pump.
- When you are ready, open the two hand valves, the one to the pump, and the one to the monochromator.

When you open these valves, you should also make sure that the valve for the larger turbo which pumps the monochromator is open. This valve is the pneumatic valve labeled "He Lamp monochromator" in the top left corner of the portable blue rack located right next to the large green bottle of Helium. Press the right (green) button to open it, it is okay if the lights do not work, the valve is still open.

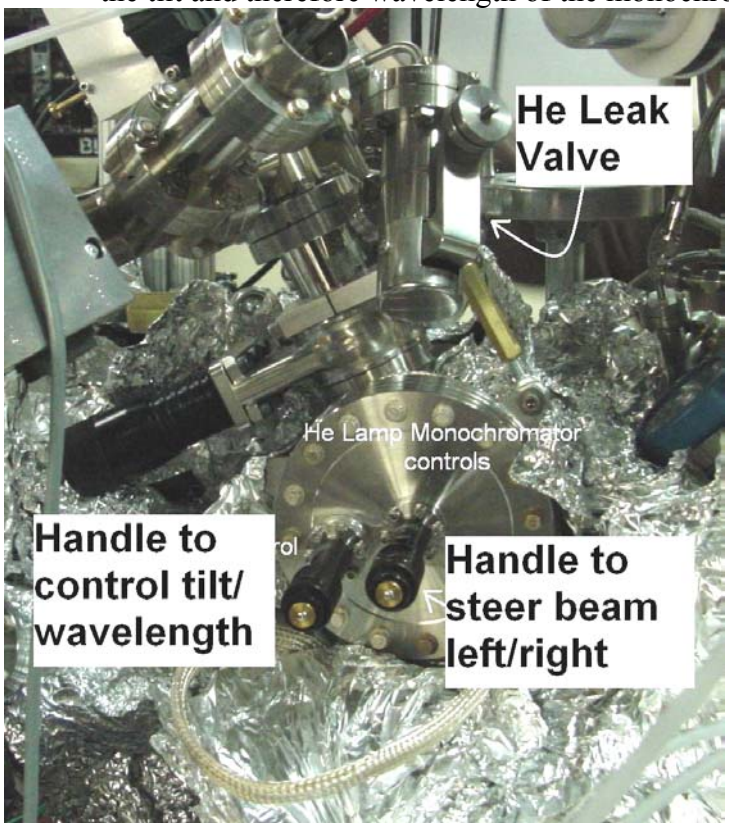
- Upon opening the valves, you may once again have to play with the He pressure to minimize reflected power and optimize the settings. When you have done this, make a quick check of all of the pressures. The pirani gauge that is read by the second slot of the Stanford Research Systems gauge in the blue rack (the top slot of the same gauge is used for the main chamber pressure) is attached to the roughing pump that gets fed by all three turbos on the He lamp system. When there is no He present, it should read below 5 mTorr pressure, but with Helium in the grating tank and the valves open, it should read between 60 and 100 mTorr pressure.

Now it is time to tune the monochromator to get the correct line of Helium. The standard setting of the monochromator should have the He 1 line in focus. However, if the He 1 line does not appear, then it is necessary to play with the monochromator.

- First off, check the pressure in the monochromator chamber on the gauge below the Sony monitor on the right side of the blue rack labeled "He Lamp monochromator." The pressure should be about 3 or 4 $x10^{-6}$. We need to know which line of Helium we are looking at, so we must move the photodiode into the path of the beam. The photodiode is located on the same rod as the YAG crystal described in the section "Beam Detection."

- Move the photodiode into place using the process described in the Beam Detection section, simply rotating the panel until the YAG crystal moves past the beam, and the photodiode moves into the line of the beam. The picoammeter located on top of the blue rack should display the current in micro- or nanoamperes. Make sure the picoammeter is hooked up to the photodiode by connecting it to the left most BNC connector next to the handle for inserting the YAG crystal/photodiode. One of the other BNC connectors should be grounded to itself.

- As you move the photodiode into the path of the beam, watch the picoammeter and stop rotating where the current is maximized. The monochromator should be set on the He 1 line, and should register about 2-3 microamps on the photodiode.
- If it does not, you adjust the monochromator using the screw handles on its back side. There are two handles. The one offset from the center of the flange controls the tilt and therefore wavelength of the monochromator.



- Play with this to find the line- if you are having trouble, move it all the way out (turn it counter clockwise/left) to find the zero order, which should be very bright. Then, move it back. The first line you should see is the He 2 line. The second is the He 1 satellite line, and finally, the third should be the He 1 line. Check to see that the current is between 2 and 3 microamps.

Controlling the alignment of the He Lamp Monochromator

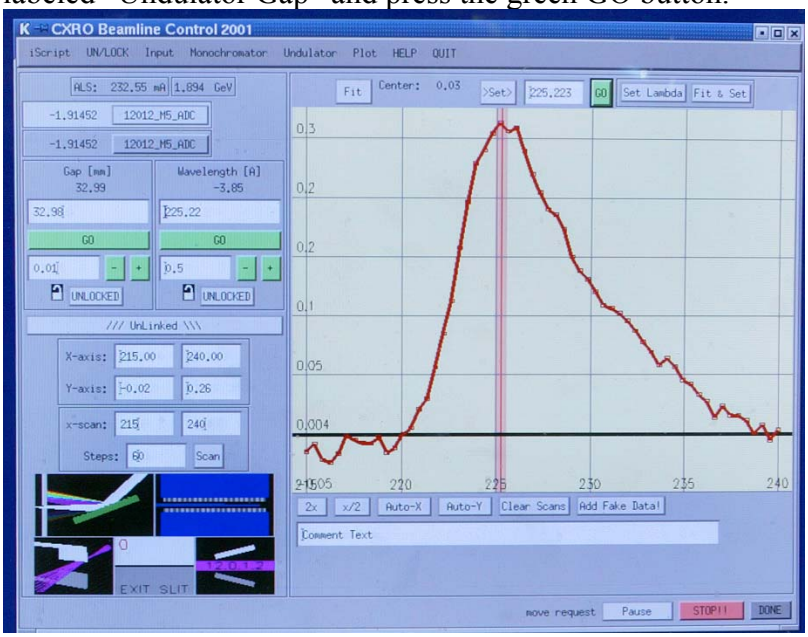
- The other handle, in the center of the monochromator, will steer the beam further left or right, so be careful. Remember that making adjustments to increase the flux or change the pressure will affect the reflected power, which should be kept as low as possible while still allowing a little play to maximize flux. Should the reflected power somehow exceed 10%, the microwave generator will shut down automatically. To restart it, simply check all of your connections and settings again to see that they are okay, and hold the UHV ON button down again until the green lights come back on.

*At this point, a small note is to ensure that water is flowing to the He lamp to cool it. The two tubes leading to the lamp, one red and one green, supply cool water to and return it from the lamp. The small black valve should be open to allow water flow to the lamp. In general this is open, but it is worth taking a few seconds to check.

- **To turn the He monochromator off, simply press the UHV OFF button. Do NOT turn off the orange power button right away- the fan must continue to run for a while, or the Gammadata microwave generator could overheat and be damaged.**
- After you have pressed the UHV OFF button, close the He leak valve, close the two hand valves (but not the pneumatic He Lamp Mono. valve), and wait for the temperature to drop to ~25° before turning of the main power with the orange button on the Gammadata.

Setting the Undulator Gap and Monochromator Wavelength

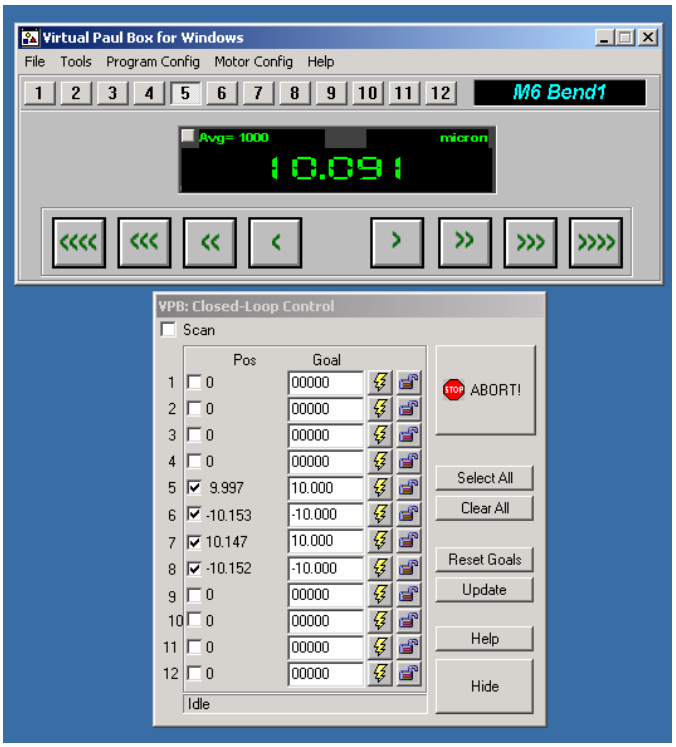
The undulator gap and monochromator wavelength are set using the program on the computer by beamline 12.0.1.2, near the screen where valves and beam direction is controlled. On the left computer, you will see a program which allows you to control various hardware from the upstream part of the beamline. Type your desired gap width for the undulator into the small box labeled "Undulator Gap" and press the green GO button.



The gap width is shown in the program, and also can be seen throughout the ALS on the television screens displaying the Ring Status- in the bottom right corner, all gap widths are listed. This is a good way to double check the size of the undulator gap. The monochromator position, and therefore wavelength, may be adjusted in much the same way via its respective control and display in the program. It is also possible to take monochromator scans with this program.

The Monochromator and Undulator Gap Software

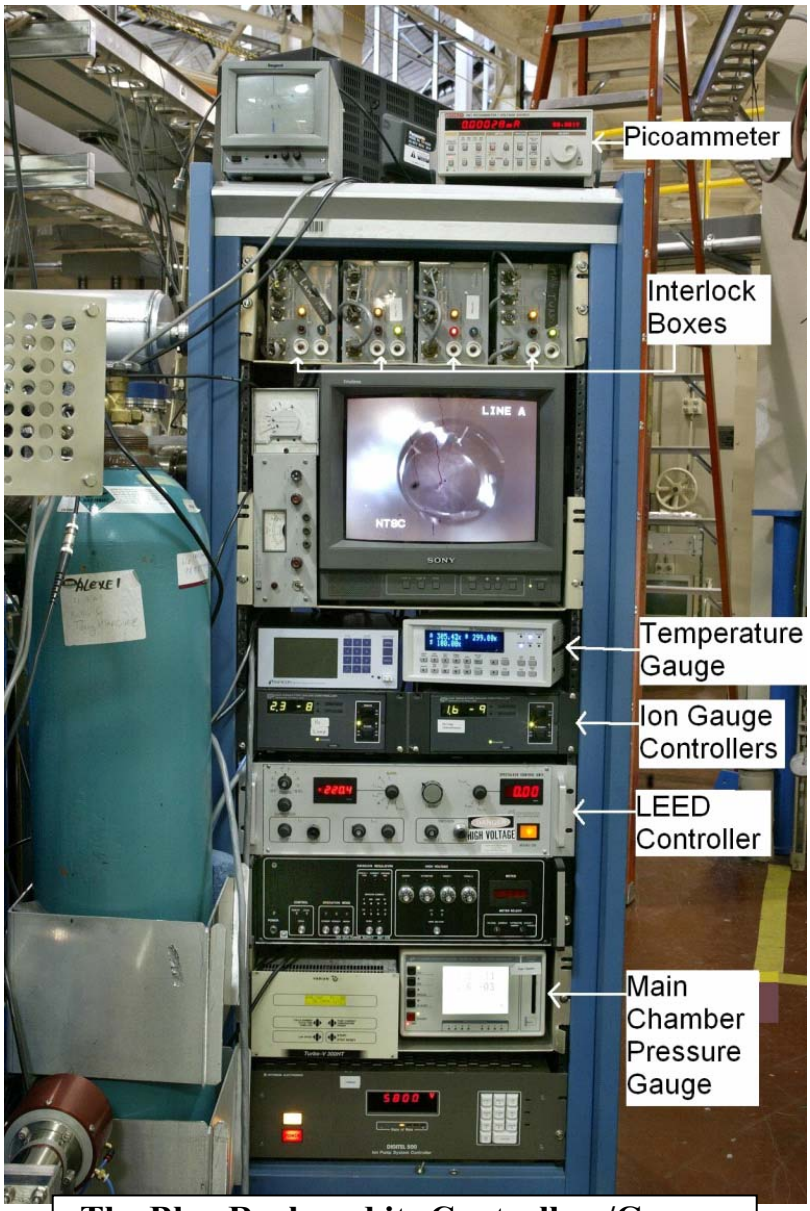
On the computer to the right, you will see the controls for the exit slit width. The 4 positions of the respective corners of the slit are shown as positions 5, 6, 7, and 8. You can only change these one by one, so if you are going from a very small to very large gap, or vice versa, move incrementally (say first, move all motors from 170 to 50 microns, then all motors from 50 to 20 microns, and finally 20 to 5).



The Software to Control Exit Slit Width

Using the LEED

In order to obtain a good LEED image, first you must move the sample into place. Move the manipulator into place by using the motor control software and the one-touch trajectory called "LEED." The sample should now be in place. The camera is connected to the same cords as the analyzer camera, simply remove the wires and attach to the LEED if it is not already done. Switch on the monitor in the blue rack, switching to channel A to see the camera image. The controls for the LEED voltage, the Omicron Vakuumphysik GMBH, are in the same rack, below the two Ionization gauge controllers. Turn it on, and set the following reference voltages:



The Blue Rack and its Controllers/Gauges

With a reference Energy
E=333 eV
I filament = 1.78 A
I emission = 2.436 mA
W= 108
L 1/3= 213
L2= 50
A= 329
Suppr. = 44
Screen = 10kV
(Note: With these voltages, the LEED gets really bad below 290 eV)

Settings for Energies below 290 eV

LEED for E= 170.4eV
L 1/3= 131
L2= 34
A= 328

At E= 60 eV, LEED is very bad, but the best voltages are at:

L 1/3= 128
L2= 35
W= 108
A= 330

In order to rotate the sample post itself about its axis (to rotate the image on the screen around the center of the screen) there is a dial attached to a screwdriver that is inside the chamber. This dial is a bit hard to reach; it is located just to the left of load lock chamber 1. Rotating the base brings the screwdriver closer or further towards the sample back, and rotating the dial itself spins it. Slowly and carefully move the screwdriver into place, rotate the dial, and be careful not to push the entire sample forward. When you have reached the optimal position, make sure to withdraw the screwdriver all the way back out of the way from the sample, so it does not strike the cryostat as it is raised, lowered, or rotated.