

MicroMott operation and upgrades

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September 2022 - August 2023

The microMott polarimeter has undergone a series of upgrades in hardware and software over the past decade. This aims to describe the functioning of the various systems of the microMott, give troubleshooting information and serve as an operational manual for the system.

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1 Introduction

The microMott polarimeter is in Test Lab room 1137 for routine use. Longitudinally polarized electrons are excited in the polarized source with circularly polarized light incident on a GaAs photocathode biased at -258 V using a battery bias box or Keithley 6487 biasing picoammeter. The electrons are bent 90 degrees using an electrostatic bend then steered and focused with electrostatic tube lenses. The electrons are accelerated to scattering energy (5-30 kV) between two hemispheres, scatter off the thick gold target, and are decelerated to incident energy passing back through the hemispheres. Retarding field grids are used to for energy analysis of the scattered electrons: multiply scattered electrons have lost much of their incident energy and polarization information, and when the retarding field grids are near the incident electron energy, only elastically scattered electrons pass through to the CEM detectors where they are counted. The details of setting up and operating this polarimeter are detailed in this tech note.

2 MicroMott systems

The systems of the microMott are broken into several interrelated systems, which I've broken down into vacuum, photocathode preparation, electrostatic steering lenses, laser, high voltage, detectors, retarding field and software. I'll describe the build of each of these and routine operation.

3 Vacuum

3.1 Source vacuum chamber

The source vacuum chamber consists of a cylindrical chamber with two 10" (DN200) Conflat flanges. The chamber contains a windows, activation chemicals, pumps and interfaces to adjacent vacuum chambers. The laser illumination window is suitable for 780 nm transmission. Other windows have been used for special purposes. There is also a side window for white light illumination of the photocathode.

3.1.1 layout

The source steering lenses are in the source chamber. These are the deflector and pusher lenses, mounted on a 2.75" flange with



↑ Figure 1: Connections for source lenses a and b

a linear manipulator for alignment, and the steering and focusing lenses which are held on a ceramic support in the 4.5" (DN63) port going to the Mott chamber. The steer/focus lenses are now connected to a feedthrough in the double knife edge 10" flange at the upper edge of the chamber.

This double knife edge flange has the capability of adding an electrically isolated dock, with the goal of providing reproducible positioning of the stalk. This has not been commissioned. The stalk has very little clearance within the bore of the cross and valve, and getting it seated while not shorting could prove difficult or impossible.

The system has a NF3 leak valve with a reservoir behind it, and Cs strips for activation. Cathode heating is performed using a stalk heater external to the vacuum with a N2 purge to avoid oxidation. The Cs cannot be placed directly below the cathode during activation since the electrostatic deflector and pusher lenses need to be there. The deflector is on a bellows, and could be moved out, but repositioning properly after moving it has been problematic.

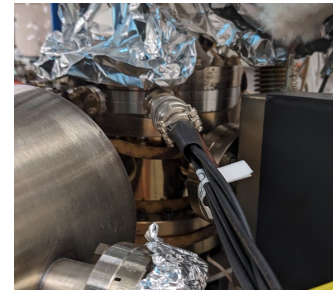
3.1.2 pumping

The system is pumped through an ion pump and a NEG pump. The NEG has been removed from its support and is laying in the bottom of the chamber; it can't be activated except passively during the bakeout. The ion pump is connected to a bake pump outside of the hot zone and isolated with a right angle valve (which leaks slightly). The roughing port for the chamber is on the other side of the bake pump.

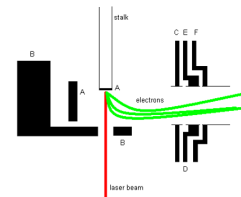
3.1.3 source internal wiring

The internal wiring of the Source chamber attached using feedthroughs at two locations. The source lenses A and B are connected through pins on the 2.75" flange opposite the Mott chamber. The source lenses C, D, E and F are connected through a 4 pin connector on a mini flange on the back side of the system. Figure 3 shows a schematic of the source lens layout.

The stalk is biased from the BNC cable connected to the bias and picoammeter. The Cs strips are connected to a current supply through the feedthroughs on the Cs flange. The NF3 is behind the leak valve.



↑ Figure 2: connector for source lenses c-f



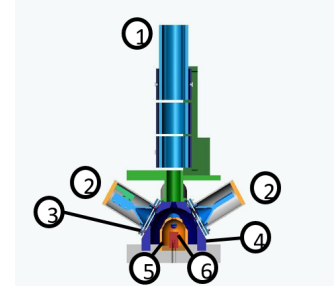
↑ Figure 3: Source lens schematic with stalk shown

3.2 Mott vacuum chamber

The microMott chamber is connected to the source chamber through a 4.5" port reduced down to a 2.75" flange. The gasket between the chambers is a solid gasket with a hole drilled in it, approx 1 mm diameter and counter-bored so there should not be plural scattering of electrons through the orifice. This limits the electron transmission from the source to the Mott chambers, and was instituted to reduce detector backgrounds. We have not checked if it can be removed without affecting the operation of the polarimeter.

3.2.1 layout

The Mott chamber has the polarimeter lenses, detectors and retarding field grids all installed on a self-supporting 10" flange as well as the inner and outer hemispheres for the electron acceleration, scattering, deceleration and detection. The three Mott lenses all have focusing ability, and the first and third lenses also have both x and y steering capability. See Fig 5 and 4 for schematics. A side port in the chamber has an isolated gasket mounted on a bellows. This can be inserted just downstream of the orifice and it will allow measurement of current leaving the source chamber for initial steering. There is also a sheet of metal set in the chamber, held by tabs and friction, that shields stray electrons from bouncing around the sides into the detectors.



↑ Figure 4: Polarimeter with mott steering lenses: 1 is mott lenses, 2 is the CEM, 3 are the retarding field grids, 4 is the outer hemisphere at ground, 5 is the inner hemisphere, biased with the target, and 6 is the target

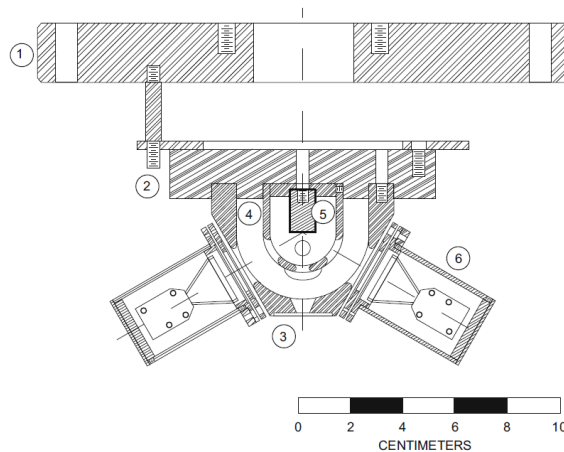


Figure 5: Cross-section drawing of the polarimeter showing: 1) 10" (DN200)Conflat mounting flange with five 2.75" (DN35) ports. 2) insulating ceramic 3) outer hemisphere 4) inner hemisphere 5) target 6) CEM detector with can and retarding field grids

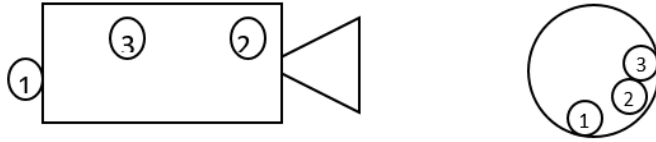


Figure 6: CEM Connections: Collector is 1, front bias (ground) is 2, and back bias is 3.

The details of the microMott polarimeter are published in McCarter et. al, Nucl. Instr. and Meth., A618 (2010) 30 or also found here.

Mott wiring The Mott chamber has complex wiring, which all is connected through feedthroughs on the 10" flange.

3.2.2 retarding field controls

The first of the Mil-spec multi-pin vacuum feedthroughs carries the retarding field biases and CEM front bias. The retarding field is applied to the grids in front of the CEMs and the Cans surrounding the CEMs. The CEM fronts are also biased at 0 V through this flange. The internal wiring diagram is as shown in the documents on the O drive and paper copies in the logbook. Currently, the wiring setup is as shown in Figure

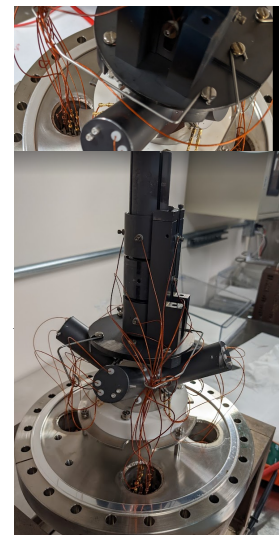
The CEM cans have feedthroughs for the collector, back and front biases. The terminals on the CEM and the position of the teflon feedthroughs at the back of the can are as shown in Figure 6 Figure 8 shows the internal wiring for the CEMs and the retarding field connections. 7.

3.2.3 mott lenses

The Mott lenses are all connected through the second Mil-spec multi pin vacuum feedthrough. The mott lenses are configured as shown in Fig 10, which is also kept up to date in hard copy and on the o drive. Figure 9 shows an internal view of the wiring from the lenses to the feedthrough.

3.3 Bellows load-lock system

The photocathode are mounted onto a long (26") stalk for use in the microMott. The bellows section is attached to the source chamber with an all metal gate valve between. The bellows section has a cross with two windows (used when we attached the



↑ Figure 9: Mott lens connections to feedthrough

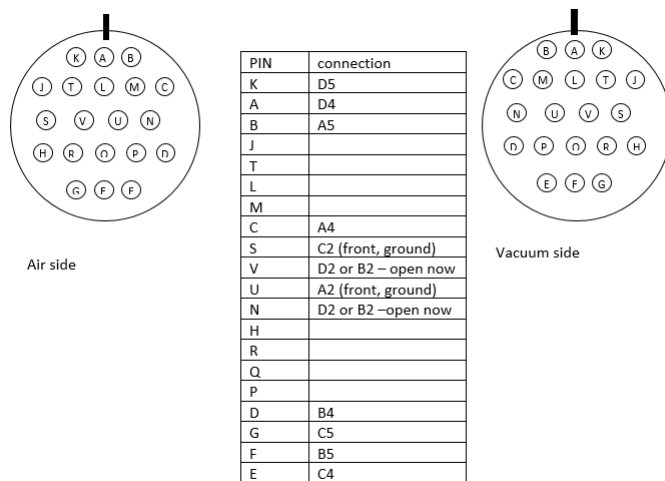


Figure 7: CEM retarding field feedthrough setup as of July 2023. Updates will be updated in both hard copy and in the O: drive

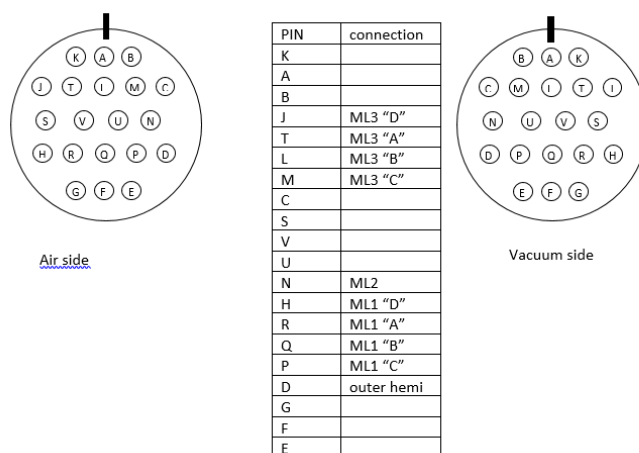


Figure 10: Mott lens connections to feedthrough

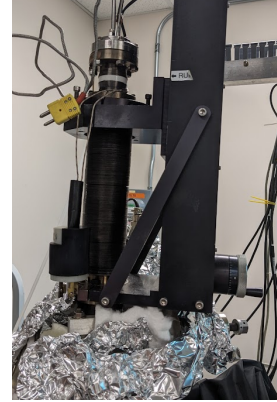
Euclid load lock), a valve for roughing out the bellows section, and a right angle valve to an ion pump. The ion pump is closed off and not vented when the stalk is changed to facilitate faster vacuum recovery.

To change a stalk, the bellows is retracted using the McAllister support strongback and usually using an electric screwdriver or the rotary manual dial on the side to move the manipulator. The threads of the strongback need to be greased occasionally. The bellows must not be vented without support - install the steel tube to support between the top of the bellows and the bottom, securing with hose clamps. Then the McAllister can be lowered until the steel tube is resting against the bolts on both the top and bottom flanges of the bellows.

3.3.1 changing photocathode

To change the photocathode,

1. turn off bias and disconnect cable at picoammeter end
2. remove bias cable from the stalk
3. retract the stalk,
4. close the gate valve to the prep chamber, and the valve to the
5. support the bellows with the steel tube
6. attach top flange to McAllister plate using screws so bellows doesn't expand out of top
7. close the valve to the bellows ion pump
8. Vent slowly with dry nitrogen from a pump cart attached to the bellows roughing port - watch the pressures in the bellows ion pump and the source chamber to verify the valves are holding
9. Remove the ceiling tile above the system
10. With a nitrogen purge, disconnect the flange at the top of the system and remove the stalk. Immediately install the new stalk with a fresh gasket and tighten flange.
11. tighten flange being careful of torque on ceramic break
12. pump down



↑ Figure 11: Bellows loadlock system

3.3.2 bellows bakeout

Once tightened, rough the system down, leak check if desired and set up bakeout.

1. remove screws holding top flange clamp to mcallister
2. Disconnect the flange clamp at the top of the bellows since the bellows is supported by the tube.
3. Retract the McAllister clear of the top of the stalk
4. Install the custom heater jacket for the bellows
5. Once ready for the bake, open the valve to the bellows ion pump. Often the rough cart isn't helping much - the rough valve can be open or closed during the bakeout since the ion pump was not vented.
6. Locate the two heat tapes wrapped around the gate valve, cross and ion pump of the bellows section - these are manually wrapped heat tapes and insulation. A custom blanket would help here. Find the plug ends for these, plug both into an extension cord connected to a variac.
7. Connect the power and thermocouple for the bellows to a heater controller (the stalk heater doesn't have enough power, use something higher power).
8. set up a bake cycle - usually 2 hours to 150C or 250C, 10 hours at 150/250C, 2 hours to room temperature.
9. The stalk can be heated using a stalk heater during the bakeout. If not using the stalk heater for additional temperature (usually 25 - 50C higher than the bake temperature), cover the top of the stalk with insulation to prevent thermal gradients and leaking flanges.

If doing a full oven bake, remove the McAllister strongback. It is not bakable. Vacuum will hold the bellows in position with the support tube - be careful when installing the top panel with the hole.

To take down the bake:

- Remove heater jacket
- Lower McAllister into position and clamp bellows flange below ceramic break
- Raise McAllister and remove support tube.

- Open gate valve
- Make sure screws attaching bellows flange clamp to McAllister top plate are removed
- Lower stalk into chamber using power screwdriver or hand tools. The stalk can catch on the entrance to the cross or to the valve - go slowly in these areas, keep your hand near the top plate and stop if there is any catching. Stop when you reach the marked "run" position on the McAllister.
- replace ceiling tile
- attach wires for stalk bias and secure isolation box

3.4 Full chamber bakeout

- Remove Optics table, disconnecting everything: x-y stage, shutter, power meter, attenuator, laser, etc
- Remove Lens and CEM cables
 1. A,B from 2.75 flange
 2. C,D,E,F from mini on source top
 3. Mott Lenses 1, 2 and 3 from Mil spec connector on 10" Mott flange
 4. CEM cables from Mil spec connector and SHV connectors on 10" Mott flange
- Remove Cs power cables
- Disconnect target connection and Can
- get loadlock bellows ready for bake
 1. disconnect cathode bias
 2. remove heater
 3. retract stalk
 4. support bellows with support tube and hose clamps
 5. close gate valve if needed, change stalk if needed
 6. remove McCalliser strongback
- Vent chamber
 1. Attach pump cart with 1 PSI pop-off
 2. Pump and backfill line to overboard bake pump with dry N₂

3. Turn off bake, source and mott ion pumps. If gate valve closed, bellows IP can remain on, otherwise turn it off too
 4. Vent slowly with dry nitrogen, monitoring bellows IP if it is on
 5. Open system and do work as needed
- Pump down
 1. close all flanges
 2. make sure bellows venting line is evacuated for bakeout
 3. leak check
 4. make sure NF3 is evacuated for bake
 - Set up for Bake
 1. Mott chamber has teflon, can't go above 200C
 2. Source chamber can be heated to 250C
 3. Remove McAllister strongback
 4. Remove gate valve handle
 5. Remove load lock heat tape plugs so they don't melt
 6. set up heater bars, an additional heat tape on source chamber if desired
 7. a center panel exists to reduce heat on target side - this can be added if desired.
 8. attach thermocouples: at least 1 for control, 1 for monitor, ideally also for source vs Mott
 9. set up panels
 - a) 3 back panels fit on table
 - b) front panel doesn't fit well - use corners to give it the additional room it needs
 - c) top panel has to be lowered down over stalk, which protrudes out of oven. Add a half panel to cover the remainder of the top of the box
 - d) put insulation "top hat" on top panel to keep stalk heated through bake
 - e) use small panel to cover gap left by top panel being off center for stalk
 10. set up temperature control: SOLO software to control heater relay box
 11. set up bake monitor software: ion pump current, turbo cart gauge, at least 1 temperature

4 Photocathode preparation

4.1 Stalk heater

The stalk heater has a temperature differential between the measured heater temperature and the cathode surface temperature. See Fig 12

1. Bulk or strained GaAs: surface temperature 550C, stalk heater 675C
2. Strained superlattice GaAs: surface temperature 500C, stalk heater 630C.
3. Strained superlattice GaAs with As cap: The As cap will evaporate around 440C. The cathode does not need to be heated much above this since there is no oxide.
4. Cool to at least 30C before starting activation

4.2 Cs

The Cs source is standard to all our systems - Use an external current source to apply current to Cs strips. The Cs is not below the stalk, so response time can be up to 15-20 minutes for the first peak, and there is measurable ion current. During operation, the deflector, directly below the stalk, suppresses some of the photocurrent. This is fine for operation, but the deflector can be grounded at the back of the equipment rack for the most accurate photocurrent measurements.

4.3 NF3

NF3 (or oxygen) is introduced into the chamber using a leak valve with a reservoir of NF3 behind it as in all our photocathode activation chambers. NF3 is introduced into the volume behind the leak valve by attaching the pumping tee (with burst disk for safety), pumping and backfilling 3x with nitrogen, then once to 2-3 PSI with NF3, then filling with NF3 to 3-5 PSI before shutting valves and evacuating the line to the bottle. The NF3 bottle line can then be vented with nitrogen for disconnection.

4.4 cathode activation

The photocathode is activated using the yoyo method:

1. Turn on either white light or laser illumination

2. Bias photocathode to about -250V with biasing picoammeter
3. Set up photocurrent monitoring – “picoammeter chart” program on data acquisition computer can be used to monitor and record photocurrent.
4. Turn on Cs to operation current - about 4.8A for fresh strips, rising to 5.2A for older strips. Pressure on ion pump should rise, usually to about 1 uA.
5. Wait for initial peak in photocurrent, then for the photocurrent to fall to half its maximal value. Turn off Cs. The first peak can have a double bump, with a small peak, a slight decrease, then a larger peak. In the Micro-Mott, the distance to the photocathode is small, so the first peak usually happens in less than 10-15 minutes. When Cs is turned off, excess NF3 remaining in the chamber can make the photocurrent rise immediately.
6. Slowly open the NF3 leak valve until there is photoresponse and pressure rise on the ion pump. Let NF3 into the chamber until the photocurrent reaches a maximum and starts to flatten out, then close valve (1 turn from open is usually sufficient). WARNING: excessive NF3 will destroy the photocathode, requiring a re-heat or replacement. Do not open the valve too much. The chamber may need to be rebaked if too much NF3 is allowed into the chamber.
7. Repeat Cs until current falls to 50 percent of its peak, then NF3 to maximize current in “yo-yo” cycles until there is less than 10 percent increase between adjacent peak currents.
8. Turn off Cs and fully close NF3 valve (Do not overtighten NF3 valve: sapphire seal will crack or VAT needle valve will be damaged)

4.4.1 Heat Cycle

The interlock must be disconnected and the bias must be removed from the stalk before the heater and thermocouple for heating can be connected. During the heat cycle, measure pressure on the ion pump using the picoammeter program through the, and control the heat cycle using the blue heater box with the N2 interlock or the silver bake box with a gray relay box. There must be slow N2 flow into the stalk enclosure to avoid having the stalk heater oxidize and seize inside the stalk during heating. For the blue box,

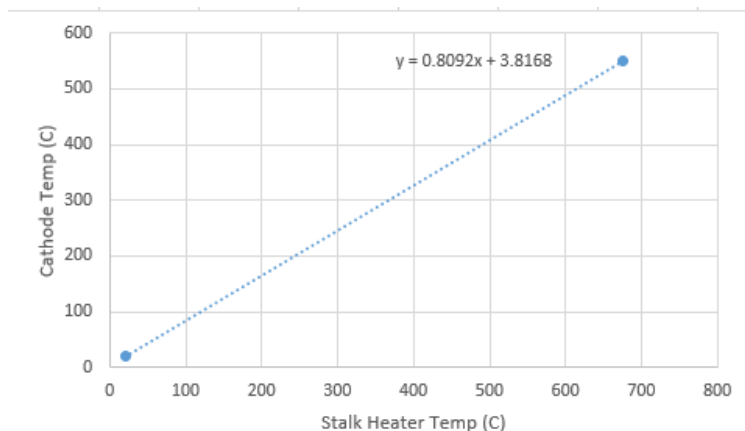


Figure 12: formula for approximating cathode temperature from temperature set on the stalk heater

the nitrogen has to be in the low flow position during heating, then can go to max flow to cool. The stalk heater must be disconnected from power and thermocouple before the stalk is biased.

4.5 Stalk bias

The stalk is biased using a BNC cable broken out such that the center pin is attached to the top of the ceramic break with a lug connector on a screw, and the ground is attached to the bottom part of the ceramic break with a hose clamp. The isolation box must be closed over the top of the stalk before turning on the bias. When the biasing picoammeter is used, the interlock ensuring the box is closed adds an additional layer of security.



↑ Figure 13: Stalk isolation box - interlock wire attached around box

4.6 optical illumination ports

There are two optical ports that can be used for illumination of the photocathode during activation - White light can be introduced using a lamp through the side window for initial activation (and also for initial attempts to get transmission to the target). The bottom port allows normal incidence laser light illumination of the photocathode. However, due to potential misalignment between the deflector, the stalk and the window, the laser is not necessarily incident on the cathode during initial alignment. The x-y stage should be used to move the laser to a position where the laser hits

the cathode. Avoid steering the laser with the mirrors on the x-y stage to preserve a beam incident normally on the photocathode.

5 Electrostatic lenses

The electron beam is emitted with longitudinal polarization. The electron beam extracted from the photocathode needs to be deflected 90 degrees to have transverse polarization incident on the Mott target. It also needs to transport to the detector. This is accomplished for this low energy (250V) electron beam using electrostatic lenses.

5.1 Source lenses

The source lenses consist of the deflector/pusher positioned under the photocathode on a bellows assembly. These are labelled A and B, and are labelled "left" and "right" to connect to the left and right pins on the feedthrough. The next lenses are mounted in an insulating holder and secured in the exit port of the source chamber. These are called C, which is held at ground to attract the beam, D and E which are a pair that can both focus and steer in the vertical direction, and F which is focusing only. The source lenses are controlled by computer controlled bias supplies using the "octal power supply" program. The Octal Power supplies each have 8 individual supplies, up to 360V, 0.8 mA each. When the USB connections are unconnected and reconnected, the computer can lose the address or swap the naming for the two octal power supplies. This needs to be checked when things are disconnected.

5.2 Mott lenses

The Mott lenses transport the beam in the Mott chamber. Mott lens 1 and 3 are split into four parts, which can be used either together for focus or in pairs for vertical and horizontal steering. These are controlled by the Mott lens octal power supply. Mott lens 2 is bias only, and is controlled by channel 8 of the source lens power supply.

6 High voltage

The 250V beam is accelerated to an energy between 5 and 30 kV (typically 20 kV) between the outer hemisphere and inner hemisphere of the Mott polarimeter assembly. The inner hemisphere

and target are isolated on a thick ceramic base and connected to high voltage through the central connector on the Mott flange. See Figure 4 The bias supply is an Spellman power supply in the large silver box (max 30 kV, 0.33 mA). The high voltage connector is shielded from contact with the aluminum can clamped over it during operation. The target can be switched from high voltage to low voltage bias for photocurrent measurement using the orange high voltage connectors. Make sure to turn down then power off and unplug the high voltage power supply before disconnecting the high voltage cable. The 250V bias for the target and picoammeter can be connected hot with this high voltage connector since the conductors are well recessed.

This high voltage system can generate x-ray radiation. Therefore all operators need to be RW1 trained, and the RCOP needs to be renewed annually for the system. The system can operate up to the RCOP limit (currently 14 nA) on target at voltages up to 30 kV: operation at higher currents requires another survey to determine if x-ray radiation can be detected outside the chamber which would require additional shielding. Up to the allowed current, the vacuum enclosure sufficiently shields any radiation.

7 Optical System

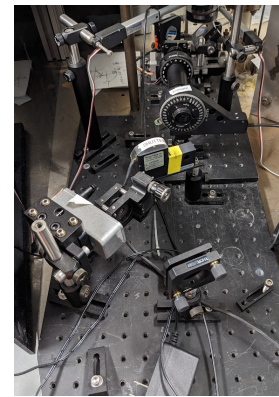
The system can be operated using the superK tuneable wavelength laser or a fixed diode laser. These both provide laser light less than 3 mW, and are minimally hazardous class 3R laser systems.

7.1 optical layout

The optics used in the DAQ program are the laser, a shutter, an attenuator if needed, a clean-up linear polarizer, two lenses on an x-y stage for steering and directing upward, then a quarter waveplate and an insertable halfwaveplate. A rotatable halfwaveplate can be added in front of the diode to rotate polarization so that it matches the nominal setup for the SuperK laser. We also use a power meter to measure optical power entering the chamber for QE measurements. For the When using the SuperK laser, a long-pass filter is needed to avoid any low wavelength light leakage.

7.2 laser control

The laser is computer controllable. Currently, power is controlled manually and wavelength is controlled through the computer



↑ Figure 14: optics table with diode laser

interface. The bandwidth of the laser output is administratively limited to 2 nm - larger bandwidth can provide power that would exceed the LSOP output power limits in place. The LSOP is maintained by the laser safety officer and users must be trained on and sign the current LSOP before operating the polarimeter. The laser helicity is changed during operation by inserting the IHWP using a phidget motor, which is computer controlled.

7.3 power meter control

The power meter can be remotely controlled to set the wavelength and read the power. The interface for this power meter is touchy and difficult to get working. The way I've used it is to run the sample code opening and closing the power meter for each read. Otherwise it has not worked. The power meter can be automatically inserted using a phidget motor control. The alignment varies with the x-y stage position and must be manually verified.

7.4 position scans

The laser can be scanned across the surface of the photocathode using the x-y stage. The x-y steppers are controlled by the phidget box on the side of the equipment rack. This can get a QE scan or if the lenses are biased, show where the highest transmission spot on the cathode is. These cannot be plugged into a USB breakout box, and must be close enough to the computer to be plugged in directly.

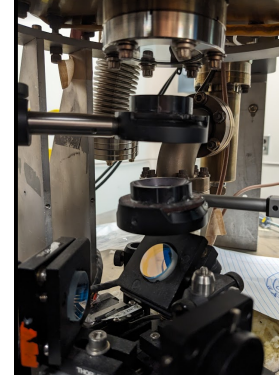
7.5 optical polarization setup

To measure the optical polarization of the laser, a rotating halfwaveplate (using the waveplate spinner from John Hansknecht's company) is placed above the quarterwaveplate. Then a linear polarizer is placed between the spinning waveplate and the power meter. The output of the power meter is sent to an oscilloscope and the amplitude of the difference is minimized by rotating the quarter waveplate. Once the quarter waveplate is set, the insertable halfwaveplate (IHWP) is inserted, and the amplitude is minimized again by rotating the IHWP.

The equation for calculating the polarization is

$$\frac{2\sqrt{V_{max}V_{min}}}{\sqrt{V_{max}+V_{min}}}$$

where Vmax and Vmin are the maximum and minimum of the sine wave as the IHWP rotates as measured on the oscilloscope.



↑ Figure 15: x-y stage, insertable halfwaveplate, and quarterwaveplate

8 Detectors

The polarization is measured using channel electron multipliers. We have been using CEM KBL-18RS from Sjuts. These are installed in aluminum holders attached to the outer hemisphere of the polarimeter. They need three connections: front, back and collector. The back and collector are connected through the SHV 5 kV connectors on the chamber, while the front is at ground and comes out on the same feedthrough as the retarding field connections. When installing, care must be taken such that the front does not short to the retarding field grids or the can (same voltage), nor can any of these short to ground.

8.1 bias

The bias for the detectors is provided by the Bertan (or CAEN) HV supplies in the NIM crate. The bias is typically between 2.3 kV when the detectors are new, up to 3.5+ kV when the detectors are aged. The front grounded, while the back and collector are biased at +3kV with current limiting resistors. The signal output of the bias box is capacitively coupled, as shown, so that the output signal can be carried on BNC cables to the preamp then discriminator.

8.2 preamps

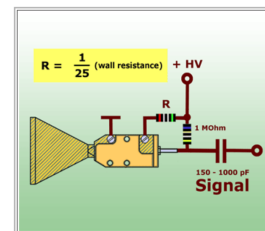
The output pulse from the CEM bias box goes directly into discrete preamplifiers. These are powered with the 12V low noise bias box, and the output goes to the discriminator

8.3 discriminators

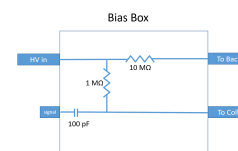
Two discrete discriminators are used to process the signal before going to the counting electronics. The lower threshold should be chosen such that the pulses when the beam is off don't register, and when the beam is on, the pulses are turned into a ttl signal. These discriminators are powered by both positive and negative 12V from the low noise 12V power source as well.

8.4 counter/timer DAQ

We use a NI USB-6341 multifunction daq card to count the signals from the detectors. This is fed into a labview program that integrates for an amount of time, (default 10 seconds), then the IHWP is inserted and the DAQ counts again. The output of this



↑ Figure 16: wiring to the CEM. The HV is applied to the back and collector through the bias box, and the capacitively coupled output signal is connected to the pre-amp then discriminator into the DAQ system



↑ Figure 17: wiring to the CEM. The HV is applied to the back and collector through the bias box, and the capacitively coupled output signal is connected to the pre-amp then discriminator into the DAQ system



↑ Figure 18: bias box and preamp

integrated count is fed into an output file that is read by the the asymmetry analysis program to determine the polarization. Currently there are 7 used channels on the USB6341. The controls on the USB6341 in use currently are as follows

Port	Function
ai0	Left CEM Voltage Monitor
ai1	Right CEM Voltage Monitor
ai2	
ai3	
ai4	
ai5	
ai6	
ai7	Source Gamma Ion Pump Monitor
ai8	
ai9	
ai10	
ai11	
ai12	
ai13	
ai14	
ai15	
ao0	350 V Control
ao1	
port0:line0	
port1:line0	
port2:line0	
port2:line6	Shutter (PFI14/P2.6)
ctr:0	
ctr:1	
ctr:2	UP CEM (PFI6/P1.6)
ctr:3	DOWN CEM (PFI3 / P1.3)

Table 1: USB6341 port usage

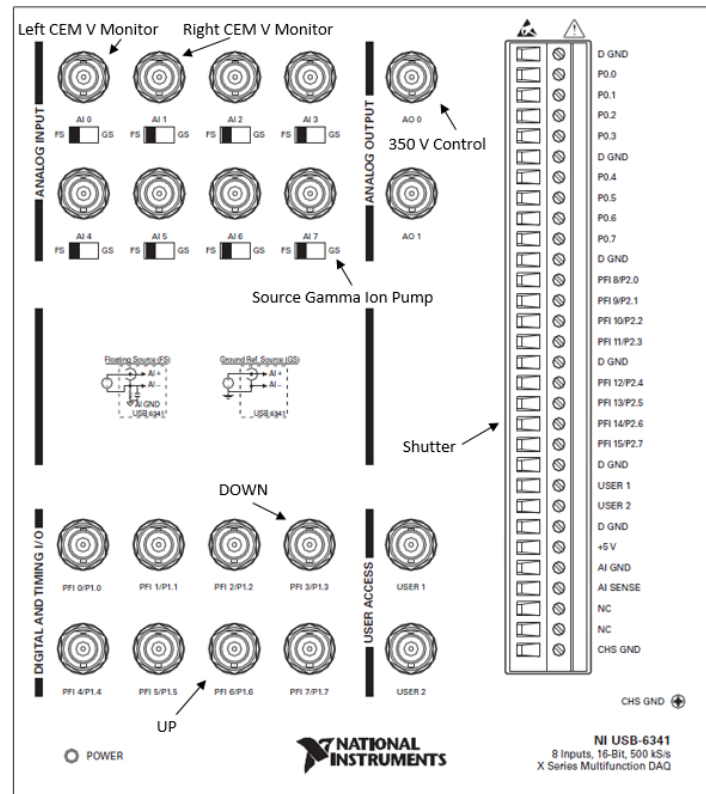
8.5 USB controlled hardware

Much of the hardware is controlled directly by the computer through USB connections.

The following components are directly controlled by the computer:

1. attenuator box connects directly by USB
2. superK laser connects directly by USB

USB-6341 (BNC)



3. x-y stage connects to a phidget box which connects by USB to the PC
4. the insertable halfwaveplate connects to a driver box that connects by USB to the PC
5. the new Keithley biasing picoammeter connects using RS232 to the computer

9 Retarding field

The retarding field Mott polarimeter operates by scattering electrons at 20 kV (variable from 5 to 30 kV) from a thick gold target. The elastically scattered electrons have the best polarization information, while electrons that have lost energy due to inelastic or multiple collisions, though higher in number, carry less polarization information. To measure polarization, retarding field scans are taken to energetically analyze the scattered electrons. The asymmetry as a function of retarding field is then extrapolated to the elastic scattering energy, where there are few counts, and this extrapolated value is the asymmetry used to measure the polarization. The analyzing power of the system was determined with cross calibration of samples between this polarimeter and the JLab 5 MeV Mott polarimeter.

9.1 retarding field grids and bias

The electrons are accelerated from 250 V transmission energy to 20,250 V between the grounded outer hemisphere and the biased inner hemisphere. The scattered electrons are then decelerated as they travel back to the outer hemisphere, and arrive at the detectors with energy up to the 250V transmission energy. To do the retarding field energy analysis, there are two parallel fine mesh gold grids located in front of the each detector. These are biased using a DC voltage source, and the voltage is measured using a Keithley voltmeter. All 8 grids are connected to a breakout panel in the equipment rack and ganged together to have the same bias. The measured bias is recorded in the data stream for each measurement. The communication to the retarding field voltage source and measurement is accomplished using the GPIB to USB National Instruments interface.

10 Software

The system uses custom Labview software to control and read all signals.

10.1 Picoammeter - monitor current, pressure

The picoammeter software reads currents from both the cathode and target picoammeters using a GPIB to USB National Instruments device. The software can also control the laser shutter, and the output from a gamma ion pump power supply is recorded through an analog input in the NI USB-6341 multifunction daq card.

10.2 AutoQE - control laser and power meter

The AutoQE program communicates with the laser through its USB interface and the laser power meter through its USB interface. It reads the cathode picoammeter using the GPIB-USB interface. Starting and ending wavelengths and step size are input, then the program runs the laser through the wavelength range measuring current, either inserts the laser power meter or prompts the user to insert the power meter, then runs back through the laser wavelengths measuring laser power. These are combined in an array and output to an excel spreadsheet.

10.3 lens power supplies

To steer the electrons through the system, we control two 8 channel DC bias supplies, all negative voltages. Channels 1 and 2 are Lenses A and B, the deflector and pusher, channels 3-6 are the remaining source lenses and channel 8 is mott lens 2. The second supply controls the 4 lenses each of mott lens 1 and mott lens 2. We have a save/restore system for the setpoints of the lenses which reproducibly returns the lenses to prior settings. The system relies on the COM port these are plugged into. If they change position, they can swap which one is called which and this needs to be an early step in troubleshooting when things won't steer.

10.3.1 steering to target

Procedure for getting beam to target is as follows. // 1) If only the light has changed See if you get transmission using white light. If there is some transmission, move to laser. If there is no white light

transmission with good current, you may need to touch up steering as in the later sections. // Once you have white light transmission, turn on the laser and do an x-y stage scan to find a position for transmission using the laser. After there is transmission, adjust lenses to increase transmission with a goal of at least 5 percent. // 2) If photocathode position has changed Steering is very sensitive to position of the photocathode. Height adjustments can be made to try to get back to previous position using transmission as a criterion to see if things are as good as they were. The deflector bias, B, is very sensitive to the position of the photocathode, so changes to B may help if photocathode position is different. Backplane A is also helpful in starting steering after a cathode position movement. // 3) Starting from scratch With as much photocurrent as possible, attach target bias to the "Faraday cup" in from the side of the Mott chamber. This will tell you when you are successfully getting beam around the electrostatic bend as you steer with the Mott lenses. When this is optimized, retract the "Faraday Cup", then gang all of MottLens1 together and bias with the target bias using BNC tees. Adjust source steering until there is current on ML1. Once there is transmission to ML1, reconnect to lens supply and bias the target. The CEMs are more sensitive than the picoammeter on the target. Bias CEMs and use program to monitor CEM counts vs. steering settings to get initial current on target. Then once you have current, you can optimize using the lenses and the picoammeter.

10.4 x-y stage - move laser

The x-y stage moves through a phidget interface to the x and y stages. The box with the controllers is located on the side of the equipment rack. When this program is stopped without closing properly, these crash and cannot be restored until the entire lab-view program is closed and restarted. This software cannot be updated to the most modern version without a complete rewrite of the program - please keep using the 32 bit older driver or these fail. The stages connect through cat5 connectors.

10.5 MottDAQ

The MottDAQ is the main program. It communicates with

-
- shutter
- insertable halfwaveplate

- retarding field supply
- retarding field measurement
- counters through NI USB-6341 multifunction daq card
- laser wavelength: wavelength scans only
- laser attenuator: wavelength scans only

CEM high voltage and Mott high voltage must be set manually, as well as SuperK laser power.

The program is set to vary retarding field voltage from 150 to 330 V in steps of 10V, counting for 10 seconds each. By default, there is a dark background measurement, 3 cycles of IHWP out/in, then another dark background before stepping to the next voltage. All data is stored in an internal array and written at the end only.

/hiThe data columns are Channel1/State 1, Channel1/State2, Channel2/State1, Channel2/State2, Channel3/State1, Channel3/State2, Channel4/State1, Channel4/State2, Retarding field voltage, Current State1, Current State2, IHWP status, integration time
A comments field is also recorded in a separate text output file in the comments folder

For wavelength scans, the wavelength is also recorded.

10.6 Asymmetry analysis

The asymmetry analysis first subtracts the average dark current from the average counts for each helicity state.

The background subtraction fits a line to the data above the cutoff voltage, then subtracts the extrapolated value of the background from the counts at each voltage.

The asymmetry is calculated using the formula

$$A = \frac{\sqrt{L1R2} - \sqrt{L2R1}}{\sqrt{L1R2} + \sqrt{L2R1}}$$

The uncertainty in the asymmetry is carried through each calculation and reported at the end

The polarization is calculated using the effective Sherman function, which depends on the high voltage used, and was determined by cross comparison of samples with the CEBAF 5 MeV Mott.

11 computer interfaces

- target picoammeter: GPIB
- cathode picoammeter: RS232 to USB
- retarding voltage supply: GPIB
- retarding voltage measurement: NI DAQ unit
- two 8 channel power supplies: USB
- Not connected: CEM voltage monitor, HV monitor
- laser wavelength set/measure: USB
- power meter wavelength set/power measure: USB
- power meter insertion: phidget to USB
- shutter: NI DAQ unit
- attenuator: USB to computer
- insertable halfwaveplate insertion: phidget to USB
- x stage and y stage: phidget box: must be directly connected to computer without a splitter box

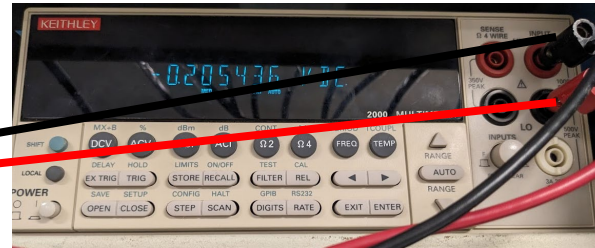
Counter/Timer Signal	Terminal Name
CTR 0 SRC	PFI 8
CTR 0 GATE	PFI 9
CTR 0 AUX	PFI 10
CTR 0 OUT	PFI 12
CTR 0 A	PFI 8
CTR 0 Z	PFI 9
CTR 0 B	PFI 10
CTR 1 SRC	PFI 3
CTR 1 GATE	PFI 4
CTR 1 AUX	PFI 11
CTR 1 OUT	PFI 13
CTR 1 A	PFI 3
CTR 1 Z	PFI 4
CTR 1 B	PFI 11
CTR 2 SRC	PFI 0
CTR 2 GATE	PFI 1
CTR 2 AUX	PFI 2
CTR 2 OUT	PFI 14
CTR 2 A	PFI 0
CTR 2 Z	PFI 1
CTR 2 B	PFI 2
CTR 3 SRC	PFI 5
CTR 3 GATE	PFI 6
CTR 3 AUX	PFI 7
CTR 3 OUT	PFI 15
CTR 3 A	PFI 5
CTR 3 Z	PFI 6
CTR 3 B	PFI 7
FREQ OUT	PFI 14

Table 2: Counter Terminal Defaults

Retarding Field Bias



Voltage Source
GPIB to computer



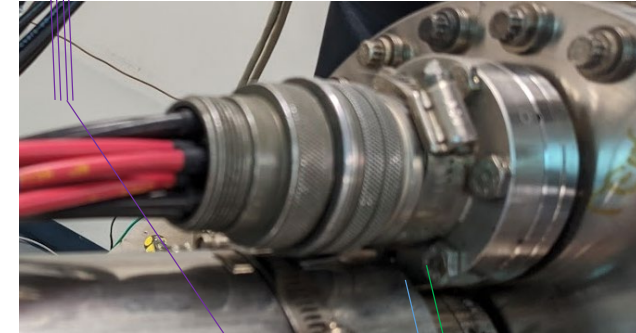
Voltage measure
NI DAQ to computer



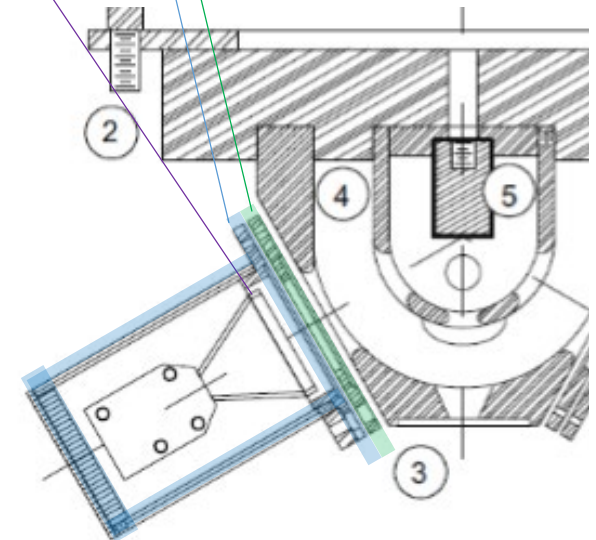
Patch panel: all wires at same voltage



CEM Front to ground

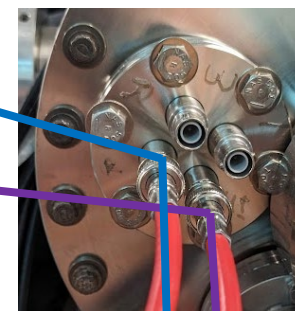
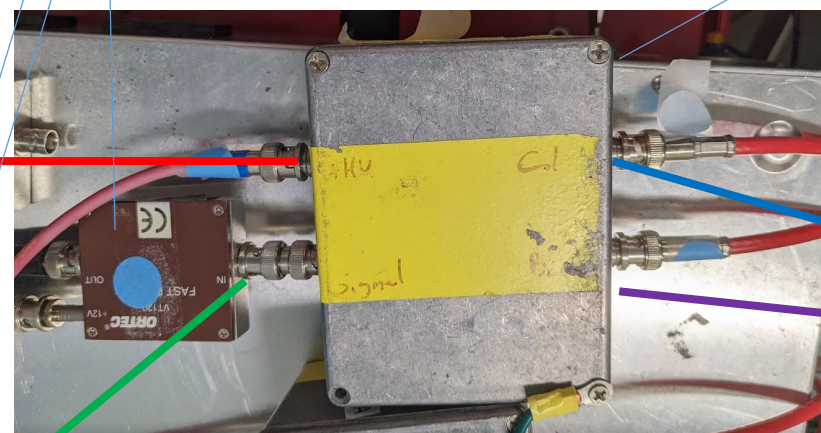
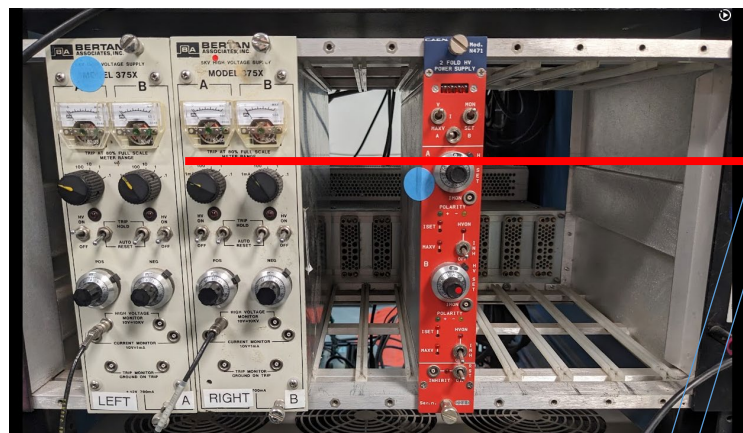
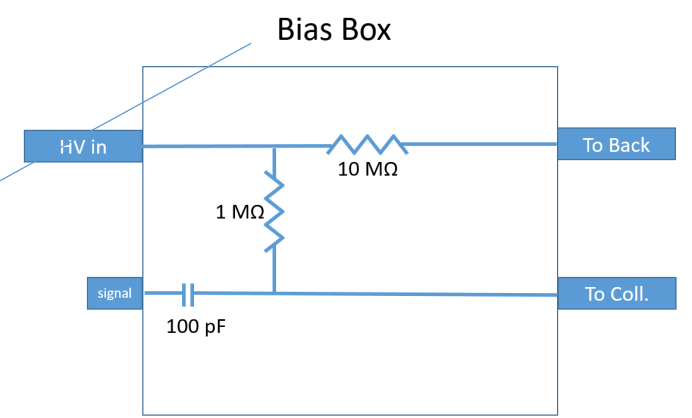


Retarding field grid 1
Retarding field grid 2 + can



CEM Bias

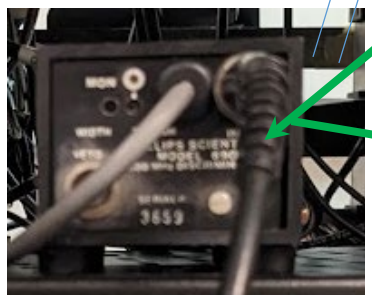
12V power for preamp and discriminator



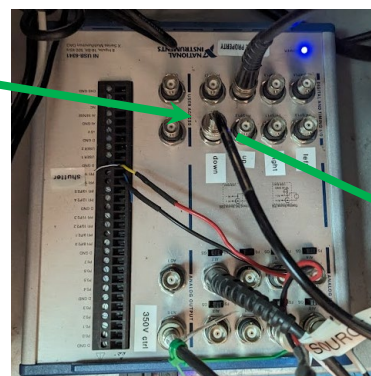
CEM bias feedthrough:
Back and Collector

preamp

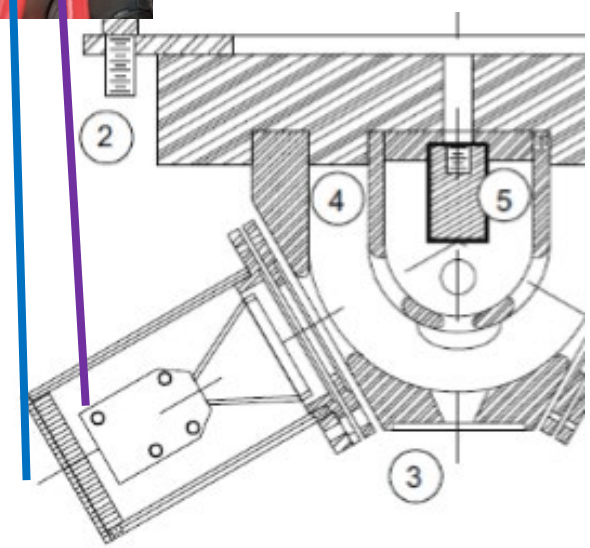
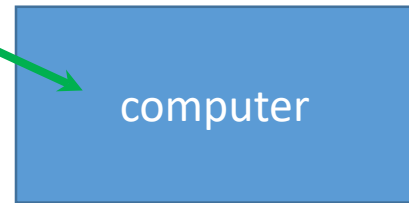
Capacitively
coupled
signal out



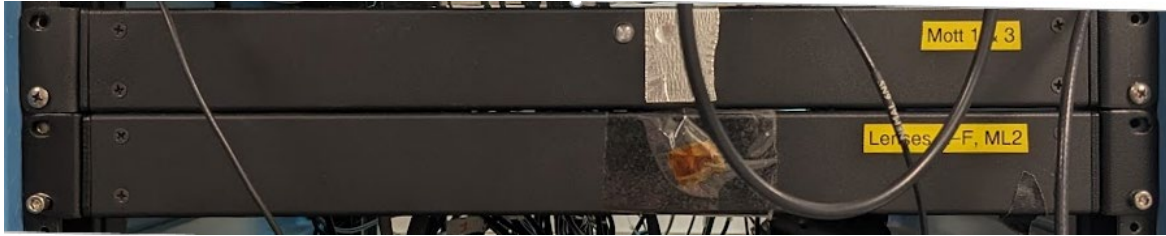
Discrete
discriminator



NI DAQ counter timer

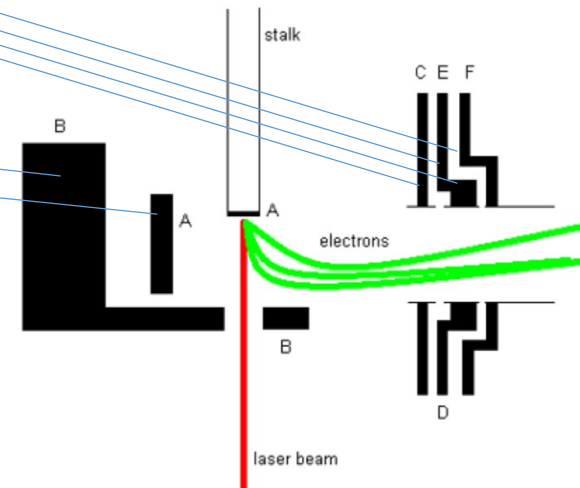
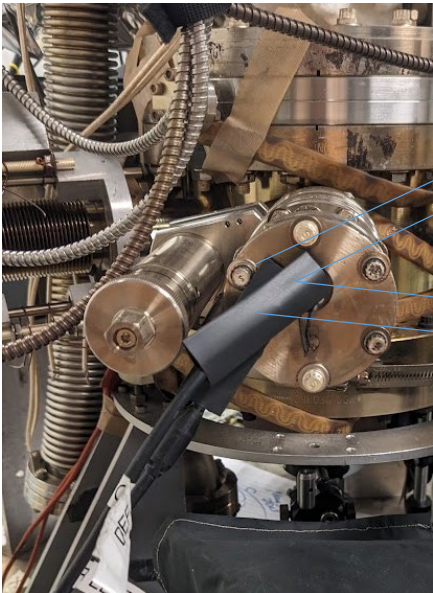
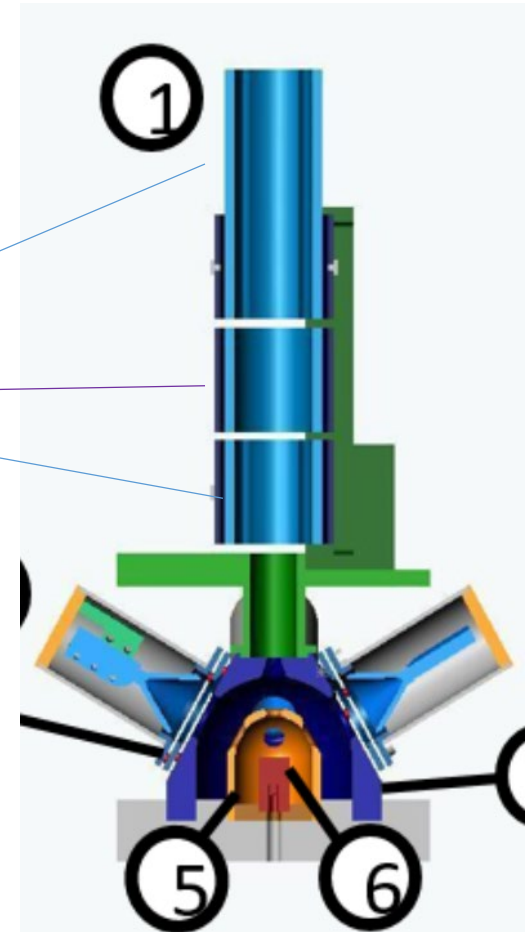
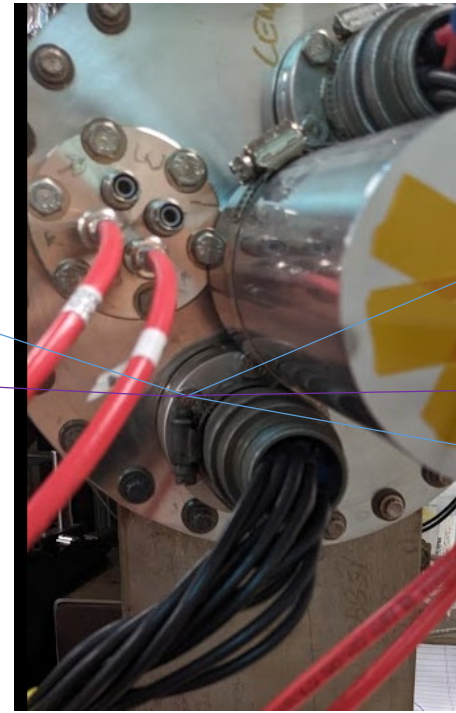


Steering Lens biases



8 channels

1 mott
6 source

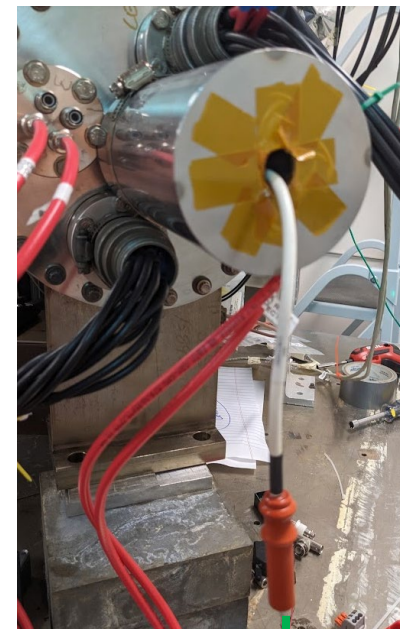


30kV bias

front



30 kV feedthrough
under shield can



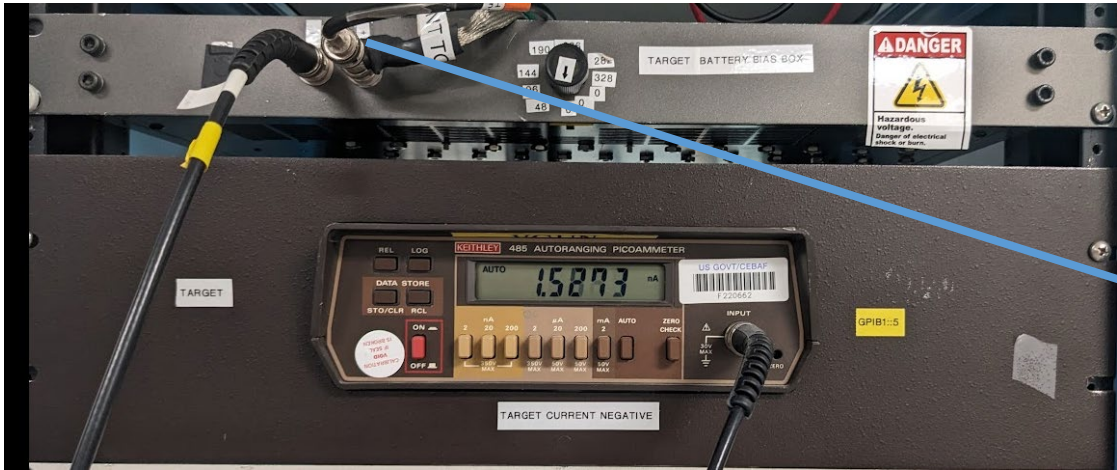
AC power cord
disconnected when
moving cable

back

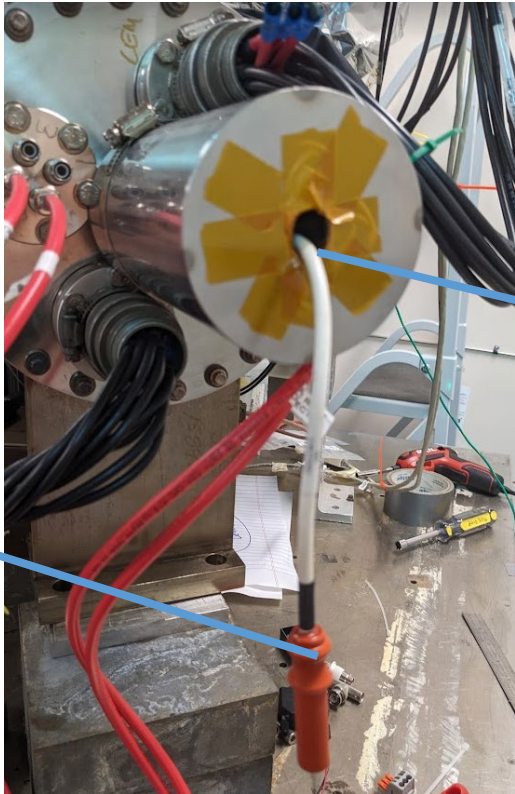
HV Bias cord

Target bias

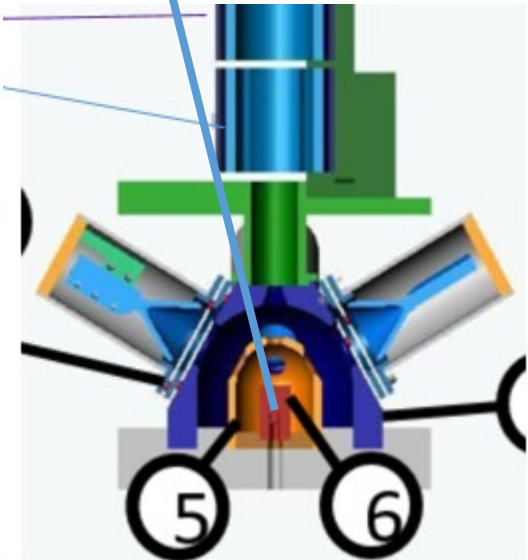
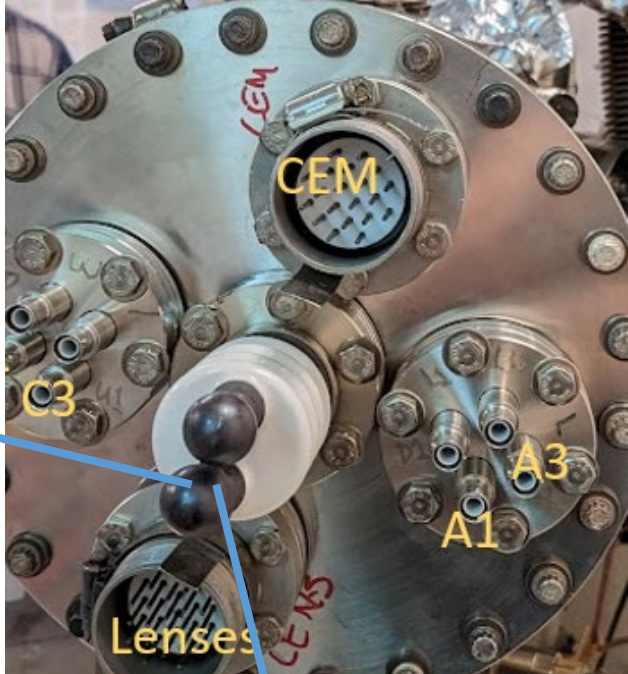
Battery bias box



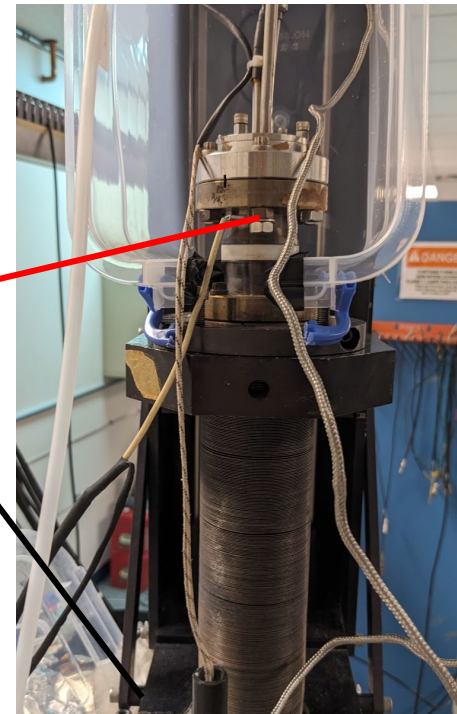
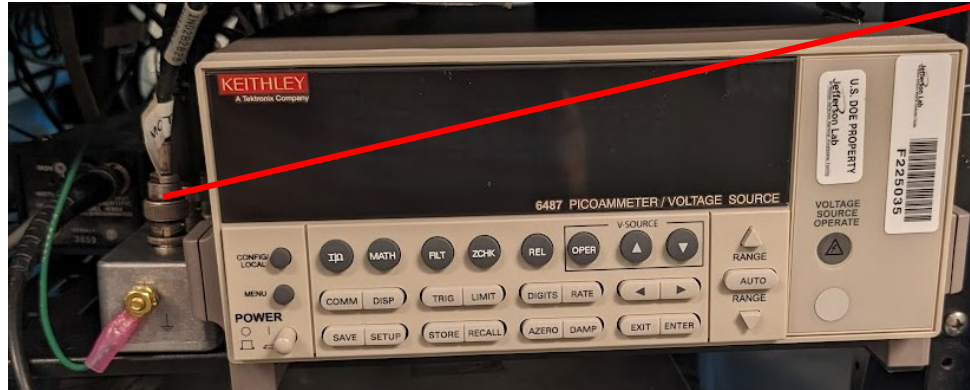
Keithley picoammeter



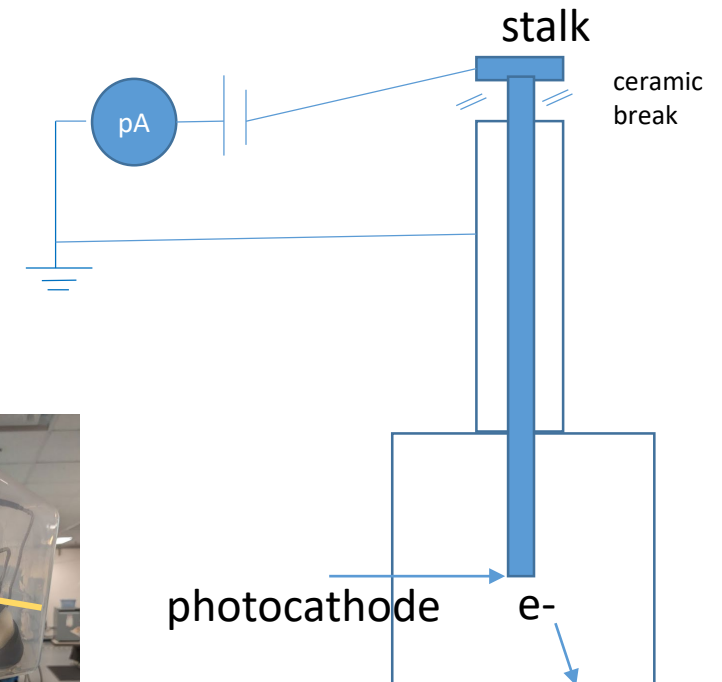
BNC terminates in 30 kV socket



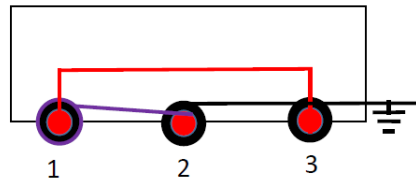
Cathode Bias



Current flow:
Stalk biased negative
Photoelectrons emitted to ground
Picoammeter measures current in circuit



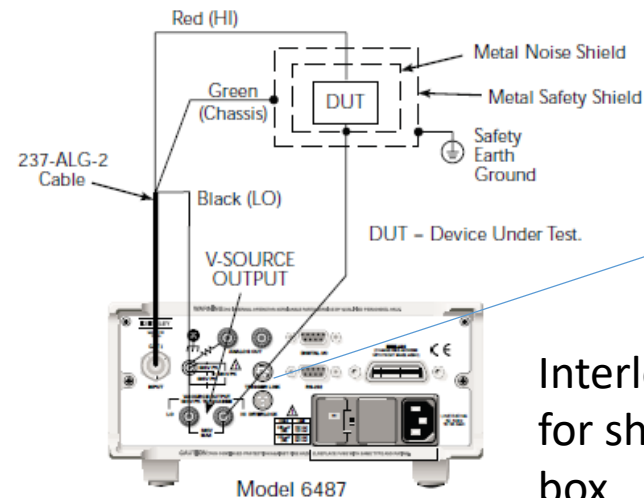
Patch box



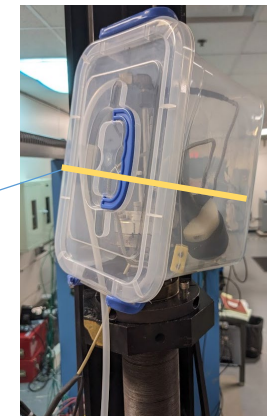
Connector 1: Isolated BNC Bulkhead
Connectors 2&3: BNC bulkhead

Connections:
Pin1 to Pin3
Shield 1 to Pin2
Shield 2 to Shield 3 to equipment ground
External ground lug

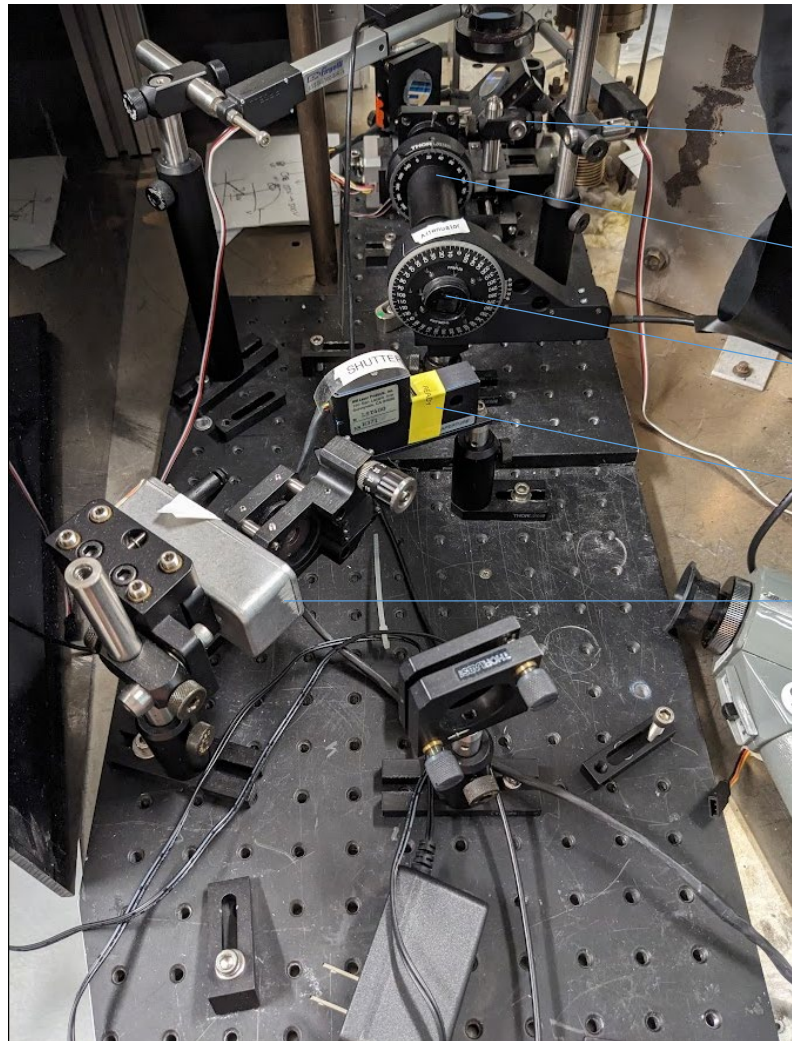
Figure 3-2
Connections for ohms measurements



Interlock
for shield
box



Optics Table



X-Y stage

Cleanup Polarizer

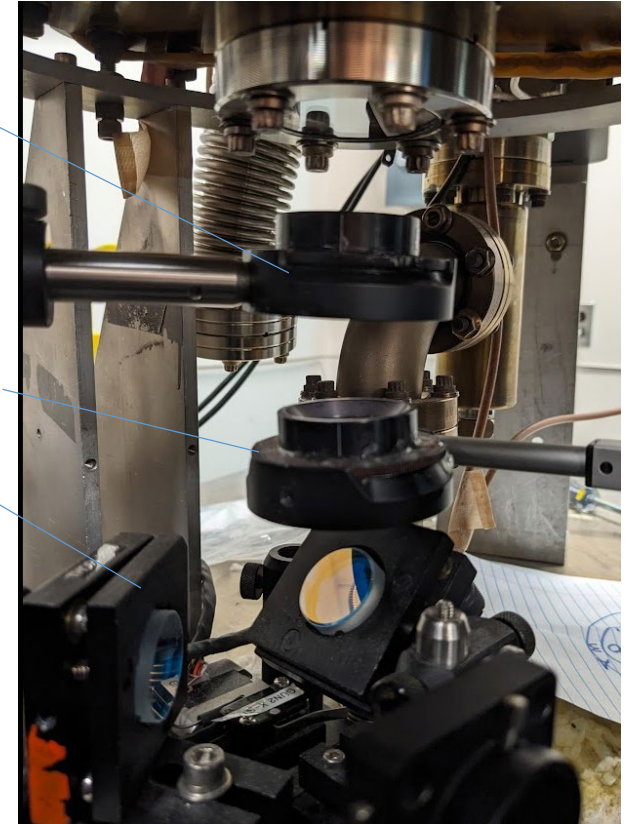
Attenuator

Shutter

Diode or SuperK laser

Quarter
waveplate

IHWP



Controls:

1. x-y stage: phidget box to PC
2. Attenuator: mfg box to PC
3. Shutter: control to NI DAQ
4. SuperK laser: direct to PC
5. IHWP: Phidget silver box on table to PC

Bias Box internal diagram

