MicroMott Polarimeter: JLAB-TN-09-062

Low Voltage Retarding Field Mott Polarimeter Setup and Operation

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Overview

The compact low-voltage Retarding field Mott polarimeter is now in routine use in room 118 EEL. 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. The electrons are bent 90° using an electrostatic bend then steered and focused with electrostatic tube lenses. The electrons are accelerated to scattering energy (5-30 kV) between the grounded outer hemisphere and the biased inner hemisphere, scatter off the thick gold target, and are decelerated to incident energy while 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 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.

Initial Setup

Internal Wiring

Channel Electron Multipliers

Each CEM has three connectors. The signal is connected at the back of the CEM and designated lead 1. The front bias, connected at the front of the CEM, is designated lead 2. The back bias, in the center of the CEM is designated 3.

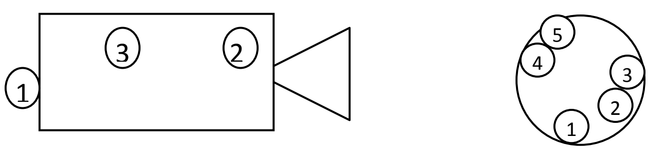
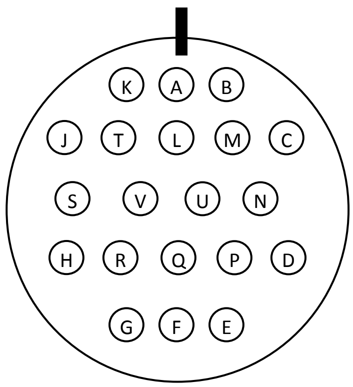


Figure 1 CEM and shielding can electrode configuration
1: collector
2: front bias
3: back bias
4: can and can grid
5: retarding field grid

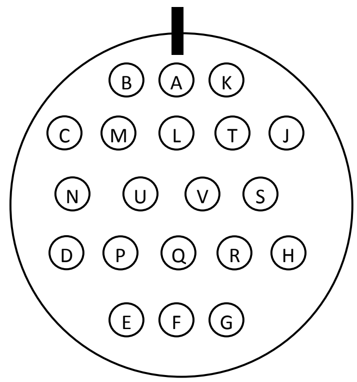
Wiring: CEM to vacuum feedthroughs

Channel electron multipliers are connected to the high voltage bias and detection electronics through the first of two multi-pin vacuum feedthroughs. The wires are connected as follows.



Air side

PIN	connection
K	L5
A	L4
B	U5
J	L3
T	U3
L	R3
M	D3
C	U4
S	L2
V	U2
U	R2
N	D2
H	L1
R	U1
Q	R1
P	D1
D	R5
G	D4
F	D5
E	R4

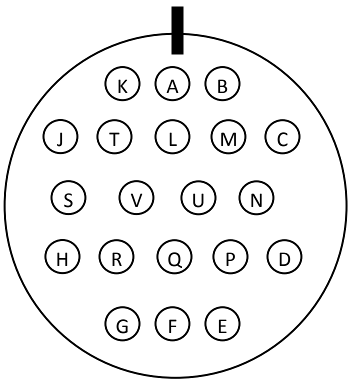


Vacuum side

Figure 2 CEM bias feedthrough. L/R/U/D designate Left/Right/Up/Down. 1-5 are the connectors for the CEM collector, front, back, can and retarding field grid.

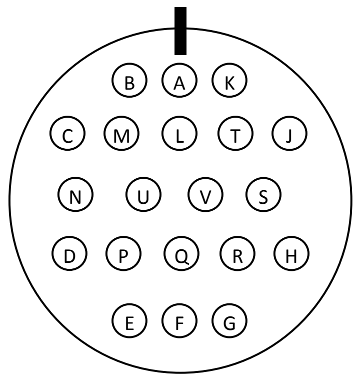
Mott Lens Vacuum feedthroughs

Mott lenses are connected to the bias supply through the second mil-spec multi-pin vacuum feedthrough. The wiring diagram is as shown.



Air side

PIN	connection
K	
A	
B	
J	3L
T	3U
L	3R
M	3D
C	
S	
V	
U	
N	2
H	1L
R	1U
Q	1R
P	1D
D	outer hemi
G	
F	
E	



Vacuum side

Figure 3 Mott lens feedthrough connection diagram. Lens 1 and 3 left/right/up/down connections, lens 2 and outer hemisphere bias connections are as listed.

Initial Bakeout

The polarimeter system consists of two vacuum chambers separated by an orifice in a copper gasket. The Mott chamber has Teflon insulators which cannot be baked above 200C, while the polarized source chamber should be baked to near 250C to obtain optimal vacuum. This is accomplished by separating the oven during the bakeout by an internal partition, and regulating the bake on the Mott chamber while running the heater on the source side of the partition, which ensures that the Mott chamber does not get to hot while the source chamber is heated as high as possible.

Preparation for venting entire system

- Make sure all voltage supplies are off

- Disconnect all bias supplies to avoid incidental contact
- Secure the long bellows with the aluminum support tube
- Turn off all ion pumps that will be vented

Bake preparation: entire system

- Rough down with a turbo-pump cart until the ion pumps can come on.
- Check for shorts: Mott lenses to ground through shield, all CEM electronics connections
- Leak check using the RGA if desired
- Pump out and pinch off a copper tube at the back of the load-lock right angle venting valve.
- Pump out the NF_3 reservoir
- Remove McAllister support for bellows
- Remove the plugs from the cross/ion pump load locked heater tapes if they are in place
- Set up bake oven
  - Install central panel to separate two sections – use minimal tape, as it will burn in oven
  - Attach control thermocouple in Mott section
  - Attach monitor thermocouples in both Mott and source sections
  - Install heater in source side of chamber
- Set up bake cycle
  - 12 hours to 200°C on Mott side (slower ramp if necessary)
  - 30+ hours at 200°C (note temperature on Source side during soak – typically below 250°C with this oven)
  - Cool to 120°C in 6 hours, soak at 120°C 6 hours, cool to room temperature in 4 hours.
- Bake with valve to overboard ion pump (below table) open.

  Ideally, run with source ion pump turned on until ~150°C, disconnect source ion pump and bake with Mott and overboard pumps on.

  During ramp down, during 120°C plateau, turn on source ion pump and close valve to overboard pump.

External wiring

Following bakeout, reconnect the multi-pin connectors in the Mott chamber, and reconnect the Source lenses according to Figure 6, ensuring that the supply is off before making connections and that the terminals are insulated before energizing the supply.

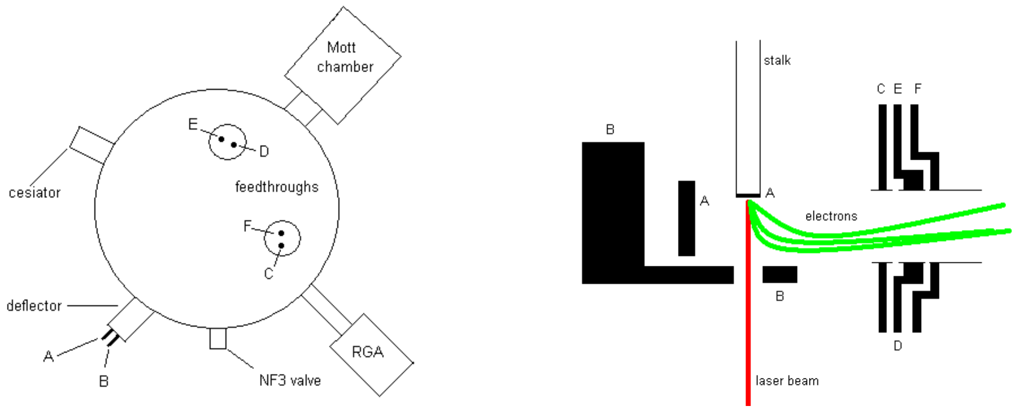


Figure 4: Vacuum feedthroughs for biasing electrostatic bend and polarized source lenses. Lettering is consistent between two diagrams.

Routine operation

Photocathode exchange

New photocathode material can be loaded into the system using the load-lock bellows and a short bake of only the bellows and associated cross.

- Retract the stalk fully into the bellows using the McAllister linear bellows translator and close the 3" gate valve.
- Support the bellows before venting with either an aluminum or cardboard tube. (Aluminum can be left in place during load-lock bake, and must be used if McAllister support is being removed.)
- Turn off the uppermost "bellows" ion pump before venting the load-lock using the turbo pump cart and dry nitrogen. When the whole system must be baked, a pinch-off valve must be used to protect the right angle valve for the load-lock system, but for load lock venting only, a CF-NW adapter can be used for venting the load lock system.
- If desired, set up a glove bag around the bellows and purge with dry nitrogen – this will reduce the amount of water in the system during the cathode exchange.
- Remove the old stalk and replace it with a stalk with the new cathode.
- Tighten the flange, pump down and when the convectron gauge on the pump cart reads zero, turn on ion pump.

Load-Lock bake

Equipment Required

All the required following equipment should be found in the test cave cabinet:

1) One long heat tape, aluminum foil, heat resistant adhesive tape (wide and narrow), the bellow insulating "blanket".
2) One thermocouple is needed for the bellow, two others should already be in place on the upper VAT valve (*ie* : cross) and one on the load lock pump.
3) Three Variacs and thermocouple readers.
4) Extension cords, ground fault interrupter (yellow plug with reset), timer.
5) Stalk heater and controller.

Prerequisites

The following procedure assumes that the MicroMott is in a "ready state" to undergo a load lock bake. This means that:

- A new stalk has been installed. The bellow, supported by the Mac Allister mount, is extended to its retracted position (~ 30" from the 10" flange).
- The heating durations for the bake given in the following procedure assume that the loading of the stalk was performed quickly under Nitrogen atmosphere. If this is not the case, you may want to proceed more slowly and increase the temperature ramp time.
- The load lock chamber is isolated from the main chamber (*ie* : load lock valve closed).

The load lock bake out procedure

The following steps need to be completed :

1) Wrap the entire bellow in an aluminum foil. Place a thermocouple near the top of the bellow, maintain with it tape. Wrap one of the long heat tape around the bellow (leaving the power plug at the bottom). **Make sure that the heat tape does not touch the thermocouple**. Finish with the " blanket". Close it tightly and maintain with large tape. The thermocouple cable will come out of the top of the blanket.
2) Plug into 3 temperature readers the areas you want to monitor:
   - The upper VAT valve (cross): **1**
   - The bellow: **2**
   - The pump: **3**
3) Connect the 3 Variacs to the heat tapes of the
   - The upper VAT valve (cross): Variac 1 ~ 75 %
   - The bellow: Variac 2 ~ 55 %
   - The load lock pump: Variac 3 ~ 65 %
4) If using 2 Variacs, combine bellows and pump, put valve on its own
   - The VAT valve (cross): Variac 1 ~ 100 % for ~200C
   - The bellows/pump: Variac 2 ~ 70 % for 240/200 C
5) Install the stalk heater, connect Nitrogen and program the bake out controller (remember that to reach 250 C on the cathode, you want the couple to be ~ 350 C):
   - Ramp to 350 C in ~ 1 hour
   - Soak at 350 C for 8 hours
   - Cool down to 27 C ~ 2 hours.
6) Plug the Variacs, through the yellow ground fault interrupter, to the timer and set it for about 12 hours:
   - Turn the timer so as to set the time in the inner circle to the present time
   - Place the red part to the time you want the bake to stop
   - MAKE SURE THE TIMER IS ON THE '**ON**' POSITION

- MAKE SURE TO **RESET** THE GROUND FAULT INTERRUPTER (the bake has now begun)
- Start the heat cycle of the stalk (make sure you start the Variacs and the stalk heater at the same time).

7) Make sure that the heated areas do not touch any cable, or anything. Make sure that the thermocouple cables don't touch any other cable to avoid cross-talk. Adjust the settings of each Variac to try to keep all temperatures increasing at the same rate. The cross is the most massive part of the heated system, so the temperature rise of the cross will impose the rate for the other elements.
8) Record bake parameters – Labview program or manual recording. Log any changes to Variac power.
9) As the temperature increases, you want to monitor the vacuum, *ie*: the ion pump current of the:
   - Load lock pump: should not exceed 3 mA (peaks expected around 110 C and 250 C)
   - Main gun pump: should not exceed ~2 uA (pressure in the gun will rise because of heat transfer).

If the load lock pump exceeds the above value, lower the settings on the Variacs. If the main gun pump rapidly spikes, turn off all Variacs: you may have created a leak.

10) Once the 3 elements have reached 250 C, make sure you adjust the Variacs settings so that all temperatures **remain stable at 250 C** (~ 75/60/60%). Check to make sure the remaining time is at least 8 hours on the Variacs timer AND ON THE STALK HEAT CONTROLLER. Go home.
11) The next morning as you come in, the bake should be over and all temperatures should be close to room temperature. Write down date, time and ion pump current on the strip chart before you stop it. Both pumps should close to zero (< 0.2 uA). Unplug everything, unwrap the bellow.
12) By now, both the load lock and the main gun chambers should have good vacuum. Slowly open the load lock valve while watching the main gun ion pump current.
13) While monitoring the ion pump currents, slowly close the valve to the load lock pump. If vacuum conditions remain unchanged, unplug the pump.

Photocathode activation

The polarized source chamber is designed to activate GaAs photocathodes using cesium and an oxidant, typically NF_3.

Before first activation after venting entire system

- Load NF_3 behind leak valve
  - Pump and backfill line to turbo pump 3x
  - Pump and backfill NF_3 reservoir with nitrogen 3x
  - Pressurize NF_3 tank regulator by opening tank valve then closing
  - Close Nupro valve on NF_3 tank system
  - Fill NF_3 reservoir to 3 psi, close regulator secondary valve, then open Nupro valve to pump out lines
  - Fill NF_3 reservoir to desired operating pressure, (3-5 psi), then close reservoir valve
  - Pump out NF_3 tank lines
  - Disconnect NF3 $_3$tank system from Source chamber

- Degas cesiator
  - Connect power supply to Cs vacuum feedthroughs and insulate
  - Turn up current to 1.5 or 2 Amps, monitoring pressure on ion pump
    - Try to keep ion pump pressure below 10-20 microAmps
  - Continue turning up current slowly as vacuum recovers until you reach operating current of 4.8-5 Amps

To activate a GaAs photocathode

- If necessary, open valve and insert stalk into source chamber, at the “heat” or “run” position
- Heat using stalk heater
  - 675°C stalk temperature for bulk or strained layer GaAs
  - 630°C stalk temperature for strained superlattice GaAs
- Typical ramp: 1 hour to temperature, 2 hours at temperature, cool in 30 minutes
- Disconnect thermocouple and heater supply
- Bias stalk to ~-250 volts using battery supply
- Monitor current with picoammeter and recorder (computer or chart recorder)
- Illuminate photocathode – white light or laser
- Start activation with Cs: Monitor photocurrent while depositing Cs at 4.8-5.2 Amps
  - Pressure as monitored by the ion pump controller should rise by at least 0.2 microAmps
- When photocurrent peaks then drops to half its maximum value, turn off Cs
- Open valve to let in NF3
  - Number of turns to open typically kept on a piece of tape on the table leg
  - Pressure should rise slightly – less than 2 microAmps – while admitting NF3
  - Careful of the leak valves – the spring degrades through bakes and you typically need to squeezed the valve while opening to prevent a burst of NF3 from suddenly entering the chamber
- When photocurrent peaks, close NF3 (1 turn from “open” position typically enough)
- Turn on Cs, and apply Cs until photocurrent = 0.5 max photocurrent
- Repeat with cycles of NF3 and Cs until subsequent peaks increase less than 10%
- End with NF3, close NF3 valve fully, and turn off Cs.

Optics setup

The cathode is illuminated either with laser light or variable wavelength (300nm to 900nm) light from a monochromator. In either case, the light initially passes through a linear polarizer, is deflected upward into the polarized source entrance window with a mirror, an insertable half-waveplate is used to vary the orientation of the polarization of the light and a quarter waveplate just before the vacuum window generates circularly polarized light. With the monochromator system, a long pass filter to avoid illumination by higher order, short wavelength light is added to the system and a long focal length lens is used to minimize the monochromator spot size on the photocathode. Power is adjusted at the white light source or through manually adding neutral density filters to the system. The laser system uses a manual attenuator system consisting of a linear polarizer and a half waveplate to vary laser power incident on the photocathode. A computer controlled x-y stage with stepper motors allows scans of the QE across the cathode surface and/or the transmission to the target. The laser shutter allows dark backgrounds to be routinely measured and subtracted from the asymmetry measurement – no provision for this has yet been implemented in the monochromator setup.

Steering Beam to Target

The electron beam from the photocathode must make it to the target with at least 1% transmission from photocathode to target in order to get good polarization data. The electrostatic bend and system of electrostatic lenses as well as the position of the laser spot on the photocathode is used to accomplish this. Nominal good settings for the lens biases are shown in Table 1.

NOTE: If currents greater than 14nA at target are desired, a RadCon survey MUST be conducted to ensure that no radiation hazards exist.

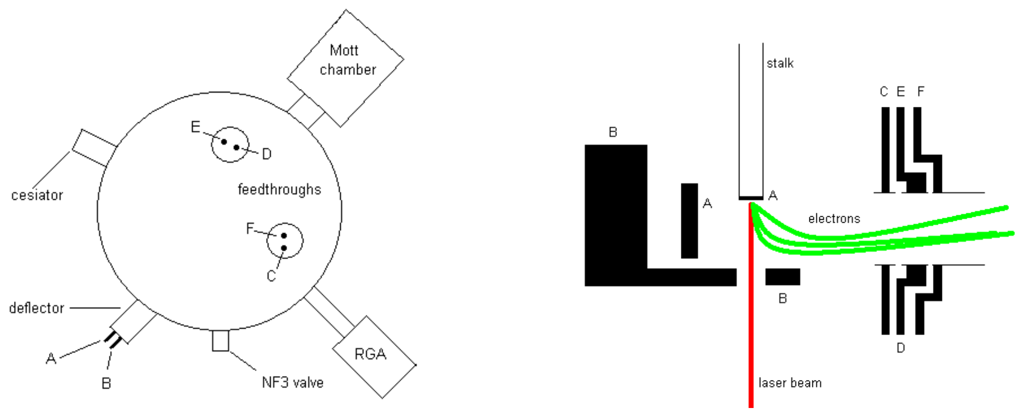


Figure 6: Vacuum feedthroughs for biasing electrostatic bend and polarized source lenses. Lettering is consistent between two diagrams.

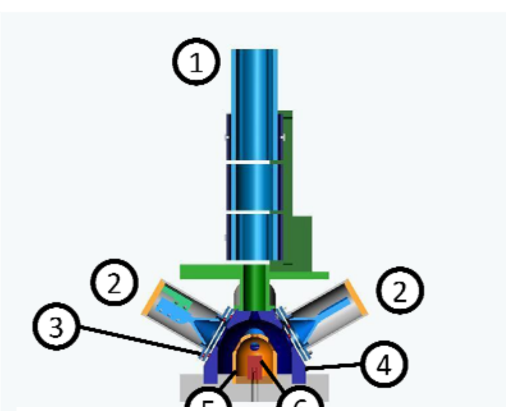


Figure 5 Mott electrostatic lenses are designated as 1 on diagram. First MottLens1 is split in 4, L/R/U/D with respect to the electron travel direction. Center MottLens2 is a single lens. Final MottLens3 is also split in 4 L/R/U/D. Support is at "down" direction.

Element	Feedthrough	Lens bias box designation	Bias: 4/3/09	Bias: 5/14/09 30% trans	Bias: 6/8/09 22% trans
Backplane	Source A	8 ganged with Diff 3	-271.8 + 10.4 = -282.2	-266.9+??= -278.8	-266.4 ->- 275.3
Deflector	Source B	9	-308.7	-282.4	-283.6
First source lens	Source C	ground	Ground	ground	ground
Upper split lens	Source D	4	-187.6	-226.8	-225.3
Lower split lens	Source E	7	-262.1	-144.1	-139.8
Third source lens	Source F	5	-191.2	-203.5	-203.8
Mott Lens 1	Pins H/Q/R/P Left/Rt/Up/Down	Diff 1 L/R	12.86/-12.76	12.85/1.9	12.85/-4.55
Mott Lens 2	Pin N	3	-191.2	-163.1	-163.3
Mott Lens 3	Pins J/L/T/M Left/Rt/Up/Down	Diff 2 L/R	10.66/24.8???	-4.4/-21.7	-10.06/ -5.87

Table 1: Electrostatic lens and deflector settings.

Procedure for getting beam

If only the light has changed

First, get maximum photocurrent from cathode by adjusting the laser spot position. Ensure that retroreflected spot is coincident with incident spot on steering mirror. The more current available that is available, the easier the system is to steer up. Bias the target with +200-300V, and monitor current drawn on target with second picoammeter. Vary laser spot position with x-y stepper stage until current is seen on target. Optimize with iterative movements. Alternately, use the Labview scanning program to look for a position where the current makes it to the target. The x-y controller in the equipment rack works with the computer program to scan the x-y laser position across the wafer. After unplugging the control wires or power cycling the controller, a home reset on the position is useful to make sure that the stepper motors are correctly zeroed.

Fine tuning can be done with 5 kV or more on target while monitoring CEM signals to verify that counts are maximum. Polarization measurements with less that 1% transmission from cathode to target give falsely low polarization readings. When there is some current on target, slight changes to source and Mott steering lenses can be used to further optimize transmission.

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. An additional degree of freedom is the tilt of the stalk – using the jacking screws at the top of the McAllister can reposition the stalk in the x-z plane and get back to a previous good position.

Starting from scratch

With as much photocurrent as possible, put the biased "Faraday cup" in from the side of the Mott chamber. This will tell you when you are successfully getting beam around the electrostatic bend. When this is optimized, pull the cup, bias the target, and start steering down the system in an iterative manner, monitoring current on biased target.

Data Acquisition Setup

The CEMs are biased both at the front surface and at the back, with a collector capactively coupled to the output. The signals are amplified with a Ortec VT120a preamp, then fed to the NIM crate fan-in/fan-out where they go to both an oscilloscope and discriminators. Phillips 6930 discrete discriminators are used, with discriminator levels set to a minimum of 250 mV to filter noise. Higher discriminator levels reduce count rate but are helpful in reducing background rates. CEM bias is provided using the Bertan and/or Ortec HV supplies in the NIM crate. Proper voltage values are determined either by measuring signal vs. voltage applied (keeping count rates under 10^4 as per manufacturer's spec) or by turning them on until they just start counting with no beam on target – both methods provide similar CEM bias values. The retarding field grids and the CEM cans are biased using a computer controlled voltage supply in user-specified voltage steps starting as low as 0 V and going as high as 350V (leads for all grids and cans are tied together in the uppermost box and voltage is varied using the HP voltage supply and monitored with the Keithley multimeter). The nominal incident energy of the electrons, provided by a battery bias box so voltage will very slowly vary with time, is 268eV, determined by careful analysis of where the retarding field fully suppresses count rates.

Computer DAQ

The computer DAQ program is a labview program. It controls the shutter, motion of the halfwaveplate, retarding field bias and reads the counts in a designated amount of time for each detector. Online asymmetry calculations are graphed in the acquisition program, but the full Asym analysis program calculates a more accurate asymmetry with dark and >280V bias background subtractions.

Troubleshooting: when visa errors occur, turn off all talking equipment, reboot computer, turn equipment back on.