EGG-3101 / EGPS-3101

ELECTRON GUN AND POWER SUPPLY SYSTEM

Excellence in Electron and Ion Optics

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WARRANTY

Kimball Physics standard electron gun and ion gun subsystem products, along with the associated drive electronics are guaranteed to be free of defects in materials and workmanship for a period of one year from the date of original shipment. Some expendable items, such as emitters, phosphor screens, etc., may have lifetimes in normal use which are less than one year. If such items fail to give satisfactory service as determined by Kimball Physics, they may be repaired or replaced at the discretion of Kimball Physics. Warranty does not apply in cases with evidence of accident, neglect, misuse or negligence. Some individual products carry warranties specific to the product line. Kimball Physics normally supplies technical data with products; in addition, assistance is available in the selection and use of products. However, there are no implied warranties of merchantability or of fitness for a particular purpose given in connection with the sale of any product. Kimball Physics does not assume liability for consequential, incidental, or special damages. The purchaser's sole and exclusive remedy, and the limit of the Kimball Physics liability for any loss whatsoever, shall not exceed the purchase paid by purchaser for the unit(s) or equipment to which a claim is made.

IMPORTANT INFORMATION
ON THIS ELECTRON GUN SYSTEM

Electron Gun serial #: EGG-3101B-5526

Power Supply serial #: EGPS-3101B-736

Date: October, 2004

Energy Range: 100 eV to 10 keV

System Option and Cathode Type: Small spot option with Lanthanum hexaboride (LaB_6) cathode (ES-423E)

Mounting: 2¾ CF Flange Multiplexer

Power Supply Input: 115 VAC switchable to 230 VAC, 50 to 60 Hz, single phase, 250 VA

Emission Current Control: Yes

Computer / Remote Control: National Instruments connectors for programming and metering

X and Y Deflection: Manual Control Deflection Unit (MCDU) on EGPS

Rastering: No (possible if order additional Raster Generator Deflection Unit)

Beam Blanking: No

Beam Pulsing: Slow pulsing with grid remote control only
(Capacitive pulsing possible, if order additional Pulse Junction Cylinder)

Faraday Cup Assembly: No

Additional Custom Features: No

Additional Power Supply (for High Current option): No

EQUIPMENT LIST

EGG-3101 Electron Gun in shipping tube
EGPS-3101 Power Supply
H.V. Multiconductor Source cable
Deflection cable
Focus cable
Ground strap
Power cord
Rack mounting kit
Manual

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1 INTRODUCTION AND SPECIFICATIONS

1.1 SUMMARY

1.1.1 EGG-3101 ELECTRON GUN

The Kimball Physics EGG-3101 Electron Gun, with its matching EGPS-3101 Power Supply, is a multi-purpose modular Electron Gun with applications many areas. The EGG-3101/ EGPS-3101 is a complete subsystem ready to attach to a user's vacuum system and turn on. Fitted with a small spot option, which includes a lanthanum hexaboride cathode, the gun can deliver spots down to 60 µm at long working distances. With a high current option, beam currents up to 1 mA can be obtained.

The gun has the capability of producing a collimated, small spot or flood electron beam. Beam current, beam divergence, and beam energy are all adjustable over wide ranges. The energy can be varied from 100 eV to 10 keV. The beam current and spot size range depend on the system option as shown in the table below. Pulsing, beam blanking and rastering are also available as options.

The modular design of the EGG-3101 allows either the firing unit assembly or the lens assembly to be replaced. The firing unit cartridge (including the cathode, cathode-mount, and Wehnelt aperture) is user-replaceable without removing the entire gun from the vacuum chamber. The anode is also easily replacable. To adapt for different applications, the lens assembly, which usually contains an Einzel lens and a 4-pole electrostatic deflection unit, can be exchanged for a different assembly. In addition, the cathode to anode spacing is internally adjustable to vary perveance.

The gun features an adjustable cathode feedthrough assembly that allows the mechanical alignment of the firing unit with respect to the anode and the column. This alignment can be done in real time while the gun is operating at full voltage with beam on.

Many cathode types and sizes are available: tantalum disc cathodes, small-spot single-crystal lanthanum hexaboride (LaB_6) cathodes, low-light barium oxide (BaO) cathodes, or thoria-coated (ThO_2) iridium cathodes. With the exception of BaO, the cathodes are not damaged by repeated exposure to atmospheric gases or water vapor when cold.

UHV technology is used throughout. The gun can be run in vacuums from 10^{-11} torr up to 10^{-5} torr for the refractory metal cathodes. Better vacuum is recommended for LaB_6 or BaO cathodes, while the more rugged thoria cathodes can be run in poorer vacuum conditions. The electron gun is bakable to 350ºC with cables removed.

Firing unit cartridges are user-replaceable, and used cartridges may be returned to the factory for rebuild. The electron gun itself may also be sent back to the factory for complete disassembly, cleaning, and rebuild of the firing unit assembly (including installation of a new cathode).

Table 1.1-1 EGG-3101/ EGPS-3101 system options

Option	Cathode type	Beam current	Spot size	H.V. Supply
Standard	Refractory metal disc, Barium oxide, or Thoria	10 nA to 100 µA	500 µm to 25 mm	No
Small spot	Lanthanum hexaboride	1 nA to 10 µA	60 µm to 10 mm	No
High current	High current refractory metal disc or Thoria	1 µA to 1 mA	1.5 mm to 25 mm	Yes

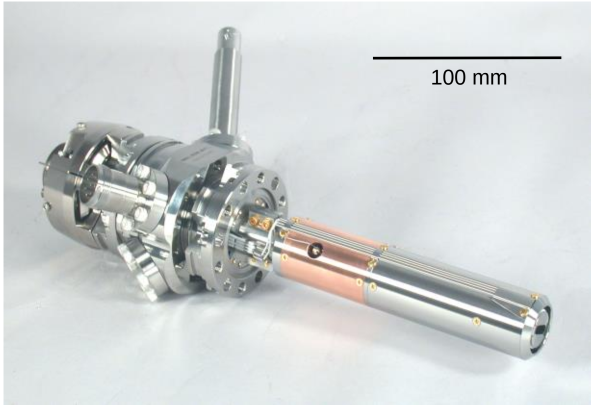


Fig. 1.1-1 EGG-3101 Electron Gun with optional copper blanker

1.1 SUMMARY cont.

1.1.2 EGPS-3101 POWER SUPPLY SYSTEM

The EGPS-3101 Power Supply unit contains all power supplies necessary to generate the required voltages to run an EGG-3101 Electron Gun. The included power supplies are Beam Energy, Focus Deflection and optional Blanker, as well as the supplies that float at the negative high voltage, Source/ECC (Emission Current Control) and Grid. A rastering option is provided by a separate power supply unit, the Raster Generator Deflection Unit (RGDU).

The high current option includes an additional High Voltage Power Supply (Glassman or Gamma) connected to and controlled by the EGPS-3101.

A rear panel connector allows control of the gun, including the floating supplies, via 0 to 10 V analog inputs at ground potential (deflection supplies use -10 to +10 V inputs). All common computer interface bus types can be supported, via appropriate digital to analog converters.

A National Instruments LabVIEW™ computer program written by Kimball Physics is available for remote computer control. The program provides the user with a virtual panel similar to the EGPS-3101 front panel.

Fig. 1.1-2 Standard EGPS-3101 Electron Gun Power Supply

H.V. Multiconductor Source cable

Focus cable

Power cord

Optional Blanker coaxial cable

Optional 68-pin DAQ computer cables

Deflection cable or optional gray Raster cable

Ground strap

Rack mounting kit

Optional H.V. Input cable for high current system only

Fig. 1.1-3 Cables and other equipment used with the EGG-3101 / EGPS-3101 System

Fig. 1.1-4 Additional High Voltage Power Supply , only with high current option (style may vary)

1.1 SUMMARY cont.

1.2 SAFETY

⚠ NOTE

Kimball Physics is not responsible for the installation, correct use, or application of this electron gun unit.

The purchaser must ensure that only knowledgeable users of high voltage and high vacuum equipment are allowed to install or use Kimball Physics equipment.

In no event will Kimball Physics be liable for damages, direct or indirect, of any type, nor for injuries to persons or property, arising out of the use of this electron gun unit.

If equipment is used in a manner not specified by Kimball Physics, then protection provided by the equipment may be impaired.

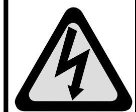
GENERAL

The Electron Gun unit is a subsystem intended to fit into a vacuum system of the customer's choice and design. Kimball Physics provides only the Electron Gun, cables, and Power Supply as listed in the specifications. Kimball Physics is not responsible for the installation, correct use, or application of this Electron Gun and Power Supply. The purchaser must ensure that only knowledgeable users of high voltage and high vacuum equipment are allowed to install or use Kimball Physics equipment. In no event is Kimball Physics liable for damages, direct or indirect, of any type, nor for any injuries to persons or property, arising out of the use of the Electron Gun and Power Supply. If equipment is used in a manner not specified by Kimball Physics, then the protection provided by the equipment may be impaired.

HIGH VOLTAGE

Proper high voltage precautions and grounding techniques must be observed. In no event should the Power Supply be energized unless the Electron Gun is bolted into a properly evacuated high vacuum chamber. Proper vacuums are better than 1 x 10^{-5} torr for refractory metal cathodes, or better than 1 x 10^{-7} torr for LaB_6 and BaO cathodes. To energize the system without proper vacuum would cause the Electron Gun to be damaged by arc-overs, that expose the operator to a severe electric shock hazard. In no event should the safety interlocks on the High Voltage cable, or in the Power Supply, be disconnected or bypassed.

⚠ WARNING



HIGH VOLTAGE

Can cause ELECTRIC SHOCK or BURN

Power Supply and vacuum system must be grounded. Use High Voltage precautions.
Do not energize Power Supply unless gun is bolted to chamber with proper high vacuum, and all cables are securely attached.
Do not disconnect safety interlocks.

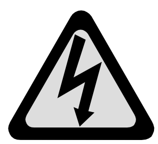
DEFINITIONS OF SAFETY TERMS AND SYMBOLS

DANGER: indicates an imminently hazardous situation which could result in death or serious injury, if not avoided.

WARNING: indicates a potentially hazardous situation which could result in serious injury, if not avoided.

CAUTION: indicates a situation which could result primarily in damage to equipment, if not avoided. However, such damaged or improperly used equipment could also cause personnel injury.

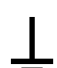
NOTE: indicates information that is useful for proper operation of the system.

 indicates a High Voltage hazard.

 indicates a hot surface.

 indicates a caution or note.

 indicates alternating current, AC

 indicates Earth ground

SAFETY NOTE: The purchasers safety officer should inspect the installation and shielding of the Electron Gun prior to operation.

1.3 SPECIFICATIONS

EGG-3101 ELECTRON GUN	
Beam Energy	100 eV to 10 keV (Independently adjustable)
Beam Current	Standard: 10 nA to 100 µA Small spot option: 1 nA to 10 µA High current option: 1 µA to 1 mA
Energy Spread	Approx 0.4 eV cathode thermal spread, calculated
Beam Divergence	Collimated beam, optimized for parallel, 1mm diameter, 10 nA to 100 µA beam
Spot Size	Standard: 500 µm to 25 mm Small spot option: 60 µm to 10 mm High current option: 1.5mm to 25 mm
Working Distance	Typical: 200 mm. Range: 100 mm to 1000 mm
Beam Deflection	4-Pole Electrostatic ± 7.6º at 10 keV, scales larger at lower energies
Pulse Capability	Optional: Capacitive Pulse Junction Cylinder: pulse width 20 ns to 100 µs, rep rates up to 20% duty cycle (using appropriate pulse generator, not supplied)
Beam Blanking	Optional: Pulse width 1 µsec to DC, rep rates to 10 kHz
Beam Uniformity	Gaussian
Firing Unit	User-replaceable firing unit cartridge includes precision-aligned cathode and Wehnelt (G-1) assembly
Cathode Type	Standard: Refractory metal cathode Optional: Low-light barium oxide coated (BaO) Thoria coated iridium (ThO_2) Lanthanum hexaboride (LaB_6) for small spot option
Internal Gun Alignment	Adjustable Feedthrough for mechanical alignment of firing unit while gun is operating
Mounting	Flange Multiplexer with 2¾ rotatable CFF, including both tapped and clear mounting holes
Faraday Cup	Optional: Faraday cup detector mounted on gun, with manual or pneumatic control
Insertion Length	Standard: 109 mm; 163 mm with optional beam blanker assembly, custom lengths available
Gun Diameter	Standard: 31.5 mm gun tube in vacuum
Feedthroughs	Multipin brazed ceramic with threaded stainless steel shell
Cables / Connectors	Multiconductor 15 kV high voltage fully ground-shielded cable, coaxial focus cable, and low voltage deflection cable, with mating aluminum shell connectors, to connect gun and power supply. Standard length: 3 m, Optional: 5 m
Maximum Bakeout	350ºC with cables removed (Faraday cup: optional removable pneumatic actuator 65ºC max)

1.3 SPECIFICATIONS cont.

EGPS-3101 ELECTRON GUN POWER SUPPLY	
Outputs	All necessary voltages to drive the EGG-3101 Electron Gun
Energy Stability	±0.01% per hour ±0.02% per 8 hours at full output
Beam Stability	±1.0% per hour with Emission Current Control or ±10% per hour after warm up without ECC
Controls	Energy, Focus, Grid, Source, Emission Current Control, X and Y Deflection, and optional Blanker
Power Supply Outputs	Energy: 0 to -10 kV @ 500 μA, Standard 0 to -10 kV @ 100 μA, Small spot option 0 to -10 kV @ 12 mA, High current option Focus: 0 to -10 kV Grid: 0 to -300 V 0 to -1000 V, High current option Source: 0 to 1.5 V @ 2 A, Standard 0 to 2.6 V @ 2 A, Small spot option 0 to 2.25 V @ 3 A, High current option X Deflection: +300 V to -300 V Y Deflection: +300 V to -300 V Blanker optional: 0 V to +600 V
Computer Remote Control	Power supplies: 0 to +10 V (-10 V to +10 V for Deflection) Optional Toggle switches: 0 or +5 V Optional Metering: varies 0 to +2 V, (-300 mV to +300 mV for Deflection)
Metering	Digital: Energy, Focus, X and Y Deflection, optional Blanker Analog: Emission, Grid, Source Voltage, Source Amperes
Input	115 VAC switchable to 230 VAC, 50 to 60 Hz, single phase, 250 VA
Environment	Temperature: 0 to 40ºC, Relative humidity: 0 to 75% RH non condensing, Classified as a pollution degree 2, installation category (overvoltage category) II environment unit.
Computer System	Optional: Industrial computer system including data acquisition and control hardware DAQ
Lab Software	Optional: National Instruments LabVIEW^{M} file
Dimensions of EGPS-3101 (width x height x depth)	17 in. x 7 in. x 17 in. excluding handles (432 mm x 178 mm x 432 mm); 19 in. rack mountable
Dimensions of optional Glassman H.V. Power Supply	17 in. x 1.75 in. x 20 in (432 mm x 44 mm x 508 mm); rack mounting overall width is 19 in. (483 mm)

OPTIONAL RASTER GENERATOR DEFLECTION UNIT	
RASTER GENERATOR	Nine separate frequency selections for both X and Y 10 to 5000 Hz left and right (X), 0.1 to 50 Hz top and bottom (Y) Variable position offset. Variable widow size. Rate and window size controllable manually; Position controllable manually or remotely.
Dimensions of RGDU (width x height x depth)	17 in. x 3.5 in. x 17 in (432 mm x 89 mm x 432 mm); with rack mounting kit: overall width is 19.5 in. (495 mm)

2 INSTALLATION

2.1 UNPACKING AND SHIPPING

NOTE

Gun surfaces exposed to vacuum, and high voltage insulator ends on the cables, should not be handled with bare hands. **Use clean room gloves** to keep parts free of fingerprints and contaminants.

Do not twist or bend cables sharply.

2.1.1 UNPACKING INSTRUCTIONS

1. Upon receiving the equipment:
   a. Check the material received against the packing list.
   b. Report any discrepancies immediately to the Kimball Physics Sales Dept. at (603) 878-1616.

2. **For guns shipped under vacuum** (i.e. the shipping tube has been evacuated and has a pinched-off copper tube): **Do not break the vacuum seal** until ready to insert the gun into the host vacuum system. If the gun has a barium oxide (BaO) cathode, it is best to store it in vacuum. If it must be stored out of vacuum, it should be placed in a clean, dry environment such as a tightly sealed plastic box with desiccant.

3. Inspect the Electron Gun/Power Supply system for possible shipping damage.
   a. Inspections should be made by a person familiar with the care and handling of high-vacuum apparatus.
   b. Wear gloves to protect the Electron Gun from fingerprints and other possible contamination.

4. Save the stainless steel Electron Gun Shipping Tube for storing the gun and for any future shipping.

5. Do not bend cables too sharply. The minimum bend radius is 0.15 m for 5 kV and under cables, 0.25 m for 10 or 20 kV cables, and 0.5 m for 30 to 100 kV cables.

6. If shipping damage has occurred:
   a. Notify the carrier immediately.
   b. Notify Kimball Physics Sales Dept. at (603) 878-1616.
   c. If the gun was shipped under vacuum, store and return the gun under vacuum.

CAUTION

All equipment must be carefully packed in protective materials and supported to prevent shipping damage.

2.1.2 PACKING AND SHIPPING FOR RETURNS

1. Before returning equipment for repair or service:
   a. Obtain a Return Authorization Number from the Kimball Physics Sales Dept. before shipping the unit back to the factory for 1) Service, 2) Repair, 3) Addition of options, or 4) Maintenance under warranty.
   b. A Return Authorization Number will be issued immediately upon a telephone or written request.
   c. Include this Return Authorization Number with package.

2. Carefully package the equipment to be shipped.
   a. **For mounted Electron Guns:** Securely bolt the electron gun into its original Shipping Tube, using a viton or copper gasket to protect the gun. If the gun has a barium oxide (BaO) cathode, evacuate the shipping tube and seal its copper tube to ship under vacuum.
   b. **For small unmounted Electron Guns or Firing Units:** Put the unit in a clean ziplock plastic bag and pack in protective materials, ex. bubble wrap and foam “peanuts”.
   c. **For cables:** Do not bend cables too sharply. The minimum bend radius is 0.15 m for 5 kV and under cables, 0.25 m for 10 kV or 20 kV cables, and 0.5 m for 30 kV to100 kV cables.
   d. Support **all** equipment in air bags, bubble wrap and/or foam. A cardboard box filled with loose “peanuts” is not adequate as heavy equipment will shift around. Even a power supply may be damaged.
   e. Proper shipping materials, including stainless steel Shipping Tubes, shaped foam, air bags, bubble wrap, and crates may be ordered from Kimball Physics Sales Dept. at (603) 878-1616.

3. Ship package via UPS, Fed Ex or appropriate international carrier to:
   Kimball Physics Inc.
   Engineering Dept.
   311 Kimball Hill Road
   Wilton, NH 03086-9742 USA

4. Prepay all shipments to Kimball Physics. The user is responsible for adequate shipping insurance.

2.2 POWER SUPPLY INSTALLATION

EGPS-3101 INSTALLATION

Fig. 2.2-1 Front Panel of EGPS-3101 Electron Gun Power Supply with optional blanker

1. Power Supply placement, allowance for cables:
   a. Using the materials provided in the rack mounting kit, attach the four rubber feet to the bottom of the EGPS-3101 Power Supply, and/or attach the unit to a rack using the two mounting brackets in place of the two small side panels.
   b. Install the EGPS-3101 Power Supply within 2.0 m of the EGG-3101 Electron Gun.
   c. Provide the Power Supply with 0.5 m rear access because the power cord and cables plug into the rear panel.

   WARNING: The power cord must be accessible to disconnect from the AC supply outlet for emergency shut down.

2. **For systems with High Current option:** An additional H.V. Power Supply (Glassman or Gamma, provided by Kimball Physics) is required. It will be installed next to the EGPS-3101 and set up to be controlled by the EGPS-3101 as described at the end of this section.

3. For computer remote control and metering
   a. Install a National Instruments LabVIEW™ program file written by Kimball Physics (EGPS-3101 Control x.xx .vi or .exe) or a similar user-supplied program on the computer.
   b. Either LabVIEW Runtime™ (included on the CD) or LabVIEW™ is required on the computer for the Kimball Physics program.
   c. If a computer system is purchased from Kimball Physics, the program and DAQ (data acquisition) boards are already installed and two 68-pin DAQ computer remote cables are provided.

(For computer remote control and metering cont.)
   d. If a computer system is not purchased, install two appropriate DAQ boards (one for metering and one for programming) on the user's computer. Two user-supplied 68-pin DAQ computer remote cables are also required. Boards and cables are available from National Instruments or Kimball Physics.
   e. See Section 4.5 for details on remote access and connector pinouts, if needed.

4. Make an initial check of the following items of the EGPS-3101 Power Supply front panel controls
   a. Key switch: The key should be in the off (vertical) position.
   b. Pushbuttons: Green **POWER** switch, red **H.V.** switch, red **SOURCE** switch, and blue **DEFL** switch should be off (out position).
   c. Potentiometers: **ENERGY**, **FOCUS**, **SOURCE/ECC**, and **GRID** (G-1) should be at zero position, fully counterclockwise, with their locking toggles in the unlock (up) position.
   d. Function switch: The rotary **FUNCTION** switch should be turned to the Energy position, fully counterclockwise.

5. If necessary, the analog meters can be zeroed using a small straight-bladed screwdriver inserted in the hole below the meter.

> **⚠ NOTE**
>
> Gun surfaces exposed to vacuum, and high voltage insulator ends on the cables, should not be handled with bare hands. **Use clean room gloves** to keep parts free of fingerprints and contaminants.
>
> The minimum bend radius of the H.V. Source cable is 0.25 meters. **Do not twist cables.**

2.2 POWER SUPPLY INSTALLATION cont.

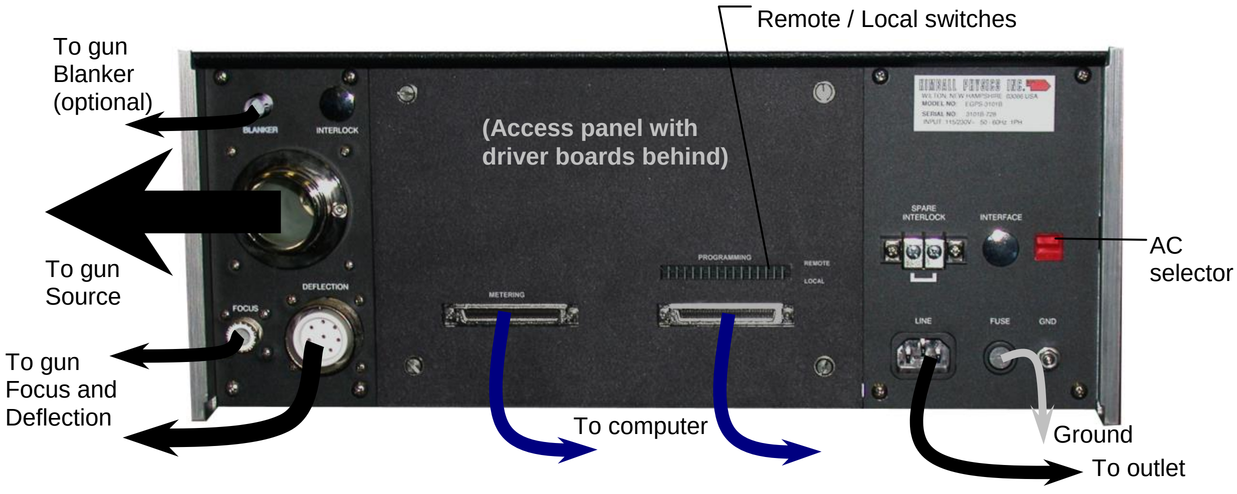


Fig. 2.2-2 Back panel of Standard EGPS-3101 Electron Gun Power Supply, showing cable connections diagrammatically

Check and connect the following items on the back of the EGPS-3101 Power Supply (See Fig.1.1-3 for cable photos):

6. AC selector switch:
   a. Switch the red **115 VAC/230 VAC** switch to either the 115 VAC or 230 VAC, depending on the AC supply voltage required.

7. Ground strap:
   a. Connect ground straps onto the grounding screws labeled **GND** on the back panel of the EGPS-3101.
   b. Connect the free end of the straps to a proper earth ground connection on the vacuum system.

8. H.V. Multiconductor Source cable:
   a. Wipe the long insulator wand on the connector with isopropanol and a lint-free cloth.
   b. Gently insert the 12-pin insulator wand of the H.V. Multiconductor Source cable into the large, keyed mating connector on the back of the EGPS-3101, all the way in, tightening the ring by hand. Avoid touching the insulator. Support the cable along its length and do not twist it.

9. 8-pin Deflection cable:
   a. Plug the black 8-pin Deflection cable into its keyed, 8-pin mating connector labeled **DEFLECTION** on the back of the EGPS-3101, tightening the ring by hand. Support the cable along its length and do not twist it.

10. Focus cable (coaxial cable with one metal 15 kV BNC-style connector and one banana connector):
    a. Plug the short banana connector of the Focus cable into the connector labeled **FOCUS** on the back of the EGPS-3101, tightening the ring. Avoid touching the insulator.

11. Optional Beam Blanker cable
    a. Connect the Beam Blanker coaxial cable to the BNC labeled **BLANKER** on the back of the EGPS3101.
    b. For pulsing, a user-supplied cable from a user-supplied TTL generator can be connected to the **TTL INPUT** BNC on the front of the EGPS-3101. See Section 4.10.

12. Optional H.V. Input **for High Current option only:**
    a. Wipe the insulators on the ends of the black H.V. Input cable with isopropanol and a lint-free cloth.
    b. Plug the short banana connector of the cable into the connector labeled **HIGH VOLTAGE INPUT** or **H.V. IN** on the EGPS-3101, tightening the ring by hand. Avoid touching the insulator.
    c. The long banana connector of this cable will be plugged into the separate High Voltage Power Supply to provide the higher currents required for electron emission with the high current cathode. (See H V POWER SUPPLY INSTALLATION below.)

13. Optional 68-pin DAQ computer remote cables:
    a. Connect computer cables to the two 68-pin connectors labeled **METERING** and **PROGRAMMING** on the EGPS-3101.
    b. Connect the other ends of the two cables to the appropriate DAQ (data acquisition) boards, which may be either mounted in the computer or separate depending on the user's system.
    c. If needed, see Section 4.5 for details on remote access, such as connector pinouts.

14. Local / Remote switches for computer control:

NOTE: Once in the Remote mode, the power supply is not controllable by the front panel potentiometers.

   a. On the back of the EGPS-2, check the position of all the small local/ remote slide switches labeled **PROGRAMMING** . Local is manual control with the front panel potentiometers; Remote is computer control. Individual supplies can be run in either mode.
   b. Only if the system is to be run **entirely** in the remote computer control mode: Change ALL the small local/ remote slide switches labeled **PROGRAMMING** to the **REMOTE** position (up)
   c. These switches may be changed later, at any time that the system is powered off. Front panel meters are not affected by these switches.

2.2 POWER SUPPLY INSTALLATION cont.

EGPS-3101 INSTALLATION cont.

15. Optional spare interlock:
    a. These terminals labeled **SPARE INTERLOCK** are provided for the user to set up a switch to shut off the power supply as desired for specific conditions, ex. for poor vacuum.
    b. Interlocks must either be jumpered (as shipped) or connected in a closed circuit with the user's system.

16. Power cord:
    a. Connect the power cord to the outlet labeled **LINE** on the rear of the EGPS-3101 Power Supply.
    b. Connect the other end of the into a standard 115 or 230 VAC 50/ 60 Hz power outlet.

17. **For systems with rastering:** See Section 4.7 on Installation of the Raster Generator Deflection Unit (RGDU). The raster unit can be used for centering deflection as well as for rastering.
    NOTE: Use the gray raster cable. Although the pinout is the same, do not use the standard black Deflection cable for rastering, as it will not give the proper response.

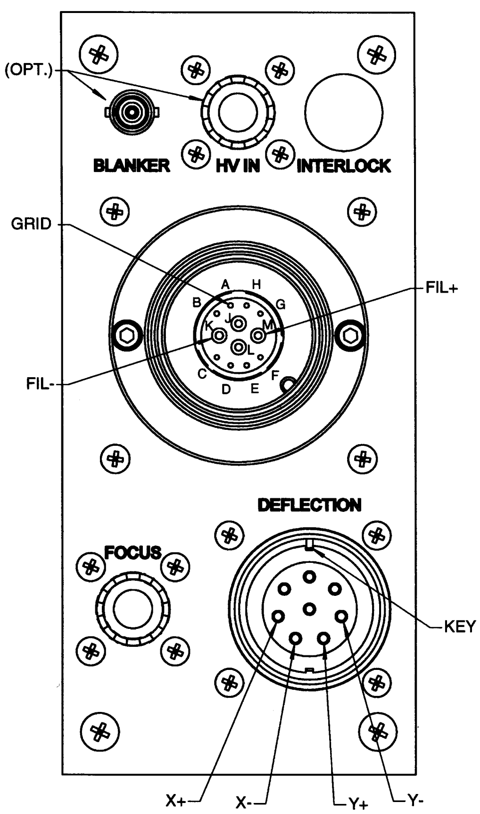


Fig. 2.2-3 Pinout of gun cable connectors on back of EGPS-3101 Power Supply, showing optional Blanker and optional H.V. input connectors
On the power supply and cables, unused Source pins are at H.V common (Energy) potential. Unused Deflection pins are grounded.

Table 2.2-1 Standard EGPS-3101 Supply Outputs

Power Supply	Range
Energy	0 to –10 kV @ 500µA
Focus	0 to –10 kV
Grid	0 to -300 V
Source (Filament +/-)	0 to 1.5 V @ 2.0 A
X Deflection	-300.0 V to +300.0 V
Y-Deflection	-300.0 V to +300.0 V
Blanker (optional)	0 V to +600.0 V

Table 2.2-2 Small Spot EGPS-3101 Supply Outputs

Power Supply	Range
Energy	0 to –10 kV @ 100µA
Focus	0 to –10 kV
Grid	0 to -300 V
Source (Filament +/-)	0 to 2.6 V @ 2.0 A
X Deflection	-300.0 V to +300.0 V
Y-Deflection	-300.0 V to +300.0 V
Blanker (optional)	0 V to +600.0 V

Table 2.2-3 High Current EGPS-3101 Supply Outputs

Power Supply	Range
Slave Energy (separate H.V. Supply)	0 to –10 kV @ 12 mA
Focus	0 to –10 kV
Grid	0 to -1000 V
Source (Filament +/-)	0 to 2.25 V @ 3.0 A
X Deflection	-300.0 V to +300.0 V
Y-Deflection	-300.0 V to +300.0 V
Blanker (optional)	0 V to +600.0 V

H.V. WARNING: When energized, all pins on the Source connector are at High Voltage (up to 10 kV), because the Source (Filament) and Grid supplies are floated on Energy (H.V. common) and unused pins are also at H.V common. However, due to safety interlocks, the Power Supply can not be turned on unless gun cables are attached so the connectors are not accessible.

This completes the EGPS-3101 Power Supply Installation.

2.2 POWER SUPPLY INSTALLATION cont.

HIGH VOLTAGE POWER SUPPLY INSTALLATION (Glassman)
For Guns with High Current Option only

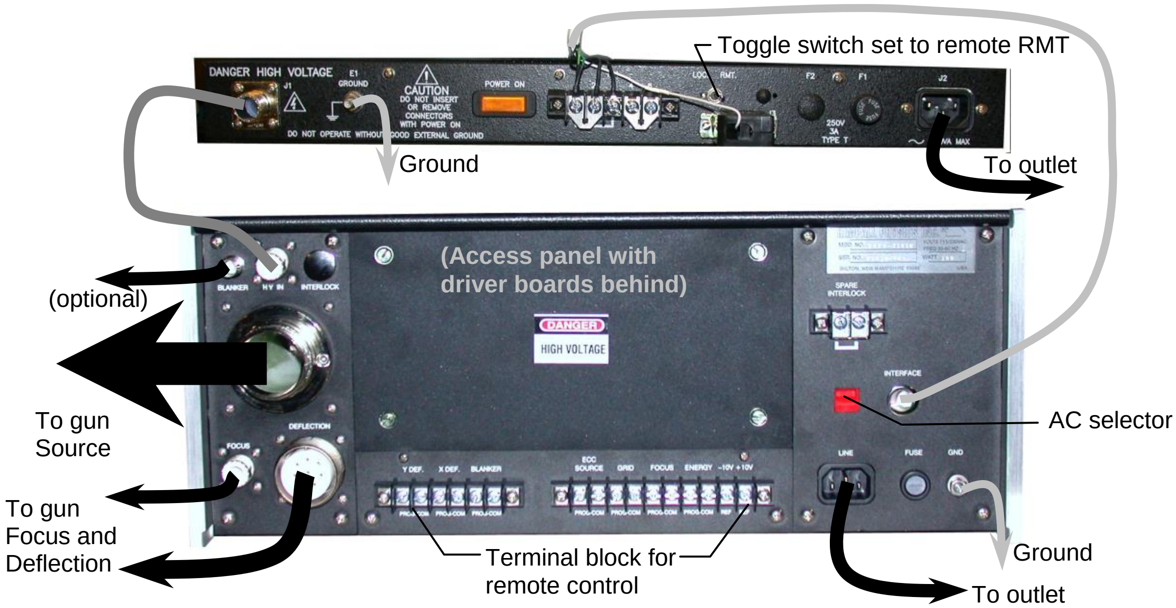


Fig. 2.2-4 Back of High Current EGPS-3101 and Glassman H. V. Supply, showing cable connections diagrammatically

NOTE: Once the High Voltage Power Supply is set up with the EGPS-3101 Power Supply it is remotely controllable through the EGPS-3101 Power Supply Energy control.

1. Refer to the enclosed Glassman High Voltage Power Supply manual for any information about the High Voltage Power Supply not concerning the EGPS-3101 Power Supply/ H.V. Power Supply set up.

2. Provide the H.V. Power Supply with 0.5 m rear access.

WARNING: The power cord must be accessible to disconnect from the AC supply outlet for emergency shut-down.

3. Make an initial check of the following items of the H.V. Power Supply front panel controls:
   a. Power switches: The orange on/off **POWER** switch should be off (**O** position), and the green **HV** switch should be off (out position).
   b. Potentiometers: **MILLIAMPERES** and **KILOVOLTS** should be at the zero position, fully counterclockwise, with their locking toggles in the unlock (up) position.

4. Ground strap:
   a. Connect the ground strap to the grounding screw labeled **GND** or **GROUND E1** on the back of the H.V. Power Supply.
   b. Connect the free end of the ground strap to a proper earth ground connection on the vacuum system.

5. H.V. Input cable
   a. Wipe the insulator on the end of the black H.V. Input coaxial cable with isopropanol and a lint-free cloth.
   b. Connect the long banana connector of the cable to the connector labeled **HIGH VOLTAGE J1** on the H.V. Power Supply.
   c. The short banana connector of the cable is connected to the connector labeled **HIGH VOLTAGE INPUT** or **H.V. IN** on the back of the EGPS-3101 Power Supply.

6. Interface cable:
   a. The gray Interface cable is wired onto the terminal strip **TB1** on the back of the H.V. Power Supply. Do not change these connections.
   b. Connect the 6-pin Lemo connector on the end of the gray cable into the Lemo connector labeled **INTERFACE** on the EGPS-3101 Power Supply.
   c. On some Glassman H.V. Power Supplies, the interface cable is also wired to a D-sub connector **J3** and has a local/ remote toggle switch. **If present, this toggle switch must be set in the RMT. position** for the interface connections to work.

7. Power cord:
   a. Connect the power cord to the outlet labeled **J2** on the H.V. Power Supply.
   b. Plug the free end of the power cord into a standard 115 VAC or 230 VAC 50/60 Hz power outlet.

This completes the EGPS-3101 Power Supply/H.V. Power Supply Installation.

2.3 ELECTRON GUN INSTALLATION

> **NOTE**
>
> Gun surfaces exposed to vacuum, and high voltage insulator ends on the cables, should not be handled with bare hands. **Use clean room gloves** to keep parts free of fingerprints and contaminants.
>
> The minimum bend radius of the H.V. Source cable is 0.25 meters. **Do not twist cables.**

> **CAUTION**
>
> **The exposed leads on the gun housing are very fragile.** Take care not to hit the gun when removing it from its shipping tube or inserting into the vacuum chamber.

1. When installing the EGG-3101 Electron Gun, do not handle connector ends or surfaces exposed to the vacuum with bare hands. Degradation of insulator and vacuum surfaces will result.

2. The electron gun may be mounted in any orientation.
   a. A 70 mm (2¾ in.) conflat style flange is required on the host vacuum system to mount the electron gun.
   b. Before installing the electron gun, check for adequate clearance and working distance in vacuum system (see Fig. 2.3-1). In the standard configuration, the insertion length into the host vacuum system is 109 mm (or 163 mm with an optional beam blanker assembly), however, custom gun lengths are available so ensure adequate clearance. An optional spool piece is available to mount the gun so that it does not extend into the vacuum chamber (zero insertion length). With an optional Faraday cup assembly, also allow adequate room for the Faraday cup to swing into and out of line.

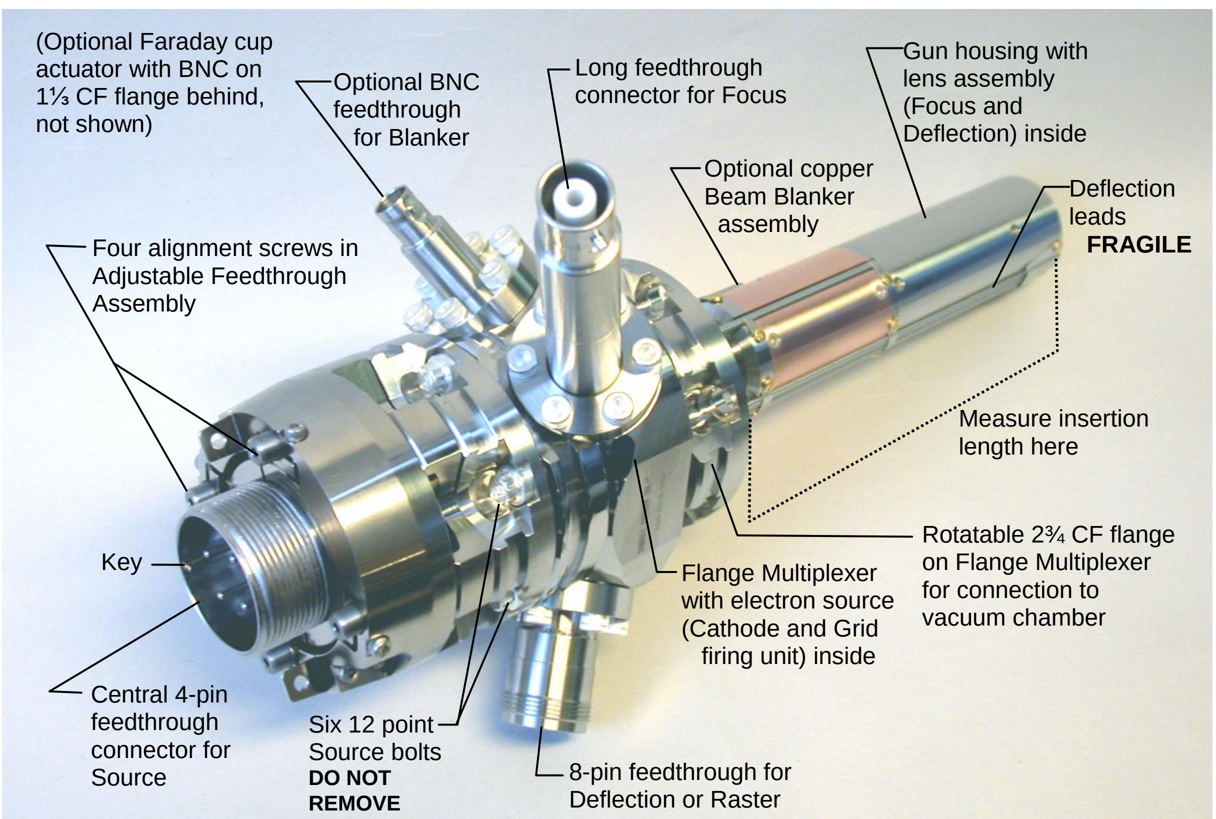


Fig. 2.3-1 EGG-3101 Electron Gun before installation

2.3 ELECTRON GUN INSTALLATION cont.

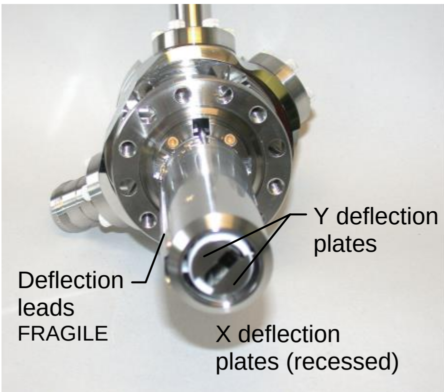


Fig. 2.3-2 EGG-3101 end of gun showing two pairs of deflection plates

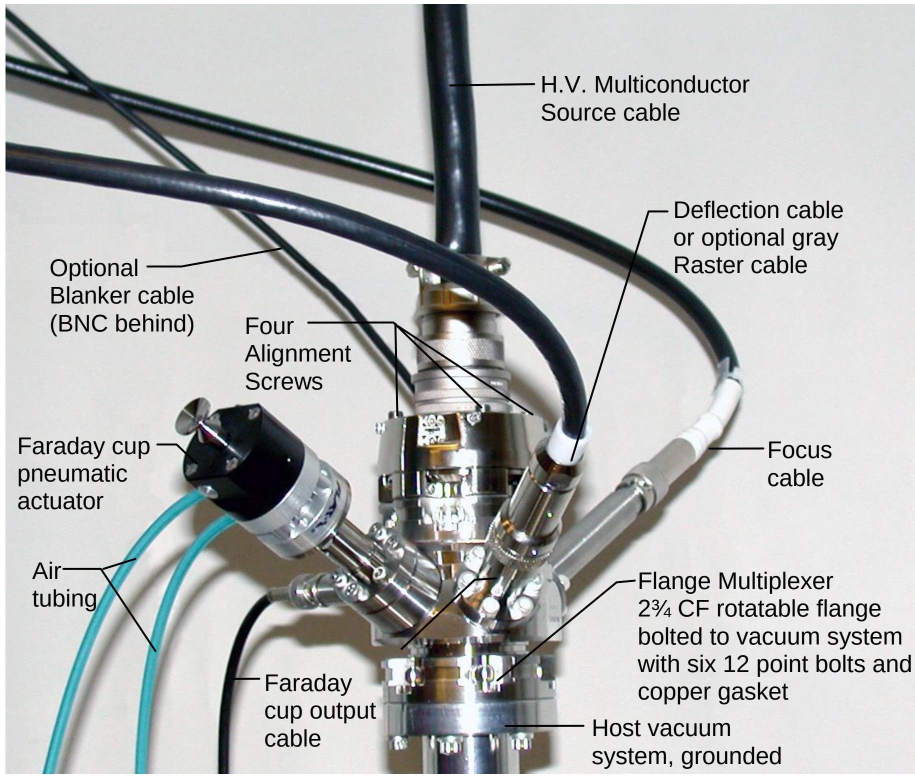


Fig. 2.3-3 EGG-3101 installed in vacuum

3. Positioning the Electron Gun:
   a. Note the orientation of the deflection plates by looking into the front end of the gun. The Y plates are the most visible. The gun is mounted on a rotatable conflat flange to permit the deflection plates to be aligned to a user-determined direction. (Fig. 2.3-2)
   b. Carefully insert the Electron Gun into the vacuum system using a new copper gasket, but do not tighten bolts yet. **CAUTION: The exposed leads on the gun housing are very fragile. Take care that the gun does not hit against the vacuum system when inserting.**
   c. Orient the Electron Gun by rotating the flange so that the Deflection plates are oriented as desired. If the gun has an optional spooling piece for zero insertion or magnetic shielding, it may be necessary to loosen and rebolt the flange, replacing the copper gasket.
   d. Hold the H.V. Multiconductor cable up to the gun and observe how the key inside the connector is oriented. **Do not touch the white insulator on the cable.** Set the cable aside.
   e. Position the cable and the gun so that the key on the gun connector will be approximately aligned with the key on the cable connector. If the keys are approximately lined up, then the cable will not be inadvertently twisted when installed.

4. Using six 12 point bolts into the rotatable flange of the Flange Multiplexer, securely bolt the Electron Gun into the vacuum system, sealing with the new copper gasket. There are tapped and clear holes so that the bolts may be installed from either side depending on the vacuum flange. **Ensure that the vacuum system is properly grounded.** (If the gun has a barium oxide (BaO) cathode, it is best to store it in vacuum, so evacuate the chamber as soon as possible.)

5. If desired, the electron gun may be baked at 350ºC with no cables attached.

6. H.V. Multiconductor Source cable
   (Figs. 2.3-3 and 2.3-4):
   a. Wipe the short white insulator on the connector with isopropanol and a lint-free cloth.
   b. Gently insert the 4-pin connector on the H.V. Multiconductor Source cable into the central keyed vacuum feedthrough on the EGG-3101 Electron Gun, all the way in, tightening the ring by hand. Observe the key position and avoid excessive twisting or force when inserting cable. It is recommended that the cable be supported along its entire length to prevent the cable from sagging.
   c. **For Capacitive Beam Pulsing option:** See Section 4.8. A Pulse Junction Cylinder is installed between the gun feedthrough and the Source cable.

7. Focus cable: Connect the long metal BNC-style connector of the Focus coaxial cable to the long 15 kV coaxial feedthrough on the on the side of the Flange Multiplexer.

8. Deflection cable: Gently insert the black 8-pin Deflection cable (or optional gray Raster cable) into the 8-pin vacuum feedthrough on the side of the Flange Multiplexer, and tighten ring by hand. Observe the key position and avoid excessive twisting or force. Always support cables.

9. **For optional Beam Blanking:** Connect the Beam Blanker coaxial cable to the short BNC feedthrough on the Flange Multiplexer. **CAUTION:** The blanker BNC must be connected to the blanker cable (or grounded), even if the blanking option is not being used, or else the plates in the gun may charge up.

10. **For optional Rastering:** See Section 4.7. Use the gray Raster cable instead of the Deflection cable.

11. **For optional Faraday Cup Assembly:** See Section 4.9. Always connect the output BNC of the Faraday cup to a user-supplied ammeter or to ground. **NOTE:** Faraday cup pneumatic actuator must be removed for bakeout.

12. **For optional barium oxide (BaO) cathodes:** Special care is required. See Appendix.
    a. Long exposure of the cathode to atmosphere may change the emission characteristics. The cathode coating is very delicate. The cathode should not be exposed to mechanical or thermal shock which can damage the emission surface. The gun or spare cathodes should be stored in vacuum or in a dry environment, such as in a sealed shipping tube with desiccant. Best lifetimes are obtained by immediate insertion in good vacuum (minimum of 10^{-7} torr).
    b. If the Electron Gun is purchased from Kimball Physics with a BaO cathode installed, then that cathode has already been activated and tested in the factory, and the gun is shipped in an evacuated shipping container to protect the BaO coating.
    c. If a new (or rebuilt) firing unit with a BaO cathode is purchased and installed by the user, then the cathode needs to be activated following instructions in the Appendix and provided with the firing unit. After BaO activation, it is important to follow proper storage procedures.
    d. Whenever the gun has been exposed to atmosphere, the BaO cathode may need to be reactivated following the instructions in the Appendix.

13. Optional viewport: There may be a viewport as one of the side CF ports of the Flange Multiplexer to allow direct observation of the cathode.

14. Electron beam detector: If desired, install a user-supplied Faraday cup and/or Phosphor screen in the vacuum chamber to monitor beam output from the electron gun. See Section 2.4.

15. The EGG-3101 is a modular design gun. The firing unit can be replaced by the user when the cathode burns out (Section 6.3) or the anode can be replaced with one of a different aperture size(Section 6.5), the cathode to anode spacing can be adjusted (Section 6.6) or the entire lens assembly can be replaced to provide an alternative experimental design (Section 6.6) These procedures involve some gun disassembly out of vacuum.

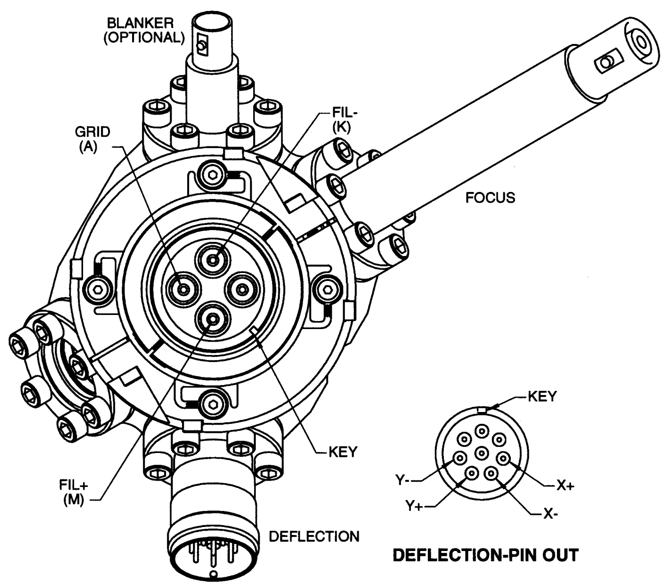


Fig. 2.3-4 EGG-3101 cable connections and pinout as seen from the top of the Flange Multiple
NOTE: The position of Source connector may be rotated with respect to Focus and Deflection connectors, so use key positions for pinouts. An optional Faraday cup actuator may be mounted on the unused 1⅓ CF flange.

This completes the EGG-3101 Electron Gun Installation.

2.4 ELECTRON GUN BEAM OUTPUT MONITORING

Monitoring the output of the electron gun is particularly recommended for initial gun operation to position the spot, or align the gun, and to determine various power supply settings for optimum performance. The electron beam can be visually monitored by observing the resultant spot on a phosphor screen or electrically monitored by measuring the beam current at the target. The most desirable arrangement is to have both visual and electrical monitoring of the electron beam.

The following are some possible monitoring choices:

A. A Faraday cup and grounded phosphor screen, mounted side by side, on a linear manipulator. Position either the phosphor screen or the Faraday cup in the beam line using the manipulator.

B. A grounded phosphor screen with a centrally located hole and a Faraday cup mounted directly behind the hole. Use deflection to position the spot on the screen when visual monitoring is desired. When electrical monitoring of beam current is desired, use deflection to aim the beam through the hole into the Faraday cup.

C. An electrically isolated phosphor screen connected to a picoammeter. View and measure the beam current directly off the phosphor screen.

It is recommended that during the initial set-up of the Electron Gun, or before high beam power operation, the actual beam current should be measured with a Faraday cup. The Faraday cup should be mounted in the target area to calibrate the operating parameters of the electron gun. The Faraday cup at the target must be able to dissipate a beam power equal to the beam current multiplied by the beam energy; for example, 1 mA at 5 keV yields 5 watts.

Generally, low beam power should be used with phosphor screens. For standard Kimball Physics phosphor screens, the recommended maximum beam power density is 1 Watt/cm^2 .

Faraday cups and phosphor screens are available from Kimball Physics.

3 THEORY OF OPERATION

3.1 INTRODUCTION AND BLOCK DIAGRAM

The EGG-3101 Electron Gun provides a medium energy, focusable electron beam. The gun consists of the following elements that produce and control the electron beam: triode, optional beam blanker, focus and deflection. Beam energy, beam current, and beam divergence are all directly controllable

The triode consists of three elements in the following sequence: cathode, Wehnelt (grid), and grounded anode. Electrons emitted from the cathode are accelerated to full kinetic energy by the triode's electric field, which also causes the beam to crossover in the triode region. This crossover forms the object imaged at the target by the focusing lens.

After the triode, the electron beam is further focused and positioned with an Einzel lens and an 4-pole deflection unit. The optional beam blanker can be used to cut off or pulse the beam.

The EGPS-3101 Power Supply consists of a group of modular power supplies that provide all the necessary voltages to drive the Electron Gun. The Source and Grid power supplies are floated at negative high voltage (i.e., at Electron Beam Energy up to -10 kV). The Energy, Focus, and Deflection supplies are referenced to ground; all supplies are controlled and metered at ground.

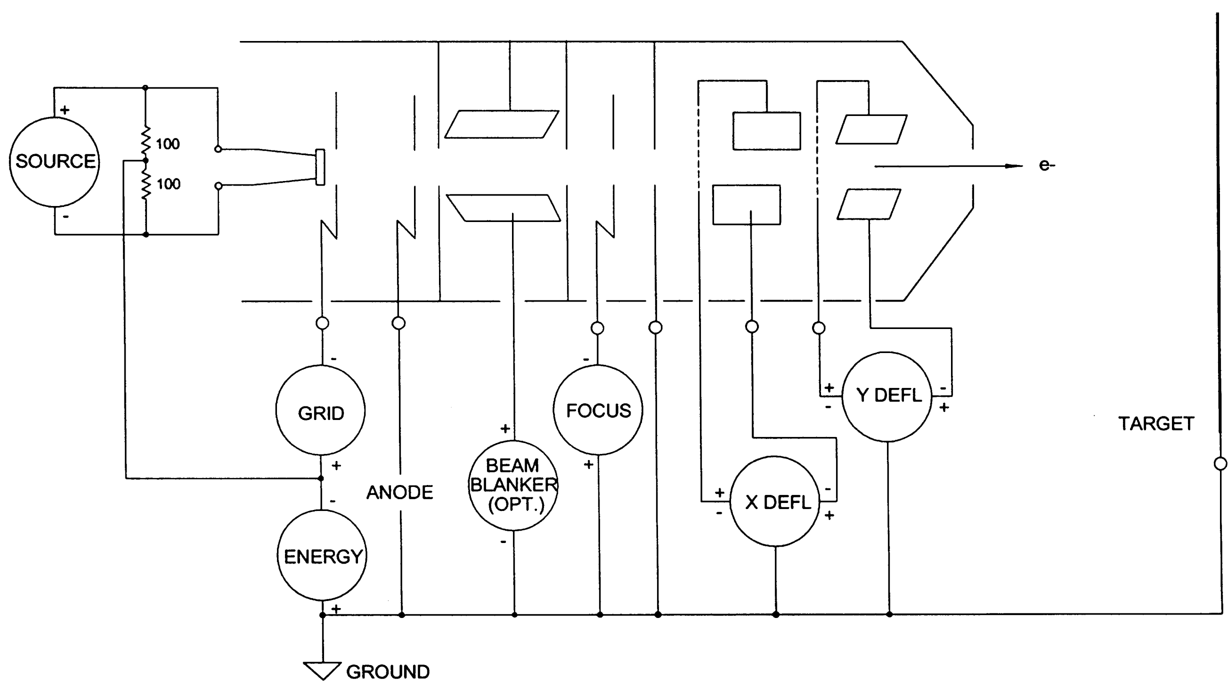


Fig. 3.1-1 Block Diagram of EGG-3101 Electron Gun with optional beam blanking

3.2 CATHODE

The standard cathode is a refractory metal thermionic emitter that is directly heated by an isolated voltage source. This voltage source is referenced to the energy supply, a negative high voltage supply (0 to 10 kV) which is referenced to ground. Electron emission is a function of both cathode temperature and energy.

When cathode temperatures are relatively low and energy is relatively high, the cathode is operating in a temperature limited mode, and an exponential relationship between electron emission and cathode temperature exists. This can be described by the Richardson-Dushman equation:

$$J = AT^2 e^{-\phi/\kappa T}$$

Where:
J = emission current density in amps/cm^2
A = Richardson's constant, for cathode material; a theoretical value for Ta is 37 amps/cm^2/K^2 (see literature for complete discussion)
T= cathode temperature in degrees Kelvin
ϕ = work function of cathode material in eV
κ = Boltzmann's constant (8.6 x 10^{-5} eV/K)

At higher cathode temperatures and lower energies, the cathode is operating in a space charge limited mode, and a relationship between electron emission and energy predominates. This can be described by the Langmuir-Child space charge equation:

$$J = 2.335 \times 10^{-6}\ V^{3/2} / d^2$$

Where:
J = emission current density in amps / cm^2
V = high energy potential applied to cathode in volts
d = distance between cathode and anode in cm

If energy is fixed at a relatively low level and cathode temperature is increased, the cathode's emission characteristic makes a transition from a temperature limited relationship to a space charge limited relationship. This is illustrated in Figure 3.2-1 where energy is held constant while the cathode temperature is increased by increasing source voltage. At low temperatures, the Richardson-Dushman equation applies and electron emission increases with increasing temperature until a space charge limited temperature region is obtained. In this space charged limited region, the emission begins to level off even as the cathode temperature continues to increase. The energy field strength is not sufficient to extract all the available electrons at these higher temperatures.

If cathode temperature is fixed and energy is increased, the cathode's emission characteristic makes a transition from a space charge limited relationship to a temperature limited relationship. This is illustrated in Figure 3.2-2 where cathode temperature is held constant by fixing the source voltage, while the energy field is increased. At lower energies, an increase in energy produces an increase in emission according to the Langmuir-Child relationship. Emission levels off at higher energies because the cathode's temperature is too low to produce additional electrons.

Operating the cathode in a temperature limited mode results in beam current drift as the cathode temperature drifts. Operating the cathode in upper space charge limited region results in shorter cathode lifetimes since the cathode temperature is excessive.

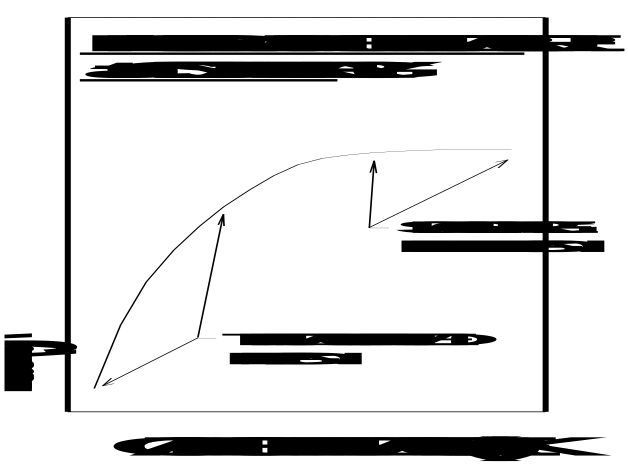


Fig. 3.2-1 Effect of Temperature on Cathode Emission at a Constant Energy

Fig. 3.2-2 Effect of Energy Voltage on Cathode Emission at a Constant Cathode Temperature

Note that the cathode lifetime is a decreasing function of cathode temperature because the cathode material evaporates away more quickly at higher temperatures. To balance the need for beam stability, adequate emission, and maximum cathode lifetime, the cathode should be operated in the transition region between temperature and space charge limited modes.

The cathode is a low power device and is driven by a voltage source rather than a current source. However, the monitoring of source current can be more useful than the monitoring of source voltage because small variations in source current are easier to observe and source current is not dependent on cable length. Thus, throughout this manual, source currents are often given as operating points.

Standard cathode—Refractory metal disc

The standard system uses a refractory metal thermionic emitter consisting of a tantalum disc mounted on a hairpin filament wire. The disc provides a circular, planar emission surface that emits electrons when the filament wire is heated by the voltage source. As the disc is welded at a single point, it is unipotential and as no heating current passes through the disc, the energy spread is kept to minimum.

Optional cathodes—Barium oxide coated (BaO)

As an option, the EGG-3101 may use a low-light, low-temperature, barium oxide-coated (BaO) disc cathode instead of the standard refractory metal one. The BaO cathode has a lower cathode heating current range and a lower operating temperature, because it has a lower work function. With the lower temperatures, there is less light emitted which could interfere with viewing the target; thus these cathodes are sometimes referred to as "low light". The BaO cathode gives a smaller energy spread than a standard cathode, and has a longer lifetime due to the lower heating current. The lifetime of a BaO-coated cathode is based on the evaporation rate of the coating materials, which is dependent on the temperature at which the cathode is run and the vacuum. The performance of all coated cathodes will degrade as coating is depleted through use, or lost due to mechanical shock or ion bombardment.

The activated barium oxide coating is susceptible to degradation from water vapor, so it is recommended that the BaO cathode be operated in a vacuum of 10^{-7} torr or better. In addition, the gun and any spare cathodes should be stored in vacuum or in a dry environment, such as a tightly-sealed plastic container with a desiccant. Exposure to moisture in the air allows the oxide to form hydrates, which can cause flaking of the barium oxide.

Optional cathodes—Thoria coated (ThO_2) Iridium

Another option for the EGG-3101 is a thoria-coated (thorium oxide, ThO_2) iridium disc cathode, which can be an advantageous choice for some applications. Thorium has a lower work function than the uncoated refractory metals, so more electrons will be emitted at a given temperature, or a given electron emission can be achieved at a lower temperature. As the cathode is heated, the thorium oxide near the surface of the coating breaks down, and the positive thorium migrates to the surface, while the more negative oxygen remains; this acts as a dipole accelerating electrons near the surface, which further decreases the work function.

Iridium, a noble metal, is more resistant to oxidation and other forms of chemical attack than the refractory metals. Thus the cathode will not easily burn out if accidentally exposed to atmosphere while running, and it can be used in poorer vacuum conditions. Unlike the BaO cathode, the thoria-coated cathode does not require any special care, other than protection from mechanical shock which could physically remove the coating. The performance of all coated cathodes will degrade as coating is depleted through use, or lost due to mechanical shock or ion bombardment.

Optional cathodes—Lanthanum hexaboride (LaB_6) Crystal

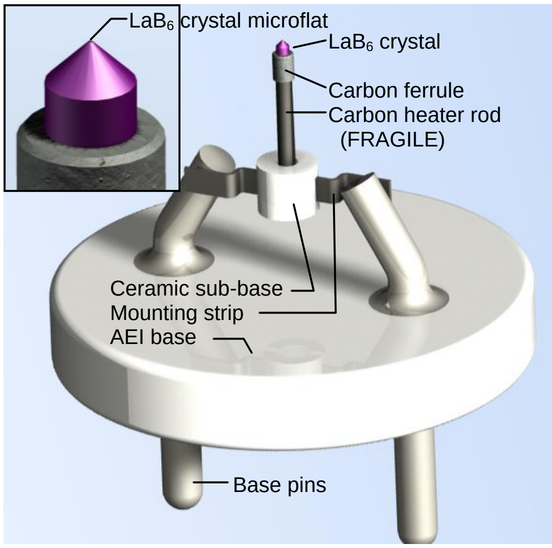


Fig. 3.2-3 LaB_6 cathode assembly showing the LaB_6 crystal (magnified on left), heater, and AEI base mounting

The small spot system uses a lanthanum hexaboride (LaB_6) crystal as part of its cathode. This cathode offers high brightness, small emission area, and long operating lifetimes.

The LaB_6 cathode assembly consists of three parts: cathode, heater and base (Figure 3.2-3) The cathode material is single crystal lanthanum hexaboride and is mounted directly on the carbon heater. This subassembly is then mounted on a two-pin ceramic base.

The cathode shape is conical with the tip of the cone blunted to form a 15 micron diameter circular planar emission surface with a <100> crystallographic orientation. This microflat region has the lowest electron work function and thus the best emission is achieved from this region. The work function and emission around the sides of the cone vary as a function of position on the cone. This variation in work function produces an emission pattern that resembles a Maltese cross (Figure 3.2-4).. The center of the Maltese cross pattern results from the electrons emitted off the cathode's microflat, while the lobes of the Maltese cross pattern result from electrons emitted off the conical portion of the cathode. The Wehnelt potential controls the region of the cathode that emits electrons. As the Wehnelt potential is increased, emission from the conical portion is suppressed, and a focused, circular, small spot is produced.

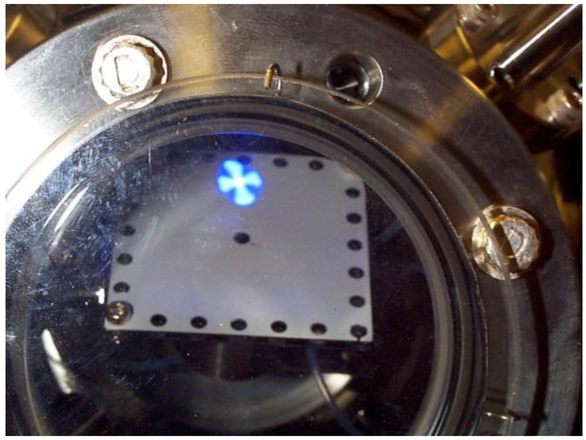


Fig. 3.2-4 LaB_6 unfocused Maltese cross spot on phosphor screen in vacuum

3.3 WEHNELT OR GRID (G-1)

The Wehnelt (‘*vayn*- alt) is a tubular structure with an aperture fixed to one end that houses the cathode. The Wehnelt is also called the Grid (as it is referred to in terms of the Power Supply), control grid, or G-1. The Wehnelt potential is controlled by a voltage source referenced to the negative energy supply. .

Increasing the Wehnelt potential makes the Wehnelt aperture more negative with respect to the cathode. As the Wehnelt potential increases (also called increasing grid bias), the electric field between the cathode and Wehnelt suppresses electron emission from the cathode perimeter, leaving only the center of the cathode to emit.

If enough Wehnelt potential is applied, the beam will be completely suppressed and the beam is said to be cut off. Figure 3.3-1 shows this cut off effect of increasing grid voltage, as well as the use of the grid to maximize the final beam current. The grid voltage required for cutoff is an increasing function of the electron beam energy (Figure 3.3-2).

Grid cut-off can be used to pulse the electron beam off and on. The various ways that pulsing can be accomplished using the grid are described in the operating section.

The electric field created by the Wehnelt also controls beam divergence and uniformity by varying electron trajectory. The grid potential can be adjusted to optimize the efficiency of beam production. As shown in Figure 3.3-1, a mid-range grid voltage can produce local maximum in the beam current curve, which also represents the best ratio of beam current (the actual current leaving the gun) to emission current (the total current off the cathode to ground). When the gun is operated at this range, the beam is well collimated before entering the focus region, and little current is lost to various gun elements.

In the EGG-301 electron gun with the High Current option, the emitting surface of the cathode projects beyond the grid element. The electric field created by the grid acts as a focusing shield and serves to shape the electron beam. As the grid potential increases, the electrons emitted from the cathode are repelled and forced forward and toward the center of the beam line. This improves the emission to beam ratio by narrowing the beam so that current does not land on other gun elements. However, the position may not allow the grid voltage to completely suppress emission from the cathode at higher energies. Thus, under some conditions, there may be no grid cut off, and beam pulsing with the grid is not considered an option in the high current gun model. The optional beam blanker assembly is recommended for pulsing particularly with high current (Section 3.5 below).

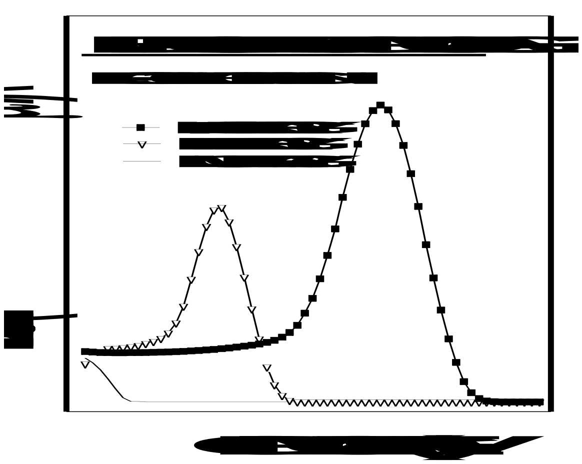


Fig. 3.3-1 Effect of Grid on final Beam Current, showing cutoff at three different Energies

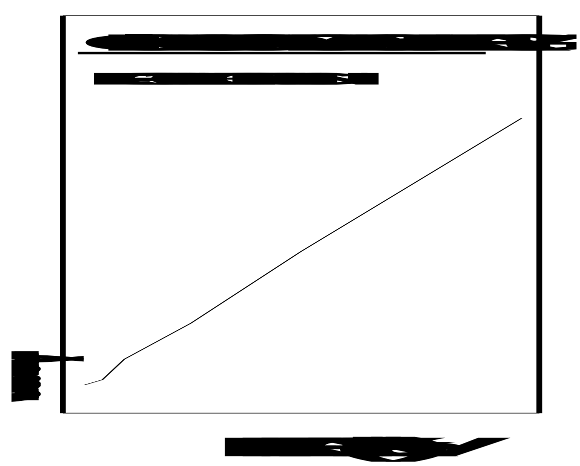


Fig. 3.3-2 Effect of Energy on the Grid Voltage required for beam cutoff

3.4 ANODE

The anode is an aperture plate that is the third element of the triode. The anode resides downstream of the Wehnelt and is at ground potential. The magnitude and direction of the electric field created by the potential difference between the cathode and anode, as modified by the Wehnelt (Grid) potential, determines the energy and trajectory of the electrons emitted from the cathode.

The remaining elements in the column serve to modify or control the beam in various ways, such as focusing and deflection, but do not alter final beam energy.

3.5 BEAM BLANKER (OPTIONAL)

The beam blanker consists of two plates followed by a blanker aperture. When beam blanking is desired, a potential is applied to one plate while the other plate remains at ground potential. The electric field created between the plates produces a force on the electrons perpendicular to their direction of travel that deflects the beam off axis, thus preventing the electron beam from passing through the blanker aperture. To reduce scattering of deflected electrons impinging on a blanker plate, one of the plates is angled away from the beam.

Figure 3.5-1 demonstrates effect of varying the blanker potential on the final beam current exiting the electron gun. Increasing blanker voltage increases the beam deflection into the beam trap and thus cuts off the beam. However, too high a beam blanker potential can cause primary electrons to scatter off one of the blanker plates and through the blanker aperture; this degrades the effectiveness of the blanker.

The blanker potential required to just cut off the beam is a linear function of energy (Figure 3.5-2). For optimal performance of the beam blanker, the potential applied to the plate can be adjusted, so that a relatively constant off-axis angle can be maintained as energy is varied.

Blanking can be used to pulse the final beam current repeatedly off and on in response to a TTL signal input. The blanker voltage, set at the cut off value, is pulsed on and off using an appropriate TTL pulse generator to control the timing. This results in the beam at the target being switched off and on. This type of pulsing is slower than capacitive pulsing which uses the grid to cut off the beam.

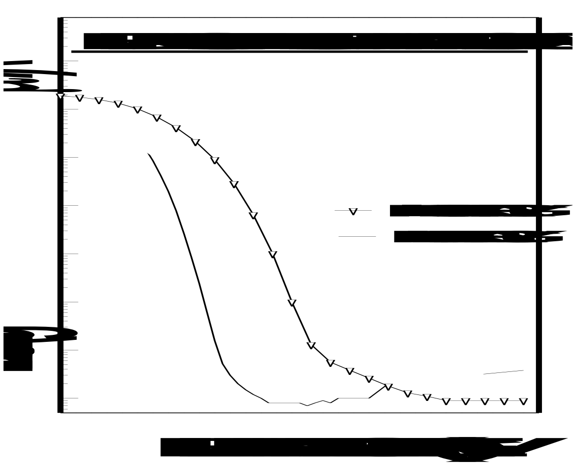


Fig. 3.5-1 Effect of Blanker Voltage on final Beam Current at two different Energies (similar gun with same Blanker element)

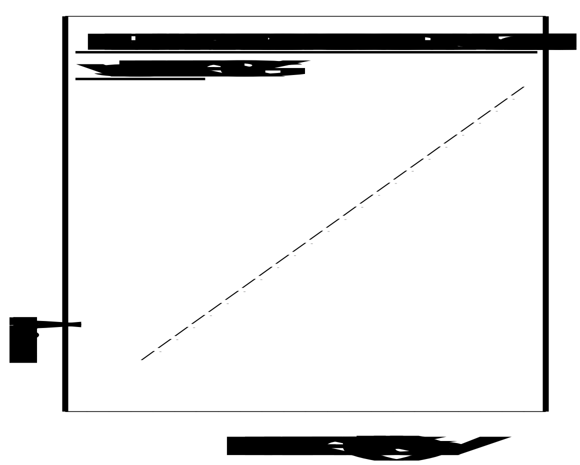


Fig. 3.5-2 Effect of Energy on the Blanker Voltage required for beam cutoff (similar gun with same Blanker element)

3.6 FOCUS

The focus elements consist of three tubes of equal diameter in series. The first and third tubes are grounded, while the second (middle) element is at a variable, focusing potential. This type of lens is referred to as an Einzel lens. The negative focusing potential controls the position of the beam's second axial crossover point, which allows the spot to be focused on a target placed at a wide range of working distances.

At a given energy and working distance, spot size is a function of focus voltage as illustrated in Figure 3.6-1. The EGG-3101 is designed so that focus is proportional to energy. During gun operation once the desired focus voltage is set, the focus will track with the energy voltage. As energy is changed by the operator, the focus will adjust automatically to maintain the original spot size at the given working distance. This effect is illustrated in Figure 3.6-2, where the focus values in Figure 3.6-1 are normalized for energy. For a fixed working distance, the focus value needed to achieve minimum spot size varies linearly with energy.

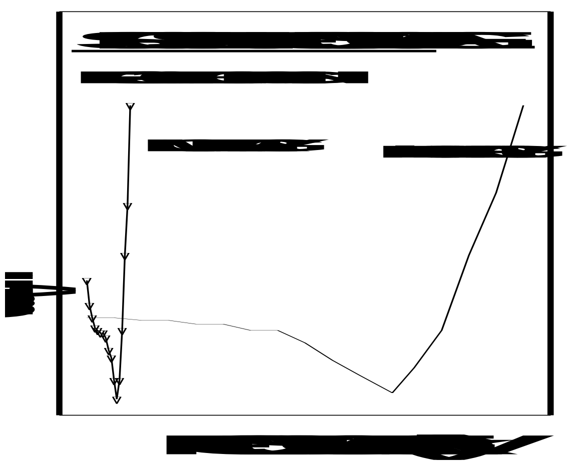


Fig. 3.6-1 The effect of focus on spot size at different energies, showing minimum spots

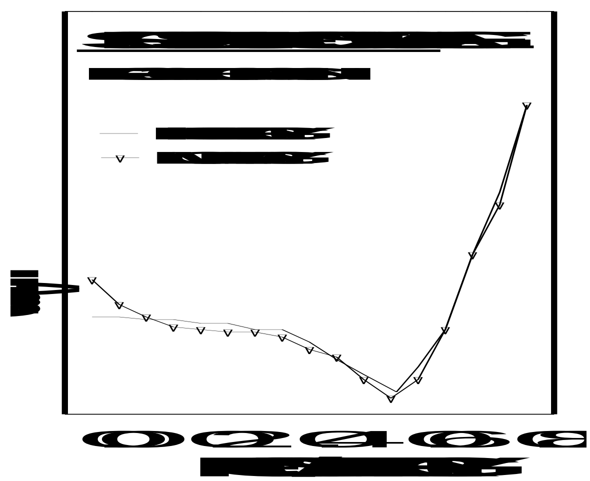


Fig. 3.6-2 The effect of focus on spot size (with focus as a proportion of energy) showing minimum spot at different energies

3.7 BEAM COLLIMATION

The EGG-3101 Electron Gun is designed to produce a collimated electron beam. Within a restricted set of parameters, the electrons can be made to travel in a parallel path, so that the spot size and beam current density remain constant while the distance to the target is varied. At a given energy, a focus voltage can be determined experimentally which maintains the same spot size over a range of working distances. Optically, this focus value places the crossover at the object so that the rays on the other side of the focus lens will be parallel.

In Figure 3.7-1, the point where the three spot size curves taken at different working distances intersect represents the collimating focus value, that is, at this focus voltage, spot size remains a constant as a function of working distance. Note that the collimated spot size can not be the minimum spot size, which involves crossover being at the particular distance of the target.

Figure 3.7-2 illustrates this collimation effect. With the focus is adjusted to produce a desired small spot size, at or near the collimation point, the working distance can be varied over a large range and the spot will remain almost contstant.

The degree to which the electron beam can be collimated will depend on factors such as energy and beam current. Increasing the source heating current, increases total beam current, but also increases the spot size somewhat. Space charge within the beam produces a diverging force on the beam. This force becomes more significant at lower energies, because the electrons have a lower velocity, and at higher beam currents, because there are more electrons in a given volume. Better collimation over a larger range of working distances can be achieved at higher energies.

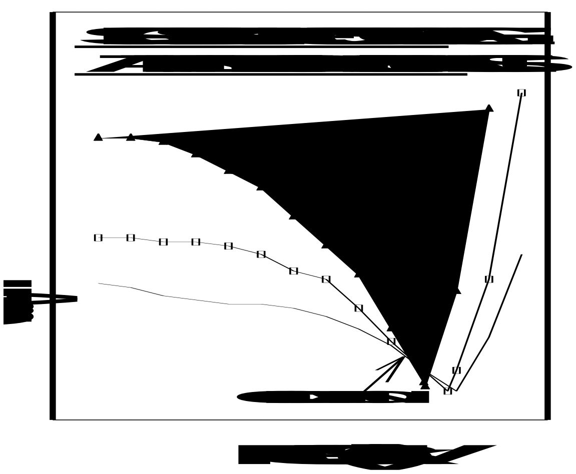


Fig. 3.7-1 The effect of Focus on spot size at different working distances, showing collimation point (arrow) data from a similar gun.

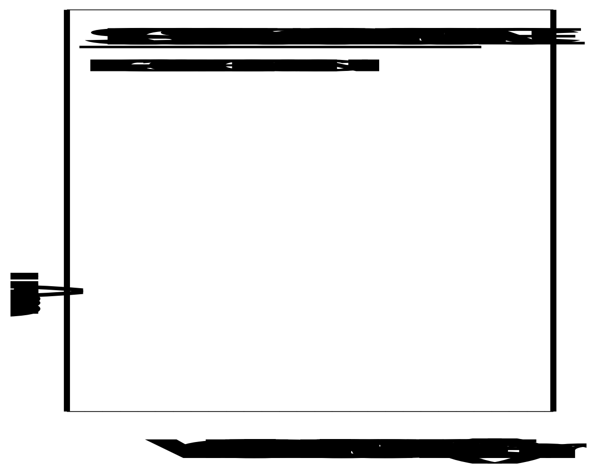


Fig. 3.7-2 Collimated beam, constant spot size at varying working distances

3.8 DEFLECTION

Deflection consists of two pairs (X and Y) of deflection plates located downstream of the focus element. Potentials applied to these plates produce a deflecting force in a plane perpendicular to the direction of electron travel, allowing the beam to be aimed or rastered (for units with the Raster Generator option). Deflection allows the beam to be guided by the operator to the target.

As shown in Figs. 3.8-1 and 3.8-2, the amount of deflection at the target is linearly proportional to the deflecting voltages applied. Deflection is very dependent on the electron beam energy. At higher energies, more voltage is required to move the spot a given amount, and the maximum possible deflection is less.

Non-uniformities in the deflecting electric field present at the edges of the deflection plates can cause the spot to become distorted if it is deflected too close to the deflection plates. Distortion varies with both the diameter of the electron beam as it passes through the deflection plate region and the potentials applied to the deflection plates. The greater the diameter of the electron beam as it passes through the deflection plates, the greater the distortion.

Beam diameter, and thus deflection distortion, can be reduced by increasing grid bias (see Section 3.3 above) but there will be a corresponding reduction in overall beam current.

Better spot shapes will be achieved if the amount of deflection is kept to a minimum.

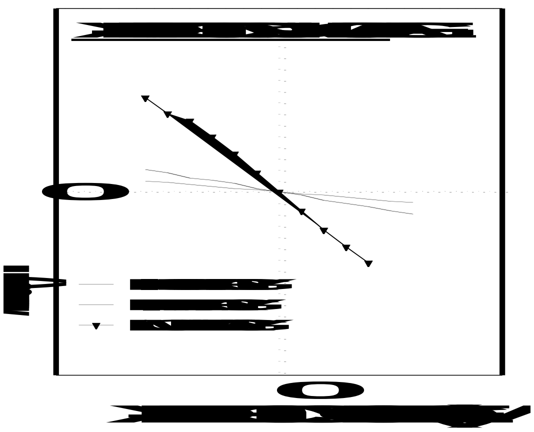


Fig. 3.8-1 Effect of X-Deflection Voltage on deflection of the spot in the X direction at three different Energies (data from a similar gun with the same deflection assembly)

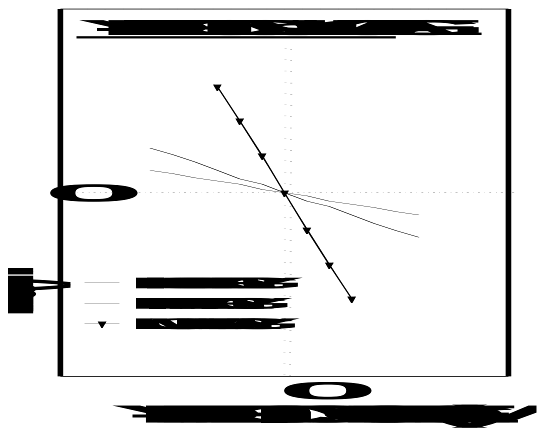


Fig. 3.8-2 Effect of Y-Deflection Voltage on deflection of the spot in the Y direction, at three different Energies (data from a similar gun with the same deflection assembly)

4 OPERATING INSTRUCTIONS

4.1 DESCRIPTION OF CONTROLS

Fig. 4.1-1 Front Panel of EGPS-3101 Electron Gun Power Supply with optional Beam Blanker

4.1.1 EGPS-3101 ELECTRON GUN POWER SUPPLY

The following is a description of the function of each control in the EGPS-3101 Power Supply

Front Panel Controls

Master Key: A safety switch that interrupts (115/230 VAC) power to the EGPS-3101 Power Supply.

Power Switch: A green pushbutton switch labeled **POWER**. One contact switches fused (2 amp slow-blow) AC voltage (115/230 VAC) from line to Auxiliary power supply circuitry. The other contact switches +24 VDC to the pushbutton indicator lamp.

Interlock LED: An amber LED labeled **INTERLOCK**. When lighted, it indicates an open interlock switch due to an incorrect set-up of the electron gun system. To clear the light, turn off the power switch and correct the fault.

High Voltage Switch: A red pushbutton switch labeled **H.V.** that enables or disenables the High Voltage Energy and Focus power supplies.

Zero LED: An amber LED labeled **ZERO**. When lighted, it indicates the Energy and/or Focus control is already turned up when initially depressing the High Voltage Energy switch. To clear light, turn **ENERGY** and **FOCUS** potentiometers fully counterclockwise to zero, then depress the **H.V**. pushbutton again.

Digital Meter: A Digital Voltmeter, DVM, (not labeled) that displays the following depending upon the position of the Function Switch, as indicated by red LEDs:

Energy	0 to 10 kV
Focus	0 to 10 kV
X Deflection	-300 V to +300 V
Y Deflection	-300 V to +300 V
Blanker	0 to +600 V

Function Switch: A multi-position rotary switch labeled **FUNCTION** that determines which quantity is displayed on the DVM. The function switch reads left to right: Energy, Focus, X-Deflection, Y-Deflection, Blanker, as indicated by the red LEDs next to the potentiometers.

Energy Control: A ten-turn dial potentiometer labeled **ENERGY** that voltage programs the Energy power supply that provides the electron acceleration energy. Range: 0 to -10 kV

Focus Control: A ten-turn dial potentiometer labeled **FOCUS** that voltage programs the Focus power supply. Range: 0 to -10 kV.

Source Switch: A red pushbutton switch labeled **SOURCE** that enables or disenables the Source power supply that heats the cathode.

Over Current LED: An amber LED labeled **OVER CURRENT**. When lighted, it indicates that the source current is exceeding recommended maximum operating current. **Running the source current this high will greatly reduce cathode lifetime.**

4.1 DESCRIPTION OF CONTROLS cont.

EGPS-3101 Electron Gun Power Supply cont.

ECC/Source Switch: A toggle switch labeled **ECC/SOURCE**. When the switch is in the ECC position, it allows the user to set the desired emission current, to be maintained by feedback circuitry, with the Source potentiometer. In the Source position, it allows the user to set the desired Source voltage directly with the potentiometer.

Source/ECC Control: A ten-turn dial potentiometer labeled **SOURCE/ ECC** that voltage programs the Source power supply which heats the cathode.

Grid (G-1) Control: A ten-turn dial potentiometer labeled **GRID** that voltage programs the Grid power supply.

Source Voltage Meter: A 0 to 3 V analog meter labeled **SOURCE VOLTS** that monitors the filament voltage.

Source Current Meter: A 0 to 2 A analog meter labeled **SOURCE AMPS** that monitors the filament current.

Emission Current Meter: An analog meter labeled **EMISSION CURRENT** that remotely monitors the emitted current from the cathode.

Grid Voltage Meter: An analog meter labeled **GRID** that monitors the Grid (G-1) bias voltage.

Deflection Switch: A blue pushbutton switch labeled **DEFL** that enables or disenables the power supplies in the deflection unit. (When off, outputs are grounded, so the deflection plates in the gun are grounded.)

X Deflection Control: A ten-turn potentiometer labeled **X DEFLECT**, adjusts the deflection voltage in the X direction. A red LED next to the potentiometer indicates monitoring of the X deflect voltage by the DVM (digital voltmeter).

Y Deflection Control: A ten-turn potentiometer labeled **Y DEFLECT**, adjusts the deflection voltage in the Y direction. A red LED next to the potentiometer indicates monitoring of the Y deflect voltage by the DVM.

Energy Proportional / Normal Switch: A toggle switch labeled **ENERGY PROP / NORMAL** that switches the deflection output from the “energy proportional mode” to the normal “non-proportional mode”.
Energy Prop. mode: The deflection voltage is proportional to the beam energy as energy is changed. This enables *approximately* constant positioning of the spot as the beam energy is changed.
Normal mode: The deflection voltage remains constant as the beam energy is changed.

NOTE: If necessary, the analog meters can be zeroed using a small straight-bladed screwdriver inserted in the hole below the meter. Meter brightness can be adjusted with a single-turn potentiometer accessed through the small hole to the right of the meters (clockwise to increase brightness, counterclockwise to decrease brightness).

Optional Front Panel Controls for Beam Blanking

Blanker Switch (optional): An amber pushbutton switch labeled **BLANKER** that enables or disenables the power supply in the blanker unit. When the switch is off, the Beam Blanker output is switched to ground to allow normal operation of the Electron Gun.

Blanker Control (optional): A ten-turn potentiometer labeled **BLANKER** that voltage programs Blanker power supply. (Range 0 to +600 V)

Blanker Normal/Invert Switch (optional): A toggle switch labeled **NORMAL/INVERT** that controls the type of output produced by the Beam Blanker unit.

Blanker TTL BNC (optional): An input BNC labeled **TTL INPUT** on the front of the Power Supply for the input of a TTL pulse generator or signal generator with +5 volts square wave output for pulsing operation of the Beam Blanker. For optional rastering, this BNC can be connected to the Raster Generator Deflection Unit for synchronization.

EGPS-3101 Back Panel Controls

Remote Control Terminal Block (standard): A multi-screw terminal block labeled by each supply **ENERGY...**, and **PROG COM...** (program / common) that takes an analog input to voltage program individual power supplies for remote control.

Local / Remote Control Switches (standard): Unlabeled, two-position slide switches for each individual power supply, located behind the access panel. They switch control of the supplies between the manual, front panel potentiometers (left=local) and the remote control terminal block input (right=remote).

AC Selector Switch: An unlabeled, red, two-position slide switch that selects the input line AC voltage as 115 V or 230 V.

Interlock Terminal Block: A 2-screw terminal block labeled **INTERLOCK** that disables the power supply when it is an open circuit, shipped jumpered.

Main Fuse: A 250 V, 2 A slow-blow fuse labeled **FUSE** that is the main fuse for the entire unit. (Individual boards have additional fuses.)

Optional Back Panel Controls for National Instruments LabVIEW™ Computer Interface

Metering Output Connector (optional): A 68-pin D-sub connector labeled **METERING** for monitoring individual power supply outputs by computer. (usually 0 to 2 V signal outputs).

Programming Input Connector (optional): A 68-pin D-sub connector labeled **PROGRAMMING** for voltage programming the individual power supplies by computer. (usually 0 to 10 V signal inputs).

Local / Remote Control Switches (optional): Two-position slide switches for each individual power supply that set the control of the supply in the **LOCAL** or **REMOTE** mode. (Metering of the supplies is not affected by these switches.)
LOCAL allows control by the manual, front panel controls.
REMOTE allows control only by computer input via the 68-pin **PROGRAMMING** connector below.

Table 4.1-1 EGG-3101 / EGPS-3101 Power Supply Ranges for different system options

	STANDARD Standard Ta disc, BaO, or Thoria cathode	**SMALL SPOT** LaB_6 cathode	**HIGH CURRENT** HC Ta disc or HC Thoria cathode
Additional H.V. Supply	No	No	Yes 0 to -10 kV @ 12 mA
Energy	0 to -10 kV		
Focus	0 to -10 kV		
Grid	0 to -300 V	0 to -300 V	0 to -1000 V
Source Voltage controlled and metered, Current metered only	0 to 1.5 V 0 to 2.0 A	0 to 2.6 V 0 to 2.0 A	0 to 2.25 V 0 to 3.0 A
Emission Current (Metered, not a separate power supply)	0 to 500 μA	0 to 100 μA	0 to 3 mA
X Deflection	-300 V to +300 V		
Y-Deflection	-300 V to +300 V		
Blanker (optional)	0 V to +600 V		

4 OPERATION

4.1 DESCRIPTION OF CONTROLS cont.

Glassman H.V. Power Supply for High Current Option only

(See the Glassman manual for more information)

Fig. 4.1-2 Front Panel of Glassman H.V. Supply included in High Current systems only (style may vary)

Power Switch: A orange toggle switch labeled **POWER (I / 0)** that enables or disenables the power supply.

H.V. Switch: A green pushbutton switch labeled **HV** that energizes the power supply.

Voltage Control: A ten-turn potentiometer labeled **KILOVOLTS** that voltage programs the voltage output of the H.V. Power Supply and sets the upper limit of voltage available for the EGPS-3101. (Range: 0 to 10 kV)

Current Control: A ten-turn potentiometer labeled **MILLIAMPERES** that voltage programs the current output of the H.V. Power Supply and sets the upper limit of current available for the EGPS-3101.
CAUTION: The supply current range may be much higher than the maximum recommended operating current for the cathode.

Voltage Meter: A digital or analog meter labeled **KILOVOLTS** that monitors the output voltage.

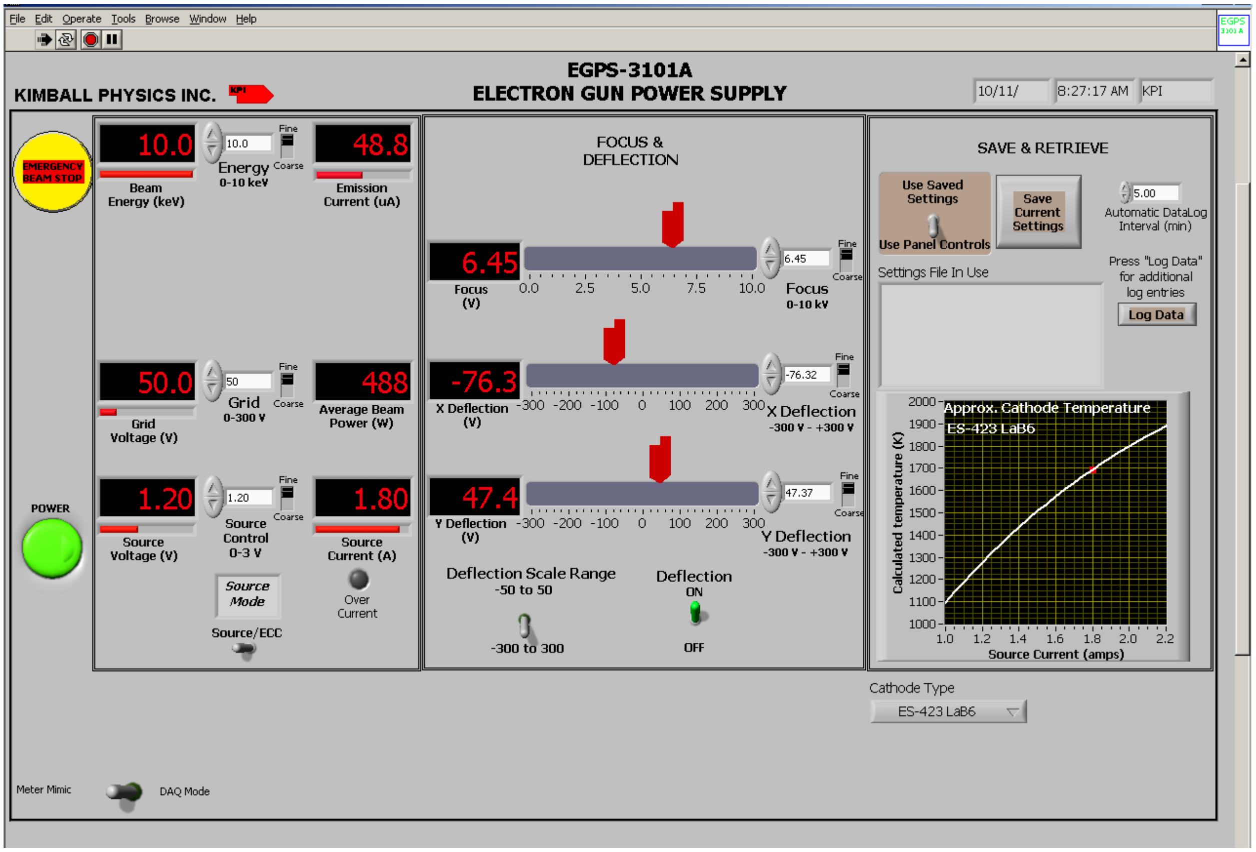
Current Meter: A digital or analog meter labeled **MILLIAMPERES** that monitors the output current.

H.V. Supply Back Panel Controls

Remote /Local Switch: A two position toggle switch on some Glassman units labeled **RMT / LOC** that sets whether the power supply is controlled remotely by the external EGPS-3101 or locally by its own front panel potentiometers. **This switch must be set to remote RMT for the High Current system to function.**

4.1 DESCRIPTION OF CONTROLS cont.

4.1.2 REMOTE CONTROL COMPUTER PANEL



(ADDITIONAL CONTROLS AND INDICATORS BELOW MAIN PANEL)

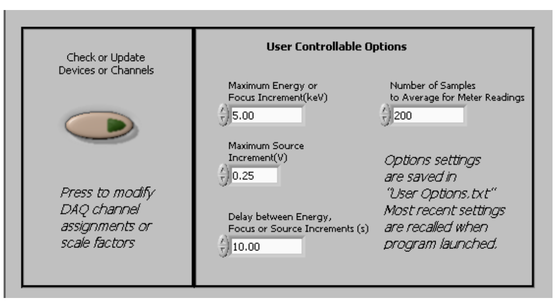


Fig. 4.1-3 Screen captures of LabVIEW™ program for EGPS-3101 Power Supply System remote control

4.1 DESCRIPTION OF CONTROLS cont.

Fig. 4.1-4 Virtual Panel of a typical LabVIEW program for computer remote control and metering (Particular controls may vary with gun model)

EGPS-3101 Power Supply Remote Control Computer Panel

The following is a description of the function of the controls in the LabVIEW™ computer remote programming of the EGPS-3101 Power Supply.

Power Button: A pushbutton labeled **POWER** with a green arrow that lights when on. It is used to start or stop the LabVIEW™ program, after the Master Key and the Power switches on the EGPS-3101 and H.V. Power Supply have been physically turned on. Although switching the computer Power button to off sets all program voltages to zero, **this button does not energize or shut down the power supplies.**

EMERGENCY BEAM STOP Button: A red and yellow pushbutton used to stop the beam temporarily in an emergency. It brings the Grid to its maximum value for beam cutoff and brings all other controls to zero. It does not turn off the power supply units and should not normally be used to shut down the system. When on (all red), it must be clicked off to restart the gun.

ENERGY, GRID VOLTAGE, SOURCE/ ECC, FOCUS, DEFLECTION X and Y

Digital Controls: Program input controls that voltage program the associated power supplies in the same way as the EGPS-3101 front panel potentiometers (see above). Labels below the control give the supply range. **It is strongly recommended that Beam Energy and Source be turned up gradually.** If too large an increase is entered, the program will automatically make the change in a more gradual series of steps.

The **Fine/Coarse** slide switch changes the input increments controlled by the up/down arrow switches by a factor of ten. For example with Energy on Fine, one click gives a 0.1 keV increase or decrease, and on Coarse, one click gives 1 keV.

Thumb Slide Controls: (Focus and Deflection only)
Program input controls that voltage program the associated power supplies in the EGPS-3101. The large slide controls with the red arrows have the same effect as the digital input controls but allow easier adjustment for alignment.

Digital Indicators: Digital meters that display the meter signals out of the associated supplies in the EGPS-3101 (see above). The indicator may not be linear with the input digital control, as it displays the actual output. The **Average Beam Power** meter displays the calculated beam power (Beam Energy x Emission Current).

Horizontal Fill Slides: Horizontal slide bars that display the meter signals out of the associated supplies in the EGPS-3101. They display more visually the same data as the digital indicators.

Source/ ECC (Emission Current Control) Switch: A toggle switch labeled **Source/ ECC**. When the switch is in the **Source** position, it allows the user to set the desired Source voltage directly. When the switch is in the **ECC** position, it allows the user to set the desired emission current. The default is Source mode.

Source mode must be used when pulsing.

Note that in ECC mode, the **Source Control** is labeled **Emission Current Control** and is used to set the desired emission current. The Source Voltage will then be varied automatically by the emission feedback circuitry to maintain the set emission current.

EGPS-3101 Computer Panel cont.

Deflection On/Off switch: A toggle switch labeled **Deflection On / Off**. When On, the deflection supplies are voltage programmed by the controls. When Off, a control voltage of 0 V is sent to the deflection supplies, regardless of the control settings. Note that this switch does not ground the deflection plates in the way that the physical Deflection On / Off toggle switch on the EGPS does; that is the computer switch does not control a relay within the power supply.

Deflection scale range toggle switch sets the range of the X and Y Deflection controls.

SAVE & RETRIEVE

Settings Toggle Switch: A two position toggle switch labeled **Use Saved Settings / Use Panel Settings.** In the Panel Settings mode, all the controls on the virtual panel can be controlled by the user. When the switch is moved to the Use Saved Settings position, a dialog box allows the user to choose a previously saved file of parameter values. The saved settings will then be entered as the supply controls, and the file will be shown in the box labeled **Settings File In Use**. The toggle switch will return to the Use Panel Controls position to allow settings to be changed by the user.

Save Settings Pushbutton: A pushbutton labeled **Save Current Settings** that brings up a dialog box to save the current parameter values in a file for future use.

Data Log File: A tab-delimited text file labeled DataLog.txt that automatically records the values of all the controls and meters at a user controllable time interval while the program is running.

Automatic Data Log Interval sets how often the data (all the control settings and meter readings) is recorded in the DataLog.txt file.

The **Log Data** pushbutton records an additional set of all values at the time it is pushed.

CATHODE GRAPH

Cathode Graph Toggle Switch: A two position labeled **View Cathode Temperature / Close View** that brings up or closes a graph that tracks the Calculated Cathode True Temperature vs Source Current in real time as the Source Control is varied.

Cathode Type: A pull-down list to select the type of cathode installed in the gun (Ta disc, LaB_6, etc.). The temperature calculation used in the cathode graph, and the Source overcurrent warning limit depend on this setting.

METER MIMIC/DAQ MODE SWITCH: A toggle switch that sets the operating mode of the computer program. When in Meter Mimic, program does not address DAQ boards. Useful for testing program on computer without DAQ boards installed. Program will make some very SIMPLE calculations to roughly mimic cathode behavior. When in DAQ mode, program addresses DAQ boards. An error message will be generated if DAQ boards are not present or are inconsistent with those expected by program.

Warning Messages:

A window with a reminder to change toggle switches on the EGPS to remote will be displayed when the program is opened initially.

A warning message will be displayed if the Energy or Source, is increased in too large a step; the program will then gradually bring the supply to that setting.

A warning message will be displayed if the system is in ECC mode and a settings file in Source mode is chosen. The Source will go to zero automatically and then need to be turned up again. A similar warning will occur if the system is

A yellow overcurrent button will light up if the source current exceeds the recommended maximum operating current. **Running the Source current this high greatly reduces the cathode lifetime.** For this warning to be correct, the appropriate cathode type, corresponding to the one installed in the gun, must be chosen in the Cathode Type pull-down list.

User Controllable Program Options: A number of program variables that can be set by the user, but will probably not be changed frequently. This area is viewed by scrolling down below the usual operating panel. These options are stored in “user options.txt” file. When the program is started, the most recent user options are recalled. If an option is changed, the new value can be saved. These preference settings include:

Max Energy increment and **Max Source increment** set the size of steps by which the controls for these high voltage elements can be changed. If a new settings file or operator enters too large change, the program will bring the supply up in smaller steps. The **Delay between increments** control sets the time interval for these steps.

Number of samples to average for meter readings

The settings with which the program is shipped are ones Kimball Physics recommends:

Max Energy increment = 5 keV
Max Source increment = 0.25 V
Delay = 10 sec
Number of samples to average = 200

Check or Update Devices or Channels: A pushbutton below the panel that brings up an array showing the ranges of all the controls and meters in the LabVIEW program. The values should only be changed if the DAQ boards or EGPS-3101 power supplies are physically modified.

Troubleshooting indicators (hidden): An additional set of indicators of program operation that were used during program development, but are not normally displayed. If needed for program troubleshooting, contact Kimball Physics.

4.2 NORMAL OPERATION

4.2.1 NORMAL START UP PROCEDURE

CAUTION

Kimball Physics recommends that the gun be run only in a **vacuum of 10^{-6} torr** or better for a refractory metal cathode (or **10^{-7} torr** or better for LaB_6 or BaO cathodes) Poorer vacuum may result in discharging or source damage.

Read instructions before operating!

1. Installation:
   a. Install the EGG-3101/EGPS-3101 Electron Gun and Power Supply system according to instructions in Sections 2.2 and 2.3.
   b. If desired, install a user-supplied Faraday cup and/or Phosphor screen to monitor beam output from the gun. This is recommended for initial operation, calibration and gun alignment. See Section 2.4.
   c. For optional bakeout of the EGG-3101, see procedures in Section 6.1.
   d. Refer to the Data Section for typical operating parameters.

2. Proper Vacuum:
   a. For **standard** refractory metal cathodes: Ensure that the vacuum in the chamber is **$1x10^{-6}$ torr** or better.
   b. For optional small spot lanthanum hexaboride **(LaB_6)** cathodes: Ensure that the vacuum is **$1x10^{-7}$ torr** or better. Mildly baking the gun and vacuum system (100°C to 250°C, with all cables removed) is desirable to improve system operation with the LaB_6. cathode.
   c. For optional barium oxide **(BaO)** cathodes: Ensure that the vacuum is **$1x10^{-7}$ torr** or better.
   d. For optional **thoria** (ThO_2) iridium cathodes: Ensure that the vacuum is **$1x10^{-4}$ torr** or better. Although the iridium cathode can survive a brief accidental loss of vacuum, the gun should not be run in poor vacuum.
   e. **CAUTION: Poor vacuum may result in discharging or source damage.**

3. Make an initial check of the following items of the EGPS-3101 front panel controls:
   a. Key switch: The key should be **off** (vertical) position.
   b. Pushbuttons: Green **POWER** switch red **H.V.** switch, red **SOURCE** switch, blue **DEFL** switch and optional amber **BLANKER** switch should be off, (out position).
   c. Potentiometers: **ENERGY**, **FOCUS**, **SOURCE/ECC**, **GRID** and optional **BLANKER** should be at the zero position, fully counterclockwise, with their locking toggles in the unlock (up) position.
   d. Toggle switch: The **ECC/SOURCE** toggle switch should be in the Source position.
   e. Function switch: The rotary **FUNCTION** switch should be turned to the Energy position, fully

4. On the back of the the **EGPS-3101**, check all the small local/ remote slide switches labeled **PROGRAMMING**
   a. For manual control using the front panel potentiometers, the slide switches should be in the **LOCAL** position (down
   b. For remote computer control, the slide switches should be in the **REMOTE** position (up).
   c. These switches may be changed at any time that the system is powered off. Different supplies can be run either locally or remotely by setting their individual switches. Front panel meters are not affected by these switches. (See Section 4.5.2 Remote Programming to identify

5. Initial energizing of the Power Supplies:
   a. On the EGPS-3101, turn the Master Key switch **on**, (horizontal position).
   b. Depress the green **POWER** switch on to energize the supplies.
   c. **For High Current option only**: On the Glassman H.V. Power Supply, switch the orange **POWER** switch on (**I** position).

6. Interlocks
   a. Check that the amber **INTERLOCK** LED is off.
   b. The LED will illuminate momentarily when the Power Supply is first energized to show that the Interlock circuitry is working.
   c. If the amber **INTERLOCK** LED stays lighted:
      i. Depress the green **POWER** switch off to de-energize the Power Supply.
      ii. Check that the Source cable is connected tightly at gun and power supply ends.
      iii. Check that the top and bottom covers of the Power Supply are closed securely.
      iv. Check that the spare interlock is a closed circuit, either jumpered as shipped, or a closed external loop to the user's system.
      v. Reenergize the Power Supply after the fault is corrected.

4.2 NORMAL OPERATION cont.

NORMAL START UP PROCEDURE cont.

> **CAUTION**
>
> **ENERGY and SOURCE/ECC supplies must be turned up gradually**.
>
> **Excessive source current will reduce cathode lifetime.** The recommended limit is **1.75 A** for a standard refractory metal cathode.
>
> **The grid should be turned to zero** prior to initial source adjustment.

7. **For High Current option only:**
   a. On the **H.V. Power Supply**, depress the green **HV** switch on.
   b. The potentiometers for **KILOVOLTS** and **MILIAMPERES** on the H.V. Power Supply are not controllable by the user. When the remote / local switch on the back of the H.V. Supply is in the **RMT** position, the EGPS-3101 controls the voltage and current limits and outputs.

8. Controlling the Power Supplies:
   a. On the EGPS-3101, depress the red **H.V.** switch to energize the Energy and the Focus power supplies.
   b. If the **ZERO** LED lights, turn down the Energy and/or the Focus control potentiometers, fully counterclockwise, until the **ZERO** LED goes out.

9. For optional remote computer control:
   a. Open the National Instruments LabVIEW™ master program file (EGPS-3101 Control x.x .vi or .exe). It will start up LabVIEW™ .
   b. Click the arrow in the menu bar to start the program.
   c. Enter the operator's name for the data log, if desired. Answer message boxes, if any appear. Note that the remote/ local switches can not be changed from the computer.
   d. On the computer control panel, start the program by clicking the **POWER** button. The button should turn all green, and the digital indicator meters should show 000. Note that this power button does not energize or shut down the EGPS.
   e. Check that the **Energy**, **Grid**, **Source**, **Focus**, **X**, and **Y Deflection** controls are all set to zero with their numerical inputs.
   f. Initially the **Source / ECC** switch should be in the **Source** position.
   g. For initial start up, the settings toggle switch should be in the **Use Panel Controls** position.
   h. The **Meter Mimic / DAQ Mode** switch must be in the **DAQ Mode** position for the program to run the gun.
   i. If desired, scroll to the bottom of the screen and change any of the **User-Controllable Program Options**. These preferences, will probably not need to be changed frequently.

10. If the gun has been run previously and all the desired settings have been saved with the LabVIEW™ remote control program, go to step # 21 Using saved parameter settings, below. The Source power supply will need to be energized by depressing the red **SOURCE** pushbutton switch on the EGPS.

11. Controlling the Electron Beam Energy:
    (Range 0 to –10 keV)
    a. Using either the manual **ENERGY** potentiometer or the computer digital control increment button, gradually adjust the electron beam acceleration energy to the user-desired value.
    b. Monitor the energy on the DVM (with the rotary **FUNCTION** switch in the Energy position as indicated by the Energy LED light on) or on the computer meter.
    c. Discharging can be seen as jumping in the digital output or on the horizontal slide bar of the computer control panel.

12. Energizing the Filament Supply:
    a. The **GRID** should be set at zero initially. Excessive grid voltage will suppress emission from the cathode, possibly causing the user to incorrectly increase the source current to increase emission
    b. Set the **ECC/SOURCE** toggle switch to the **SOURCE** position on the EGPS and the computer.
    c. On the EGPS, depress the red **SOURCE** pushbutton switch to energize the filament power supply. Even when using computer control, the supply must first be turned on with the pushbutton.
    d. GRADUALLY, adjust the voltage to the filament with the **SOURCE/ECC** ten-turn dial potentiometer or computer control.
    e. Monitor the **SOURCE VOLTS** , **SOURCE AMPS**, and **EMISSION CURRENT** meters while adjusting the **SOURCE/ECC** control.
    f. As power to the filament is increased, the Electron Gun will begin to emit. Monitor the emission current while adjusting the Source to achieve the desired emission current. A change of 0.1 amp can cause a large change in emission. For prolonged cathode lifetime, it is advisable to use the lowest filament current possible. See the Data Section for typical source current ranges to produce the desired beam current at a given Energy. The source current may be reduced somewhat after warm-up. Refer to Table 4.2-1 below for the correct current ranges for the cathode installed in the gun.
    g. **CAUTION**: If the amber **OVER CURRENT** LED lights, (or if the **Overcurrent** button on the computer turns yellow), this is a warning that indicates that the Source current has reached or exceeds the recommended maximum operating current. Running the Source current this high greatly reduces the cathode lifetime.

(continued next page)

CAUTION: To protect cathode lifetime, the filament current (SOURCE AMPS) should not exceed the following levels:
Table 4.2-1 EGG-3101/EGPS-3101 Emission and Source Currents

Cathode type	Recommended max Emission current	Typical operating range Source current	Recommended max Source current
Standard refractory metal Ta disc	500 µA	1.50 A to 1.70 A	1.75 A
Low light barium oxide (BaO)	500 µA	1.00 A to 1.20 A	1.25 A
Thoria (ThO_2) iridium cathode	500 µA	1.60 A to 1.75 A	1.80 A
Small spot LaB_6 cathode	100 µA	1.60 A to 1.80 A	1.95 A
High current refractory metal Ta disc	3 mA	2.70 A to 2.95 A	3.0 A
High current thoria cathode	3 mA	2.70 A to 2.95 A	3.0 A

(Energizing the Filament Supply cont.)

h. On the computer, the **Average Beam Power Meter** displays the calculated beam power (Beam Energy x Emission Current) which may be more than the actual final beam delivered to the target.

i. **For LaB_6 cathodes:** Run the cathode at 0.8 A for 10 minutes to outgas the firing unit when first starting electron gun. Then slowly run up the cathode to desired current setting, using the **SOURCE/ECC** potentiometer. The cathode temperature is an increasing function of Source current. See Appendix, Table 1 in Kimball Physics' Technical Bulletin # LaB_6 04B.

NOTE: Microamp discharges may occur in the electron gun after initial installation in the vacuum system. As high voltage surfaces "clean up," this discharging should cease.

13. Improving the beam characteristics, Grid voltage:
    a. Using the **GRID** potentiometer or computer control, adjust the Grid (G-1) voltage as necessary to control beam current and improve the beam uniformity.
    b. Monitor on the analog or computer **GRID VOLTS** meter.
    c. The ratio of Beam current (the actual current leaving the gun) to Emission current (total current off the cathode to ground) will be improved with some empirically-determined grid bias.
    d. Higher Grid voltages will reduce or cut off electron emission.

14. Improving the beam characteristics, Focus voltage:
    a. Use the **FOCUS** potentiometer, or either the digital input or the red arrow thumb slide control on the computer. Adjust the Focus voltage with as necessary to obtain the desired spot size.
    b. Monitor the Focus voltage on the DVM, by setting the rotary **FUNCTION** switch next to the DVM in the Focus position as indicated by the Focus LED light on. Alternatively, monitor on the computer **Focus** meter.
    c. The Focus voltage setting depends on the desired spot size and the working distance (i.e. the distance from the end of the electron gun to the target).
    d. Once the focus voltage is set, it will track with the energy voltage. As Energy is changed, the Focus adjusts automatically to maintain the original spot size at the given working distance.

15. Adjustment of any control may require “fine-tuning“ of the others to achieve the desired spot size, beam current and beam current uniformity. Magnetic fields in the vacuum lab environment may make it necessary to readjust parameters as beam energy is varied.

16. Deflection with Manual Control Deflection Unit (MCDU) **using local front panel controls**:
    a. Depress the blue **DEFL** pushbutton to energize the supplies in the Deflection unit.
    b. Select the mode with the front panel **ENERGY PROP /NORMAL** toggle switch. In Energy Proportional mode, the deflection voltage is proportional to the beam energy as energy is changed, so spot position is more constant. In Normal mode, the deflection voltage remains constant as the beam energy is changed.
    c. Using the **X DEFLECT** and **Y DEFLECT** potentiometers, vary the Deflection plate voltages as needed to center or position the beam in the X and Y directions within the target plane.
    d. Monitor the deflection voltages on the DVM by setting the rotary **FUNCTION** switch clockwise, so that either the X Deflect or Y Deflect LED light is on (next to the corresponding deflection control knob).

17. Deflection with Manual Control Deflection Unit (MCDU) **using remote computer controls**:
    a. On the EGPS-3101, depress the blue **DEFL** pushbutton to energize the supplies in the Deflection unit.
    b. Set the **ENERGY PROP / NORMAL** toggle switch in the **NORMAL** position. With the computer, there is no Energy proportional mode, but appropriate deflection voltages for different Energy levels can be saved with the Saved Settings files.
    c. On the computer, set the desired range with the **Deflection Scale Range** switch. This sets the sensitivity of the Deflection controls and meters.
    d. Using either the computer **X Deflection** and **Y Deflection** digital inputs or red arrow thumb slide controls, vary the Deflection plate voltages as needed to center or position the beam in the X and Y directions within the target plane.
    e. Monitor the deflection voltages on the computer **X Deflection** and **Y Deflection** meters.

NORMAL START UP PROCEDURE cont.

18. **With optional Port Aligner:** Beam position can be mechanically adjusted by ±2º. Loosen the two locking screws on the discs, rotate one or both Port Aligner discs as needed while observing the spot, and then lock the position by tightening the two locking screws.

19. For optional feedback-stabilized Emission Current Control (ECC): See also Section 4.4.

CAUTION: Do not use ECC with pulsing.

   a. Although protection against excessive source current is built into the ECC circuitry, it is best to employ the ECC mode **after** the approximate operating parameters have been determined in Source mode.
   b. Switch the **ECC/SOURCE** toggle switch to the **ECC** position.
   c. Using the manual potentiometer or the computer digital control increment button, GRADUALLY adjust the **SOURCE/ECC** control to set the desired emission current. Monitor as described for Source mode.

20. Saving settings with LabVIEW computer remote control program (optional):
   a. After the settings of various parameters have been determined for optimal beam alignment and gun performance, they can be saved as a file for future use. The settings will be different for different energy levels and for different operating conditions, such as working distance.
   b. Click the **Save Current Settings** button and save the file with an appropriate new name using the dialog box that appears.

21. Using saved parameter settings (optional):
   a. To use one of the previously saved files, switch the Settings toggle switch to the **Use Saved Settings** position.
   b. In the dialog box that appears, choose the appropriate file for the Energy level and other operating conditions.
   c. The numerical control boxes and digital meters will change to reflect the settings. The toggle switch will return to the Use Panel Controls position.
   d. When first starting or if the change in Energy or Source value is too great a step, the program will make the change in a more gradual series of steps.
   e. At this point the gun can simply be run with the given settings.
   f. Alternatively, some of the parameter controls can be adjusted manually with the computer panel as described above, while the preset values are used for the others. Adjustment of any control may require “fine-tuning“ of the others.

22. If needed, the cathode position in the gun column can be aligned while the gun is operating in vacuum. See Internal Gun Alignment Section 4.3.

23. For more information on the use of options and features, such as Emission Current Control (ECC), Remote Control, Deflection, Rastering, Pulsing etc., see specific sections in this chapter. **With optional Faraday cup, beam power must not exceed 2 Watts for continuous measurement,** see Section 4.9. For more information on LaB_6 cathodes, refer to the Appendix.

This completes the Normal Start Up Instructions.

4.2.2 NORMAL SHUT DOWN PROCEDURE

1. Secure (turn off) the EGG-3101 / EGPS-3101 system in the following sequence:
   a. Turn down **SOURCE/ ECC** voltage (filament power) to zero with either the manual potentiometer (fully counterclockwise) or with the computer digital control decrement button.
   b. Make sure that the **SOURCE/ECC** toggle switch is in the **SOURCE** position to ensure that the gun will not be turned on at full power.
   c. On the EGPS-2, depress the red **SOURCE** pushbutton switch off, (out position).
   d. Turn the **GRID** and **FOCUS** voltages to zero with the potentiometers (fully counterclockwise) or computer controls.
   e. On the EGPS, depress the blue deflection **DEFL** pushbutton switch off, (out position). Other MCDU controls may remain as set to simplify start up.
   f. With optional pulsing, turn off the user-supplied pulse generator. If present, set the optional **PULSE** toggle switch to **OFF**..
   g. Turn the **ENERGY** to zero with either the potentiometer (fully counterclockwise) or computer digital control. Wait until the meter reads zero.
   h. On the computer, turn off the program by clicking the **POWER** button. The green button light and digital readouts should go off. **Do not just close the window** as the program voltages may remain at the values set before the window was closed. Turning off the program does not turn off the power supply units.
   i. On the EGPS-3101, depress the red **H.V.** switch off, (out position).
   j. Depress the green **POWER** switch off, (out position).
   k. **For the High Current option only: Turn off the H.V. Power Supply** by depressing its green **HV** switch, and then switching its orange **POWER** switch off (**O** position).

2. After securing the system, **wait at least 30 minutes** for cool down of the Electron Gun, before venting the vacuum system **(with a LaB_6 cathode, wait 45 min).** This procedure avoids possible filament damage and the formation of oxidation layers on apertures caused by venting the gun while still hot.

CAUTION: The High Current electron gun and vacuum system may remain hot even after the cool down period. Handle with care.

3. If the gun has a **barium oxide (BaO) cathode**, it is best to store the gun in vacuum. If it must be stored out of vacuum, it should be placed in a clean, dry environment such as a tightly sealed plastic box with desiccant. When operation is resumed, the BaO cathode may need to be reactivated if the gun has been exposed to atmosphere. See instructions in the Appendix.

This completes the Normal Shut Down Instructions.

4.3 INTERNAL ELECTRON GUN ALIGNMENT

The goal of internal gun alignment is to produce an electron beam that travels down the gun column and through the center of the anode and focus lens apertures. All the gun elements are carefully aligned at Kimball Physics during testing. However, handling during shipping, electromagnetic fields in the laboratory, or user replacement of the firing unit could necessitate some gun realignment.

To accomplish this task the EGG-3101 is equipped with an adjustable feedthrough assembly that provides precise mechanical alignment through X-Y translation of the firing unit / feedthrough with respect to the anode aperture, while the gun is operating in vacuum. When the Alignment Screws on the feedthrough are turned in and out, they press on the spherical adjustment plate and cause the firing unit assembly to pivot back and forth. This allows the cathode in the firing unit to be aligned with the center of the stationary anode aperture.

This mechanical adjustment determines the initial trajectory of the electrons exiting the firing unit and thus defines the initial electron beam axis.

The electron beam monitoring choices outlined in the installation Section 2.4 are suitable for monitoring alignment adjustments. The usual technique with the EGG-3101 involves measuring the beam current collected by a Faraday cup. In addition, the electron beam may be observed using a phosphor screen. If the gun is not properly aligned a large unfocused spot may be seen to be cut off on one side by the second anode aperture, as illustrated in Figure. 4.3-2.

With a LaB_6 cathode, the unique Maltese cross shape of the unfocused spot can be used as a visual aid in alignment. The grid can be adjusted so that the arms of the cross and the brighter spot in the center are seen. Then the alignment can be adjusted to position the bright center in the aperture.

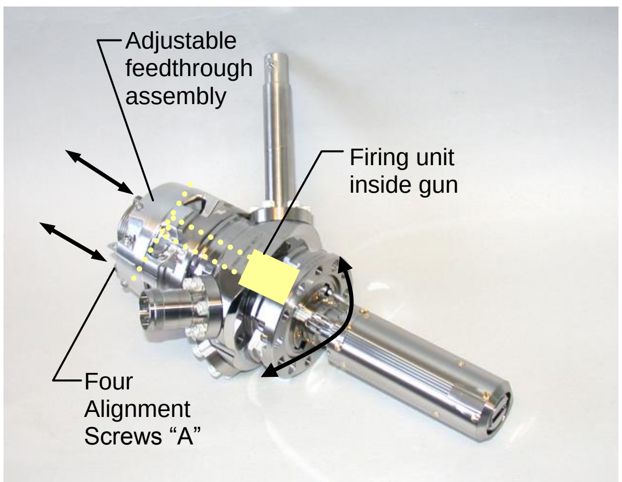


Fig. 4.3-1 EGG-3101B Alignment, arrows show motion of screws and resulting motion of firing unit assembly

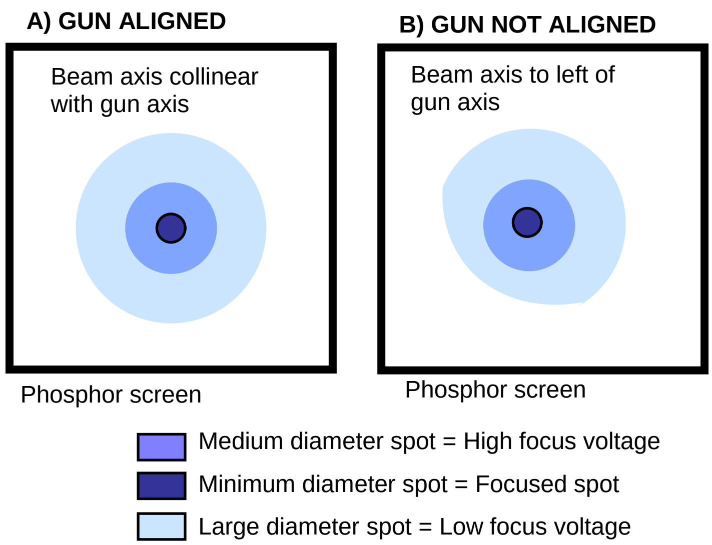


Fig. 4.3-2 Gun alignment as seen on a phosphor screen

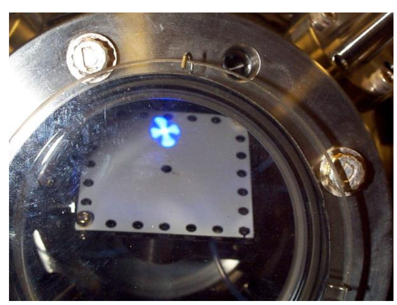


Fig. 4.3-3 LaB_6 unfocused Maltese cross spot on phosphor screen in vacuum

4.3 INTERNAL ELECTRON GUN ALIGNMENT

Beam Current Maximization Technique

This technique uses beam current measurements to determine if the electron beam is aligned in the gun. If the gun is properly aligned, this area of high current density in the electron beam should travel through the center of the focus lens. For chosen values of energy, source current and grid potential, alignment is adjusted until the beam current is maximized as measured with a centrally placed Faraday cup near the end of the gun.

1. Set-up: A Faraday cup mounted near the end of the gun in the vacuum chamber and connected to an ammeter is required for this technique**. Ensure that the Faraday cup is constructed to withstand the beam power being collected.**

2. Begin gun operation as described in Section 4.2 Normal Operation.
   a. Observe all safety precautions in starting the gun.
   b. Gradually bring the **ENERGY** to a mid range value, ex 5 keV, for initial alignment or to the desired current operating value.
   c. Set the initial bias voltages as follows or use the current operating conditions:
      GRID 0 V
      FOCUS 0 V
   d. With the **ECC/SOURCE** toggle switch in the **SOURCE** position, GRADUALLY adjust the **SOURCE/ECC** control to increase the source current to a value of about 1.5 A. If beam current is too high, it can be modulated by increasing **GRID** voltage.
   e. Deflection (blue **DEFL** pushbutton) and optional Rastering should be **off** for alignment.

3. Adjust the **FOCUS** voltage to maximize the beam current into the Faraday cup.

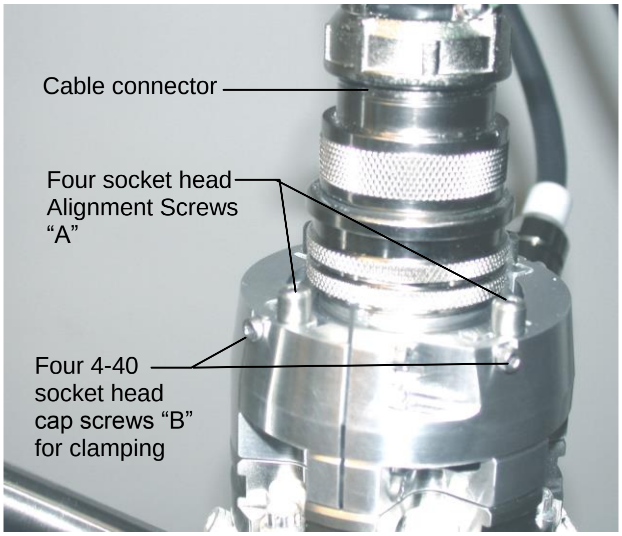


Fig. 4.3-4 Adjustable Feedthrough Assembly with Alignment Screws

4. Prepare the four Alignment Screws for adjustment: (Fig. 4.3-1 and Fig. 4.3-3)
   a. Using a $^{3}/_{32}$" Allen wrench, loosen the four 4-40 socket head cap screws ("B" in Fig. 4.3-4) in the connector shell that clamp the alignment screws Do not loosen any other screws on the connector.
   b. Using a $^{5}/_{64}$" Allen wrench, turn each socket head Alignment Screw ("A" in Figs. 4.3-1 and 4.3-4) to advance or retract the screw assembly as needed. The threads on the alignment screws are very fine and adjustments should be made very gradually.
   c. Before starting to align the gun it is recommended that the assembly set in a neutral position by adjusting the four Alignment Screws so that they are not pressing on the adjustment plate and approximately the same number of threads show on each one.

5. If no spot or beam is observed in the target area and it is suspected that a large change in alignment is needed:
   a. Completely loosen the four Alignment Screws.
   b. Very gently and gradually, move the entire cable connector back and forth until the spot or beam current is observed.
   c. Tighten the four Alignment Screws to keep this cable position. Then proceed to fine tune the alignment.

6. Adjust the four Alignment Screws by turning the socket head ("A" in Fig. 4.3-4) to maximize the beam current into the Faraday cup. As Alignment Screws are being rotated, the firing unit assembly is being translated with respect to the anode aperture. The optimum position of this assembly produces an electron beam that travels down the center of the gun into the Faraday cup.
   NOTE: Only minimal rotation of the four screws is required to affect large changes the beam current. Less frustration generally results from making many small incremental adjustments (less than a quarter turn per adjustment) in the four screws in a some prescribed pattern rather than randomly making large adjustments. Adjusting the four screws in a diagonal pattern seems to work well. **Make sure that the opposing screw is loose enough to allow movement.**

7. Locking the Alignment Screws to maintain alignment:
   a. Tighten the four 4-40 socket head cap screws ("B" in Fig. 4.3-4) to clamp the Alignment screws.
   b. Measure beam current again to check that alignment has not been shifted during the locking procedure.

8. During gun operation, magnetic fields in the vacuum lab environment may make it necessary to readjust alignment as beam energy is varied. When the firing unit is replaced by the user, the firing unit / feedthrough can be realigned by this procedure.

This completes the EGG-3101 Alignment Instructions.

4.4 EMISSION CURRENT CONTROL (ECC)

This power supply offers the option of feedback stabilized Emission Current Control (ECC). Under normal circumstances, when a constant voltage source drives the cathode, emission current varies over time. The emission current changes are due to variations in the cathode's resistance as its temperature varies and physical changes such as evaporation and contamination. To provide a stable and constant emission current, the ECC option can be used. The ECC circuitry maintains a constant emission current by using feedback control to adjust the source voltage.

Note that while the emission current is held constant, the beam current may still vary. Many factors can cause the ratio of beam current to emission current to vary such as, but not limited to: Grid and Focus values, chamber pressure, Electron Gun and target contamination, and outgassing.

Although protection against excessive source current is built into the ECC circuitry, it is best to employ the ECC mode **after** the approximate operating parameters have been determined in Source mode. For example, as the grid voltage is increased toward beam cutoff, the ECC feedback will call for more source current in order to maintain the chosen emission current value. This increased source current will raise the cathode's temperature, thus reducing the cathode lifetime.

Do not switch from ECC Mode to Source Mode while the electron gun is running.

When operating in ECC mode, the number of turns of the **SOURCE/ECC** potentiometer determines the desired emission current level. Ten turns of the potentiometer will yield the maximum emission current. For example with an ECC range of 0 to 500 µA, 10 turns will yield the full 500 µA, while 5 turns will yield a half the range or 250 µA, etc. The Emission current is read on the Emission Current meter, but the ECC range may be set to be less than the full meter range. The specific values for the ECC range vary with the Electron Gun model.

When operating in Source mode, the number of turns of the **SOURCE/ECC** potentiometer determines the source voltage; 10 turns of the potentiometer will yield the maximum source voltage. For example, with a standard refractory metal cathode, a maximum voltage of 1.5 V corresponds to a source current of about 1.8 A (the V-I characteristics of cathodes vary with cathode type and size, cathode temperature and the slight variations in cathode geometry); such a high source current will result in short cathode lifetime. If the **SOURCE/ECC** potentiometer is set to 10 turns while operating in ECC mode and the power supply is switched to Source mode, then source current will be switched to its maximum level, reducing cathode lifetime.

For systems with the Grid Pulsing option, do not operate the electron gun in ECC mode if using the Grid Pulsing. Reduced cathode lifetime may result. The ECC circuitry is designed to be a DC feedback system. During grid pulsing, the average emission current is close to zero and the ECC feedback will raise cathode temperature to try to compensate for the lack of emission current while the gun is pulsed off.

The Zener limit, which controls the maximum source current, and the gain, which determines the maximum emission current, have been preset at the factory for the Source/ECC board. If, under normal operating conditions, the desired emission current range cannot be achieved while the ECC circuit is in use, please call the Engineering Department at Kimball Physics at (603) 878-1616. Note that the Zener limit is meant to protect the cathode from high, life shortening, current. Achieving the full emission current range under all operating conditions will not be possible.

CAUTION: The Zener limit is calibrated for a particular gun and a particular cathode. When the cathode is replaced by the user or the gun is rebuilt, the Zener limit may need to be recalibrated. Call Kimball Physics at (603) 878-1616.

4.4 EMISSION CURRENT CONTROL(ECC) cont.

CAUTION

Do not switch from the ECC mode to Source mode while the gun is running.
Reduced cathode lifetime may result.

Do not use ECC with Grid Pulsing

OPERATING PROCEDURE FOR ECC MODE

1. Set-up:
    a. To assure low cathode temperatures, initial emission current adjustment should be done with little or no grid bias. Once operating in the ECC mode, the beam may be optimized by slowly adjusting the grid bias while maintaining source current. Excessive source current will reduce cathode lifetime.
    b. With the **SOURCE** pushbutton on, turn the **SOURCE/ECC** potentiometer to zero, fully counterclockwise.
    c. Switch the **ECC/SOURCE** toggle switch to **ECC**.

2. Adjusting Emission Current Control:
    a. Slowly turn the **SOURCE/ECC** potentiometer clockwise one turn and wait.
    b. In approximately 30 seconds the Source voltage and Source current will start to rise.
    c. Turn the **SOURCE/ECC** potentiometer until the desired Emission current is achieved. Monitor emission on the **EMISSION CURRENT** meter.
    d. The Emission current called for is proportional to the number of turns of the **SOURCE/ECC** potentiometer. (For example, with a 0 to 500 μA ECC range, 10 turns will yield the maximum of 500 μA, while 5 turns will yield half the ECC range or 250 μA, etc.) The ECC range varies with the gun model.

3. **For Remote Programming**: The ECC option can also be controlled by a 0 V to +10 V programming signal (such as might be provided by a D/A supply) into the back of the Power Supply. +10 V will yield the full-scale emission current value, shown in the tables below in the Remote Control section.
(For example, with a 0 to 500 μA ECC range, +10 V will yield 500 μA, while +5 V will yield half the ECC range or 250 μA, etc.)

4. **For Pulsing:** Do not use ECC mode; use normal Source mode.

5. Turning off the ECC option:
    a. Turn the **SOURCE/ECC** potentiometer fully counterclockwise. Failure to do so could severely damage the cathode and greatly shorten the cathode's lifetime.
    b. Switch the **ECC/SOURCE** toggle switch to the **SOURCE** position.

This completes the ECC Instructions.

4.5 REMOTE ACCESS: METERING / PROGRAMMING OF POWER SUPPLIES

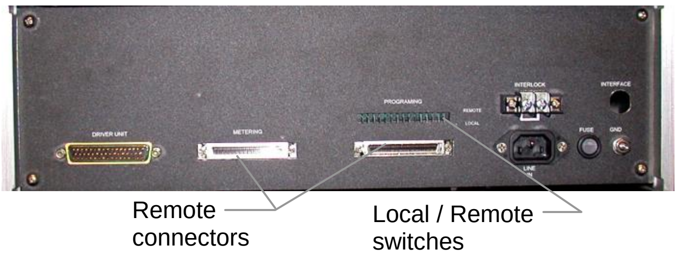


Fig. 4.5-1 A typical power supply with computer remote access connectors for metering and programming.

The Power Supply provides two types of remote access: (1) remote monitoring of all meters, and (2) remote programming control of all individual power supplies.

Remote metering allows any digital or analog meter on the front panel be read using a digital voltmeter or a computer with a data acquisition board. For example, the Emission Current meter signal can be connected to a computer, so that emission data can be recorded directly. Remote metering also permits a more sensitive reading than is possible visually on an analog meter face used in some Power Supplies.

Remote programming allows the operation of the gun to be somewhat automated. The programming voltage signal can be obtained from any source, such as a simple analog supply or a computer with a digital to analog converter. For example, a computer program can be used to control the output of an individual power supply (such as Energy or Focus) and increase that parameter in systematic small steps. Note that when a supply is in the remote mode, it can not be controlled manually with the front panel controls (potentiometers or an encoder wheel).

The remote access uses two D-sub connectors labeled **METERING** and **PROGRAMMING** on the back of the Power Supply (Fig. 4.5-1). In addition, the remote programming has individual Local/ Remote slide switches for each supply to be programmed. These switches are accessed from the back of the Power Supply. The meter signals that can be monitored and the supplies that can be programmed depend on the particular gun model and are listed in the tables below. Note that there may be extra pins and switches which are not used with a particular gun. On some systems there may be a single D-sub connector for both metering and programming.

Separate, optional Power Supply units, such as a stand-alone Rastering unit, may also have supplies that can be controlled remotely in a similar manner.

Fig. 4.5-2 Typical computer set up running LabVIEW™ program for remote programming and metering written by Kimball Physics

A National Instruments LabVIEW™ computer program written by Kimball Physics is available for remote computer control (Fig. 4.5-2). The program provides the user with a virtual panel similar to the front panel on the main Power Supply for controlling and metering all supplies.

The programming input uses standard LabVIEW™ controls such as pushbuttons, toggle switches, and digital controls with increment/decrement buttons. The digital controls have the same effect as the physical front panel controls. Using a numerical input on the digital control can cause the supply to immediately jump to that input value. This could be a problem with some critical supplies, in particular Energy and Source, which should be brought up gradually, so the program will automatically increase them in a series of steps. However, care must still be taken with these supplies. For lower voltage supplies, such as Grid or Raster size, either numerical input or increment/decrement buttons may be used.

For remote metering, the Kimball Physics program uses both LabVIEW™ digital indicators and horizontal fill slides. These virtual meters display the meter signal out of the individual supplies. The horizontal fill slide provides a more visual representation, similar to an analog meter. With the fill slide, it can be seen from a distance whether a supply is turned halfway or all the way up. Details of the control panel for a particular gun are given in Section 4.1.

Other computer programs may be designed by the user to control the power supplies in particular ways or to collect data from the supply meters.

4.5.1 REMOTE METERING

N. I. LabVIEW™ Program by Kimball Physics

1. Set up the power supplies and cable connections as described in Power Supply Installation Section 2.3.

2. If the program is not already installed, install the National Instruments LabVIEW™ program file written by Kimball Physics on the computer. Either LabVIEW or LabVIEW Runtime is required.

3. After the Power Supplies have been turned on physically as described in Normal Start-Up Procedure, start the program by clicking arrow in the menu bar and then the **POWER** button. The button should turn all green, and the digital indicator meters show 000. Note that this power button does not energize or shut down the power supplies.

4. As the gun is operated, the digital indicators and horizontal fill slides will display the meter signals out of each supply.

5. To shut down:
   a. Turn off supplies as described in the Normal Shut Down Procedure.
   b. Turn off the program by clicking **POWER** button. The green button light and digital readouts should go off. **Do not just close the window** as the program voltages may remain at the values set before the window was closed.
   c. Then the program window can be closed and the computer shut down.
   d. An **EMERGENCY STOP** button is provided on some systems. This button is for an emergency situation only and should not be used under normal circumstances. It immediately turns off all Power Supplies.

6. Proceed to the remote programming instructions below.

User-designed Remote Metering

1. Set up a user-supplied system (computer program, DAQ boards etc.) to monitor the meters.

2. Ensure that all Power Supplies are **OFF** before making electrical connections.

3. The meter output signal maps linearly onto supply-dependant ranges shown in Table 4.5-1.
   a. **For digital meters (DVM):** The output signal is either 0 to 2 V or a decimal fraction of the particular power supply output.
   For example, with a 0 to 5 keV Energy supply read on a DVM, a 500 mV signal represents 5000 eV, and a 250 mV signal represents 2500 eV.
   Also, with -150 V to +150 V Deflection supply read on a DVM, a –150 mV signal represents –150 V, and a +75 mV signal represents +75 V.
   b. **For analog meters:** The output signal is 0 to 2 V.
   For example, with a 500 µA analog Emission Current meter, a 2 V signal represents 500 µA, and a 1 V signal represents 250 µA.
   c. Refer to Table 4.5-1 and Fig. 4.5-4 below for the pinout of the **METERING** connector. For each meter, there are a pair of pins: (1) signal output to connect to the output measuring device and (2) common to reference the system to ground.

4. Connect a user-supplied cable from the monitoring system to the D-sub connector labeled **METERING** on the back of the Power Supply to the computer system.

5. Remote metering does not require Remote/ Local switches, and does not affect the use of the front panel controls or meters.

6. Proceed to the remote programming instructions below.

Table 4.4-1 EGPS-3101 Remote Metering Equivalency Table (connector NI 6034)

Meter Output	DAQ Input Channel		Meter Signal	Meter Range		
	Signal (pin#)	Ground (pin#)		STANDARD	SMALL SPOT	HIGH CURRENT
Energy Voltage	ACH 0 (68)	AIGND (67)	0 to 2 V	0 to –10 keV	0 to –10 keV	0 to –10 keV
Emission Current	ACH 1 (33)	AIGND (67)	0 to 2 V	0 to 500 µA	0 to 100 µA	0 to 3 mA
Source Voltage	ACH 2 (65)	AIGND (64)	0 to 2 V	0 to 1.5 V	0 to 3.0 V	0 to 3.0 V
Source Current	ACH 3 (30)	AIGND (64)	0 to 2 V	0 to 2.0 A	0 to 2.0 A	0 to 3.0 A
Grid Voltage	ACH 4 (28)	AIGND (27)	0 to 2 V	0 to -300 V	0 to -300 V	0 to -1000 V
Focus Voltage	ACH 5 (60)	AIGND (27)	0 to 2 V	0 to –10 kV	0 to –10 kV	0 to –10 kV
X Deflection Voltage	ACH 8 (34)	AIGND (67)	-300 to +300 mV	-300 to +300 V		
Y Deflection Voltage	ACH 9 (66)	AIGND (32)	-300 to +300 mV	-300 to +300 V		

NOTE: ACH 6 and ACH 7 are unused with this gun.

4.5.2 REMOTE PROGRAMMING

N. I. LabVIEW™ Program by Kimball Physics

1. Set up the power supplies and cable connections as described in Power Supply Installation Section 2.2.

2. If the program is not already installed, install the National Instruments LabVIEW™ executable program file written by Kimball Physics on the computer. Either LabVIEW or LabVIEW Runtime is required.

3. On the back of the main Power Supply, set the small local/ remote slide switches labeled **PROGRAMMING** to the **REMOTE** position (up) for each supply that is to be remotely controlled. Individual supplies can be run in either local or remote mode. (Fig. 4.5-3)

NOTE: Once in the Remote mode, the individual power supply is not controllable by the front panel controls (potentiometers or encoder wheel). Front panel meters are not affected by these switches.

(Some Power Supplies do not have any front panel potentiometers/ meters and are always controlled remotely by computer; thus these "black box" units do not have any local/ remote slide switches.)

4. After the Power Supplies have been turned on physically as described in Normal Start-Up Procedure, start the program by clicking the arrow in the menu bar and then the **POWER** button. The button should turn all green, and the digital indicator meters should show 000. Note that this power button does not energize or shut down the power supplies.

5. Operate the gun as described in the Normal Start Up or ECC Procedures, using the toggle switches and digital controls on the virtual panel instead of those on the Power Supply front panel.

CAUTION: For critical supplies, such as Energy and Source, it is strongly recommended that the supplies be turned up gradually..

6. To shut down:
   a. Turn off supplies as described in the Normal Shut Down Procedure.
   b. Turn off the program by clicking the **POWER** button. The green button light and digital readouts should go off. **Do not just close the window** as the program voltages may remain at the values set before the window was closed.
   c. Then the program window can be closed and the computer shut down.
   d. An **EMERGENCY STOP** button is provided on some systems. This button is for an emergency situation only and should not be used under normal circumstances. It immediately turns off all Power Supplies. If the **EMERGENCY STOP** button has been used, it must be reset by clicking reset on the button, before any supplies can be turned on.

User-designed Remote Programming Control

1. Set up a user-supplied system (computer program, DAQ boards etc.) to provide a source for controlling the individual power supplies.

2. Ensure that all Power Supplies are **OFF** before making electrical connections.

3. The voltage source signal maps linearly onto the supply-dependant range shown in Table 4.5-2 below.
   a. **For supplies with a range of 0 to X** (most supplies): Provide a voltage source that produces a 0 to +10 V signal.
      For example, with a 0 to –5 keV Energy power supply, a +10 V signal supplies –5000 eV, and a +5 V signal supplies –2500 eV.
   b. **For supplies with a range of ± X** (Deflection or Alignment): Provide a voltage source that produces a –10 V to +10 V signal.
      For example, with a –150 V to +150 V Deflection power supply, a -10 V signal supplies –150 V, a +5 V signal supplies +75 V, and a 0 V signal supplies no deflection.
   c. **For toggle switches:** Provide an on/off, +5 V or 0 V signal. For example, with the Source/ECC switch, +5 V sets the switch to ECC, and 0 V sets it to Source mode.
   d. Refer to Table 4.5-2 and Fig. 4.5-4 for the pinout of the **PROGRAMMING** connector. For each supply, there are a pair of pins: (1) signal program to connect to the voltage programming signal and (2) common to reference the system to ground.

4. On the Power Supply front panel, turn all controls (potentiometers or encoder wheel) fully counterclockwise, to avoid problems due to unexpected settings if the unit is switched back to local mode.

5. On the Power Supply front panel, preset any toggle switches that are not controlled by the remote programming, such as PULSE or HIGH/ LOW switches.

7. On the back of the main Power Supply, set the small local/ remote slide switches labeled **PROGRAMMING** to the **REMOTE** position (up) for each supply that is to be remotely controlled. Individual supplies can be run in either local or remote mode. (Fig. 4.5-3)

NOTE: Once in the Remote mode, the individual power supply is not controllable by the front panel controls (potentiometer or encoder wheel). Front panel meters are not affected by these switches.

6. Connect a user-supplied cable from the programming control system to the D-sub connector labeled **PROGRAMMING** on the back of the Power Supply to the computer system.

7. Follow the Normal Start Up Procedure to energize the system and operate the controls that are not programmed remotely. Front panel pushbuttons or rocker switches need to be on (lighted) for the remote programmed supplies to operate.

4.5.2 REMOTE PROGRAMMING cont.

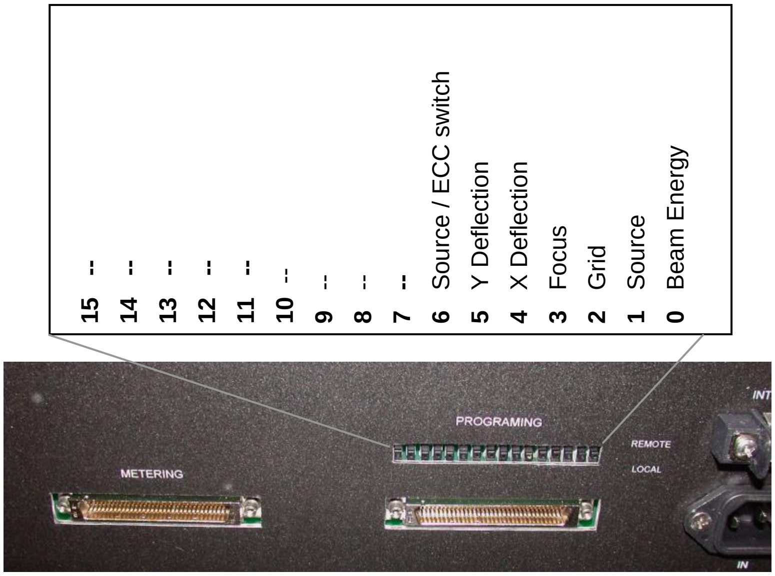


Fig. 4.4-3 Local / Remote Switches on the back of the EGPS-3101 (not all 16 switches are used)

Table 4.4-2 EGPS-3101 Remote Programming Equivalency Table (connector NI 6703)

Power supply controls	DAQ Output Channel		Control Signal	Power Supply Range		
	Signal (pin#)	Ground (pin#)		STANDARD	SMALL SPOT	HIGH CURRENT
Beam Energy	VCH 0 (34)	AGND 0 (68)	0 to +10 V	0 to –10 kV	0 to –10 kV	0 to –10 kV
Source (in ECC mode)	VCH 1 (66)	AGND 1 (33)	0 to +10 V (0 to +10 V)	0 to 1.5 V (0 to 500 µA)	0 to 2.6 V (0 to 100 µA)	0 to 2.25 V (0 to 3 mA)
Grid	VCH 2 (31)	AGND 2 (65)	0 to +10 V	0 to -300 V	0 to -300 V	0 to -1000 V
Focus	VCH 3 (63)	AGND 3 (30)	0 to +10 V	0 to –10 kV	0 to –10 kV	0 to –10 kV
X Deflection	VCH 4 (28)	AGND 4 (62)	-10 V to +10 V	-300 V to +300 V		
Y Deflection	VCH 5 (60)	AGND 7 (27)	-10 V to +10 V	-300 V to +300 V		
Source / ECC Switch	DIO0 (2)	DGND (36)	0 V = Source +5 V = ECC	--		

NOTE: For Deflection computer control, the Deflection mode toggle switch on the EGPS-3101 front panel must be in the **NORMAL** position, not Energy Proportional.

NOTE: With the EGPS-3101, pulsing and blanking are generally controlled directly, not by the basic computer program.
With an optional **Pulse Junction Cylinder**, use a user supplied pulse generator.
With optional **Dual Grid Pulsing**, use the front panel Pulse toggle switch and a user-supplied external TTL input for the pulsing signal.
With optional **Beam Blanking**, use the front panel controls and a user-supplied external TTL input signal.

4.5 REMOTE ACCESS: METERING / PROGRAMMING OF POWER SUPPLIES cont.

4.5.2 REMOTE PROGRAMMING cont.

EGPS METERING CONNECTOR PIN OUT (Device 1)

ACH8	34	68	ACH0
ACH1	33	67	AIGND
AIGND	32	66	ACH9
ACH10	31	65	ACH2
ACH3	30	64	AIGND
AIGND	29	63	ACH11
ACH4	28	62	AISENSE
AIGND	27	61	ACH12
ACH13	26	60	ACH5
ACH6	25	59	AIGND
AIGND	24	58	ACH14
ACH15	23	57	ACH7
DAC0OUT*	22	56	AIGND
DAC1OUT*	21	55	AOGND*
EXTREF*	20	54	AOGND*
DIO4	19	53	DGND
DGND	18	52	DIO0
DIO1	17	51	DIO5
DIO6	16	50	DGND
DGND	15	49	DIO2
+5 V	14	48	DIO7
DGND	13	47	DIO3
DGND	12	46	SCANCLK
PFI0/TRIG1	11	45	EXTSTROBE*
PFI1/TRIG2	10	44	DGND
DGND	9	43	PFI2/CONVERT*
+5 V	8	42	PFI3/GPCTR1_SOURCE
DGND	7	41	PFI4/GPCTR1_GATE
PFI5UPDATE*	6	40	GPCTR1_OUT
PFI6/WFTRIG	5	39	DGND
DGND	4	38	PFI7/STARTSCAN
PFI9/GPCTR0_GATE	3	37	PFI8/GPCTR0_SOURCE
GPCTR0_OUT	2	36	DGND
FREQ_OUT	1	35	DGND

*Not available on AT-AI-16XE-10, PCI-6032E, DAQCard-AI-16E-4, DAQCard-AI-16XE-50

I/O CONNECTOR for NI 6034

(NI 6070E, NI 6060E, NI 6062E, NI 6041E, NI 6040E, NI6036E, NI 6035,and NI 6034E)

EGPS PROGRAMMING CONNECTOR PINOUT (Device 2)

+5 V	1	35	DGND
DIO0	2	36	DGND
DIO1	3	37	DGND
DIO2	4	38	RFU
DIO3	5	39	DGND
DIO4	6	40	RFU
DIO5	7	41	DGND
DIO6	8	42	DGND
DIO7	9	43	AGND
ICH31*	10	44	VCH15
AGND15/AGND31	11	45	ICH30*
VCH14	12	46	AGND14/AGND30
ICH29*	13	47	VCH13
AGND13/AGND29	14	48	ICH28*
VCH12	15	49	AGND12/AGND28
ICH27*	16	50	AGND11/AGND27
VCH11	17	51	ICH26*
AGND10/AGND26	18	52	VCH10
AGND	19	53	ICH25*
AGND9/AGND25	20	54	VCH9
ICH24*	21	55	AGND8/AGND24
VCH8	22	56	AGND
ICH23*	23	57	VCH7
AGND5/AGND21	24	58	ICH22*
VCH6	25	59	AGND6/AGND22
ICH21*	26	60	VCH5
AGND7/AGND23	27	61	ICH20*
VCH4	28	62	AGND4/AGND20
ICH19*	29	63	VCH3
AGND3/AGND19	30	64	ICH18*
VCH2	31	65	AGND2/AGND18
ICH17*	32	66	VCH1
AGND1/AGND17	33	67	ICH16*
VCH0	34	68	AGND20/AGND16

*No connect on NI 6703

I/O CONNECTOR for NI 6703

(NI 670x Family)

Fig. 4.4-4 Pin outs of 68-pin DAQ (Data Acquisition) cable connectors NI 6034 for metering and NI 6703 for programming

4.5 REMOTE ACCESS: METERING / PROGRAMMING OF POWER SUPPLIES cont.

File Saving for the EGPS-3101 Remote Control Program

SAVE CURRENT SETTINGS saves the following in a tab-delimited file.			
These values are called up if USE SAVED SETTINGS is chosen.			
30 items saved			
Index	**Item Saved**	**Units**	**Notes**
0	Energy	V	
1	Source / ECC in Source mode	V	If in ECC mode when saved, this is set to 0
2	Source / ECC in ECC mode	µA	If in Source mode when saved, this is set to 0
3	Grid	V	
4	Focus	V	
5	X Deflection	V	
6	Y Deflection	V	
7	unused		Even though 7-29 are unused,
to 29	unused		they exist in the file and the positions are filled with zeros
30	Source / ECC mode switch	0 or 1	Switch state 0 = Source, 1 = ECC

LOG DATA saves the following in a tab-delimited file.			
These values cannot be called up by the program. Purpose is for data-logging.			
22 items saved in Desktop\Subvis&Data\DataLog.txt. or in same directory as program			
This file can be opened, data copied and pasted to other files, data deleted if desired.			
Index	**Item Saved**	**Units**	
TIME MARKERS			
0	Date		
1	Time		
2	Operator's name		Entered when program starts, optional
CONTROL SETTINGS			
3	Energy	keV	
4	Source / ECC in Source mode	V	Depends on switch position
5	Source / ECC in ECC mode	µA	Depends on switch position
6	Grid	V	
7	Focus	kV	
8	X Deflection	V	
9	Y Deflection	V	
10	Source / ECC Switch	0 or 1	Switch state 0 = Source, 1 = ECC
METER READINGS			
11	Energy	keV	
12	Emission Current	µA	
13	Source Volts	V	
14	Source Amps	A	
15	Grid	V	
16	Focus	kV	
17	X Deflection	V	
18	Y Deflection	V	
19	unused		
OTHER			
20	Cathode Temperature	K	Temperature calculated from source current

4.6 MANUAL CONTROL DEFLECTION UNIT (MCDU)

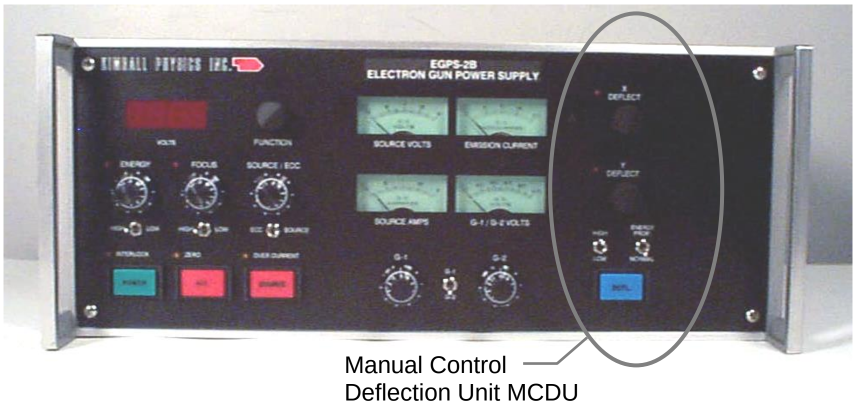


Fig. 4.6-1 Front Panel of a typical Power Supply with Deflection, showing MCDU controls including optional High/Low range switch (Other controls may vary with power supply model)

Deflection, also called centering deflection, allows the beam to be guided by the operator to the target. For initial set-up and positioning, the spot can best be observed using a phosphor screen in the target area.

The Deflection assembly consists of two pairs (X and Y) of deflection plates located near the beam-exit end of the gun. Potentials applied to these plates produce a deflecting force in a plane perpendicular to the direction of beam travel.

DESCRIPTION OF CONTROLS

Deflection Switch: A blue pushbutton switch labeled **DEFL** that enables or disenables the power supplies in the deflection unit. (When off, the outputs are grounded, so the deflection plates in the gun are grounded).

X Deflection Control: A ten-turn potentiometer labeled **X DEFLECT** that adjusts the deflection voltage in the X direction. A red LED next to the potentiometer indicates the monitoring of the X deflection voltage by the DVM (digital voltmeter).

Y Deflection Control: A ten-turn potentiometer labeled **Y DEFLECT** that adjusts the deflection voltage in the Y direction. A red LED next to the potentiometer indicates the monitoring of the Y deflection voltage by the DVM.

Energy Proportional / Normal Switch: A toggle switch labeled **ENERGY PROP /NORMAL** that selects the deflection output as either the "energy proportional mode" or the normal "non-proportional mode".
ENERGY PROP. mode: The deflection voltage is proportional to the beam energy as energy is changed. This enables *approximately* constant positioning of the spot as the beam energy is changed.
NORMAL mode: The deflection voltage remains constant as the beam energy is changed.

Range switch: (Optional): An optional toggle switch labeled **HIGH/LOW** that sets the range of the Deflection controls and DVM to be either -150 V to +150 V, or -10 V to +10 V..

DEFLECTION OPERATION

1. Power Supply:
   a. Depress the blue **DEFL** pushbutton to energize the supplies in the Deflection unit; the pushbutton will light.

2. Select the mode with the **ENERGY PROP / NORMAL** toggle switch:
   a. **In Energy Proportional mode:** The deflection voltage is proportional to the beam energy as energy is changed. This enables *approximately* constant positioning of the spot as the beam energy is changed.
      i. For example: If Energy = 1000 V initially and X Deflection = 50 V, when Energy is turned down to 500 V, the X Deflection voltage "tracks" down to 25 V.
   b. **In Normal mode:** The deflection voltage remains constant as the beam energy is changed.
   c. When using computer/ remote control, this toggle switch will still need to be set manually on the EGPS.

3. Monitoring Deflection voltages:
   a. Set the rotary **FUNCTION** switch (on the Power Supply next to the DVM) so that either the X Deflect or Y Deflect LED (next to the corresponding deflection control knob) lights up.
   b. Monitor the voltages on the deflection plates using the **DVM** (Digital Volt Meter).

4. Adjusting the Deflection plate voltages:
   a. Using the **X DEFLECT** and **Y DEFLECT** potentiometers, vary the output voltage between -150 V and +150 V as needed to center or position the beam in the X and Y directions within the target plane.
      (For an EMG-12 or EMG 14 Electron Gun: The range is -300 V to +300 V.)
   b. **With the optional range switch**: This toggle switch controls the sensitivity of the X and Y potentiometer controls and the DVM display.
      HIGH range = -150 V to +150 V,
      LOW range = -10 V to +10 V.
   c. For initial set-up and positioning, the spot can best be observed using a phosphor screen in the target area.

5. To turn off the MCDU: Press the **DEFL** pushbutton switch off, (out position). Other MCDU controls may remain as set to simplify start up. When off, outputs are grounded, so the deflection plates are grounded.

NOTE: Depending on the gun model, non-uniformities in the deflecting electric field may cause the spot to become distorted if the beam is deflected too close to the deflection plates. Better spot shapes will be achieved if the amount of deflection is kept to a minimum. (See discussion in the theory section.)

This completes the Manual Control Deflection Unit Instructions.

4.7 RASTER GENERATOR DEFLECTION UNIT (RGDU) OPTION

Fig. 4.7-1Raster Generator Deflection Unit (RGDU)

Fig. 4.7-2 Raster cable

Rastering can be added to any electron or ion gun system with 4-pole electrostatic deflection and a separate 8-pin deflection connector on the gun. Rastering involves movement of the beam in a pattern and is used to cover an area of the target region fairly uniformly over time. It is produced by applying cyclical voltages to the X and Y deflection plates in the gun. These voltages are controlled by a separate power supply, the Raster Generator Deflection Unit (RGDU). The system can be used either to center the spot manually as a deflection unit or to raster the beam.

INSTALLATION OF RASTER GENERATOR DEFLECTION UNIT

1. Follow the Power Supply and Electron or Ion Gun installation procedures in Sections 2.2 and 2.3.

2. On the RGDU, the green **POWER** pushbutton switch should be off, in the out position.

3. Connect the included ground strap onto the grounding screw on the back panel of the RGDU. Then connect the other end of the ground strap to a proper earth ground connection.

4. Plug the 8-pin gray Raster cable into its keyed 8-pin mating connector on the back of the RGDU. tightening the ring by hand. Support the cable along its length and do not twist it.
   NOTE: Use the gray raster cable. Although the pinout is the same, do not use the standard black Deflection cable for rastering, as it will not give the proper response.

5. On the back of the RGDU, select either 115 or 230 VAC with the red switch. Plug the power cord into the LINE outlet.

6. The four output BNCs (X POS, X NEG, Y POS, and Y NEG) on the back panel may be used to connect user-supplied equipment, such as an oscilloscope.

7. An **optional** BNC labeled **TTL OUTPUT** on the back panel may be used to synchronize the RGDU with other user-supplied equipment or with the blanker on electron guns with a Beam Blanking option. Connect a coaxial cable from this BNC on the RGDU to the Blanker BNC labeled **TTL INPUT** on the front of the EGPS Power Supply or to a BNC on some other equipment.

DESCRIPTION OF CONTROLS

The only **Inputs** are Remote Control Inputs (+10 V to -10 V) for X and Y positioning on the back of the RGDU.

The following is a description of the **Manual** controls on the front of the RGDU:

Power Switch: A green push button labeled **POWER** that enables or disenables the power supplies in the RGDU. (When off, outputs are grounded, so the deflection plates are grounded).

Mode Switch: A toggle switch that selects either **Centering** or **Rastering**.
CENTER: When the Mode Switch is in the Center position, the unit will operate like a Manual Control Deflection Unit (MCDU-4C) to position the beam.
RASTER: When the Mode Switch is in the Raster position, the X Channels and the Y Channels raster according to the preset conditions of rate, position, and size.

Voltage Switch: A toggle switch labeled **HIGH / LOW** that selects the output voltage range of either ±100 volts peak to peak or ±10 volts peak to peak.

Function Switches: Two toggle switches that select metering of either **Size** or **Position** for the X and the Y channels.

Rate Controls: Two rotary switches labeled **RATE**, one for setting the sweep rate of the X Channels (10 to 5 kHz) and one for the sweep rate of the Y Channels. (0.1 to 50 Hz).

Digital Meters: Two DVMs, one labeled **X** and one **Y**, that read either the **position** in volts (0 to 100 V or 0 to 10 V depending on the hi/low voltage switch) or the **size** in percentage of the possible window (0 to 100%).

Position Controls: Two potentiometers labeled **POS**, one for offsetting the beam along the X-AXIS, and one for offsetting the beam along the Y-AXIS. These are used to manually control the electron beam position in center mode, or to position the window in raster mode.

Size Controls: Two potentiometers labeled **SIZE**, one for setting the sweep amplitude of the X Channels (so setting the sweep angle of deflection along the X-AXIS), and one for setting the sweep amplitude of the Y Channels (so setting the sweep angle of deflection along the Y-AXIS). These control the size of the raster window and do not function in center mode.

Raster Mode Switch: A three-position switch, located inside the RGDU under the top cover, that selects the rastering mode: Off, Synchronized, or Free run.

DESCRIPTION OF OUTPUTS

The outputs of the RGDU consist of four channels: +X, -X, +Y, and -Y. In synchronized mode, the X Channels are blanked off during the retracing of the Y Channels.
Fig. 4.7-3 shows examples of the output wave forms, where X is set at four times the Rate of Y, Position has zero offset on both X and Y axes, and Size is set at 75 V for both X and Y Channels.

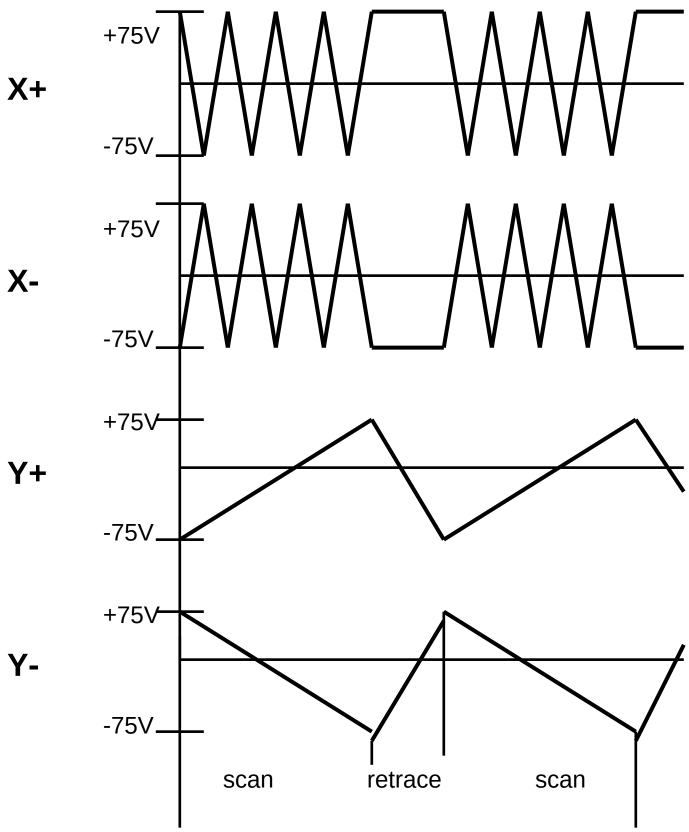


Fig. 4.7-3 Synchronized Raster Output Wave Forms

WARNING

HIGH VOLTAGE
Can cause ELECTRIC SHOCK or BURN

Turn off and unplug the RGDU before accessing the raster mode switch. Failure to do so could result in dangerous HIGH VOLTAGE when the cover is open.

The raster generator has the possibility of running in one of two modes: synchronized or free run. These modes are selected using a three-position switch located under the top cover of the raster generator, as shown below in Fig. 4.6.4. The raster generator may be shipped in either mode depending on the gun; the mode can be checked by opening the cover and checking the switch position, or by observing the type of raster pattern produced.

In **synchronized mode**, the X- trace signal and the Y-trace signal are synchronized. This yields a raster pattern in which the pattern seen on the target appears to be stationary. During the Y-retrace, the X deflection signal goes to its maximum value producing a line that can be seen outside the target region. Whether the electrons during retrace are included in the total beam current would depend on the size of the target, on whether they fall off the target with maximum X deflection.

In **free run mode**, the X and Y signals are not synchronized; patterns on the target appear to move. This mode probably yields the most uniform electron dose over the target area.

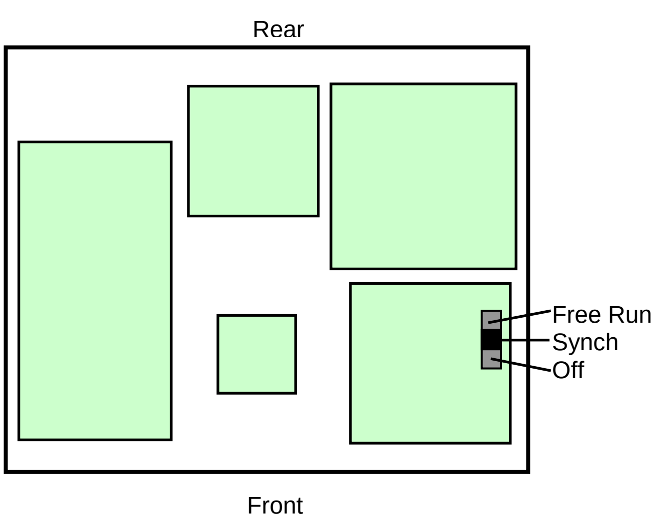


Fig. 4.7-4 Top view of opened RGDU, showing Raster Mode Switch positions

OPERATION OF RASTER GENERATOR DEFLECTION UNIT (RGDU)

1. Turn on the RGDU: Depress the green **POWER** pushbutton switch on (in position).; the pushbutton will light.

2. Set the Voltage switch to **HIGH** (±100 volts peak to peak) or **LOW** (±10 volts peak to peak) to set the maximum sweep size or maximum deflection. For low beam energy operation, the unit should be run in the **LOW** mode for increased control to reduce the ripple on the raster outputs.

3. **For manual deflection:**
   a. Set the mode switch to **CENTER** and the two function switches to **POS** as indicated by the red LEDs.
   b. Adjust the two **POSITION** potentiometers to center the electron beam along the X and Y axes.
   c. Use the DVMs to monitor potentiometer settings.

4. For guns with Beam Blanking option only (see also Section 4.9):
   a. On the EGPS Power Supply, disconnected the coaxial cable from the Blanker **TTL INPUT** BNC, if connected. Turn on the Blanker unit with the amber **BLANKER** pushbutton. Set the **INVERT/NORMAL** toggle switch to **NORMAL**.
   b. Using the **BLANKER** potentiometer, adjust the Blanker voltage to that needed for beam cut-off.
   c. Connect a coaxial cable from the optional BNC labeled **TTL OUTPUT** on back of RGDU to the Blanker **TTL INPUT** BNC on the front of the EGPS. This will synchronize the blanking of the retrace during rastering.

5. **For rastering:**
   a. Set the sweep rates for X and Y using the two **RATE** rotary switches.
   b. Set the mode switch to **RASTER** and the two function switches to **SIZE**, and then adjust the two **SIZE** potentiometers to give the desired window size of the raster pattern.
   c. Set the function switches to **POS** and then adjust the two **POSITION** potentiometers to position the raster pattern window within the operating area.
   d. Use the DVM to monitor potentiometer settings.
   e. The optional **TTL OUTPUT** BNC can be used to synchronize other user-supplied equipment. It provides +5 V during X and Y sweeps (scan) and 0 V during the retrace.

6. Run the gun as described in normal or ECC operation, sections 4.2 and 4.3, readjusting deflection or rastering as desired.

7. To turn off the RGDU: Press the **POWER** pushbutton switch off (out position). Other controls may remain as set to simplify start up.

4.7 RASTER GENERATOR DEFLECTION UNIT (RGDU) OPTION cont.

OPERATION OF RGDU cont.

8. For computer/ remote control:
   a. Remote control terminals can be used for X and Y positioning, not for rastering. The supplies may be either voltage programmed or resistance programmed.
   b. Turn off the RGDU with the **POWER** switch, and **UNPLUG THE RGDU POWER CORD** before making electrical connections.
   c. For voltage programming:
      i. Set up a user-supplied system (analog supply, or computer program, breakout boards DAQ boards etc.) for controlling the individual power supplies. Provide a voltage source that produces a **-10 V to +10 V** signal for X and for Y.
      ii. For example, with a –100 V to +100 V Deflection power supply, a -10 V signal supplies –100 V, a +5 V signal supplies +50 V, and a 0 V signal supplies no deflection.
      iii. Attach the voltage source signal (computer board, analog supply, etc.) to the program terminal labeled **PROG** by inserting a bare wire end and tightening the terminal screw.
      iv. Reference the system to ground on the second terminal of the supply labeled **COM.**
   d. For resistance programming:
      i. Provide a **100 kΩ** potentiometer for X and for Y.
      ii. For example, with a -100 V to +100 V Deflection power supply, if the potentiometer is turned fully counterclockwise, it will provide a -10 V signal which supplies -100 V deflection, if fully clockwise, it will provide +10 V which supplies +100 V deflection. At the mid-point, it will provide 0 V, and so no deflection.
      iii. Attach the wiper terminal of the potentiometer to the program terminal labeled **PROG** by inserting a bare wire end and tightening the terminal screw.
      iv. Attach the clockwise potentiometer terminal to the **+10 V REF** terminal, and the counter-clockwise potentiometer terminal to the **-10 V REF** terminal.
   e. On the back of the RGCU, set the remote/local toggle switch to the **REMOTE** position.

   NOTE: Once in the Remote mode (switch in right position), the X and Y supplies are not controllable by the front panel potentiometers.

   f. Plug in the power cord and turn on the RGDU as above. The POWER pushbutton must be on and the toggle switches must be set on the front panel before the X and Y position is controlled remotely.
9. To change the raster mode (synchronized or free run) if desired:

   WARNING: Failure to disconnect the RGDU, could result in HIGH VOLTAGE hazard when the cover is open.

   a. Turn off the RGDU with the **POWER** switch, and **UNPLUG THE RGDU POWER CORD**.
   b. Remove the top cover of the RGDU.
   c. Set the raster mode switch on the front right board to either **synchronized mode (center)** or **free run mode (rear)** position. (See Fig. 4.7-4 above.)
   d. Replace the top cover, plug in the power cord, and turn on the RGDU again.

This completes the Raster Generator Deflection Unit Instructions.

4.8 BEAM PULSING OPTIONS

COMPARISON OF VARIOUS BEAM PULSING METHODS

In most guns, the electron beam may be turned off and on while the gun is running. The way this is accomplished depends on the particular gun design; often several methods are available for a gun. The beam pulsing options currently available for this gun model are described in detail following the summary Table 4.8-1.

The grid (G-1) provides the first control over the beam and usually can be used to shut off the beam. In an electron gun, if the grid voltage is sufficiently negative with respect to the cathode, it will suppress the emission of the electrons, first from the edge of the cathode and at higher (more negative) voltages from the entire cathode surface. The minimum voltage required to completely shut off the flow of electrons to the target is called the grid cut off. The grid voltage is controlled manually by a potentiometer knob on the power supply; thus, in most guns, the beam can be turned off while the gun is running by setting the grid to the cut off voltage.

Pulsing is stopping and starting the flow of electrons in a fast cycle. This pulsing is usually accomplished by rapidly switching the grid voltage to its cut off potential to stop the beam. The grid voltage can be controlled by several different methods, which are summarized in Table 4.8-1 (listed in order of speed).

Not all guns are designed to be pulsed. For example, a few electron guns have a positive grid in order to extract more electrons, and so these guns do not usually have grid cut off, unless a dual grid supply is ordered. In some high-current electron guns, the optical design, the position of the cathode, does not allow for cut-off by the grid, and so a different option, called blanking, must be used to interrupt the beam instead of pulsing.

The simplest method of turning the beam off and on is just to cycle the grid voltage by hand with the control potentiometer or encoder wheel on the front of the power supply. Clearly, this would be slow and not reproducible.

A more systematic method of controlling the grid is by an input signal into the remote connector on the rear panel of the power supply. Remote control is a standard feature on all power supplies, so this method does not require any system options. However, it may not provide sufficiently fast pulsing.

With the dual grid pulsing option, there are two grid power supplies built into the main power supply. A pulsing TTL (transistor-transistor-logic) signal switches rapidly between the two supplies, pulsing the beam on and off. For most guns, the dual supplies are (1) the normal, variable control grid supply which is adjusted to allow the electron flow and (2) a fixed grid supply which is set at the cut-off grid voltage at the factory. For guns that usually have a positive grid, the dual supplies are (1) a variable positive grid supply which allows the electron flow, and (2) a variable negative grid supply which is adjusted to cut-off.

For the capacitive or fast pulsing option, many guns can be equipped with a capacitor-containing device (either a separate pulse junction box or cylinder, or a cable with a box) that receives a signal from an external pulse generator. The grid power supply and pulse generator outputs are superimposed to produce the voltage at the grid aperture. The general pattern of the beam pulsing is a square wave with a variable width (time off and time on) and a variable repetition rate. Capacitive pulsing can provide the fastest rise/ fall time and shortest pulse length of the various methods. However, the capacitor does not permit long pulses or DC operation. If there is a separate grid lead on the gun, this capacitive pulsing option can be added to most existing gun systems without modification.

Beam blanking is a different type of pulsing that does not rely on grid cut-off and is used in some high current guns. Blanking deflects the electron beam to one side of the gun tube to interrupt the flow of electrons to the target without actually turning off the beam. It is controlled by a TTL signal input.

Table 4.8-1 following is intended to provide a general comparison of different pulsing methods. Specifications may vary for some gun models, and custom designs are available for particular pulsing requirements. The pulse height is from no beam at grid cut-off to full beam current with no grid, all other parameters unchanged. The pulse length is defined as the time the beam is on, measured as the width at 50% of full beam and may include some ringing. The rise/ fall time is measured between 10% and 90% of full beam. Shortening the rise/fall will typically increase ringing. Pulsing performance may also depend on the performance of the user-supplied pulse generator

Table 4.8-1 Summary of Beam Pulsing Methods for Various Electron Guns

PULSING TYPE	CONTROL METHOD	FEATURES & DRAWBACKS
Manual	Manual control with grid dial potentiometer on front of power supply	Pulse lengths ~ 1 min to DC, Rise /fall ~ 10 sec
		Available on all guns that cut off with grid
		Operator needs to control grid potentiometers
		Drawbacks: Slow and irregular Not available on guns with positive grid or no cutoff

4.8 BEAM PULSING OPTIONS cont.

PULSING TYPE	CONTROL METHOD	FEATURES & DRAWBACKS
Remote Control	Remote control with computer input into grid power supply terminals	Pulse lengths ~ 100 msec to DC, Rise /fall ~ 20 msec
		Available on all guns that cut off with grid
		0 to 10 V control signal required (e.g. D/A converter or DAQ board with analog input)
		Drawbacks: May not be sufficiently fast Not available on guns with positive grid or no cutoff
Dual Grid Power Supply Option	Dual grid power supplies with a TTL signal input	Pulse lengths ~ 2 μsec to DC, Rise /fall ~ 500 nsec
		Repetition rates to 1 kHz
		Controlled by any TTL generator (computer or stand alone)
		Optional, built into main Power Supply requested at time of order, or separate pulsing supply
		Drawback: May not be sufficiently fast
Beam Blanking	Blanker power supply with a TTL signal input, Blanker assembly in gun (not grid cutoff)	Pulse lengths ~ 1 μsec to DC
		Repetition rates to 10 kHz
		Controlled by any TTL generator (computer or stand alone)
		Optional, blanker assembly built into gun and supply built into main Power Supply, requested at time of order,
		Drawbacks: May not be sufficiently fast Shunts beam to the side, does not suppress emission Available on only a few gun models
Capacitive Fast Pulsing Option	Pulse junction box connected to grid, or grid pulsing cable (depends on gun model) and an external pulse generator	Rise /fall ~ 10 nsec
		Pulse lengths ~ 20 nsec to 100 μsec (box or cylinder) ~ 100 nsec to 1 msec (cable)
		Maximum duty cycle ~ 20%
		Controlled by a external pulse generator with voltage at least equal to grid cut off value
		Removable pulse junction box or special cable
		Optional, can sometimes be added to existing system
		Drawbacks: Long pulses not achievable Requires pulse generator with desired rise /fall and sufficient voltage Not available on guns with no cutoff Guns with positive grid require dual grid supplies

4.8 BEAM PULSING OPTIONS cont.

4.8.1 PULSING with GRID REMOTE CONTROL

Pulsing of the beam current can be accomplished by varying voltage applied to the control grid (Wehnelt) aperture, so that the beam is alternately turned on or cut off. The grid potential must be negative with respect to the cathode. When the grid voltage set to zero or some empirically-determined low value, the beam current will be at its maximum. As the grid voltage is increased, the cathode emission is suppressed and eventually completely cut off. This cut-off voltage is dependent on other operating parameters, such as Energy. Before pulsing, It is advisable to determine the optimum grid voltage and the cut-off grid voltage for the conditions.

The full range of grid voltage is controlled remotely by a pulsed 0 to 10 V signal into the remote control Grid connection on the back of the EGPS Power Supply. The remote connector may be a terminal block, an external interface D-sub connector, or a programming connector for a computer DAQ board, depending on the power supply model. The output grid voltage varies proportionally from 0 to its full range. The input voltage signal can be obtained from any source (i.e., a computer with a digital to analog converter, or an analog supply).

For example, if the grid range is 0 to -500 V, and grid cut-off is -200 V, the beam can be pulsed on and off with computer/remote input pulses of +4 V as shown in Fig. 4.8-1. The voltage that turns on the beam does not need to be zero. The actual values of cut off and beam current will vary with the gun model and operating parameters. (see Data Section)

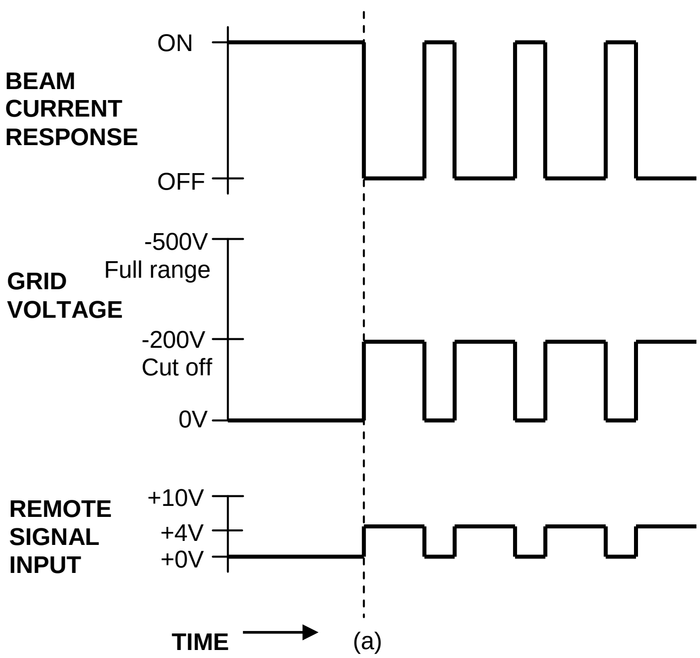


Fig. 4.8-1 Beam Pulsing with Grid Remote Control.
At time (a) the pulsed signal into the Grid remote terminal is turned on

PULSING with GRID REMOTE CONTROL: OPERATION

1. Set-up the remote control system as described in the Remote Control Section or Remote Access (Programming) Section, above.

2. Voltage program the Grid Power Supply as follows:
   a. Connect the output of the pulsing source to the Grid program terminal/pin. The pulsed signal should not exceed the 0 to +10 V range.
   b. Reference the system to ground on the other Grid terminal/pin.
   c. The way this is accomplished will depend on the type of remote connector and details of the computer program.

3. Operate the Electron Gun as described under Normal Start Up Procedure:

NOTE: In the Remote mode, the Grid is not controllable by its front panel manual control.
   a. The remote signal must be off initially, so that the Grid will be zero while setting the Source current.
   b. Set the magnitude of the input signal so that the Grid will alternate between the value that yields the desired beam current and the appropriate cut-off voltage for the operating parameters, such as Energy. (See Data Section for Beam Current vs. Grid Voltage graphs.) The remote voltage source signal maps linearly onto the Grid supply range.
   c. Set the frequency of the input to the desired pulse rate. The maximum usable pulse rate depends on electrical components in the program signal and grid supply circuitry, and will vary from system to system. In general, the maximum pulse rate is 100 Hz.
   d. With pulsing, the Grid meter does not give an accurate reading; it will either fluctuate rapidly or will give an averaged value.

Note that this type of pulsing may not work with the high current version of some guns, as the position of the cathode does not allow for complete grid cut-off at higher energies. Such guns, for example the high current EGG-3101 or high current EMG-12, require a separate blanker assembly.

This completes the Beam Pulsing with Grid Remote Control Instructions.

4.8 BEAM PULSING OPTIONS cont.

4.8.2 CAPACITIVE PULSING with PULSE JUNCTION CYLINDER

PULSE JUNCTION CYLINDER: INSTALLATION

CAUTION

Support the Pulse Junction Cylinder so that no force is exerted on the gun feedthrough. Otherwise the ceramic feedthrough may be damaged.

NOTE

Gun surfaces exposed to vacuum, and high voltage insulator ends on the cables, should not be handled with bare hands. **Use clean room gloves** to keep parts free of fingerprints and contaminants.

The minimum bend radius of the H.V. Source cable is 0.25 meters. **Do not twist cables.**

1. An electron gun with a four pin central feedthrough, a Pulse Junction Cylinder, and a separate, user-supplied, pulse generator capable of producing appropriate voltages (equal to the Grid cut off value) are required for installation of the Fast Beam Pulsing Option.

2. Refer to the power supply and electron gun installation procedures in Sections 2.2 and 2.3. Mount the gun on the vacuum system as described, but do not attach the cables yet.

3. Install the Pulse Junction Cylinder on the 2¾ CF gun flange, as shown in Fig. 4.8-2. Observe the key when connecting the four pins. **CAUTION: Avoid tilting, twisting or excessive force**, otherwise the ceramic feedthroughs may be damaged.
   a. **If the electron gun is mounted horizontally, the Pulse Junction Cylinder must be supported**, because the gun feedthrough cannot withstand the weight of the unsupported Pulse Junction Cylinder and cable.
   b. If the electron gun is mounted vertically, ensure that the Pulse Junction Cylinder and cable are **protected from rocking or bumping**, otherwise feedthrough breakage could occur.

4. Connect the H.V. Multiconductor Source cable to the flange end of the Pulse Junction Cylinder.
   a. Wipe the short white insulator on the connector with isopropanol and a lint-free cloth.
   b. Gently insert the 4-pin connector on H.V. Multiconductor Source cable into the central keyed vacuum feedthrough on the EGG-3101 Electron Gun, tightening the ring by hand. Observe the key position and avoid excessive twisting or force when inserting cable. It is recommended that the cable be supported along its entire length to prevent the cable from sagging.
   c. Check that the small green grounding wire on the connector is tightly attached.

5. Using a user-supplied coaxial cable, connect the pulse input BNC on the side of the cylinder to the output of a separate user-supplied pulse generator.

6. Complete gun installation, attaching other gun cables as described in Section 2.3.

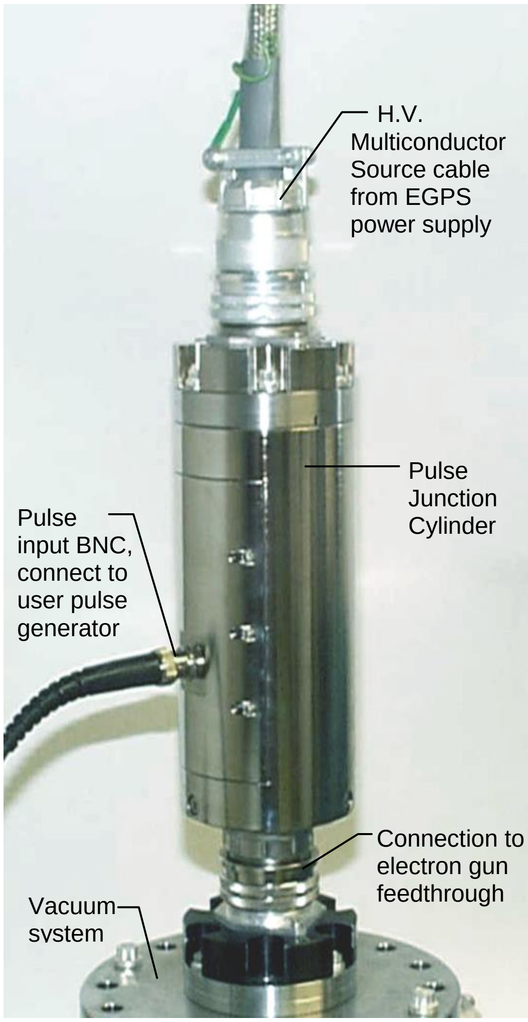


Fig. 4.8-2 Pulse Junction Cylinder, installed on a typical electron gun, showing connections

CAUTION

Do not use ECC mode when pulsing.
The ECC feedback may raise the cathode temperature and reduce cathode lifetime.

The input BNC on the Pulse Junction Cylinder must NOT be grounded, even when not in use.

CAPACITIVE BEAM PULSING with PULSE JUNCTION CYLINDER: OPERATION

1. Start up the electron gun in normal Source mode according to Section 4.2.
   CAUTION: Do not use ECC mode when pulsing.

2. On the EGPS, adjust the Grid voltage with the **GRID** potentiometer to just completely cut off the electron beam current. (The way the voltages control the beam is described below.)

3. On the user-supplied pulse generator, set the input pulse:
   a. Turn on the generator, and set the desired pulse rate.
   b. Adjust the positive voltage input to the Pulse Junction Cylinder so that the desired pulsed beam current is achieved.
   c. Using an oscilloscope, the pulse amplitude and the grid voltage can be fine-tuned to reduce ringing and improve beam output. Note: When monitoring the beam pulse, the input impedance of the oscilloscope may need to be changed by use of a terminating resistor.

4. When not using the pulsing option: Disconnect the user-supplied pulse generator.

CAUTION: The input BNC on the Pulse Junction Cylinder must NOT be grounded even when not in use. If the BNC is grounded, the grid in the gun will be grounded, and not at the voltage set.

CAPACITIVE BEAM PULSING with PULSE JUNCTION CYLINDER: DESCRIPTION OF GRID PULSING VOLTAGES AND BEAM RESPONSE

Pulsing of the beam current is accomplished by sending a pulse through a capacitor to the control grid Wehnelt aperture. A pulse width from 20 nsec to 100 µsec, with up to a 10 MHz repetition rate (20% duty cycle maximum) can be created with an appropriate pulse generator.

The grid voltage is negative with respect to the cathode. To pulse the gun on, positive voltage pulses are required. The grid voltage on the EGPS Power Supply should be turned up so that the electron beam is cut off. Data is supplied in the Data Section showing the grid cutoff values for the gun. By sending a pulse of the appropriate amplitude through the Pulse Junction Cylinder, the gun will be turned on for the duration of the pulse.

A capacitor in the Pulse Junction Cylinder isolates the high voltage from the low voltage pulse generator. The pulse is transmitted from a ground-referenced pulse generator, through this capacitor to the control grid which is floating at the high voltage of the Energy supply.

The figure on the following page illustrates the beam current response in fast beam pulsing. The grid power supply and pulse generator outputs superimpose to produce the voltage applied to the grid aperture. This grid voltage then controls the beam current.

4.8 BEAM PULSING OPTIONS cont.

CAPACITIVE BEAM PULSING with PULSE JUNCTION CYLINDER: DESCRIPTION OF GRID PULSING VOLTAGES AND BEAM RESPONSE cont.

For example, a grid cut off voltage of -300 V plus a positive pulse of +200 V yields a pulse of –100 V on the grid inside the gun. This combined voltage then pulses the beam on. The values shown for illustration purposes are for a typical EGG-3H Electron Gun at high Energy range. The actual values of grid cut off and beam current will vary with the gun model and operating parameters (see the Data Section at the end of the manual).

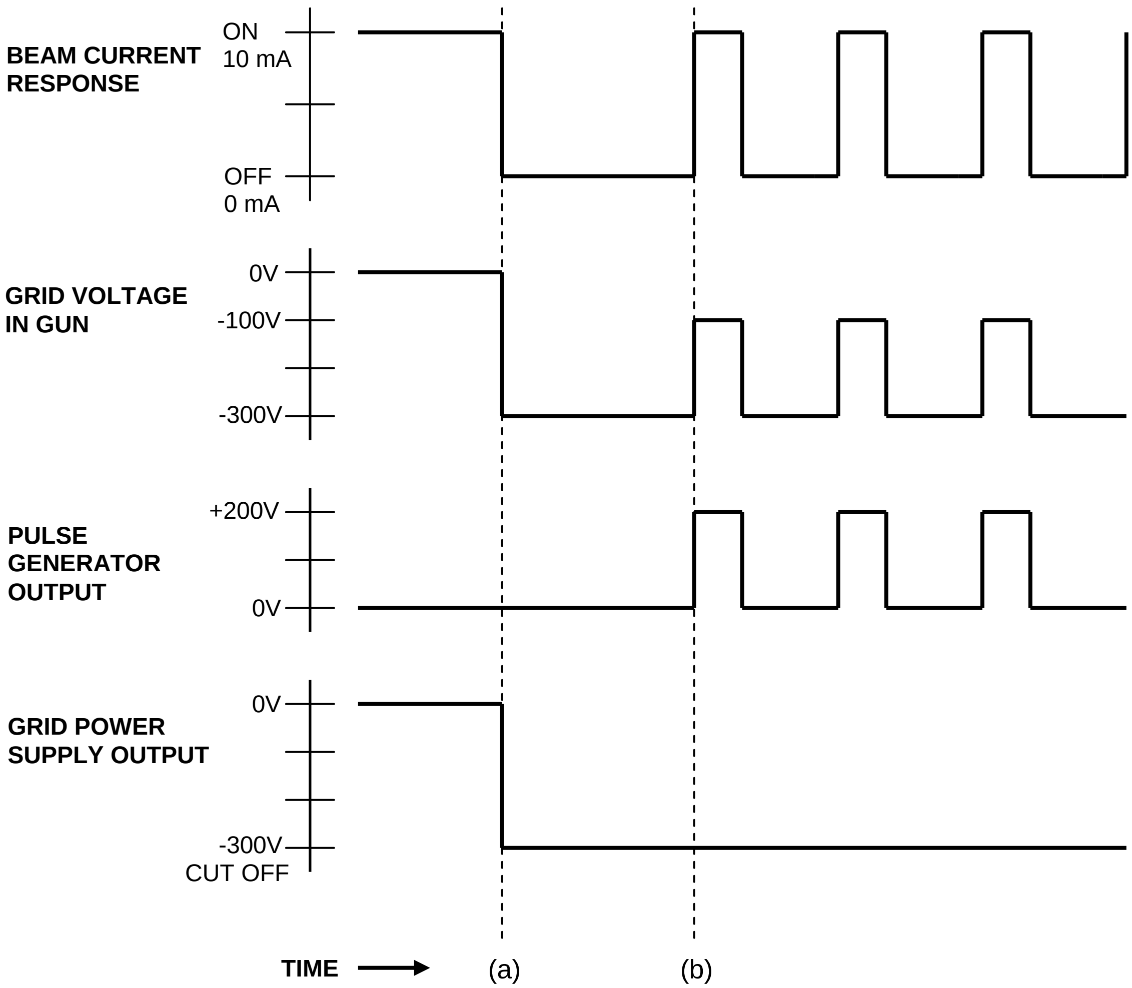


Fig. 4.8-3 Capacitive Fast Beam Pulsing diagram: At time (a) the grid power supply control is set to the cut off voltage, and at time (b) the pulse generator is turned on.

This completes the Capacitive Beam Pulsing Instructions.

4.9 FARADAY CUP ASSEMBLY OPTION

The Faraday cup assembly, mounted on the front end of the Electron Gun, is positioned by either a rotary feedthrough or a pneumatic actuator assembly, located on one of the 1⅓ inch (34 mm) conflat flanges on the Flange Multiplexer. The two types of gun-mounted Faraday cup are shown below in Figures 4.8.1 and 4.8.2. The Faraday cup assembly is UHV compatible, and can be heated to 350°C; however, the optional pneumatic cylinder and its external plastic tubing should be removed for bakeout. Some guns which were purchased without a Faraday cup can be modified for the addition of a Faraday cup assembly at the factory.

The Faraday cup assembly consists of three basic parts: the electrically-isolated stainless steel collector cup / aperture, the grounded external shield cup, and the hinge / link assembly. The collector cup is mounted coaxially inside the shield cup on an Al_2O_3 insulator. The cup assembly rotates around the hinge pin mounted on the rim of the shield cup. The hinge / link assembly is connected to either the rotary feedthrough via a rod which turns the cup to one side of the beam, or to the pneumatic actuator assembly via a push / pull slide rod. The beam current signal is transmitted by a stainless steel wire isolated in Al_2O_3 tubing to a BNC feedthrough located on one of the 1⅓ CF flanges on the Flange Multiplexer. The Faraday cup can be biased at a non-ground potential to increase collection efficiency.

The rotary feedthrough consists of a calibrated knob and a locking screw. The zero position on the knob indicates that the Faraday cup is in position in the beam line; turning the knob rotates the cup into and out of the beam line. The rotary feedthrough is operated manually.

The pneumatic actuator assembly consists of two basic parts: the removable dual-action pneumatic cylinder, and the 1⅓ CF flange / welded metal bellows feedthrough sub-assembly. The cylinder can be actuated either with air pressure or optionally with a manual knob. A sliding lock button provides positive positioning of the cup assembly when operating the Faraday cup in the manual mode.

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POWER INPUT CAUTIONS

For continuous measurement, the maximum recommended beam power into the standard gun-mounted Faraday cup is 2 watts. The Faraday cup temperature should not be raised above 350ºC due to outgassing. The overall power input is of concern mainly with the EGA-1106, EFG-11, High Current EMG-12, and High Current EMG-14 Electron Guns. The focused beam power density is of concern with any focusable gun.

The power input can be calculated by multiplying the beam current times the electron acceleration voltage; for example, 1 mA at 20 keV gives 20 W, much too high for continuous measurement. The temperature of the Faraday cup increases approximately linearly with the power input. A 2 W input results in approximately 150ºC, and a 4 W input in 300ºC.

To use the Faraday cup at high power, measure currents briefly and then let the Faraday cup cool down before repeating the measurement. For a large Faraday cup (such as on the EFG-11, EMG-12, or EMG-14), a 20 W input for 20 sec will raise the cup temperature by approximately 100ºC, due to the heat capacity of the cup. The cup will then dissipate this heat and cool to the initial gun temperature in 10 to 15 min. For a small Faraday cup (such as on the FRA-2X1-2, ELG-2, ELG-5, or EFG-7), the lower heat capacity of the smaller cup is compensated for by the low maximum power output of the gun. For non-standard applications, the acceptable power into the cup and the heat dissipation should be verified.

Care must always be exercised when using a highly focused beam, as a high power density can bring the Faraday cup to melting temperature in the impact region of the beam. For example, an electron gun with an output of 1 mA at 10 keV focused to a 1 mm spot size has a power density of approximately 13 kW/cm^2. Assuming no heat flow, this would bring the Faraday cup stainless steel at the spot to its melting point in only 11 μsec.

4.9 FARADAY CUP ASSEMBLY OPTION cont.

4.9.1 FARADAY CUP with PNEUMATIC ACTUATOR

CAUTION

High beam power can melt Faraday cup components.
Maximum recommended beam power into the Faraday cup is 2 WATTS continuous.

INSTALLATION OF ELECTRON GUN AND FARADAY CUP WITH PNEUMATIC ACTUATOR

1. Ensure that there is proper clearance in the host vacuum system for the Faraday cup to rotate out of the beam line when in the retracted position.

2. Manually position the Faraday cup to the measuring position (in-line position) and lock in position using the sliding lock button. Note: The red indicator on the sliding lock button is visible when the pneumatic cylinder is locked. (If there is no manual knob and lock button, use the shipping bracket at the end of the actuator to lock the Faraday cup in position.)

3. Install the Electron Gun according to the instructions in Section 2.3.

4. Connect the pneumatic cylinder to a 4-way electro-pneumatic valve (not supplied) using 1/8 inch plastic tubing.

5. Connect the valve via an air regulator to a clean dry air supply. Adjust the air regulator to 40 - 60 psi.

6. Connect a suitable ammeter or pico-ammeter to the Faraday cup output BNC located on the Flange Multiplexer.

7. **Remove pneumatic unit for bakeout**: Remove plastic tubing. Remove the two 6-32 socket head cap screws. Press the pin on tube toward the actuator, and slide unit sideways to remove.

CAUTION: The maximum temperature allowed for the pneumatic cylinder is 65ºC.

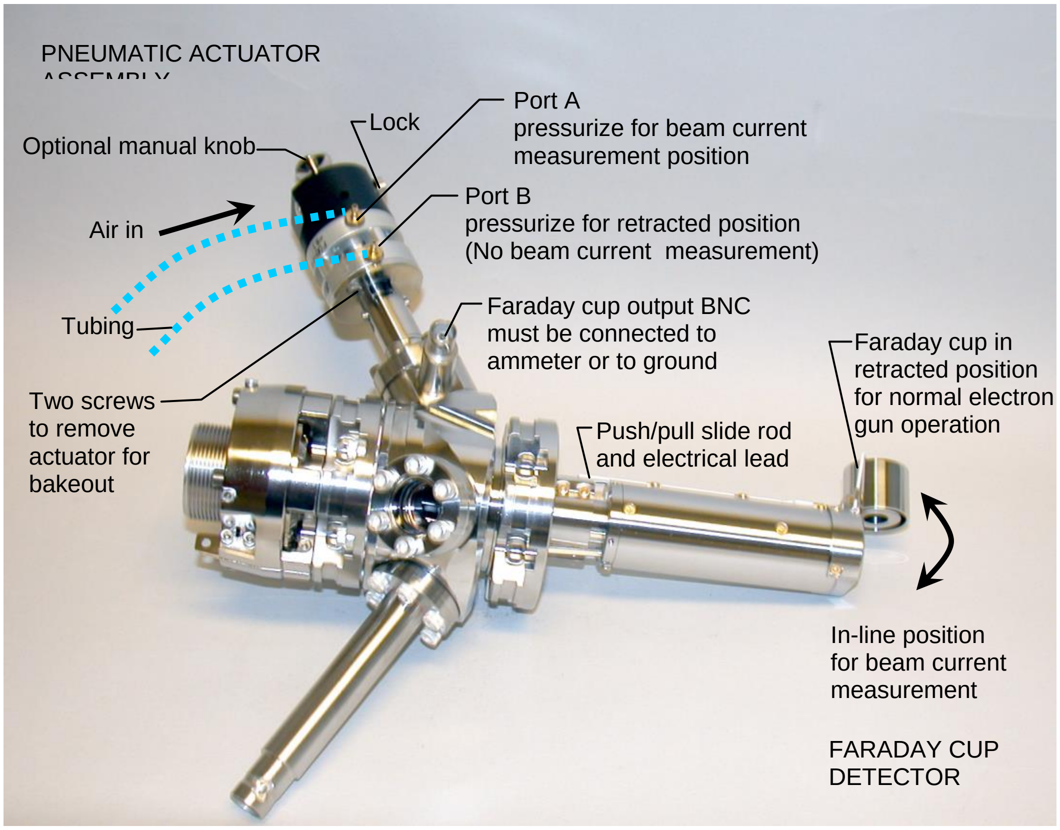


Fig. 4.9-1 Faraday Cup Assembly with Pneumatic Actuator

4.9 FARADAY CUP ASSEMBLY OPTION cont.

NORMAL OPERATION OF FARADAY CUP WITH PNEUMATIC ACTUATOR

1. Ensure that an ammeter is connected to the Faraday cup BNC located on the Flange Multiplexer. ***NEVER* collect beam current in the Faraday cup without proper termination of this BNC** (connected to an ammeter or grounded using a "shorting" BNC connector). Without proper termination the Faraday cup, the BNC center terminal will charge up to full beam acceleration voltage and electrical discharging will result.

2. Check the actuator:
   a. With the optional manual controls: Unlock the actuator by positioning the sliding lock button so that the red indicator is not visible. Check the actuator for free movement by cycling with the manual actuator knob at the end of the actuator cylinder.
   b. Without optional manual controls: Remove the shipping bracket from the end of the actuator to unlock it. Check the actuator for free movement by alternately applying air pressure and venting the ports.

3. Calculate the expected power input into the Faraday cup and check that it is within the acceptable range. See the discussion of power input cautions.

4. To measure beam current:
   a. Apply air pressure to Port “A” and vent Port “B” to position the Faraday cup in the measuring position (in-line position); see Fig 4.8.1
   b. Read beam current on the ammeter.
   c. Check beam power (beam current x electron acceleration voltage). If power exceeds 2 Watts, measure briefly, then move Faraday cup off line to cool down before repeating.

5. To operate the Electron Gun so the beam current is delivered to the target.
   a. Apply air pressure to Port “B” and vent Port “A” to position the Faraday cup to the non-measuring position (retracted position).

OPTIONAL MANUAL OPERATION OF FARADAY CUP WITH PNEUMATIC ACTUATOR

1. Ensure that an ammeter is connected to the Faraday cup BNC located on the Flange Multiplexer. ***NEVER* collect beam current in the Faraday cup without proper termination of this BNC** (connected to an ammeter or grounded using a "shorting" BNC connector). Without proper termination the Faraday cup, the BNC center terminal will charge up to full beam acceleration voltage and electrical discharging will result.

2. Calculate the expected power input into the Faraday cup and check that it is within the acceptable range. See the discussion of power input cautions.

3. To measure beam current:
   a. Unlock the actuator by positioning the sliding lock button so that the red indicator is not visible.
   b. Push in the manual actuator knob at the end of the actuator cylinder.
   c. Lock the Faraday cup in position by pushing the sliding lock button so that the red indicator is visible.
   d. Read the beam current on the ammeter.
   e. Check beam power (beam current x electron acceleration voltage). If power exceeds 2 Watts, measure briefly, then move Faraday cup off line to cool down before repeating.

4. To operate the Electron Gun so the beam current is delivered to the target:
   a. Unlock the actuator.
   b. Pull the manual actuator knob out.
   c. Lock the Faraday cup in the retracted position by pushing the sliding lock button so that the red indicator is visible.

This completes the Faraday Cup with Pneumatic Actuator Instructions.

4.9 FARADAY CUP ASSEMBLY OPTION cont.

4.9.2 FARADAY CUP with ROTARY FEEDTHROUGH

CAUTION

High beam power can melt Faraday cup components.
Maximum recommended beam power into the Faraday cup is 2 WATTS continuous.

INSTALLATION OF ELECTRON GUN AND FARADAY CUP WITH ROTARY FEEDTHROUGH

1. Ensure that there is proper clearance in the host vacuum system for the Faraday cup to rotate into and out of the beam line.

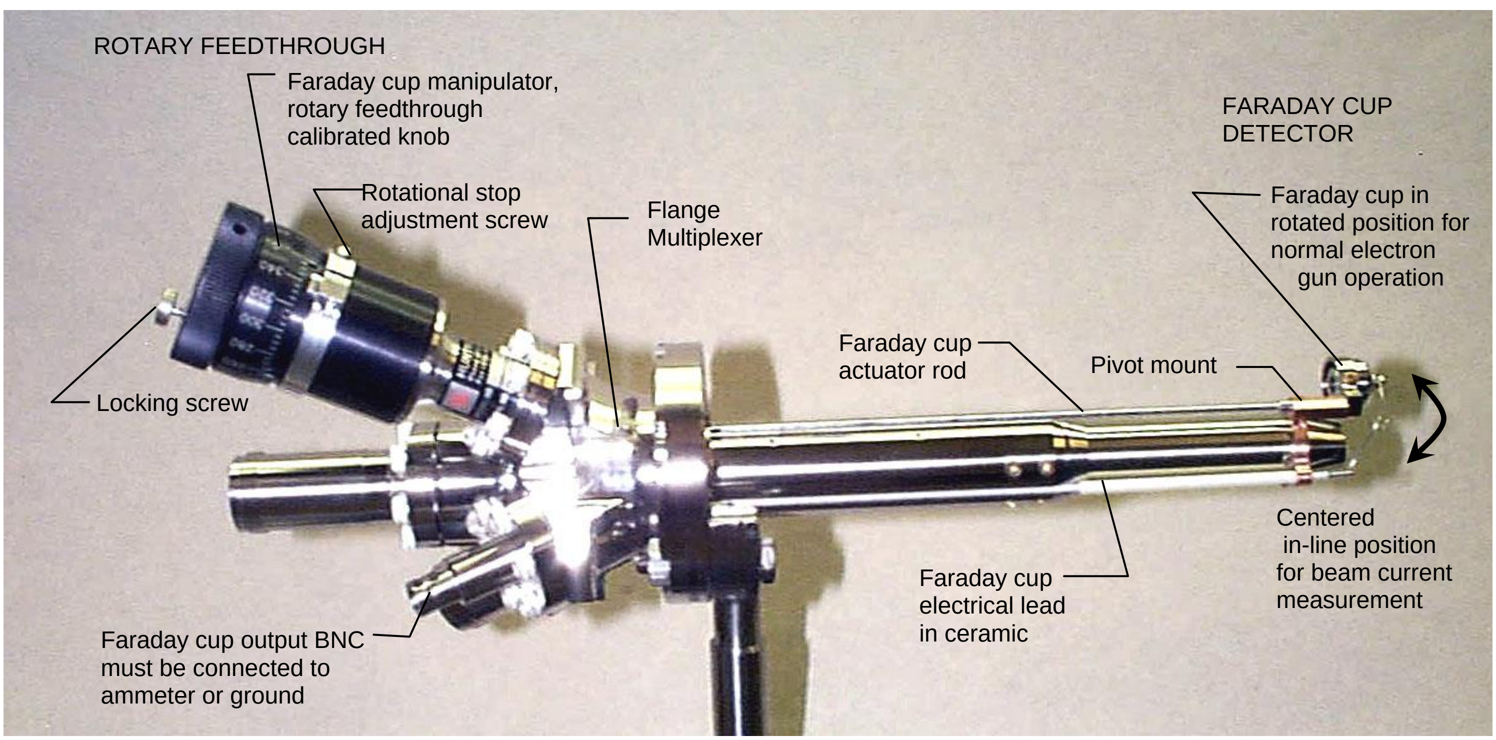
2. Manually position the Faraday cup to the centered measuring position by turning the black calibrated knob to zero, and lock in position using locking screw (the large screw on top of the black knob, not visible in photo).

3. When the gun is built, the degree of rotation is set so that the Faraday cup rotates between the centered in-beam position and an out-of-beam position which does not interfere with gun operation. The rotational stop can be adjusted with its adjustment screw, but this should not be necessary unless the Faraday cup is disassembled.

4. Install the Electron Gun according to the instructions in Section 2.3.

5. Connect a suitable ammeter or pico-ammeter to the Faraday cup output BNC located on the Flange Multiplexer. If there are two BNCs, the Faraday cup one will be stamped with an **F.**

CAUTION: The maximum bake out temperature of the Rotary Feedthrough is 300ºC, which is less than that for the Faraday cup, its feedthroughs and the rest of the gun (usually 350ºC).



OPERATION OF FARADAY CUP WITH ROTARY FEEDTHROUGH

1. Ensure that an ammeter is connected to the Faraday cup BNC located on the Flange Multiplexer. ***NEVER* collect beam current in the Faraday cup without proper termination of this BNC** (connected to an ammeter or grounded using a "shorting" BNC connector). Without proper termination the Faraday cup, the BNC center terminal will charge up to full beam acceleration voltage and electrical discharging will result.

2. Calculate the expected power input into the Faraday cup and check that it is within the acceptable range. See the discussion of power input cautions.

3. To measure beam current:
   a. Unlock the locking screw.
   b. Turn the black, rotary feedthrough knob to **0** indicating the Faraday cup is centered in the beam line.
   c. Lock the Faraday cup in position by tightening the locking screw on the top of the black knob.
   d. Read the beam current on the ammeter.
   e. Check beam power (beam current x electron acceleration voltage). If power exceeds 2 Watts, measure briefly, then move Faraday cup off line to cool down before repeating.

4. To operate the Electron Gun so the beam current is delivered to the target:
   a. Unlock the locking screw.
   b. Turn the black, rotary feedthrough knob, rotating fully to the stop, to move the Faraday cup out of the beam line.
   c. Lock the Faraday cup in the off-line position with the locking screw.

This completes the Faraday Cup Instructions.

4.10 BEAM BLANKING AND PULSING OPTION

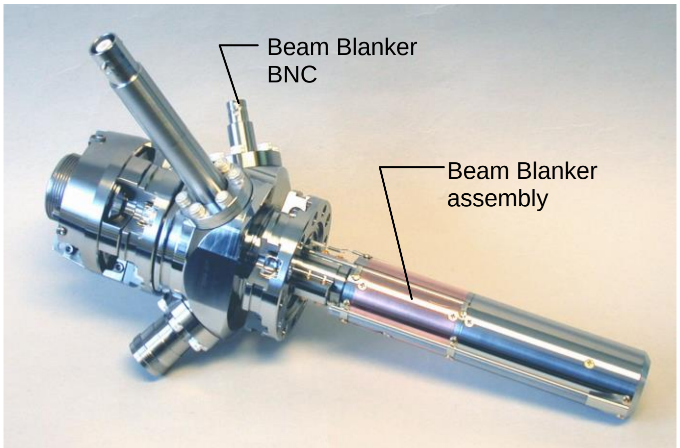


Fig. 4.10-1 Typical electron gun with an optional Beam Blanker (copper section)

Fig. 4.10-2 Typical EGPS power supply, showing controls for optional Beam Blanking unit

The beam blanking and pulsing option requires a blanker plate assembly built into the Electron Gun and an additional blanker supply unit in the main Power Supply. Beam blanking deflects the electron beam into a beam trap on the side of the gun tube, so that the flow of electrons to the target is interrupted without actually turning off the beam. The deflecting voltage applied to the blanker plate in the gun is controlled by a potentiometer on the EGPS Power Supply. The blanker voltage required for beam cutoff depends on the gun configuration and on the beam energy.

Blanking can be used to pulse the final beam current repeatedly on and off in response to a TTL signal input. A TTL (transistor-transistor logic) pulse source is required, such as a separate user-supplied pulse generator unit. Typically, beam pulse widths from 1 μsec to DC and repetition rates up to 10 kHz maximum can be achieved with appropriate TTL inputs.

DESCRIPTION OF CONTROLS

The following terminal(s) are found on **the Electron Gun**:

Blanker BNC: An input BNC on one of the mini conflat flanges on the Flange Multiplexer on the Electron Gun that connects the input from the Power Supply to the blanker plates inside the gun.

Blanker BNCs for ERG 21 only: An input BNC with a black ring on the blanker control box on the side of the Electron Gun that connects the input from the Power Supply to the blanker plate inside the gun. The other BNC (unmarked) on the blanker control box on the side of the Electron Gun must be grounded; it is shipped with a BNC grounding cap.

The following controls and terminals are found on the **EGPS Power Supply**:

Blanker Switch: An amber pushbutton switch labeled **BLANKER** that enables or disenables the power supply in the blanker unit. When the switch is off, the Beam Blanker output is switched to ground to allow normal operation of the Electron Gun.

Blanker Control: A ten-turn potentiometer labeled **BLANKER** that voltage programs Blanker power supply (Standard range: 0 to +600 V)

Normal/Invert Switch: A toggle switch labeled **NORMAL/INVERT** controls the type of output produced by the Beam Blanker unit.

TTL BNC: An input BNC labeled **TTL INPUT** on the front of the Power Supply for the input of a TTL pulse generator or signal generator with +5 volts square wave output for pulsing operation of the Beam Blanker. For optional rastering, this BNC can be connected to the Raster Generator Deflection Unit for synchronization.

Blanker Output: An output BNC, labeled **BLANKER** on the back panel of the Power Supply that connects with the BNC connector on the Electron Gun via a 3.0 m length of 50 ohm (RG-58) coaxial cable.

4.10 BEAM BLANKING AND PULSING OPTION cont.

CAUTION

The **Beam Blanker BNC(s)** on the gun must always be either

A) connected to the Blanker amplifier of the power supply via the coaxial cable OR

B) shorted to ground.

This is necessary to prevent the Blanker plates inside the electron gun from charging up during normal gun operation.

OPERATION OF THE BEAM BLANKER

1. Set up:
   a. Connect a user-supplied TTL generator with a **0 V to +5 V** square wave signal to the **TTL INPUT** BNC on the EGPS Power Supply. Monitor the input signal with an oscilloscope.
   b. Connect the Blanker coaxial cable between the **BLANKER** BNC on the EGPS Power Supply and the Blanker BNC on the Electron Gun.
   c. **For ERG-21 only**, connect the cable from the Power Supply to the BNC marked with a **black band** on the blanker control box on the side of the Electron Gun, and ensure that the other BNC on the blanker control box is grounded.

2. **On the EGPS,** depress the amber pushbutton labeled **BLANKER** to energize the Beam Blanker system.

3. Set the blanker voltage with the **BLANKER** potentiometer, as read on the DVM, with **FUNCTION** in the Blanker position and the Blanker LED light on.

4. Determine the appropriate blanking voltages needed for beam cutoff (See graphs in the Data Section). If the blanker voltage is too low, the beam will not be deflected into the beam trap. If the voltage is too high, there may be some scattering. Due to small system variations, the user should independently confirm that beam cutoff is achieved.
   NOTE: The cutoff voltage increases linearly with Energy, and so Blanker Voltage must be readjusted if the Energy is varied.

5. Turn the blanker on and off using the 0 V to +5 V TTL input signal for pulsing. Alternatively, the blanker can be controlled manually by switching the **NORMAL/INVERT** toggle switch up and down.

6. Monitor the beam current using a Faraday cup at the end of the gun, connected to a high speed current amplifier which is then connected to an oscilloscope. The amplifier is needed due to the input capacitance of the oscilloscope, and must have a rise time fast enough for pulse width desired.

7. Depending on the operating conditions, the voltage applied to the blanker plate, and the amount of electron scattering inside the gun, there may still be some beam current at the target, when the blanker is on; further adjustment of parameters may be needed.

8. Inverting the signal (optional): If desired, the signal can be reversed by changing the toggle switch labeled **NORMAL/INVERT** to the **INVERT** position. (See Fig. 4.10-3) For example: If the beam is on for 1.0 msec and blanked for 10.0 msec with the switch in the **NORMAL** position, switching to the **INVERT** position will cause the beam to be on for 10.0 msec and blanked for 1.0 msec.

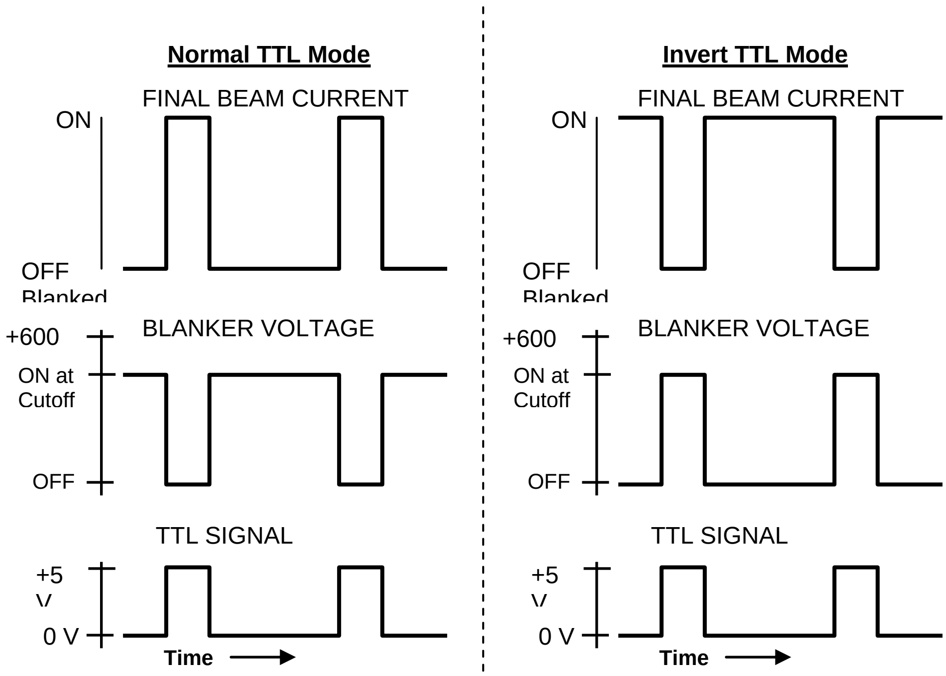


Fig. 4.10-3 Normal and inverted TTL pulsing signal, Blanker response to signal, and final beam current response.

5 GENERAL OPERATING HINTS

5.1 HINTS ON HANDLING ELECTRON GUNS

5.1.1 HANDLING

Although the electron gun is quite rugged, it should be handled carefully and not knocked or dropped. Some guns have obviously-fragile ceramics and fine connections on the exterior of the gun tube; others have similar fragile parts inside the gun, which could also be damaged. Care should be taken that the gun does not hit against anything when inserting it or removing it from the vacuum chamber. Careful handling and storage are important when the gun is out of vacuum.

5.1.2 DUST AND DEBRIS

Precautions should be taken to keep dust and debris out of the electron gun and vacuum system. Some useful procedures are: wearing clean room gloves when handling the part of the gun that goes into vacuum, observing clean room procedures when working around UHV equipment, covering open vacuum ports when equipment is removed even temporarily, storing the gun properly.

Debris inside the electron gun can decrease performance and may cause discharging. Particles can sometimes be seen as irregularities in the spot viewed on a phosphor screen, while discharging may be observed as spikes in the emission current or pressure pulse in the vacuum chamber pressure.

Dust and debris can sometimes be blown off equipment using a can of compressed, microscopically-clean gas; this is not a substitute for keeping the gun clean. Bakeout (heating the gun to a high temperature, with any cables and heat-sensitive assemblies removed) can help to remove contaminants. The electron gun may be sent back to the factory for complete disassembly, cleaning, and rebuild of the firing unit assembly.

5.1.3 STORAGE

When the electron gun is not in vacuum, it should be stored carefully. Mounted guns can be bolted into their original stainless steel shipping tube to protect the knife edge on the flange and to keep the gun clean. Small unmounted guns and other parts can be placed in sealed bags, foil, or covered containers. The gun and other equipment which goes into vacuum should be stored on closed shelves.

Most guns can be stored in the laboratory at normal temperatures and pressures. While at room temperature, the standard refractory metal cathodes used in most electron guns are not harmed by repeated exposure to atmospheric gases. If a gun has a barium oxide (BaO) cathode, it is best to store the gun in vacuum; if it must be stored out of vacuum, it should be placed in a clean, dry environment such as a tightly sealed plastic box with desiccant, as BaO is susceptible to degradation by water vapor.

5.2 HINTS ON WORKING WITH VACUUM

5.2.1 HIGH VACUUM MATERIALS

All materials used in constructing the electron guns are compatible with ultra-high vacuum (UHV) technology. It is important that any materials used in vacuum with the gun be UHV-compatible or not out-gas, that is not release molecules when put into ultra-high vacuum.

The tiny gold-colored screws used in the gun are actually gold-plated stainless steel, which does not out-gas appreciably; if any screws are lost they should not be replaced with brass or other metal screws which could cause a problem with out-gassing. Gaskets used on the vacuum flanges should not be rubber, but either Viton or copper.

Feedthrough insulators are made of ceramic, which is extremely fragile and can be degraded by finger prints. Sometimes cutting a feedthrough wire or bending a pin can crack the ceramic insulator causing a leaky feedthrough.

In general, a number of common materials (such as most types of insulated wire, rubber tubing, electrical tape, tape labels, duct tape or anything with adhesive) are not vacuum compatible and must be avoided.

5.2.2 VACUUM TECHNIQUES

The quality of the vacuum affects the performance of the electron gun. The vacuum is usually achieved by the use of two pumps: a rough pump and a turbo-molecular pump. A trap between the pump and the vacuum system can help prevent oil from the pumps getting back into the system.

An ion gauge, which is actually an ion gun and detector system, is used to measure the gas molecules present in the vacuum chamber and so monitor the chamber pressure. The ion gauge should be attached to the vacuum chamber near the electron gun, but out of the way of the electron beam and target.

When starting the vacuum pumps, be sure to shut the vent valve; a hissing noise will be heard if the valve is not closed. While the system is pumping down, the pressure should be monitored by appropriate gauges (TC gauge, ion gauge, Penning gauge, etc.), as well as by listening to the sound of the pumps. It is a good idea to make an experimental pump down curve of the laboratory vacuum system, measuring the pressure in the vacuum chamber vs time; this graph can be useful for comparing the system's performance if there is a problem and for determining the time to establish a stable vacuum for the gun.

When bolting the electron gun or other equipment to a vacuum port, a new copper gasket should be used for a good permanent seal, because the knife edge on the flange cuts into the copper as the bolts are tightened. However, a Viton O-ring gasket can be used, and reused, for pieces that are frequently removed; with Viton, care should be taken that the gasket is clean, free of debris, properly-seated, and not pinched, or else it will leak. The bolts on the vacuum port should not be tightened all at once, but gradually in a (usually triangular) pattern such that bolts across from each other are tightened partially; the pattern is repeated until all the bolts are tight. This procedure should produce an even, tight seal.

If a hissing noise is heard (indicating a gross leak) when the chamber is evacuated, or if the turbo pump does not go up to full speed, or if the pressure does not seem to go down normally (for example, if it goes down but then goes up or varies), check the vacuum connections for possible leaks. Inspect Viton O-rings for pinches, debris, or slight irregularities, then replace or reposition them; tighten all the bolts on vacuum flanges with Viton or copper gaskets evenly.

Cleanliness is very important in maintaining a proper vacuum. In addition to dust or debris from the environment, the target itself can cause a problem. For example, phosphors from a phosphor screen target are sometimes found in the electron gun and on other surfaces in the vacuum chamber. The outside of the gun and other vacuum surfaces can be wiped off with Isopropyl alcohol and blown off with a can of microscopically-clean compressed air. For more complete cleaning, disassembled parts can be washed in distilled water and a concentrated cleaning solution (such as Micro-90, a mixture of water, glycine, benzenesulfonic acid and other agents) and cleaned by ultrasonic vibration.

Before turning on the electron gun, it is essential to establish a stable vacuum. After the gun is turned off, the cathode must be allowed to cool down before the vacuum system is vented. A poor vacuum can damage the cathode or reduce its lifetime.

If the electron gun is energized without a proper vacuum, it can be damaged by arc-overs and can expose the operator to a severe electric shock hazard.

(See also Hints on Setting up the System- Vacuum Requirements.)

5.3 HINTS ON SETTING UP THE SYSTEM

5.3.1 INSERTING THE GUN

When inserting the electron gun into the vacuum system, care must be taken to avoid damaging either the gun or the cables. Plastic gloves should be worn when handling the gun, so that the whole gun can be held and supported without contaminating the vacuum surfaces with fingerprints, (unless the gun is very small and can be easily held by just the part of the flange which is outside vacuum). Do not handle connector ends, gaskets, or other surfaces exposed to the vacuum with bare hands, because degradation of the insulator and vacuum surfaces will result if contaminates are present in the system.

Be sure that there is adequate clearance and working distance in the vacuum system before inserting the gun, and then be sure to insert the gun carefully straight through the port. If the gun is knocked against the vacuum system, the lens elements in the gun can become misaligned, and fragile insulators can easily be broken. If there is a Faraday cup on the end of the gun, additional clearance will be needed to allow room for the Faraday cup to swing into and out of line.

Before bolting the gun into vacuum or connecting the cables to the gun, it is a good idea to check the positioning of the gun and cables. Observing the location of the key on the gun connector and the key on the end of the cable will allow the gun and cable to be approximately lined up before they are connected. The cables may be damaged if they are twisted or bent, or if too much force is used when connecting them; excessive force could also damage the gun. In addition, the gun deflection plates should be oriented relative to the experimental target before tightening the bolts and connecting cables.

When bolting the gun on to the vacuum port, the bolts should be tightened gradually and evenly, in a pattern that alternates sides, so that there is a good seal and so that the gun is not pushed over to one side. If a mechanical alignment device, such as a Port Aligner, is used, care must be taken that it dose not cause the gun to hit the vacuum system which can bend the gun body.

5.3.2 WORKING DISTANCE

In setting up the system, the working distance (the distance from the end of the electron gun to the target) will need to be determined. Many of the gun specifications are affected by the working distance; for example, at a longer working distance, there is more effect of noise, and beam current may be less, or the spot size may be larger. In general, the minimum working distance possible for the experiment should be chosen in order to reduce problems associated with transport of electrons including space charge spreading of the beam and beam distortions from stray magnetic fields and stray electric fields (i.e. the Earth's magnetic field and insulator charge-up).

5.3.3 BAKE OUT

To remove contaminants, adsorbed materials, water vapor etc. that may interfere with vacuum or with the electron gun performance, the gun as well as the vacuum chamber can be heated to the temperature given in the gun specifications. When heating the entire vacuum chamber, do not exceed the recommended maximum temperature for the laboratory turbo-pump flange.

After all cables and any heat-sensitive assemblies are removed from the gun, bakeout may be accomplished by a variety of methods, including electrical heating tapes, heating pads, an oven-like bakeout chamber, or UV light for some gases. For example, heating tapes can be wrapped flat around the vacuum chamber, a temperature probe laid against the metal, and the whole chamber wrapped in aluminum foil, being careful not to put tapes or foil over any glass windows. The heating tapes can be turned on and off to maintain the desired temperature for the desired time, usually several hours to 24 hours for the first bakeout depending on the size of the chamber.

In some guns, there are magnetic coils, a pneumatic Faraday cup actuator or other assemblies which are more heat-sensitive and must be removed or heated differentially. For example, on a gun with magnetic focus coils, heating tapes could be applied to only a part of the gun and the temperature could be monitored in the different areas. Care should be taken that these assemblies are not heated above their recommended maximum temperatures.

The time can be reduced for subsequent bakeout by back-filling with a dry gas, such as N_2 , when venting the chamber instead of letting in normal atmosphere. The removal of some materials, such as hydrogen, may take a long time.

The amount of water vapor or other materials present can be measured by a residual gas analyzer (RGA) to determine when bakeout is complete. Be careful to monitor the temperature of the gun and chamber with a probe during bakeout so that the temperature does not exceed the recommended value for either the gun or the pump.

5.3.4 THE ENVIRONMENT (Vacuum Requirements, Chamber, Electric and Magnetic Fields)

Vacuum Requirements

Before turning on the electron gun, it is essential to establish a stable vacuum. An electron gun with a standard refractory metal cathode requires a vacuum of 10^{-5} torr or better, while a gun with a BaO (barium oxide) or a LaB_6 (lanthanum hexaboride) cathode requires 10^{-7} torr, but one with a ThO_2 (thorium oxide-coated iridium) cathode requires only 10^{-4} torr. It is important to consider that, depending on how the vacuum system is set up in the laboratory and the position of the ion gauge, the actual vacuum level in the region of the electron gun may not be as good as where the vacuum is being measured.

A poor vacuum can damage the cathode or reduce its lifetime. For example, the presence of oxygen or water vapor while the refractory metal cathode is hot (over 700 K) will cause oxidation of the metals, while at higher temperatures (over 1200 K) nitrogen will further degrade the cathode. Thus, the vacuum must be well established before the gun is turned on, and after the gun is turned off, the cathode must be allowed to cool down (usually for at least a half hour) before the vacuum system is vented.

If the electron gun is energized without a proper vacuum, it can be damaged by arc-overs and can expose the operator to a severe electric shock hazard.

Vacuum Chamber

When the electron gun is run, there is danger that the vacuum chamber and objects inside it may charge up causing discharging and a HIGH VOLTAGE HAZARD. The vacuum chamber must be connected to a proper Earth ground. In addition, any unused electrical feedthroughs on the vacuum system, such as BNCs, need to be grounded or they will charge up.

Space inside the chamber should be kept as clear as possible. Non-conductive materials inside the vacuum system, such as plastics, ceramics, or coated wires, can charge up and affect the electric field inside the chamber. For example, a stray coated wire near the beam could repeatedly charge up and discharge, causing the electric field to vary; this would distort the beam and make the spot appear to jump repeatedly.

Electric and Magnetic Fields

Tools, metal pens, metal rulers, magnets and similar objects should not be left in the working area around the electron gun. Such objects and nearby electrical equipment can cause distortion or deflection of the electron beam. Background 60-cycle noise can also affect performance. In some cases, a sheet of μ-metal *(mu-metal)* wrapped around the gun can be used to help shield the gun from stray electromagnetic fields.

5.3.5 SETTING UP THE POWER SUPPLY (Location, Cable Support)

In general, the Power Supply must be located close enough to where the electron gun will be installed in vacuum that the cables will reach easily and not be bent sharply, usually within 2 meters of the gun. There must also be adequate clearance in back of the Power Supply for access to the rear panel, usually at least 0.5 meters of clearance. Space is needed so that cables can be plugged in without being bent and so that the remote controls on the rear of the Power Supply can be reached.

It is important that the High Voltage cables from the power supply to the gun not be bent or twisted excessively. Multiple cables can be held together with plastic cable ties and fastened to a nearby rack or pipe at several spots to support the cables and prevent them from being twisted, bent at a sharp angle or stepped on in the lab.

5.4 HINTS ON OPERATING ELECTRON GUNS

5.4.1 HIGH VOLTAGE AND X-RAY SAFETY

Safety from possible hazards due to High Voltage or X-ray radiation must be a consideration in setting up and operating the entire system. Proper high voltage precautions and grounding techniques must be observed.

In no event should the Power Supply be energized unless the electron gun is bolted into a properly evacuated high vacuum chamber. Proper vacuums are better than 1 x 10-5 torr for refractory metal cathodes, or better than 1 x 10-7 torr for LaB6 and BaO cathodes. To energize the system without proper vacuum would cause the gun to be damaged by arc-overs, that expose the operator to a severe electric shock hazard.

In no event should the safety interlocks on the High Voltage cable, or in the Power Supply, be disconnected or bypassed.

For a higher-powered electron gun (over 10 keV): Since high energy electrons striking targets or any other surface on the interior of the vacuum chamber may generate x-ray radiation, x-ray radiation shielding is recommended when using the electron gun. This x-ray shielding is part of the host vacuum system. Therefore, the purchaser must observe proper radiation shielding procedures to protect personnel and/or property when designing the host vacuum system into which the gun is to be inserted.

When observing the target area of a higher-powered electron gun (over 10 keV), it is necessary to cover standard glass viewports with leaded glass; failure to do so could increase the risk of exposure to x-rays. Unleaded viewports are transparent to x-rays, so direct viewing of the cathode or target area through normal glass viewports is a radiation health hazard.

The purchaser's safety officer should inspect the installation and shielding of the electron gun prior to operation.

5.4.2 APPLYING HV: DISCHARGING

Discharging (sparking) can occur during operation of the electron gun if there is contamination, or a potential that builds up on gun elements, or a short somewhere in the gun. Such discharging can usually be observed as a momentary jump of the emission current meter needle; occasionally it can be heard.

If the gun has been out of vacuum, it is not unusual for there to be a small amount of discharging when the gun is first brought to high voltage or when the source current is first turned up to warm up the cathode. These initial discharges are due to impurities picked up by the gun while out of vacuum; however, this condition should not persist.

Discharging which continues or recurs cyclically probably indicates a problem with the gun, power supply or cables, and the gun should be turned off. Of course, if the user experiences a shock from touching any part of the system, there is a problem, and the system should be shut off immediately and indirectly (without touching the system).

5.4.3 APPLYING SOURCE CURRENT: CATHODE LIFETIME CONSIDERATIONS

In general, the higher the source current which is applied, the hotter the cathode becomes, and the shorter its expected lifetime. The cathodes used in the electron guns are quite rugged. The two factors that affect the cathode most are the temperature at which it is heated and the quality of the vacuum. Typical lifetimes for refractory metal cathodes range from less than 500 hours to over a thousand hours, depending on the filament current used and the vacuum environment.

Useable lifetimes for the lanthanum hexaboride (LaB_6) cathode can be thousands of hours. The lifetime of a BaO-coated or ThO_2-coated cathode or of a LaB_6 crystal cathode is based on the evaporation rate of those materials, which is dependent on the temperature at which the cathode is run and the vacuum.

The work function of the cathode also affects its lifetime; contamination of the cathode surface can increase the work function, increasing the filament current needed to produce the same beam current, and so burning out the cathode more quickly.

Cathodes should not be run at more than the recommended emission current given in the operating instructions. A higher current and high cathode temperature will cause the cathode to fail rapidly. In general, when the gun has been out of vacuum, the source current should be increased gradually, allowing the cathode to warm up. There is a trade off between overall cathode lifetime and speed of warm up; for some applications the user may choose to increase the source current quickly, but this will decrease the lifetime. Most cathodes which remain in vacuum may be brought to the desired temperature more quickly without causing damage.

Throughout the cathode▮s lifetime, the achievable beam current should be stable once the cathode has warmed up. It is a sign that the cathode is failing, if the operating parameters change drastically and a much higher source current is required to achieve the previous normal level of emission. Electron guns can be rebuilt at Kimball Physics, including the installation of a new cathode; in many guns, the cathode (firing unit assembly) is also user-replaceable according to detailed instructions in Section 6.

5.4.4 ADJUSTING AND OPTIMIZING PARAMETERS

For optimal performance of the electron gun, the various operating parameters should be carefully adjusted. Some typical values at which the gun was run during testing at Kimball Physics can be seen in the graphs in the Data Section. However, as the experimental set-up may vary, it is necessary to empirically adjust the parameters and evaluate the results by measuring beam current or spot size or whatever else is critical for the particular application.

Adjusting one parameter often has an affect on the others, and so some fine-tuning is necessary. For example, changing the grid voltage affects the position of the crossover in the triode, so that the focus voltage will need re-adjusting to maintain a constant spot size. In addition, there is a change in emission over the warm up period, so parameters may need adjusting later from their initial settings. Not only the settings of the controls on the power supply, but other system variables such as pressure or working distance, have an effect on the results.

5.4.5 USING THE POWER SUPPLY CONTROLS

The individual power supplies which apply voltage to various gun elements can be controlled either manually by the potentiometers on the front of the Power Supply or indirectly by a signal into the remote controls on the rear of the Power Supply. The dial potentiometers control a 0 to 10 V signal which directly controls the output of the individual power supply proportionally.

If a potentiometer control knob will not turn, check that the small locking toggle is up, in the unlock position. To be sure not to accidentally change a setting once the desired value has been determined, put the toggle down to lock the knob.

The output range of a particular power supply may not be the same as the corresponding analog meter used to monitor the power supply. For example, the Source Volts meter face may read from 0 to 2.0 V, but the Source power supply may be set with a limit of 1.5 V to prevent cathode damage, so that the actual range is 0 to 1.5 V; in this case, turning the Source potentiometer knob all the way up will yield 1.5 V, not 2.0 V.

The manual and remote controls for any individual power supply (e.g. energy, source, grid , focus, etc.) are mutually exclusive; that is, the supply can not be in manual and remote mode at the same time. It is possible though for one supply to be in remote mode while another is in manual mode. For example, energy and source can be controlled manually, while grid and focus are remotely controlled.

For each individual power supply, the manual or remote mode is selected by one of a set of switches behind the access panel on the back of the Power Supply. These switches are in the same order as the remote terminals on the back of the Power Supply, but do not necessarily line up with the terminals.

If a potentiometer on the front of the power supply turns but does not produce a change, check that the corresponding switch in back is not in the remote position; the switch must be pushed left for local manual control, not right for remote control. Conversely, if a remote control signal does not appear to produce an effect, check that the corresponding switch is not in the local position.

5.4.6 DETECTION TECHNIQUES (Faraday Cups, Phosphor Screens)

Faraday Cups

A Faraday cup connected to an ammeter can be used to detect and measure the actual beam current emitted from the electron gun. The Faraday cup consists of a hollow stainless steel cylinder closed at the base, with an appropriately sized aperture for collecting the electrons. An electrical connection is made to the Faraday cup to conduct the current to a vacuum electrical feedthrough and then to an ammeter. For best performance, an outer, grounded cylinder can be used for shielding.

The user can construct an appropriate Faraday cup (a full line of eV parts is available from Kimball Physics) or can order a Faraday cup and mounting system from Kimball Physics. The Faraday cup can be completely separate from the gun, or with some gun models, it can be part of an assembly mounted to the end of the electron gun and manipulated remotely with a manual knob or a pneumatic control.

To reduce scattering of electrons collected in the Faraday cup and to reduce secondary electron emission, the Faraday cup can be electrically biased. For electrons, +50 V, is typically adequate. This can be accomplished by placing a battery between the vacuum feedthrough and the ammeter.

A good way to assess beam uniformity is with a small Faraday cup on a device which can be made to scan across the beam. A closely packed set of three or four electrically-isolated Faraday cups on a manipulator would allow for simultaneous comparison of beam current density along several chords across the spot. Close to the end of the gun, spot size will be small and so a small Faraday cup translation will traverse a large percentage of the spot, while beam current density will be relatively high. Farther from the end of the gun, the spot size is larger, allowing for either more Faraday cups in the set or larger step sizes in the translation of a single Faraday cup. Beam current density will be correspondingly smaller. It may be useful to assess the beam current density distribution at a longer working distance where the spot is larger, then apply a transformation to these measurements to obtain beam current density across a spot at the desired working distance.

Phosphor Screens

During the initial operation of the electron gun system, the use of a grounded phosphor target screen is helpful as it allows visual, real-time observation of the spot. The phosphor screen emits light (photons) when bombarded by high energy particles (threshold value approximately 500 eV for electrons). The light color, typically blue or green, depends on the phosphor material. The screen can be used for alignment and to set the proper operating parameters necessary to obtain maximum beam uniformity.

Note that excessive power may cause phosphor screen damage. To preserve screen brightness, it is advisable to use the lowest power density that provides a clear spot. This density is calculated as the beam current times the beam energy divided by the spot size area. For standard Kimball Physics phosphor screens, the recommended maximum beam power density is 1 Watt/cm^2 .

Phosphor screens of various sizes made with high luminosity P22 phosphor (ZnS:Ag) can be purchased from Kimball Physics.

5.5 GENERAL LABORATORY REFERENCES

The following books may be useful in working with electron or ion guns:

Bakish, R., ed. *Introduction to Electron Beam Technology*. John Wiley & Sons, New York, 1962.

Cherepin, N.V. *Treatment of Material for Use in High Vacuum Equipment.* Ordentlich, , 1976.

Cumo, J.J., S.M. Rossnagel, and H.R. Kaufman. *Handbook of Ion Beam Processing Technology-- Principles, Deposition, Film Modification and Synthesis.* Noyes Publications, Park Ridge, NJ, 1989.

Kohl, W.H. *Handbook of Materials and Techniques for Vacuum Devices*. Reinhold Publishing Co., New York, 1967.

Lafferty, J.M., ed. *Foundations of Vacuum Science and Technology.* John Wiley & Sons, New York, 1998.

Lide, D. R. ed. *CRC Handbook of Chemistry and Physics.* CRC Press, Boston, 1991.

Moss, H. *Narrow Angle Electron Guns and Cathode Ray Tubes.* Academic Press, New York, 1968.

O'Hanlon, J.F. *A User's Guide to Vacuum Technology.* John Wiley & Sons, New York, 1980.

Pierce, J.R. *Theory and Design of Electron Beams.* Van Nostrand Co., New York, 1954.

Redhead, P.A., J.P. Hobson, and E.V. Kornelson. *The Physical Basis of Ultrahigh Vacuum.* American Institute of Physics, New York, 1993.

Roth, A. *Vacuum Technology.* North Holland Physics Publishing, Amsterdam, 1986.

Sedlecek, M. *Electron Physics of Vacuum and Gaseous Devices.* John Wiley & Sons, New York, 1996.

Wilson, R.G and G.R. Brewer. *Ion Beams with Application to Ion Implantation.* John Wiley & Sons, New York, 1973.

6 MAINTENANCE

6.1 ELECTRON GUN MAINTENANCE AND CLEANING

These are general maintenance recommendations; some guns may have specific care, handling, or vacuum requirements.

HANDLING

Although the Electron Gun is quite rugged, it should be handled carefully and not knocked or dropped. Some guns have obviously-fragile ceramics and fine connections on the exterior of the gun tube; others have similar fragile parts inside the gun, which could also be damaged. Care should be taken that the gun does not hit against anything when inserting it or removing it from the vacuum chamber. Careful handling and storage are important when the gun is out of vacuum.

GENERAL CLEANING

Optimum performance of the Electron Gun requires clean vacuum surfaces. As described in the Operating Hints, it is important to keep the gun clean by using proper handling procedures, such as wearing gloves, maintaining a good vacuum, and storing the gun properly. The system into which the gun is mounted should also be clean, including the flanges and gaskets. Dust and debris can be blown off equipment using compressed, microscopically-clean gas, such as nitrogen or a can of tetrofluroethane. Exterior surfaces can be wiped with isopropanol and a lint-free cloth.

Before cleaning the Power Supply, ensure that the system is off and the power cord is unplugged from the AC outlet. Exterior surfaces can be wiped with a slightly damp cloth.

STORAGE

When the Electron Gun is not in vacuum, it should be stored carefully. Mounted guns can be bolted into their original stainless steel shipping tube to protect the knife edge on the flange and to keep the gun clean. Small unmounted guns and other parts can be placed in sealed bags, foil, or covered containers. The gun and other equipment which goes into vacuum should be stored on closed shelves.

Most guns can be stored in the laboratory at normal temperatures and pressures. While at room temperature, the standard refractory metal cathodes used in most electron guns are not harmed by repeated exposure to atmospheric gases. If a gun has a barium oxide (BaO) cathode, it is best to store the gun in vacuum; if it must be stored out of vacuum, it should be placed in a clean, dry environment such as a tightly sealed plastic box with desiccant, as BaO is susceptible to degradation by water vapor.

BAKEOUT

Bakeout involves heating the gun while in vacuum to remove and pump away contaminants, adsorbed materials, water vapor etc. that may interfere with vacuum or gun performance. **Before bakeout, all the gun cables must be removed.** In some guns, there are magnetic coils, a pneumatic Faraday cup actuator or other assemblies which are more heat-sensitive and must also be removed or heated differentially; care should be taken that these assemblies are not heated above their recommended maximum temperatures. Maximum temperatures for bakeout are given in the gun specifications. Some bakeout methods are described in the Operating Hints Section 5.3.3.

FIRING UNIT MAINTENANCE

As the Electron Gun is operated, insulating layers may build up on the Wehnelt (G-1) and other apertures. These insulating layers are usually formed from evaporated cathode material, oil, or other vacuum system contaminants. As these layers form, changes in the operating characteristics may be observed. At some point, the performance of the electron gun may deteriorate so that the firing unit requires cleaning. The best method of removing the insulating layers is to install a new firing unit, which has the benefit that the cathode is replaced at the same time.

Alternatively, the cathode may fail suddenly, due to the loss of leg material over time. If the cathode burns out, the firing unit will need to be replaced with a new or rebuilt firing unit.

Firing units can be rebuilt at Kimball Physics; a rebuilt firing unit includes a new cathode. Spare firing units may also be purchased from Kimball Physics. Detailed gun disassembly and firing unit replacement instructions are given in Section 6.3. For a few gun models, it is not recommended that users replace the firing unit themselves, and no disassembly instructions are given.

POWER SUPPLY MAINTENANCE

No routine maintenance or inspection procedures are required for the power supply. However during normal operation, the user should be aware of any changes that might indicate a problem, such as excessive heat, popping sounds, fluctuating meters, etc.

The entire system, gun, firing unit, or power supply can be returned to Kimball Physics for evaluation, disassembly, cleaning and rebuild; see shipping instructions in Section 2.1.

6.2 GENERAL TROUBLESHOOTING

DANGER

HIGH VOLTAGE
Can cause ELECTRIC SHOCK or BURN

If the cables are connected to the power supply and not connected to the gun, **HIGH VOLTAGE** will be present at the exposed gun end of the cables when the power supply is on.

Do not touch cable end or power supply components when energized

At any point in the troubleshooting process, Kimball Physics Engineering will be glad to provide technical assistance. Some information which is useful when calling includes: the gun model, serial numbers and other system information listed in front of this manual, the operating conditions when the problem occurs, the settings of the various controls, the vacuum environment.

It is often useful to attempt to **isolate the problem** and determine which part of the system is affected:
the gun, the power supply, or the cables. This procedure is especially useful when a short circuit is suspected.
(1) With all gun cables disconnected, the leads on the gun can be checked with an ohmmeter to see if there is a short to ground in the gun or if the filament has burned out. (2) The cables alone can also be checked with an ohmmeter. (3) The power supply can be checked to see if the response on the meters is normal for no gun attached.
Call Kimball Physics Engineering for guidance in troubleshooting the power supply.

If the system requires modification to provide for a new experimental design or due to operating problems, please consult Kimball Physics Engineering before making alterations. Additional components or design options may be available. Modifications by the user (such as cutting wiring or gun parts, substituting electrical components, using non-standard materials, or not adhering to standard high vacuum practices) can invalidate the warrantee, make rebuild difficult, and may cause a safety hazard to the user.

The gun, firing unit, and/or power supply can be returned to Kimball Physics for evaluation, disassembly, cleaning, repair and rebuild. It is best to return both the gun and power supply, so they can be tested together as a system. See shipping instructions in Section 2.1.

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DANGER

HIGH VOLTAGE
Can cause ELECTRIC SHOCK or BURN

FOR EMERGENCY SHUT DOWN, DISCONNECT THE POWER CORD FROM THE AC OUTLET.

Some Sections That May Be Useful For Troubleshooting

3 Theory of Operation: Block diagram, Description of gun elements, Graphs showing how they operate

6.2 General Troubleshooting: Tables of symptoms, causes, and solutions
NOTE: Some instructions may not apply to the user's particular gun system. This is a general section with information for all Kimball Physics electron and ion gun systems.
6.2.1 Main Power Supply
6.2.2 Discharging
6.2.3 Energy
6.2.4 Emission
6.2.5 Beam Current
6.2.6 Individual Power Supplies
6.2.7 Grid and Pulsing
6.2.8 ECC and Source
6.2.9 Spot Size and Shape
6.2.10 Remote Control
6.2.11 Deflection and Rastering
6.2.12 Ion Guns
6.2.13 Cables and Connectors
6.2.14 Other Misc. Problems

6.3 Gun Disassembly/ Reassembly for Firing Unit Replacement: Step-by-step instructions, Pin outs

6.4 Power Supply Driver Boards: Description, Step-by-step instructions, Fuses, Wire code and pin out tables

6.5 Special maintenance procedures for specific gun model: only some manuals

8 Drawing Section: Gun drawings, Block diagram, Pinouts, Power supply schematics

9 Data Section: Performance graphs taken during testing, Power supply calibration chart

6.2 GENERAL TROUBLESHOOTING cont.

6.2.1 MAIN POWER SUPPLY

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
Main Power Supply unit does not turn on.	Power Supply is not plugged in.	Check power cord connection to outlet (labeled LINE or J1 on back panel) and to wall socket. For higher powered guns only: Check connections to H.V. Supply (Gamma or Glassman) and power cord on H.V. Supply.
	Main Power Supply fuse has blown.	Replace fuse on rear panel with a 2 A slo-blo fuse. On some units pry open small panel labeled **F1** to replace fuse (Also look for problem that caused fuse to blow, ex discharge in gun can cause a backsurge of high voltage.)
Hot electrical smell from the power supply unit.	Power Supply (or cable) has a short.	Call KPI first for advice to isolate the problem. Check individual boards for shorts, see Sect 6.4. H.V. DANGER: DO NOT CHECK VOLTAGE DIRECTLY
	An element in the power supply has overheated/ burned out.	Disconnect power supply. See sine wave driver board troubleshooting, Sect 6.4. Remove cover and inspect elements, check fuses.
	A cable has a short.	Unplug cable at both ends. Check leads with ohmmeter. Clean pins (Chemtronics Ultra Jet Duster or equivalent) Clean insulator with isopropanol.
Interlock LED is on.	H.V. Multiconductor Source cable is not connected correctly.	Disconnect cables and reconnect more tightly. The power supply connector must be screwed tight enough to engage the interlock pin; a click should be heard. Some guns have a separate small interlock cable, next to the source cable, with a lemo connector. On 50-100 keV guns, the interlock is part of the gun connector, so retighten it.
	Power supply case is open, a H.V. hazard.	Keep top and bottom panels closed on unit; tighten screws that secure case.
	Spare interlock is on. (located on back of Power Supply)	If not being used, check that spare interlock terminals are jumpered and screws are tight, as shipped. If user has wired the interlock, check trigger conditions, and check that wiring is a closed loop to the user's system.
Zero LED is on.	Energy (or other supply) is already turned up when H.V. power is first turned on.	Turn Energy potentiometer fully counterclockwise to zero. For FlexPanel controls, call KPI for advice on evaluating program through RS-232 port.

Continued on next page

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

6.2 GENERAL TROUBLESHOOTING cont.

6.2.1 MAIN POWER SUPPLY cont.

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
FlexPanel display screen does not come on, when green Power switch is on.	There is a software error.	Call KPI for advice on evaluating program through RS-232 port.
	Auxiliary power supply board has a blown fuse or other problem.	Call KPI for advice on checking voltage at test points on the auxiliary board.
FlexPanel display or controls have erratic operation.	Operation is not as the user expects.	See operating instructions, description of controls, use of FlexPanel controls Sect. 4.1. Note that encoder wheel is a variable control, rate of signal change depends on speed of rotation.
	Discharging in gun or power supply is causing Energy or other metering to fluctuate.	See 6.2.2 Discharging, below
	There is a software error; program may need to be reset.	Call KPI for advice on evaluating program through RS-232 port.

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

6.2 GENERAL TROUBLESHOOTING cont.

6.2.2 DISCHARGING IN GUN OR POWER SUPPLY

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
Discharging in the gun or power supply, (may be seen as spikes in current, heard as popping noises, or felt as a shock).	Minor discharging in gun caused by slight impurities introduced while gun is out of vacuum. (This often occurs briefly at start up.)	Let gun warm up longer; see if discharge is only when gun first at high voltage or only when source is first turned on. If brief this is not a problem, as gun will clean up when heated. (For higher power guns only) repeat conditioning and alignment procedures.
	Vacuum is poor.	Check vacuum level. Check vacuum pump. Wait for better vacuum (10^{-5} torr) before running gun.
	Charge is building up on gun elements due to contaminants (from target or when out of vacuum) or due to misalignment (from mechanical shock).	See if discharge is periodic, result of gradual charging up. Bake out gun. Adjust alignment, focus or deflection. (For higher power guns only) repeat conditioning and alignment procedures.
	Contaminants from target.	Look for phosphors and other debris on gun and in vacuum chamber.
	Cathode/ion source leads are shorting due to thermal expansion.	Disconnect cable from gun. Check filament pins with ohmmeter. Gun may need to be hot to see short. Disassemble gun and bend leads away from each other and tube wall.
	For ION GUNS: Excess ionization gas is present in other parts of gun.	Decrease pressure of gas admitted to be ionized.
	Rough edge, loose screw, etc is a site for charge build up.	For gun, remove from vacuum and check externally, partially disassemble and look in gun tube.
		For Power supply, with power off, remove cover and look inside.
	Power supply (or cable) has a short.	Call KPI first for advice to isolate the problem. See sine wave driver board troubleshooting, Sect.6.4. Check fuses, inspect elements. H.V. DANGER: DO NOT CHECK VOLTAGE DIRECTLY
	A cable has a short.	Unplug cable at both ends. Check leads with ohmmeter. Clean pins (Chemtronics Ultra Jet Duster or equivalent) Clean insulator with isopropanol.

Continued next page

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

6.2 GENERAL TROUBLESHOOTING cont.

6.2.2 DISCHARGING IN GUN OR POWER SUPPLY cont.

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
When Energy is increased with no Source on, Emission current meter goes up (leakage current). **Discharging in gun.**	A short in the gun (or cable), often source (filaments) to ground or grid to ground. If firing unit was just reinstalled, leads may be touching housing or each other. Short may be thermal.	Turn off system; disconnect ALL cables. With ohmmeter, check pins on gun (filament leads should be continuous, others open). Gun may need to be hot to see short; operate gun and check pins while hot. Pinout drawing at end of Sect 6.3. Check firing unit installation and bend leads if necessary, Sect 6.3, or return to KPI for evaluation and rebuild.
WARNING **When troubleshooting the Energy supply:** **For higher-energy guns, do not go above 2000 eV, and for lower-energy guns, do not go above 400 eV.**	Power supply (or a cable) has a short. If meter pegs (all the way up), there is probably a short.	Call KPI first for advice to isolate the problem. Check individual boards for shorts, see Sect 6.4. Check fuses, inspect elements. H.V. DANGER: DO NOT CHECK VOLTAGE DIRECTLY
	A cable has a short.	Unplug cable at both ends. Check leads with ohmmeter. Clean pins (Chemtronics Ultra Jet Duster or equivalent) Clean insulator with isopropanol.
	Main insulator in gun is contaminated.	(Meter behavior is initial test.) For higher power guns, partially disassemble and look for burn marks on large insulator. Insulator damage may require returning to KPI for rebuild.
	Burrs on firing unit or insulators cause field emission. If firing unit was just reinstalled or gun handled, unseen burrs may have been made which can rise up when high voltage is applied or when gun is heated.	(Meter behavior is initial test.) Run at high Energy for a while to burn off burrs. Remove gun and inspect for scratches.
NOTE: **Excessive discharging may have caused further damage.**	Backsurge of High Voltage can damage power supply elements.	Check main fuse, check driver boards for fuses or other burnt out elements, Sect 6.4
	Back bombardment by ions can damage cathode, especially coated or LaB_6 .	After discharge problem is fixed, check if beam behavior is normal, check V-I characteristic graph. Observe cathode by removing gun from vacuum and looking in tube with microscope.
	For high power guns only: Cable acts like capacitor, charges up and can damage power supply.	Check main fuse, check driver boards for fuses or other burnt out elements, check potting compound in junction box. Check H.V. Supply (Gamma or Glassman) Sect 6.4 and H.V. Supply manual

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

6.2 GENERAL TROUBLESHOOTING cont.

6.2.3 ENERGY

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
Energy (read on DVM) does not increase when control is turned up. **WARNING** **When troubleshooting the Energy supply:** **For higher-energy guns, do not go above 2000 eV, and for lower-energy guns, do not go above 400 eV.**	Energy supply not turned on, H.V. switch not on.	Press pushbutton H.V. in (should light, but bulb could be burned out).
	For multi-functional DVM: Function switch is not set correctly for DVM to display Energy supply.	Turn rotary Function switch next to DVM fully counterclockwise, so that LED next to Energy potentiometer is lighted.
	Energy control is set in remote mode.	Check switch inside, behind access panel on back of power supply: left for local manual control, not right for remote.
	Power supply is current limited.	Decease beam current by reducing Source or increasing Grid, see if Energy returns.
	Power supply (or a cable) has a short. If meter pegs (all the way up), there is probably a short.	Call KPI first for advice to isolate the problem. Check individual boards for shorts, see Sect 6.4. Check fuses, inspect elements. H.V. DANGER: DO NOT CHECK VOLTAGE DIRECTLY
	A cable has a short.	Unplug cable at both ends. Check leads with ohmmeter. Clean pins (Chemtronics Ultra Jet Duster or equivalent) Clean insulator with isopropanol.
	For higher powered guns only: H.V. Supply is not supplying power or is limiting voltage.	H.V. Supply must be on. Check H.V.Supply connections, ON switch, and turn voltage fully clockwise.
Zero LED is on.	Energy is already turned up when H.V. power is first turned on.	Turn Energy potentiometer fully counterclockwise to zero. For FlexPanel controls, call KPI for advice on evaluating program through RS-232 port.
Energy decreases suddenly, when Source is turned up.	Emission current is too high, causing poly-fuse to trip.	Turn off Power Supply to reset poly-fuse, then turn back on. Run with slightly lower emission.
Energy decreases after a length of time running.	Poly-fuse has tripped due to excessive heat.	Turn off Power Supply to allow reset of poly-fuse, then turn back on. If it runs again for a little while, it must be the poly-fuse. Disconnect power supply. Remove cover and inspect elements to see what has overheated. See sine wave driver board troubleshooting, Sect 6.4. Replace poly-fuse on Source/ECC driver board, see Sect 6.4
	Power supply is current limited. Beam current increased as gun warmed up, so now current-limited.	Decease beam current by reducing Source or increasing Grid, see if Energy returns.
	For higher powered guns only: H.V.Supply is current limited, causing voltage to drop.	Increase H.V.Supply current with its potentiometer (but full current may be too high for cathode). H.V.Supply voltage should be fully on, clockwise.

Continued on next page

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

6.2 GENERAL TROUBLESHOOTING cont.

6.2.3 ENERGY cont.

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
When Energy is increased with no Source on, Emission current meter goes up (leakage current). **Discharging in gun.** **WARNING:** **When troubleshooting the Energy supply:** **For higher-energy guns, do not go above 2000 eV, and for lower-energy guns, do not go above 400 eV.**	A short in the gun (or cable), often source (filaments) to ground or grid to ground. If firing unit was just reinstalled, leads may be touching housing or each other. Short may be thermal.	Turn off system; disconnect ALL cables. With ohmmeter, check pins on gun (filament leads should be continuous, others open). Gun may need to be hot to see short; operate gun and check pins while hot. Pinout drawing at end of Sect 6.3. Check firing unit installation and bend leads if necessary, Sect 6.3 or return to KPI for evaluation and rebuild
	Power supply (or a cable) has a short. If meter pegs (all the way up), there is probably a short.	Call KPI first for advice to isolate the problem. Check individual boards for shorts, see Sect 6.4. Check fuses, inspect elements. H.V. DANGER: DO NOT CHECK VOLTAGE DIRECTLY
	A cable has a short.	Unplug cable at both ends. Check leads with ohmmeter. Clean pins (Chemtronics Ultra Jet Duster or equivalent) Clean insulator with isopropanol.
	Main insulator in gun is contaminated.	(Meter behavior is initial test.) For higher power guns, partially disassemble and look for burn marks on large insulator. Insulator damage may require returning to KPI for cleaning and rebuild.
	Burrs on firing unit or insulators cause field emission. If firing unit was just reinstalled or gun handled, unseen burrs may have been made which can rise up when high voltage is applied or gun is heated.	(Meter behavior is initial test.) Run at high Energy for a while to burn off burrs. Remove gun and inspect for scratches.

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

6.2 GENERAL TROUBLESHOOTING cont.

6.2.4 EMISSION

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
NO emission current when the source is turned up.	Filament is not hot enough.	Wait longer for warm up. Gradually turn Source higher. Reactivate cathode by "hot shot" by turning Source to 10% over normal for a few minutes. Do not exceed recommended limit except briefly. Higher source currents cause a shorter lifetime. Call KPI to reset Zener limit; drawing #000S971.
	Grid is cutting off emission.	Turn grid to zero while setting source current, adjust grid to low value after emission is stable. (Guns with dual grid pulsing only) Check TTL and invert switch.
	Vacuum is poor.	Check vacuum pump; wait for better vacuum (10^{-5} torr) before running gun.
	Energy is not high enough for potential to extract electrons/ions from emitter region.	Increase Energy. Adjust Anode if variable, not grounded.
	Cathode/ ion source (filament) is burnt out.	Monitor Source Volts and Source Amps meters, if voltage increases, but current is zero, an open filament is likely. (With higher voltage guns, current may not be zero, but V-I characteristics will be different than normal, compare with V-I graph in Data Section.) Check filament pins on gun connector with an ohmmeter to see if filament is no longer a closed loop. See pinout drawing at end of Sect 6.3. See also gun disassembly for firing unit replacement instructions, Sect 6.3.
	Cathode/ ion source is near end of its lifetime.	Check V-I characteristics. Vary Source Volts, record Source Amps, and compare with V-I graph in Data Section.
	Cathode/ ion source is contaminated.	Bake out gun. For some high power guns, repeat conditioning. Burn off contaminants by "hot shot", by turning Source to 10% over normal for a few minutes. Do not exceed recommended limit except briefly. Higher source currents cause a shorter lifetime. Call KPI to reset Zener limit; drawing #000S971.
	For coated cathodes only: Coating has been damaged by physical shock or back bombardment of ions during discharge or (for BaO) by atmosphere.	Remove gun and inspect cathode. See also gun disassembly for firing unit replacement instructions, Sect 6.3. Refer to BaO instruction sheet for care and handling of BaO cathodes; reactivation may be possible.
	For Alkali metal ION GUNS only: Solid chemicals in ion source cartridge are used up.	Gradual degradation of beam current should have been observed during previous operation. See gun disassembly for firing unit replacement instructions, Sect 6.3
	For Gas ION GUNS only: Ionization gas pressure is too low or not stable.	Check valves, lines, and gas meters. Increase pressure slowly. not too high. Let stabilize for 5 to 10 min, then recheck. Gas is too high if beam begins to jump around or has glow discharge.

Continued next page

6.2 GENERAL TROUBLESHOOTING cont.

6.2.4 EMISSION cont.

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
Overcurrent LED is on.	Source current is too high, excessive current through cathode/ ion source.	Turn down Source. Check appropriate level for the cathode/ion source type. Call KPI to reset Zener limit; drawing #000S971.
Emission or Beam is drifting or is not stable.	Cathode/ ion source is still warming up.	Wait longer for warm up. For some high power guns, repeat conditioning procedures. For gas ion guns, go very slowly when adjusting admitted gas. Make small changes, and wait 5 to 10 min between.
	Energy, Source or Grid supply is fluctuating.	Observe meters. Ensure cables are well connected. If using remote, check that program signal is stable. Call KPI.
	Cathode/ ion source is contaminated.	Burn off contaminants by "hot shot", by turning Source to 10% over normal for a few minutes. Do not exceed recommended limit except briefly. Higher source currents cause a shorter lifetime. Bake out gun. For some high power guns, repeat conditioning procedures.
When Energy is increased with no Source on, Emission Current meter goes up (leakage current). **Discharging in gun.**	A short in the gun (or cable), often source (filaments) to ground or grid to ground. If firing unit was just reinstalled, leads may be touching housing or each other. Short may be thermal.	Turn off system; disconnect ALL cables. With ohmmeter, check pins on gun (filament leads should be continuous, others open). Gun may need to be hot to see short; operate gun and check pins while hot. Pinout drawing at end of Sect 6.3. Check firing unit installation and bend leads if necessary, Sect 6.3, or return to KPI for evaluation and rebuild.
	Main insulator in gun is contaminated.	(Meter behavior is initial test.) For higher power guns, partially disassemble and look for burn marks on large insulator. Insulator damage may require returning to KPI for rebuild.
	Burrs on firing unit or insulators cause field emission. If firing unit was just reinstalled or gun disassembled, unseen burrs may have been made which can rise up when high voltage is applied or when gun is heated.	(Meter behavior is initial test.) Run at high Energy for a while to burn off burrs. Remove gun and inspect for scratches.
Energy decreases suddenly, when Source is turned up.	Emission current is too high, causing poly-fuse to trip.	Turn off Power Supply to reset poly-fuse, then turn back on. Run with slightly lower emission.

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

6.2 GENERAL TROUBLESHOOTING cont.

6.2.5 BEAM CURRENT

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
NO final beam current at the target.	No initial emission.	Check that Source is at usual setting, then see 6.2.4 above for Emission problems.
	Beam is not properly aligned. Beam is present, but not observable at target.	Check deflection, raster, rocker, or magnetic alignment settings. Adjust position of gun or Port Aligner. Move phosphor screen to see where beam is aimed.
	Near-by electromagnetic fields are deflecting beam.	Remove metal tools, magnets, etc. Shield gun with μ-metal (mu-metal).
	Energy is not high enough to set up enough potential to pull electrons/ions through the lenses.	Increase Energy. Check emission and beam graphs for different Energies in Data Section.
	A lens is acting as a mirror, reversing the electron/ion flow.	Adjust Focus and other bias voltages.
	Faraday cup assembly attached to gun is not retracted.	Cycle Faraday cup manipulator or pneumatic actuator to move cup in and out of beam line. Remove gun from vacuum with cup in closed position, move cup, and check linkage wire and Faraday cup alignment. Check hinge connections. See photo in Sect. 6.3.
	Beam blanker is shutting off (deflecting) beam.	Turn off blanker with pushbutton. If beam comes on, adjust blanker and TTL controls, if needed.
	A lens element is charging up and interfering with beam.	Look for signs of discharging, such as spikes in current.
	Contamination is blocking beam path.	Bake out gun. Remove gun from vacuum and look down tube with a light, may be difficult to see. Return to KPI for evaluation and rebuild.

Continued next page

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

6.2 GENERAL TROUBLESHOOTING cont.

6.2.5 BEAM CURRENT cont.

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
LESS final beam current than expected.	Not enough emission current.	For most guns, the normal ratio of emission to beam is not 1:1. Increase SOURCE to increase emission current. (Higher currents mean shorter lifetime.) Refer to Data Section for graphs of Emission and Beam vs Source Current. See 6.2.4 above for Emission problems.
	Parameters, such as Focus, Grid etc, are not adjusted optimally so part of beam is being lost.	Adjust parameters. When one parameter is changed, others need to be adjusted, ex Focus varies with Energy. Refer to Data Section.
	It is not possible to achieve maximum beam current under all operating conditions.	Adjust parameters. Check performance graphs in Data Section.
	Beam is not properly aligned. Beam current is present, but not maximized at target.	Check deflection, raster, rocker, or magnetic alignment settings. Adjust position of gun or Port Aligner. Move phosphor screen to see where beam is aimed.
	Near-by electromagnetic fields are deflecting beam.	Remove metal tools, magnets, etc. Shield gun with μ-metal (mu-metal).
	For higher powered guns only, H.V.Supply is current limiting the main supply.	Adjust current potentiometer on H.V.Supply. If supply is current limiting, Energy will have dropped also.
	For coated cathodes only: Coating has been damaged.	Check if there has been physical shock, discharge, etc. recently. Remove gun and inspect cathode.

Continued next page

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

6.2 GENERAL TROUBLESHOOTING cont.

6.2.5 BEAM CURRENT cont.

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
Beam or Emission is drifting or is not stable.	Cathode/ion source is still warming up.	Wait longer for warm up. For some high power guns, repeat conditioning procedures. For gas ion guns, go very slowly when adjusting admitted gas. Make small changes, and wait for 5 to 10 min between changes.
	Energy, Source or Grid supply is fluctuating.	Observe meters. Ensure cables are well connected. If using remote, check that program signal is stable. Call KPI.
	Cathode/ion source is contaminated.	Burn off contaminants by “hot shot”, by turning Source to 10% over normal for a few minutes. Do not exceed recommended limit except briefly. Higher source currents cause a shorter lifetime. Bake out gun. For some high power guns, repeat conditioning procedures.
	For gas ion guns: Gas pressure has not stabilized or is too high. Excess gas may cause discharging.	Go very slowly when adjusting admitted gas. Reduce pressure.
Beam is unstable. Spot moves unexpectedly.	Insufficient ground on system.	Make sure entire system has good ground connections, especially with Viton gaskets.
	An exposed insulator in the vacuum system is charging up.	Remove any coated wires, glass, ceramic, or Teflon from near the beam path.
	Target not grounded, e.g. phosphor screen charging up.	Ensure that target is grounded.
	Raster or beam rocking is on.	Turn off Raster or Beam Rocking unit.
Problems with beam spot size or shape		See 6.2.9 Spot Size and Shape, below
Problems measuring beam with gun-mounted Faraday cup		See 6.2.14 Other Misc. Problems, below

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

6.2 GENERAL TROUBLESHOOTING cont.

6.2.6 INDIVIDUAL POWER SUPPLIES

Observed Symptom	Possible Problem	Test / Solution
Individual power supply (e.g. Grid, Focus, Deflect) does not turn on or its meter does not increase when its control is turned up.	Individual pushbutton or switch is need to energize system, before using potentiometer.	Use pushbutton: DEFL, BLANKER, H.V. (for Energy & Focus), SOURCE (for Source & ECC), PULSE (toggle switch)
	For multi-functional DVM: Function switch is not set correctly for DVM to display particular supply (Energy, Focus, X Deflect, Y Deflect, etc).	Turn rotary Function switch next to DVM so that LED next to potentiometer of desired supply is lit.
	Control is set in remote mode.	Check switch inside, behind access panel on back of power supply: left for local manual control, not right for remote control.
	Fuse on individual driver board has blown.	Open rear access panel, slide out board, replace fuse (1 A, 0.5 A or 0.3 A). See Sect. 6.4.
	Element on board is faulty.	See sine wave driver board troubleshooting, Sect. 6.4.
	Meter or meter protection circuit is faulty.	See if the gun responds to voltage change normally (by observing beam or spot), but there is no response on the individual meter.
After troubleshooting, supply does not provide usual output.	Boards were removed and replaced incorrectly	See sine wave driver board troubleshooting, Sect. 6.4. Check jumper position on board, and order of boards in slots.
Problems with Grid supply		See also 6.2.7 Grid and Pulsing, below
Problems with Source supply		See also 6.2.8 ECC and Source, below

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

6 MAINTENANCE

6.2 GENERAL TROUBLESHOOTING cont.

6.2.7 GRID and PULSING

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
Grid does not cut off the beam	Grid voltage is not high enough.	Gradually increase voltage. Check grid sweep graph in Data sect. Grid cutoff depends on Energy and other parameters
	Grid control is set in remote mode.	Check switch inside, behind panel on back of power supply: left for local manual control, not right for remote control.
	The gun is not designed for grid cutoff.	Check grid sweep graph in Data section to see if cut off shown. Read theory section. Some electron guns have positive grid. Some guns produce too much current to cutoff completely, and so require Blanker.
Less emission or beam current than expected.	Grid is cutting off emission.	Turn grid to zero while setting source current, adjust grid to low value after emission is stable. (Guns with dual grid pulsing only) Check TTL and invert switch.
Pulsing not working.	Grid voltage not set correctly for cut-off. Required voltage varies with conditions, Energy.	Adjust Grid voltage. See Data for grid sweeps graphs.
	Pulse input (remote computer program, or TTL or pulse generator) not set up correctly	See sect 4.7 for how pulse input and grid control produce pulse for different types of pulsing
	Pulsing is working correctly, but pulse width or rep rate of pulse generator may too fast to see if trying to observe pulsing on phosphor screen.	Try longer pulses or slower rep rates. Observe using Faraday cup detector with oscilloscope.
	The gun is not designed for pulsing (no grid cutoff).	Check grid sweep graph in Data section to see if cut off shown. Read theory section. Some electron guns have positive grid (so require positive/negative power supply) . Some produce too much current to cutoff completely (so require Blanker).
With pulsing, grid volts or emission meter fluctuates or is not accurate.	(This is normal.) Meter may give averaged value or vary with pulse. With dual grids, only variable control grid value is shown.	Check meters with pulsing off. To see pulsed beam, use Faraday cup detector with oscilloscope.
Capacitive pulsing used to work, but grid no longer cuts off beam.	Insulator between cathode a G-1 is contaminated. Pulse Junction Box or cable has faulty part or connection	Remove Pulse Junction Box (or cable or cylinder) and see if Grid cuts off normally with manual control. Provide two known inputs to box and check that output is sum. Call KPI.

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

6.2 GENERAL TROUBLESHOOTING cont.

6.2.8 ECC and SOURCE

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
Emission does not increase when Source/ECC is turned up.	Emission current has reached Zener limit set at factory to protect cathode/ion source. (This is normal.)	Check appropriate level for the cathode/ion source type. Change to Source mode, but do not exceed recommended limit. Call KPI to reset Zener limit; drawing #000S971.
ECC does not work when beam is pulsed.	ECC must not be used with pulsing. The varying emission can cause the circuitry to go into a positive feedback loop.	Use Source mode with pulsing.
Source/ECC does not go up as high as expected.	The full range of the potentiometer is set to be less than the meter, eg. Source Volts meter may have a 2 V face, but control is only 0 to 1.5 V.	See Drawing section schematics for supply ranges. Limited source is to protect cathode/ion source.
(For gas ion guns only) **Ion emission varies even though ECC is being used.**	ECC is designed to control the electron emission which then ionizes the gas, but other factors, especially gas pressure, also affect ion emission and ion beam current.	Set up conditions first without ECC. Wait for warm up and adjust gas pressure gradually, not too high. Let stabilize for 5 to 10 min, then recheck. Then use ECC when stable. Carefully regulate introduced gas pressure, as above.
Operating parameters have changed drastically over time; more Source is needed for a given emission level.	Cathode/ion source is near end of its lifetime. Depletion of emitting material has occurred.	Check V-I characteristics. Vary Source Volts, record Source Amps, and compare with V-I graph in data section. See also gun disassembly for firing unit replacement instructions, Sect 6.3.
	Contaminants have built up on apertures.	Bakeout gun, and see if improve. Look for phosphors and other debris on gun and in vacuum chamber. Disassemble gun and clean, or send to KPI for rebuild. See gun disassembly instructions, Sect 6.3, some guns also Sect 6.5.
Cathode/ ion source burns out quickly	Source current is too high, so filament is running too hot.	Check parameters and compare with graphs in Data Section. Use lowest Source Amps possible, keep current below recommended limit.
	Zener limit on ECC board is set incorrectly for that particular cathode/ ion source, so source current is running too high and filament is too hot.	When cathode or ion source is replaced, Zener limit may need to be recalibrated. Call KPI to reset Zener limit; drawing #000S971. Check parameters in Source mode before using ECC mode.

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

6.2 GENERAL TROUBLESHOOTING cont.

6.2.9 SPOT SIZE and SHAPE

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
Spot is not the desired size.	For FLOOD guns only: By design, spot size is not directly controllable, depends on parameters and working distance.	Adjust grid (may also change beam current). Move target to change working distance.
	For FOCUSABLE guns only: Focus is not adjusted optimally, needs to be readjusted when other parameters changed.	Adjust Focus or G-2 or Extract control. Also adjust Grid. See Theory section and spot size graphs in Data section. Focus varies with Energy and other parameters. For some guns, there are two values which produce the minimum spot for given conditions.
	It is not possible to achieve the minimum spot size under all operating conditions.	Adjust parameters. Check performance graphs in Data Section.
	Near-by electromagnetic fields or 60-cycle noise are vibrating beam so it covers larger area.	See if spot appears fuzzy. Temporarily turn off near-by equipment, ex fans, or run gun at different time of day. Shield gun with μ-metal (mu-metal).
Beam spot shape is not round.	The gun elements are out of alignment or tilted.	Vary spot size and move beam, see if edge of spot is cut off by a curve. Look in end of gun to see the positions cathode/ion source and lens if possible; use an otoscope.
	Near-by electromagnetic fields are distorting beam.	Remove metal tools, magnets, etc. Shield gun with μ-metal (mu-metal).
	Deflection lens is distorting spot shape.	Vary Deflection and/or Focus. Use less Deflection.
	Part of phosphor screen is not emitting light.	Deflect beam relative to screen. Replace or recoat screen
	Debris on the cathode/ion source or lenses.	Deflect beam; see if spot has a rough edge or dark spot that moves with it. See also gun disassembly instructions sect 6.3 to disassemble gun for cleaning, blow off apertures.
	For LaB_6 cathodes only: Edges of the crystal are interfering, forming a Maltese Cross pattern.	Adjust alignment, grid and focus to get a small spot; the cross is seen only with a large, unfocused spot.
Beam is unstable. Spot moves unexpectedly.	Insufficient ground on system.	Make sure entire system has good ground connections, especially with Viton gaskets.
	An exposed insulator in the vacuum system is charging up.	Remove any coated wires, glass, ceramic, or Teflon from near the beam path.
	Target not grounded, e.g. phosphor screen charging up.	Ensure that target is grounded.
	Raster or beam rocking is on.	Turn off Raster (RGDU) or Beam Rocking unit.

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

6.2 GENERAL TROUBLESHOOTING cont.

6.2.10 REMOTE CONTROL

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
A remote or computer signal to power supply has NO effect.	Control is set in local (manual) mode.	With terminal block remote, check switch inside unit, behind panel on back of power supply: right for remote control, not left for local manual control. With small PROGRAMMING slide switches on back panel, check switch position REMOTE (up), not local (down) for 50-pin external interface or 68-pin National Instruments.
	Connections are needed to COM terminals or ground pins, as well as PROG, for each supply being programmed.	Connect COM terminals or ground pins to ground.
	For RS-232, RS-422 or RS-485, control is set in remote (external) mode.	With small PROGRAMMING slide switches on back panel, check switch position LOCAL (down) for communication with internal FlexPanel, not remote (up).
	For RS-232, RS-422 or RS-485, program type does not match serial port.	Standard is RS-232. Check indicator LED, if unit has option of RS-422/RS-485
A remote or computer signal to power supply does not have desired effect.	Program input is incorrect.	Check tables for power supply ranges in Sect 4.4. Check program. Calculate input using following proportion, Input volts: 10 V = desired output: range
	For RS-232, RS-422/RS-485, standard cable is used with 9-pin D-sub.	Use null-modem cable.

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

6.2 GENERAL TROUBLESHOOTING cont.

6.2.11 DEFLECTION and RASTERING

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
Deflection does not center beam.	Near-by electromagnetic fields are distorting beam path.	Remove metal tools, magnets, etc. Temporarily turn off near-by equipment or run gun at a different time of day. Shield gun with μ-metal (mu-metal).
Deflection does not move the beam far enough.	Deflection voltage is designed to make only slight change in beam path, a few degrees.	Check specifications. Too much change would affect spot size and shape. Mechanical method may be needed for positioning.
	Optional Hi/Low Deflection switch is set at Low	Change switch to High.
Raster will not turn on.	Switch inside RGDU is set incorrectly.	Unplug RGDU, open cover and check switch position Synchronized / Off / Non-synchronized mode, Sect 4.6
Raster pattern is not synchronized.		
Raster or Deflection is not giving usual results.	Incorrect cable is being used. Deflection and Raster cables have same pinout, but different construction (PVC-coated wire for deflection; coaxial cable for raster).	Check cables, should have label attached.

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

6.2 GENERAL TROUBLESHOOTING cont.

6.2.12 ION GUNS

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
Emission or beam is not stable.	For GAS ion guns: Gas pressure has not stabilized.	Go very slowly when adjusting admitted gas. Make small changes, and wait for 5 to 10 min between changes.
	For GAS ion guns: Gas pressure is too high, causing unstable electron emission or interfering with ion extraction. Excess gas may cause discharging.	Reduce pressure of gas admitted. Check Data Section for typical pressures (if measured at a different site, pressures may not be comparable).
	For GAS ion guns: Pressure regulators on tanks, tubes, or valves etc are faulty. Swagelock on gas inlet can be damaged by over tightening.	Check gas system. Redo connections. Inspect gas inlet valve; if copper gasket is cut it was over tightened, replace it.
	For GAS ion guns: Optional Variable leak valve is delicate and easily damaged.	See enclosed Variable leak valve manual for instructions.
	For ALKALI METAL ion guns: It takes time to reach full emission due to heat capacity of solid cartridge. ECC responds faster than cartridge heats so emission may oscillate.	When adjusting Source or ECC make small changes and wait 1 to 2 min. If large changes are made wait 5 min.
Emission and beam fluctuates rapidly. Discharging in gun.	For GAS ion guns: If there is excessive gas pressure, un-ionized gas can be present in the gun column and cause discharging or become ionized. These ions will not have the same energy or path as those emitted normally from the ion source.	Adjust gas pressure. Glow discharge may be visible.
Problems with optional Variable Leak Valve		See enclosed Variable leak valve manual for instructions.
For problems common to all guns.		See other tables

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

6.2 GENERAL TROUBLESHOOTING cont.

6.2.13 CABLES and CONNECTORS

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
Cable is not supplying power.	Connections are poor.	With system turned off, disconnect cable at both ends. Check connectors for bent or loose pins. Clean pins (with Chemtronics Ultra Jet Duster or equivalent). Clean insulators with isopropanol and lint-free cloth. Reconnect cable, check that connections are tight, but do not force. On some guns, it is difficult to line up key, so connector may not be all the way in.
	Cable has a short. Wiring can be broken by cable being sharply bent or connector end being twisted.	With system off, disconnect cable at both ends. Check leads at opposite ends with ohmmeter. See Drawing section for pinouts in block diagram.

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

6.2 GENERAL TROUBLESHOOTING cont.

6.2.14 OTHER MISC. PROBLEMS (Gun Color, Faraday Cups, Power Supply Lighting)

OBSERVED SYMPTOM	POSSIBLE PROBLEM	TEST / SOLUTION
Gun has discolored over time.	Repeated bakeouts can discolor stainless steel. (This is normal.)	Color is brownish. Gun can be disassembled and cleaned (with solution such as Micro-90 and distilled water). This does not affect performance.
	Material from target or phosphor screen has coated gun. This can affect cathode/ion source or apertures.	Phosphorescence or appearance is like target material. Bake out gun. Gun can be disassembled and cleaned, or returned to KPI for rebuild.
Faraday cup assembly on gun will not move in or out of beam line.	Fragile hinge has broken or become disconnected, due to extended use or being knocked.	Carefully remove gun from vacuum. Inspect hinge connections. See photo in Sect. 6.3. Also check linkage wire and Faraday cup alignment.
	Not enough room for Faraday cup to move.	Check clearance in vacuum chamber.
	Faraday cup pneumatic actuator is not functioning.	If manual control is available, try cycling several times. Check tubing. Remove gun from vacuum, check connections and activate. Actuator can be damaged by bakeout (over 65°C) and should be removed.
	Faraday cup rotary feedthrough is not connected to linkage wire.	Remove gun from vacuum, push wire into feedthrough tightly, check connections and rotate.
Faraday cup used to work, but no longer measures current.	Faraday cup or electrical connections have been damaged, possibly by excessive power.	Remove gun from vacuum with cup in the closed position. Inspect cup and wires for melting.
	Connections are loose or shorted.	Remove gun from vacuum with cup in the closed position. Check cup and connections. See photo in Sect. 6.3.
All meters are too bright or too dim.	For analog meters, brightness potentiometer is not set for room conditions.	Adjust potentiometer with screwdriver through small hole next to meters.
	For Flexpanel display, screen brightness is not set for room.	Click red menu button, choose set brightness, and reset (scale 1 to 4)
A meter does not light up.	Bulb is burnt out.	Unplug Power Supply, remove front panel and remove entire meter. For supplies with adjustable lighting, return meter to KPI to replace light/ calibrate. (With older-style power supplies, remove front panel and replace 28 V bulb.)
A pushbutton/switch does not light up.	Bulb is burnt out.	Pull off plastic pushbutton cover, and replace 28 V incandescent bulb (14 V on some units). Rocker switches do not have bulbs, call KPI

The gun and/or power supply can be returned to Kimball Physics for evaluation and rebuild.

This completes the Troubleshooting Tables.

6.3 GUN DISASSEMBLY / REASSEMBLY for FIRING UNIT CARTRIDGE REPLACEMENT

⚠ NOTE

Use of **clean room gloves** is recommended to keep parts free of fingerprints and other contaminants.

READ ALL INSTRUCTIONS BEFORE DISASSEMBLY

6.3.1 ELECTRON GUN DISASSEMBLY

Before attempting to disassemble or reassemble the EGG-3101, or before attempting to replace the Firing Unit Cartridge, obtain the following tools:

12 point socket wrench
0.050" Allen wrench
#1 Phillips screwdriver
tweezers
ohmmeter
can of compressed (microscopically clean) gas

All tools should be clean to prevent contamination of parts.
USE CLEAN ROOM TECHNIQUES

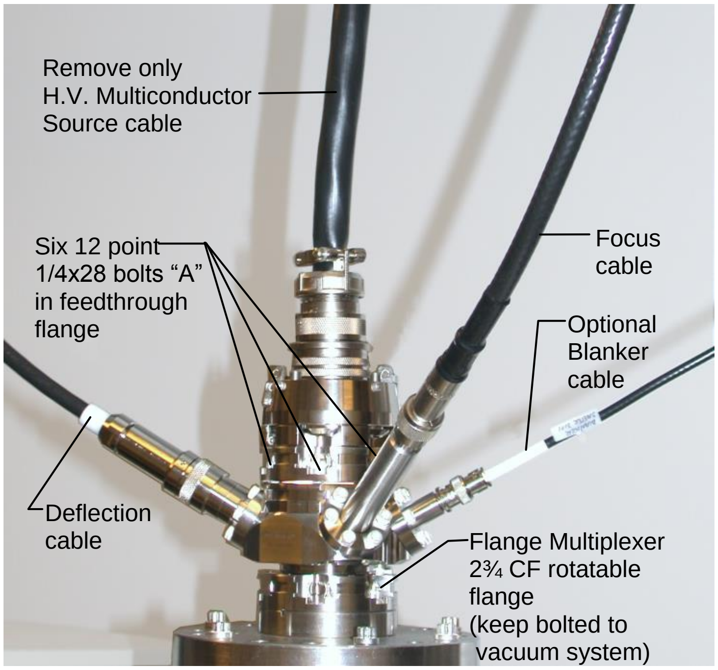

Fig. 6.3-1 EGG-3101 Electron Gun before disassembly

1. Secure (turn off) the EGG-3101/EGPS-3101 Electron Gun System according to the directions in Section 4.2.

2. Disconnect the H.V. Multiconductor Source cable from the electron gun.

HIGH VOLTAGE WARNING for optional Grid Pulsing cable only: Always discharge cable to ground before handling.

3. The gun may remain bolted to the vacuum system with the Flange Multiplexer , focus and deflection cables in place, as the Firing Unit is removed from the cable end of the gun.

4. Before proceeding, note the orientation of the key / flange for ease of later realignment.

5. To remove the Firing Unit Feedthrough Assembly: (Figs. 6.3-1 and 6.3-2).
   a. Using a 12 point socket wrench, remove the six 1/4x28 bolts ("A" in Fig. 6.3-1) in the 2¾ CF feedthrough flange.
   b. Carefully, lift out the whole firing unit feedthrough assembly straight out from the Flange Multiplexer. Stand upright on cable connector end. (Fig. 6.3-2)

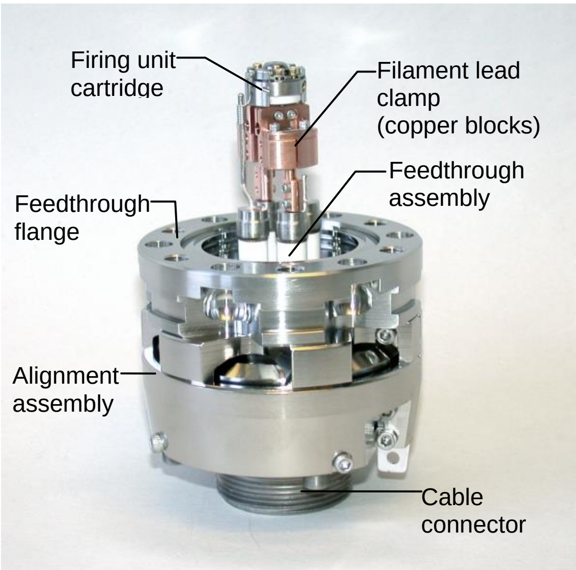

Fig. 6.3-2 EGG-3101 Firing Unit Feedthrough Assembly removed from gun

6 MAINTENANCE

6.3 GUN DISASSEMBLY for FIRING UNIT CARTRIDGE REPLACEMENT cont.

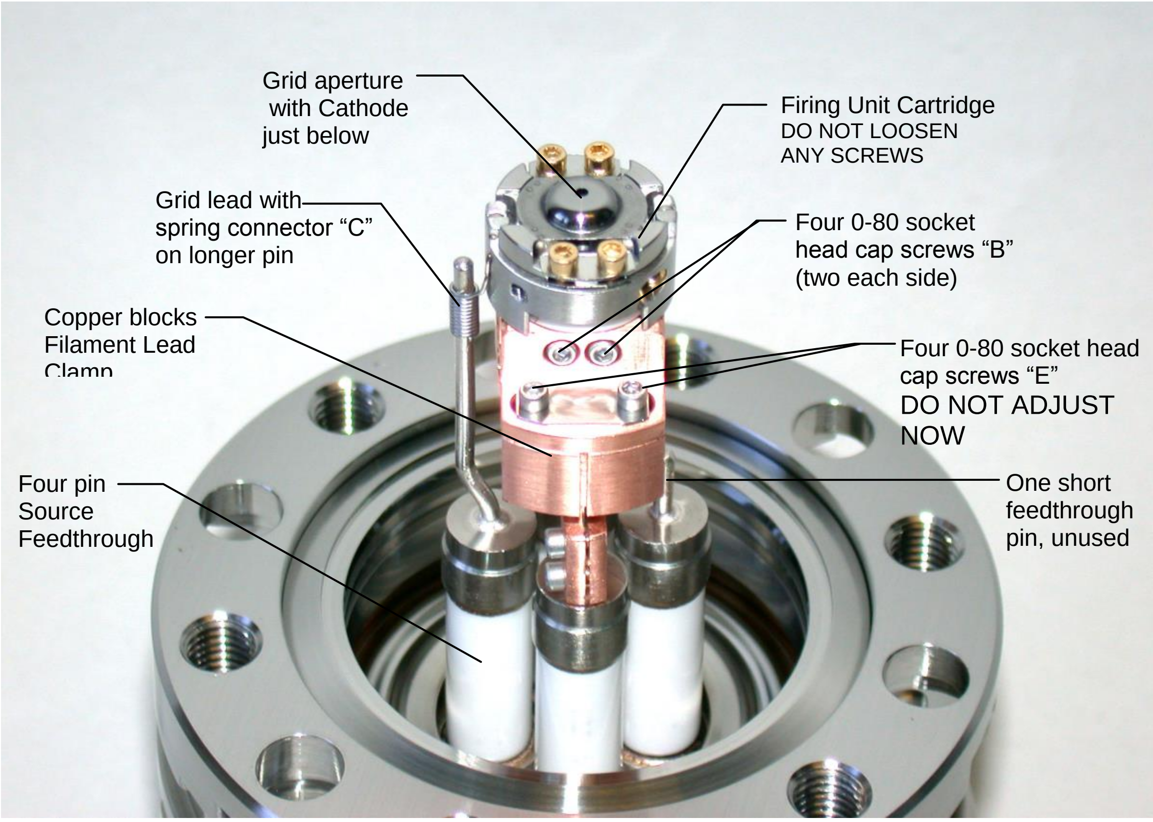

Fig. 6.3-3 EGG-3101 Firing Unit Cartridge in Filament Lead Clamp

6. To remove the Firing Unit Cartridge from the Filament Lead Clamp:
   a. Using a 0.050" Allen wrench, loosen the four horizontal 0-80 socket head cap screws (“B” in Fig. 6.3-3) on two sides of the clamp near the top.
   b. Gently, pull off the complete Cartridge, while sliding the Grid lead spring connector (“C” in Fig. 6.3-3) off its long copper pin with tweezers.

7. The Firing Unit Cartridge (including Cathode and Grid) is replaced as a whole unit (Fig. 6.3-4).

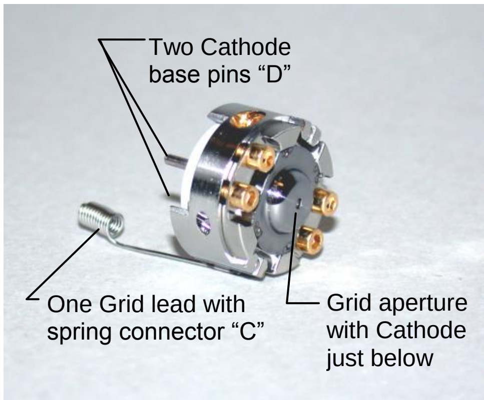

Fig. 6.3-4 EGG-3101 Complete Firing Unit Cartridge (Grid and Cathode) to be replaced

Firing units can be repaired and cleaned.
Call Kimball Physics for information at (603) 878-1616.

This completes the EGG-3101 Electron Gun Disassembly Instructions.

6.3 GUN REASSEMBLY for FIRING UNIT CARTRIDGE REPLACEMENT

> **CAUTION**
>
> Between each step of reassembly, **blow all dust** and other particles off all gun surfaces.
>
> When reassembling keep proper **clearance between the high voltage electrical leads and the housing.** Otherwise, **discharging** will result during electron gun operation

6.3.2 ELECTRON GUN REASSEMBLY

1. Disassemble the EGG-3101 Electron Gun according to Section 6.3.1 Refer to the figures above during reassembly.

NOTE: The screws used in the Electron Gun are stainless steel, gold-plated for lubrication (not brass); any substitution with screws which are not gold-plated will invalidate the warrantee on the Electron Gun. Replacement screws are available from Kimball Physics.

2. To replace the Firing Unit Cartridge in the Filament Lead Clamp:
   a. Insert the new/rebuilt cartridge into the top of the clamp (Fig. 6.3-4), fitting the two cathode base pins ("D" in Fig. 6.3-4) into the two holes in the center of the clamp, and at the same time, sliding the Grid spring connector ("C" in Fig. 6.3-3) onto the long feedthrough pin next to the clamp using tweezers. The short feedthrough pin is at High Voltage common, but is not used in the EGG-3101 gun.

CAUTION: The Firing Unit will need to be firmly pressed into position to ensure that it seats fully and uniformly on the copper blocks. However, DO NOT PRESS on the domed Grid aperture. This is thin tantalum and could become damaged or damage the cathode behind it.

   b. **If necessary,** adjustment for a slightly different pin spacing is possible with the four lower 0-80 socket head cap screws ("E" in Fig. 6.3-3) on the Filament Lead Clamp.
   c. Tighten the four horizontal 0-80 screws ("B" in Fig. 6.3-3) near the top of the clamp to secure the firing unit.

3. Carefully insert the whole Firing unit feedthrough assembly straight into the Flange Multiplexer, in the orientation noted during disassembly. The copper block clamp should be visible through the optional glass viewport if present.

4. Replace and tighten the six 1/4x28 bolts ("A" in Fig. 6.3-1) in the 2¾ CF feedthrough flange.

5. With an ohmmeter, short check the Firing Unit Cartridge installation. The two filament lead pins on the central gun connector should be continuous (~0.2 ohms) with each other and open circuit to everything else. Check that the other electrical leads are not shorted to any of the other gun elements. (See pin out in Fig. 6.3-5.)

6. Reconnect the H.V. Multiconductor Source cable or reinstall the Electron Gun according Section 2.3. **HIGH VOLTAGE WARNING for optional Grid Pulsing cable only: Always discharge cable to ground before handling.**

7. When resuming normal operation, be sure to check the internal gun alignment. (Section 4.3).

8. **If a new/rebuilt firing unit with a BaO cathode is installed by the user, then the cathode needs to be activated following instructions provided with the firing unit.** After BaO activation, it is important to follow proper storage procedures.

The Kimball Physics Engineering Department should be contacted before any attempt to disassemble the firing unit. Firing units can be rebuilt at Kimball Physics (603) 878-1616.

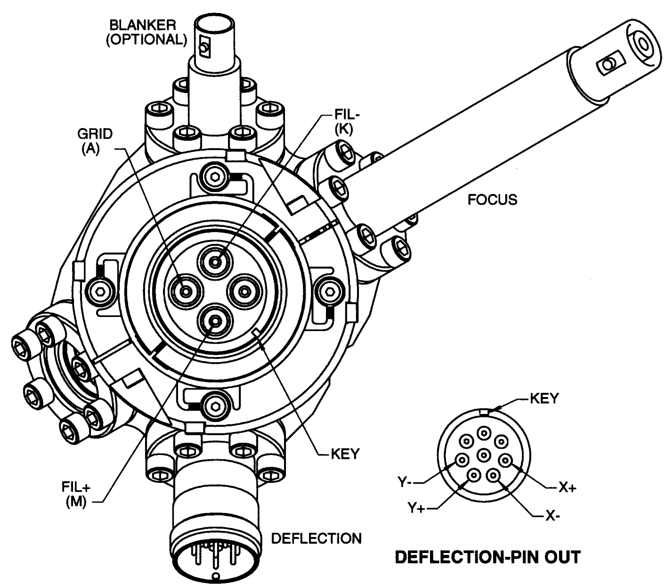

Fig. 6.3-5 EGG-3101 pinout as seen from the top of the Flange Multiple
NOTE: The position of Source connector may be rotated with respect to Focus and Deflection connectors, so use key positions for pinouts. An optional Faraday cup actuator may be mounted on the unused 1⅓ CF flange.

This completes the EGG-3101 Firing Unit Replacement Instructions.

6.4 POWER SUPPLY BOARDS AND MAINTENANCE

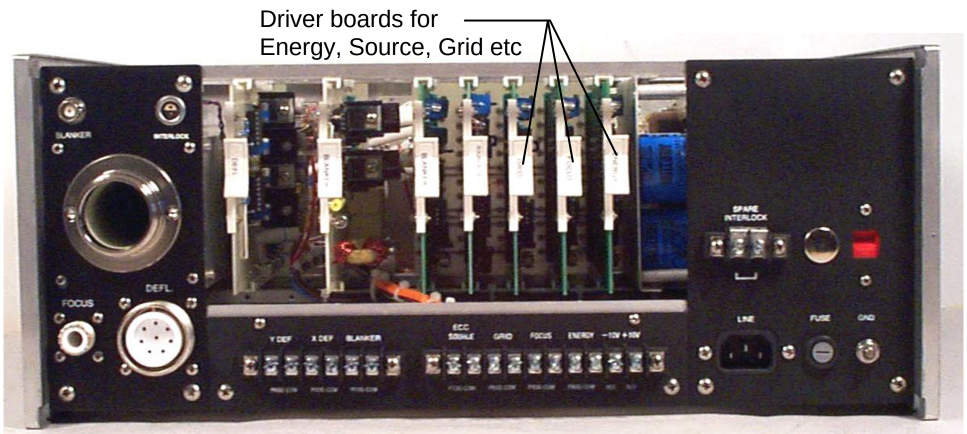

Fig. 6.4-1 A typical Power Supply with rear access panel removed, showing sine wave driver boards in slots (connectors and number of boards will vary with power supply model)

DANGER

HIGH VOLTAGE

Can cause ELECTRIC SHOCK or BURN

FOR EMERGENCY SHUT DOWN, DISCONNECT THE POWER CORD FROM THE AC OUTLET.

The Power Supply employs a modular design for ease of operation and repair. The main Power Supply unit includes a number of separate sine-wave driver boards, depending on the particular gun. The driver board is a sine-wave oscillator and is common to all of the control supplies such as Energy, Source, Grid, etc. Each individual power supply has a corresponding sine-wave driver board that provides transformer drive and remote metering signals. In some power supply systems, instead of individual boards, there is one auxiliary board that drives a transformer that provides power for all floating supplies, except Source. The driver boards are accessible by removing the rear center access panel of the Power Supply (or the entire back panel in some cases) and can be **temporarily** interchanged for quick troubleshooting. Refer to the troubleshooting instructions below.

Each board is factory-adjusted for a dedicated slot position, using feedback jumper positioning and trim potentiometer adjustments. The feedback jumpers on each board plug into two of the three sockets. The position of the feedback jumper determines whether a power supply is floating or grounded: vertical (perpendicular to the fuse) for floating supplies, and horizontal (parallel with the fuse) for grounded supplies. Some grounded supply boards, such as Deflection, do not include a jumper. For normal operation of the gun-control supplies, the feedback jumper should not be removed or its position changed.

Additionally, the trim potentiometers on each board (current limit, frequency adjustment, voltage adjustment, meter adjustment, etc.) usually should not be changed, as their values are adjusted at the factory. Refer to the Sine Wave Driver Board Drawing (000S930) in the Drawings Section for the location of each. However, if the cathode in the gun is changed, it may be necessary to adjust the Zener limit trim potentiometer on the Source/ ECC board (Fig. 6.4-3). Consult Kimball Physics before making any adjustments.

The boards are labeled on their tabs and are positioned in the same order as the labels on the panel for the remote terminals (with the exception that there is no corresponding board for the +10 V and -10 V terminals, or in some guns for Low Energy and Low Focus terminals).

Tables giving the board pin-outs and wire color codes are at the end of this section. Power Supply schematics are included in the Drawings Section.

6.4 POWER SUPPLY BOARDS AND MAINTENANCE cont.

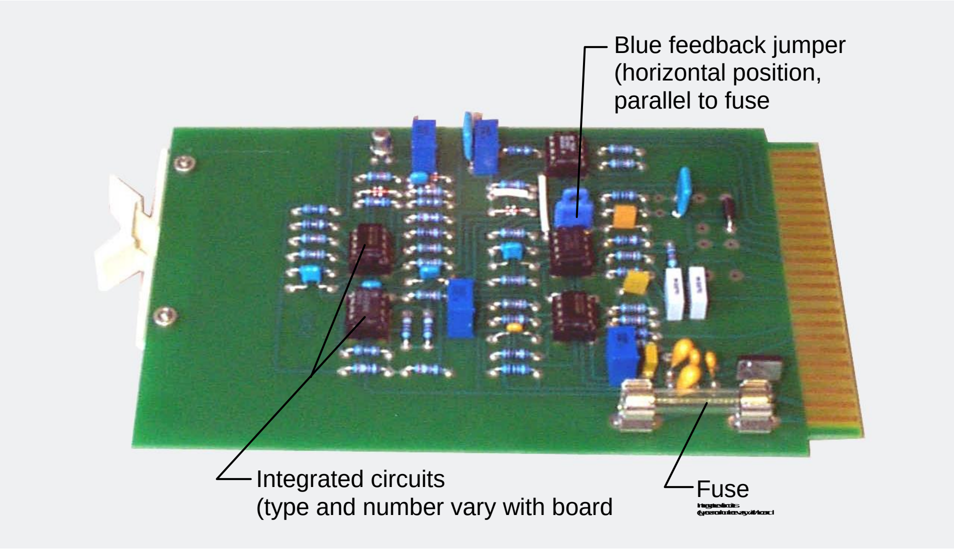

Fig. 6.4-2 A typical sine-wave driver board with the feedback jumper in the grounded position (an Energy board)

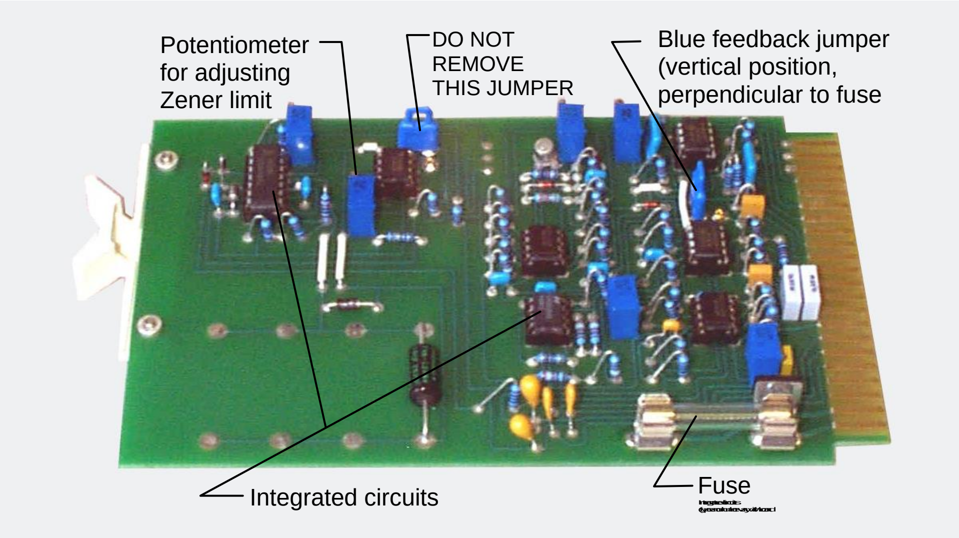

Fig. 6.4-3 A typical sine wave driver board with the feedback jumper in the floating position (a Source/ECC board), showing Zener adjustment trim potentiometer

CAUTION: Call Kimball Physics for advice before adjusting Zener limit with potentiometer.

6.4 POWER SUPPLY BOARDS AND MAINTENANCE cont.

6.4.1 DRIVER BOARD TROUBLESHOOTING

DANGER

HIGH VOLTAGE
Can cause ELECTRIC SHOCK or BURN

High Voltage will be present on the exposed gun connector end of the cable and inside the power supply during this troubleshooting procedure. **Do not touch cable end or power supply components.**

If a modular power supply, such as Energy, Source, Grid etc., becomes inoperative, perform the following steps.
H.V. WARNING: Proper electrical safety precautions must be observed during troubleshooting operations.

1. Secure (turn off) operation of the Electron or Ion Gun according to Section 4.2. Disconnect **ALL** of the cables from the gun. The other ends of the cables must remain connected to the Power Supply.

2. Remove the rear center access panel from the Power Supply (see Fig. 6.4-1).

3. To find out if a driver board is at fault:
   a. Remove the suspected driver board.
   b. Check the fuse (Figs. 6.4-2 and 6.4-3). Measure resistance across the fuse with an ohmmeter. **If resistance is greater than 1 Ω, the fuse needs to be replaced.**
   c. If the fuse is blown:
      i. Replace the fuse (usually 1 amp, sometimes ½ amp, see fuse).
      ii. Reinstall the driver board in its slot in the card cage.
      iii. Energize the power supply and check operation of the supply.

4. If the fault still exists:
   a. Remove the suspected driver board.
   b. Note the position of the blue-colored feedback jumper (see Figs. 6.4-2, 6.4-3 and Table 6.4.1). The blue feedback jumper must be oriented correctly according to the feedback requirements of the slot that the board is being tested in.

5. To replace the suspected driver board with one from another slot:
   a. Ensure that the feedback jumper is in the proper location (the same as the suspected board).
   b. Insert the replacement board in the slot.
   c. Energize the power supply and check operation of the driver board.
   d. If, after switching the driver boards, the circuitry operates, it can be concluded that the original board malfunctioned.
   e. **NOTE: Each driver board is calibrated for a specific slot. Therefore, the output will differ if boards are interchanged.**

6. Once a driver board has been determined to be faulty:
   a. Reinspect the fuse. Replace the fuse if necessary.
   b. Replace the integrated circuit chips. Any one of these could have been damaged by a transient. (Standard -- two MC1458, one CA3028AS, and either two TL082, or one TL082 and one AD706. ECC board -- addition one LM324 and one TL431., see Drawings 000S930 and 000S971)
   c. Replace the board, and check operation of the power supply.

7. Return all boards to their original locations, with their jumpers in the original positions (Table 6.4.1). Replace the rear access panel.

If these steps do not repair the Power Supply, call Kimball Physics Engineering at (603) 878-1616.

6.4 POWER SUPPLY BOARDS AND MAINTENANCE cont.

6.4.2 POWER SUPPLY BOARDS, FUSES, AND WIRING TABLES

Table 6.4-1 Boards used in EGPS-3101 (Pull-out boards in order of position in slots)

BOARD LABEL	BOARD TYPE	KIMBALL PHYSICS BOARD # / PART #	JUMPER	FUSE	POSITION
Deflection	Deflection Control MCDU (±300V)	197B230C	No jumper	0.3 A (two)	Pull-out
Blanker (optional)	Blanker Power Supply	197B310A	No jumper	--	
Blanker (optional)	Sine wave Driver	197B191F / 20-019100	Vertical (Floating)	1 A	
Source / ECC	Sine wave Driver w/ ECC	197B190E / 20-019000	Vertical (Floating)	1 A	
Grid	Sine wave Driver	197B191F / 20-019100	Vertical (Floating)	1 A	
Focus	Sine wave Driver	197B191F / 20-019100	Horizontal (Ground)	1 A	
Energy	Sine wave Driver	197B191F / 20-019100	Horizontal (Ground)	1 A	
	Main Auxiliary Power Supply	197B150D / 20-015000			Fixed
	MCDU Power Supply (dual xfmr)	197B240B			
	TTL Relay (ECC & MCDU) (for computer program only)	20-070500 / 20-070500			
	Remote Interface (std C.C) ***OR*** Remote Interface (C.C w/ D-subs, for computer program)	235M910A ***OR*** 197A390C / 20-03900			

NOTE: For High Current option, the external H.V. Power Supply replaces the Energy board.

Table 6.4-2 Fuses used in EGPS-3101 Power Supply

FUSE LOCATION	FUSE REFERENCE DESIGNATORS	VALUE	RATING / SIZE	KIMBALL PHYSICS PART NUMBER
Main Fuse (Rear Panel of EGPS)	FUSE	2A	250 V, TYPE T / 3AG slo-blo	19-402003
197B190E / 20-019000 Sine Wave Driver Board **Source / ECC**	No label	1 A	250 V, Type F / 3AG	19-401001
197B191F / 20-019100 Sine Wave Driver Board **Energy Focus Grid, Blanker**	No label	1 A	250 V, Type F / 3AG	19-401001
197B230C / MCDU Control Board **Deflection**	No label (two fuses)	0.3 A	250 V, Type F / 3AG	19-400301

Table 6.4-3 Sine-wave Driver Board Pin Out Assignment

PIN OUT	DESCRIPTION
1 top	Emission meter IN (Source/ECC only)
2	ECC program OUT (Source/ECC only)
3	ECC program IN (Source/ECC only)
4	Switching transistor base drive
5	--
6	Switching transistor base drive
7	Voltage meter output
8	--
9	Isolation transformer feedback
10	Isolation transformer feedback and ground
11	--
12	(Negative) current feedback
13	(Positive) current feedback
14	--
15	Control voltage 0 - 10 V
16	-15 V
17	Ground
18	+15 V
19	--
20	--
21	Fused +100 VDC to center tap of isolation transformer, primary side
22 bottom	+100 V DC input to fuse

6.4 POWER SUPPLY BOARDS AND MAINTENANCE cont.

Table 6.4-4 Wire Color Codes

GAUGE	WIRE COLOR	DESCRIPTION
18	Green	Ground
18	Black	AC Hot
18	White	AC Neutral
18	Blue	AC Hot
18	Brown	AC Neutral
18	Red	100 V
24	Yellow	+24 V Common
24	Yellow / White	+24 V
24	Red / White	+15 V
24	Blue / White	-15 V
24	Orange / White	+10 V
24	Gray / White	-10 V
24	Violet / White	+5 V
24	Brown / White	-5 V
24	Green / White	Meter Signals
24	Orange	Control 0 - 10 V
24	Gray	LED Positive, base drive signals
24	Brown	Feedback
24	Black and Violet (twisted pair)	Interlock

6.4 POWER SUPPLY BOARDS AND MAINTENANCE cont.

Table 6.4-5 Deflection MCDU-4C (300 V) Control Board Pin Out Assignment

PIN OUT	DESCRIPTION
1 top	+ X Output ±300 V
2	- X Output ±300 V
3	+ Y Output ±300 V
4	- Y Output ±300 V
5	Ground
6	X Meter Output
7	Y Meter Output
8	Ground
9	24 V Common
10	+24 V from DEFL Pushbutton Switch
11	--
12	-15 V Input
13	+15 V Input
14	--
15	--
16	--
17	--
18	--
19	Y Program Input
20	X Program Input
21	-300 V Input
22 bottom	+300 V Input

6.5 GUN DISASSEMBLY / REASSEMBLY for ANODE REPLACEMENT

The aperture in the anode (G-2) element can limit the electron beam. A smaller aperture can be an advantage in improving beam uniformity or producing a small spot, while a larger aperture can be an advantage in increasing total beam current or allowing a larger spot. Thus, for different experimental designs or with a different cathode type, it may be desirable to replace the anode with one with a different aperture size. The modular design of the EGG-3101 allows the anode to be exchanged with only a little gun disassembly.

> ⚠ **NOTE**
>
> Use of **clean room gloves** is recommended to keep parts free of fingerprints and other contaminants.
>
> **READ ALL INSTRUCTIONS BEFORE DISASSEMBLY**

Before attempting to disassemble or reassemble the EGG-3101, or before attempting to replace the Anode, obtain the following tools:

- 12 point socket wrench
- 0.050" Allen wrench
- tweezers
- can of compressed (microscopically clean) gas

All tools should be clean to prevent contamination of parts.
USE CLEAN ROOM TECHNIQUES

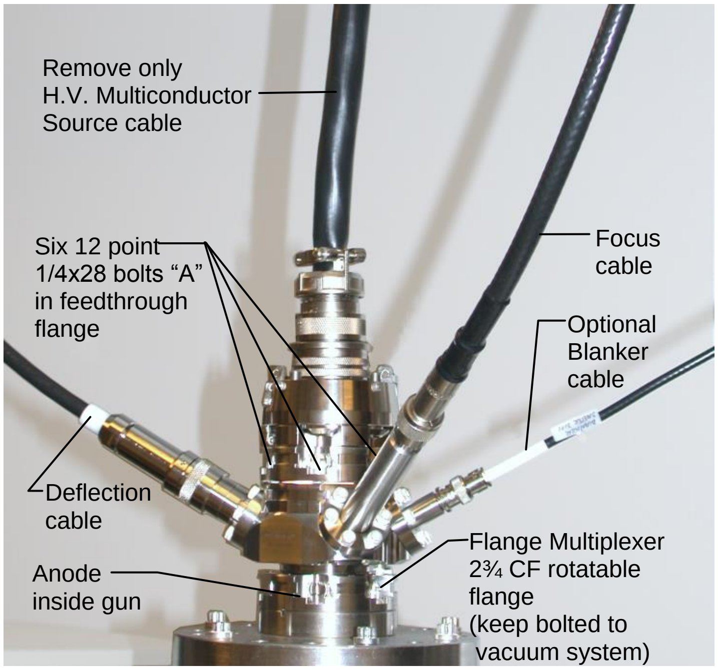

Fig. 6.5-1 EGG-3101 Electron Gun before disassembly

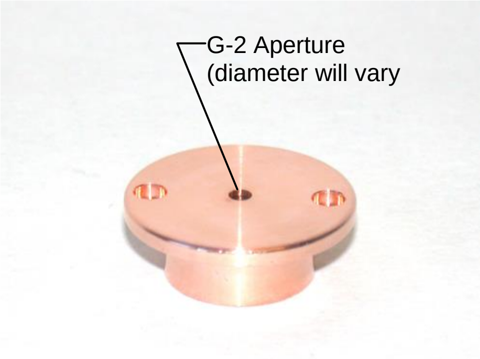

Fig. 6.5-2 Copper Anode element, G-2 aperture

8. Secure (turn off) the EGG-3101/EGPS-3101 Electron Gun System according to the directions in Section 4.2.

9. Disconnect the H.V. Multiconductor Source cable from the electron gun.

10. If there is sufficient access, the gun may remain bolted to the vacuum system with the focus and deflection cables in place, as the Anode can be removed from the cable end of the gun.

11. Before proceeding, note the orientation of the key / flange for ease of later realignment.

12. To remove the firing unit feedthrough assembly: (Figs. 6.5-1 and 6.5-3).
    a. Using a 12 point socket wrench, remove the six 1/4x28 bolts ("A" in Fig. 6.5-1) in the 2¾ CF feedthrough flange.
    b. Carefully, lift out the whole firing unit feedthrough assembly straight out from the Flange Multiplexer. Set this assembly aside. (Fig. 6.5.3)
    c. The lens assembly will remain in place inside the gun housing. Looking down the Flange Multiplexer the copper Anode should now be visible. (Figs. 6.5-2 and 6.5.4 below)

Fig. 6.5-3 EGG-3101 Firing Unit Feedthrough Assembly removed from gun Do not disassemble.

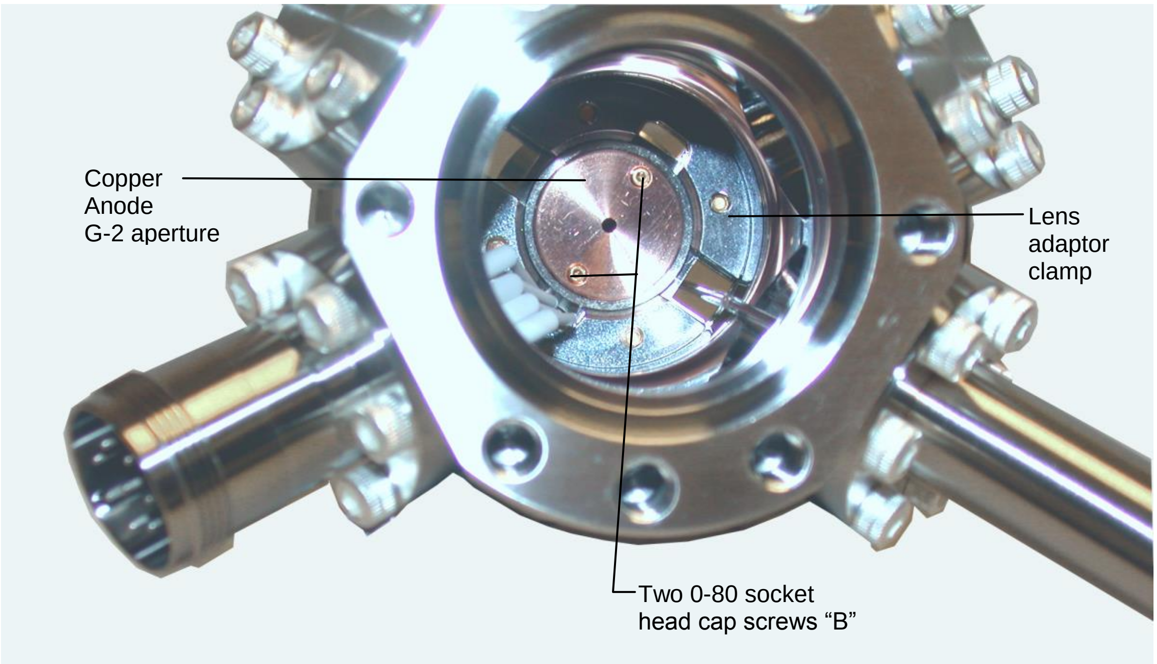

Fig. 6.5-4 Copper anode as seen through the Flange Multiplexer
(The gun can remain in vacuum system; parts removed for photo only)

NOTE: The screws used in the Electron Gun are stainless steel, gold-plated for lubrication (not brass); any substitution with screws which are not gold-plated will invalidate the warrantee on the Electron Gun. Replacement screws are available from Kimball Physics.

13. To remove the Anode G-2 aperture
    a. Reaching into the Flange Multiplexer, remove the two 0-80 socket head cap screws ("B" in Fig. 6.5-4) in the Anode, using a 0.050" Allen wrench
    b. Lift the anode out of the lens assembly with tweezers.

14. When reassembling, **blow all dust** and other particles off all gun surfaces.

15. To replace the Anode:
    a. Insert the new anode (G-2) with a different aperture size into the lens adaptor clamp. Check that it is seated evenly.
    b. Secure with the two screws ("B" in Fig. 6.5-4).

16. With a new copper gasket in place, carefully insert the firing unit feedthrough assembly straight into the Flange Multiplexer, in the orientation noted during disassembly. Replace and tighten the six 12 point bolts ("A" in Fig. 6.5-1).

17. Reconnect the H.V. Multiconductor Source cable or reinstall the Electron Gun according Section 2.3.

18. When resuming normal operation, be sure to check the internal gun alignment as it may be different with the new anode aperture. (Section 4.3).

This completes the EGG-3101 Anode Replacement Instructions.

6.6 GUN DISASSEMBLY / REASSEMBLY for LENS ADJUSTMENT OR REPLACEMENT

The modular design of the EGG-3101 allows the entire lens assembly of the gun to be replaced by the user. The lens assembly contains the anode, an Einzel focusing lens assembly and a 4-pole electrostatic deflection unit. To adapt for a variety of applications, this entire modular assembly can be exchanged for a different one with some gun disassembly. For example, the lens assembly that produces a focused collimated beam could be replaced with one that produces a flood type beam. The anode alone can also be replaced for a different aperture size.

In addition, the cathode to anode spacing of the gun can be adjusted, due to the modular gun design. This adjustment will affect both the total beam current and the focusing of the electron beam

If the anode is moved closer to firing unit cartridge (cathode and grid), the triode spacing is decreased and the field strength between the cathode and anode will be increased, all other parameters being equal. Increasing this extraction field can increase beam current.

This increasing field strength also changes the beam trajectory, generally decreasing beam divergence (making the beam “tighter”) as the beam enters the focusing lens and so affects focusing.

Changing the triode spacing does not alter the beam energy, which is determined only by the potential difference.

To replace only the anode, see Section 6.5 above. Anode replacement does not require removing the lens assembly and the gun body can remain installed on the vacuum system.

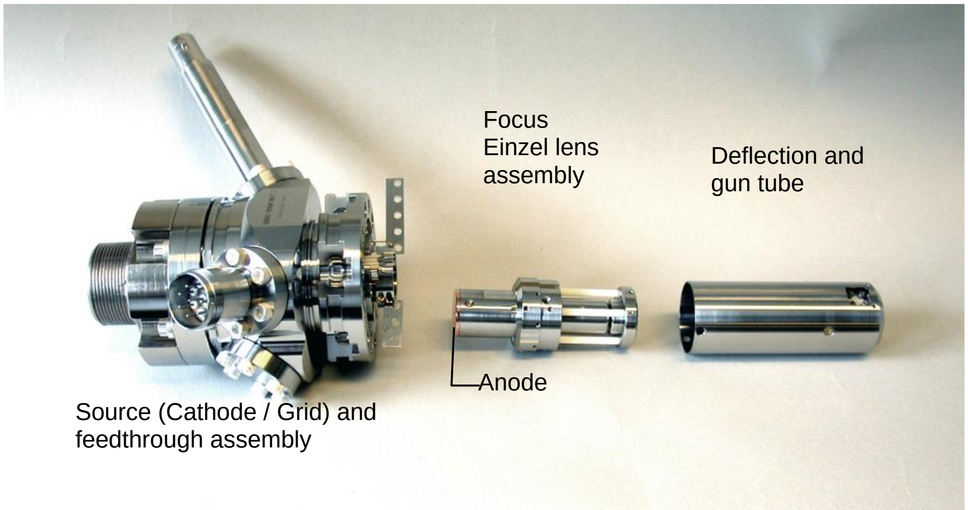

Fig. 6.6-1 Modular Electron Gun partially disassembled, showing Source, Focus and Deflection modules (details of assemblies may vary with gun model, optional blanker not shown)

6.6.1 ELECTRON GUN DISASSEMBLY

> **⚠ NOTE**
>
> Use of **clean room gloves** is recommended to keep parts free of fingerprints and other contaminants.
>
> **READ ALL INSTRUCTIONS BEFORE DISASSEMBLY**

Before attempting to disassemble or reassemble the EGG-3101 obtain the following tools:

- 12 point socket wrench
- 0.035" Allen wrench
- 0.050" Allen wrench
- #00 Phillips screwdriver
- #1 Phillips screwdriver
- Straight blade screwdriver
- Tweezers
- ohmmeter
- can of compressed (microscopically clean) gas

All tools should be clean to prevent contamination of parts. USE CLEAN ROOM TECHNIQUES

1. Secure (turn off) the EGG-3101/EGPS-3101 Electron Gun System according to the directions in Section 4.2

2. Disconnect all cables from the electron gun.

3. Remove entire electron gun from vacuum:
   a. Remove the six 12 point bolts in the rotatable flange of the Flange Multiplexer.
   b. Pull the gun straight out of the vacuum chamber, being careful not to damage the exposed leads on the gun housing.

4. Remove the deflection leads:

CAUTION: The deflection and focus leads and their insulators and tabs are all very fragile.

   a. Using a straight blade screwdriver, remove the deflection lead cover and clamping strap by removing the two 1-72 binder head screws ("A" in Fig. 6.6-2) in the strap and two 1-72 binder head screws ("B" in Fig. 6.6-2) in the cover.
   b. Using a # 00 Phillips head screw driver, remove the four 0-80 Phillips fillister screws ("C" in Fig. 6.6-4) at the end of the four deflection leads in the square window near the front of the gun. These leads and tabs are fragile.
   c. Remove the four deflection leads by sliding their spring connectors off the pins ("D" in Fig. 6.6-3). For reassembly, make note of the position and orientation of each of the four leads as they are removed.

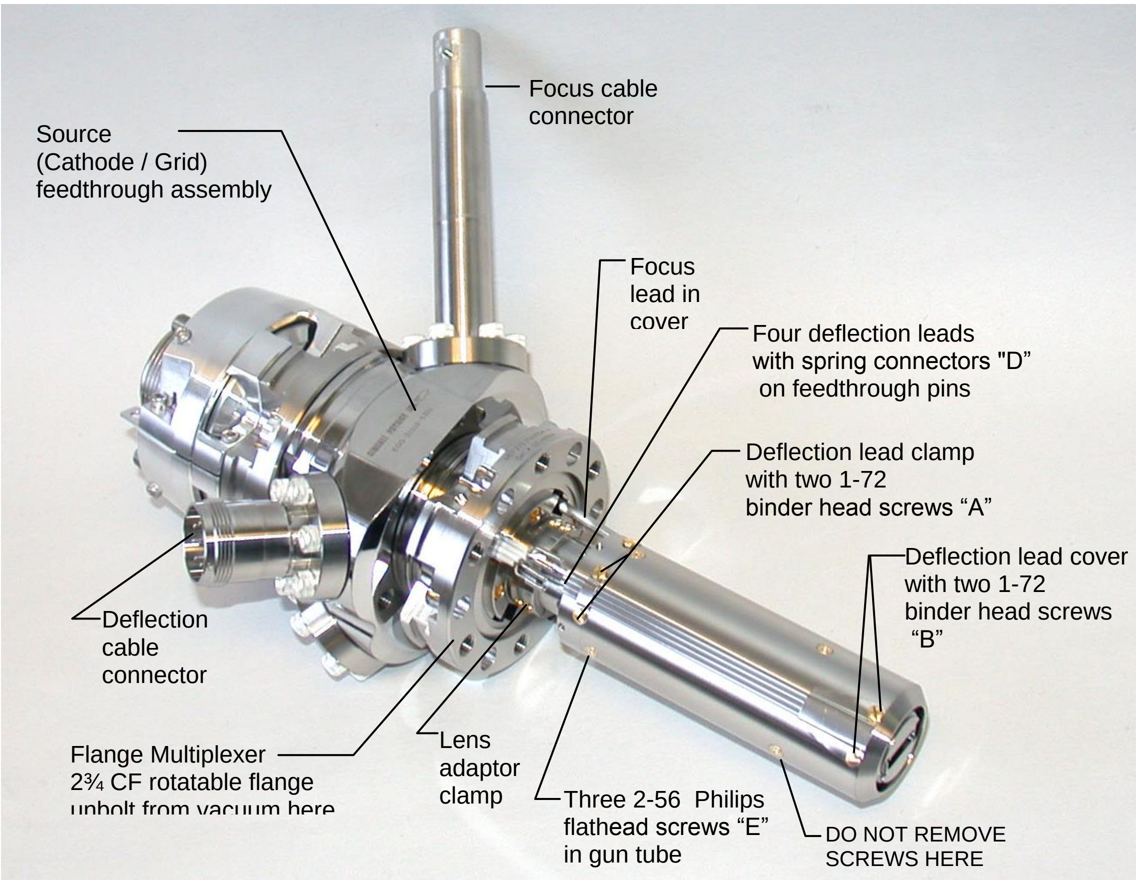

Fig. 6.6-2 EGG3101 before disassembly

6.6 GUN DISASSEMBLY for LENS ADJUSTMENT OR REPLACEMENT cont.

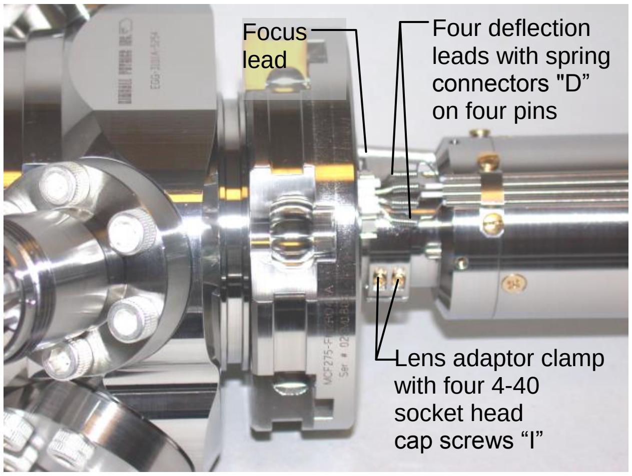

Fig. 6.6-3 Lens adaptor clamp and flange connections

5. Remove the gun tube / deflection assembly.
   a. Using a #1 Phillips screwdriver, remove the three 2-56 Phillips flat head screws ("E" in Fig. 6.6-2) in the gun tube nearer to the flange.
   b. Carefully slide the gun tube forward off the end of the gun, exposing the Einzel lens focus assembly.

6. Remove the focus lead:
   a. Using a straight blade screwdriver, remove the single 1-72 binder head screw ("F" in Fig. 6.6-5) near the quartz tube focus lead cover. **This focus lead is extremely fragile.**
   b. Using a 0.035 in. Allen wrench, loosen the 1-72 socket head set screw ("G in Fig. 6.6-5) that clamps the focus lead in the focus ring.
   c. Carefully, pull the quartz tube back toward the flange to expose the copper wire. ("H in Fig. 6.6-5) Pull the copper wire forward and out. Remove the fragile quartz tube and metal focus lead cover.

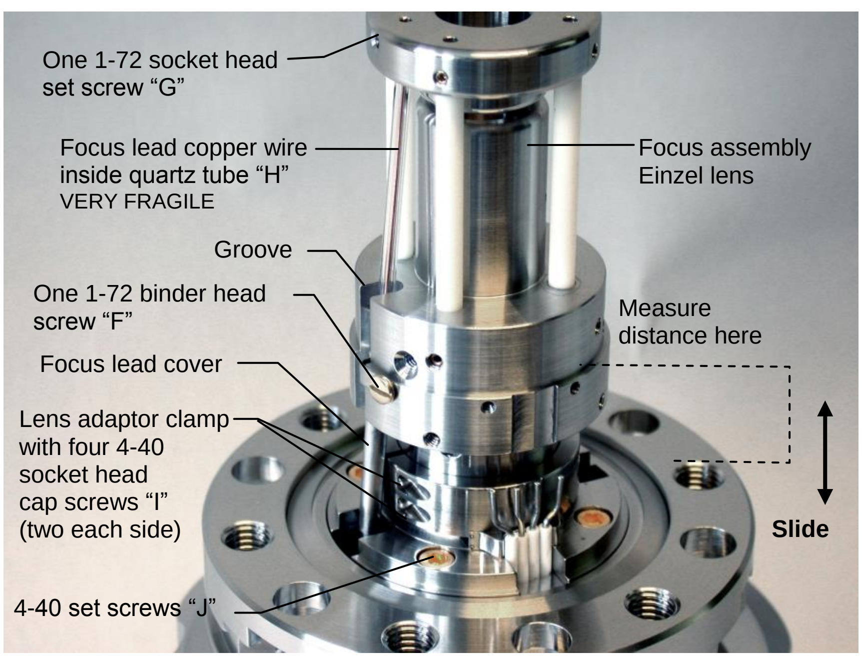

Fig. 6.6-5 Lens assembly on feedthrough flange

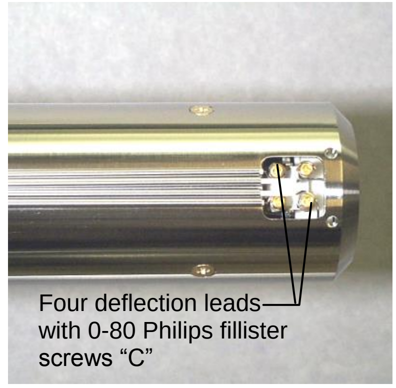

Fig. 6.6-4 Deflection connections at end of gun

7. Loosen the lens assembly adaptor clamp:
   a. For reassembly; **measure exactly and record** the distance from the sealing surface of the Flange Multiplexer to the edge of the lens assembly, see Fig. 6.6-5.
   b. Using a 5/64 in. Allen wrench, loosen the four 4-40 socket head cap screws in the lens adaptor clamp ("I" in Fig. 6.6-4 and Fig. 6.6-5). It may also be necessary to slightly loosen the 4-40 set screws next to the flange ("J" in Fig. 6.6-5).
   c. Gently, attempt to slide the focus assembly slightly on the tube, using a drop of isopropyl alcohol as a lubricant.
   d. **If it is difficult to slide the assembly,** use two strips of sheet metal to enlarge the clamp diameter slightly. (Fig. 6.6-6)
      i. Remove the top two socket head cap screws and insert a strip of metal into the screws' slot on each side.
      ii. Thread the screws into the threaded screw hole (the reverse of the screws normal orientation), until the screw presses against the sheet metal strip.
      iii. A small amount of screw pressure will allow the assembly to slide.
      iv. When finished, remember to remove the metal strip if used and replace the screws in their normal orientation.

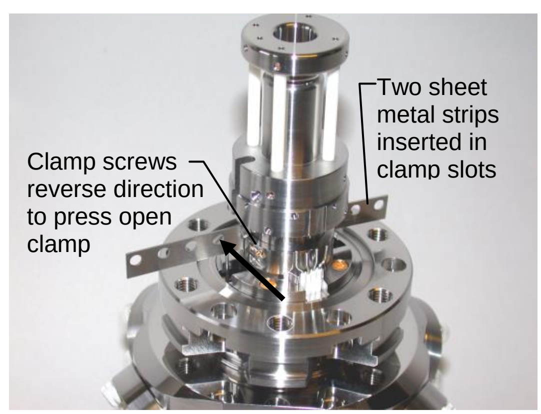

Fig. 6.6-6 Lens with strips to spread clamp

6.6 GUN DISASSEMBLY for LENS ADJUSTMENT OR REPLACEMENT cont.

8. At this point the lens assembly can either be slid to adjust the cathode to anode spacing, or else the assembly can be removed to exchange the whole assembly.

9. **To adjust the cathode to anode spacing**:
   a. The amount of possible change is only 1 or 2 mm, as limited by the amount of play in the deflection and focus leads.
   b. Carefully, slide the entire lens assembly to change the spacing between the cathode and the copper anode at the end of the lens assembly, as desired. It is not necessary to remove the lens assembly from the clamp.
   c. Tighten the four screws (“I” in Fig. 6.6-4 and Fig. 6.6-5) in the lens adaptor clamp. Also tighten the 4-40 set screws (“J” in Fig. 6.6-5) if loosened.
   d. Measure the new position.
   e. Proceed to the reassembly instructions.

10. **To replace the entire lens assembly (Fig. 6.6-7):**
    a. Slide the entire lens assembly out of the clamp.
    b. Proceed to the reassembly instructions.

11. To replace the anode in the lens assembly, if desired.
    a. Using a .050” Allen wrench, remove the two 0-80 socket head cap screws in the copper anode (“K” in Fig. 6.5-7
    b. Pull the copper Anode (G-2 aperture) out of its holder with tweezers. It should come out easily.
    c. Insert a new copper anode with a different aperture size, and secure by replacing and tightening the two screws.

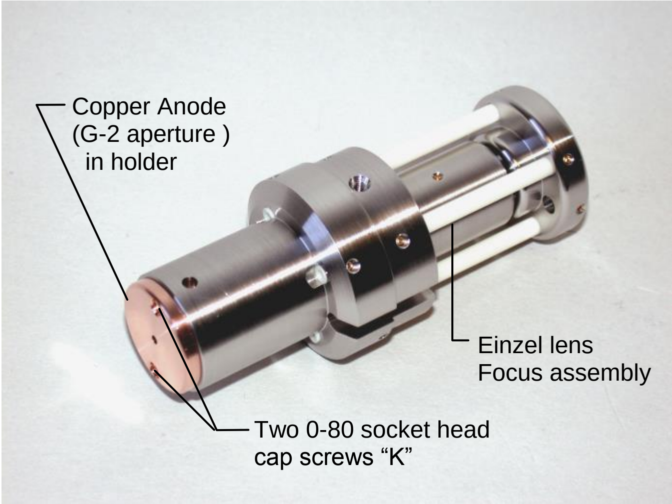

Fig. 6.6-7 Lens assembly removed from gun (details of lens assembly may vary)

This completes the Gun Disassembly Instructions.

6.6 GUN REASSEMBLY for LENS ADJUSTMENT OR REPLACEMENT

CAUTION

Between each step of reassembly, **blow all dust** and other particles off all gun surfaces.

When reassembling keep proper **clearance between the high voltage electrical leads and the housing.** Otherwise, **discharging** will result during electron gun operation

6.6.2 ELECTRON GUN REASSEMBLY

1. Disassemble the EGG-3101 Electron Gun according to Section 6.6.1 Refer to the figures above during reassembly.

NOTE: The screws used in the Electron Gun are stainless steel, gold-plated for lubrication (not brass); any substitution with screws that are not gold-plated will invalidate the warrantee on the Electron Gun. Replacement screws are available from Kimball Physics.

2. To replace the Lens assembly, **if removed**:
   a. Slide the lens assembly into the lens adaptor clamp. Position the lens assembly so that the groove for the focus lead lines up with the focus cable connector and the split in the clamp (Fig. 6.6-5).
   b. Adjust the spacing to exactly that measured during disassembly
   c. Tighten the four screws ("I" in Fig. 6.6-3 and Fig. 6.6-5) in the lens clamp. Also tighten the 4-40 set screws next to the flange ("J" in Fig. 6.6-5) if loosened.

3. Reconnect the focus lead:

CAUTION: The focus and deflection leads and their insulators and tabs are all very fragile.
   a. Replace the focus lead quartz tube and cover ("H" in Fig. 6.6-5) in the groove of the G-2 holder and the flange.
   b. Replace the copper wire, through the hole in the focus ring, through the quartz tube and cover, and into the connector. It may be necessary to jiggle the wire to get it to slide into the connector.
   c. Push the copper wire down until it is just below the surface of the focus ring.
   d. Tighten the set screw ("G" in Fig. 6.6-5) in the focus ring.
   e. Replace and tighten the binder head screw ("F" in Fig. 6.6-F) in the focus cover.

4. Replace the gun tube and deflection assembly:
   a. Carefully, slide the gun tube over the lens assembly, Position the tube so that the window lines up with the deflection pins.
   b. Replace the three Phillips flat head screws ("E" in Fig. 6.6-2).in the gun tube. Do not overtighten the screws.

5. Reconnect the deflection leads:
   a. Replace the four deflection leads in their original positions as noted during disassembly, sliding the spring connectors onto their appropriate pins ("D" in Fig. 6.6-3). In the correct orientation the bent leads should slide easily onto the pins.
   b. Replace and tighten the four 0-80 Phillips fillister screws ("C" in Fig. 6.6-4) on the tabs in the window.
   c. **CAUTION: Make sure that the four tube covers do not touch the bare wires at the ends and short against them.**
   d. Replace the deflection lead cover and strap and secure with their four 1-72 binder head screws ("A" and "B" in Fig. 6.6-2).

6. With an ohmmeter, check the Focus and Deflection connectors to see that the leads are not shorted to each other or any other gun elements. (See pin out in Fig. 6.6-8.)

7. Reinstall the Electron Gun according Section 2.3

8. When resuming normal operation, be sure to check the internal gun alignment. (Section 4.3).

The Kimball Physics Engineering Department should be contacted before any attempt to disassemble the Einzel lens or deflection assemblies. These assemblies can be rebuilt at Kimball Physics (603) 878-1616.

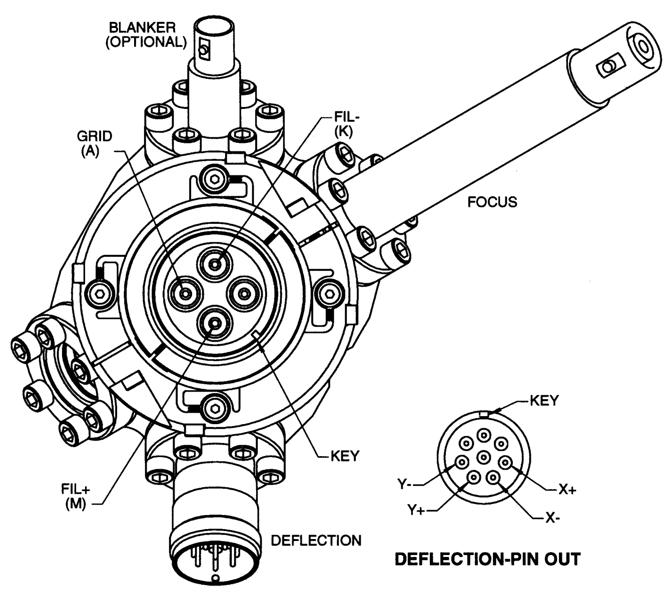

Fig. 6.6-8 EGG-3101 pinout as seen from the top of the Flange Multiplexer
NOTE: The position of Source connector may be rotated with respect to Focus and Deflection connectors, so use key positions for pinouts An optional Faraday cup actuator may be mounted on the unused 1⅓ CF flange.

This completes the Lens Adjustment or Replacement Instructions.

7 GLOSSARY FOR ELECTRON AND ION GUNS

Alignment: (1) Positioning of the physical elements of the electron/ion gun so that the charged particles travel in the optimal path through the gun.
(2) **Mechanical beam alignment:** A mechanical adjustment of the gun that changes the orientation of elements of the gun with respect to other elements or with respect to the target; use of a device to line up gun with the target, for example, using a Port Aligner which consists of two rotating angled disks.
(3) **Magnetic compensation alignment:** Displacement of the electron/ion beam in a plane (X-Y) perpendicular to the line of travel (Z) of the beam, by means of the magnetic fields produced by electric coils (X+,X- and Y+,Y-) arranged around the beam; used to position the beam on the target and improve beam current and beam uniformity.

Analog meter: A meter with a dial and pointer which displays current or voltage.

Anode: (also **G-2**) (1) The second electrostatic lens element in the gun, which usually provides the potential difference that accelerates the electrons; the third element of the triode; usually a tube with an aperture (hole); often grounded, but may be referenced to Energy and have a varied voltage.
(2) The power supply that applies voltage to the anode element in some guns. Also, the potentiometer that controls this power supply.

Aperture: A small hole that the electron/ion beam goes through, which can control the path and/or diameter of the beam.

Barium oxide (BaO): A coating applied to a cathode that reduces the work function enabling electron emission at lower temperatures, thus reducing light output.

Bake out: Heating the electron/ion gun while in vacuum to remove and pump away contaminants.

Beam blanking: Deflecting the electron/ion beam to one side of the gun tube to interrupt the flow of particles to the target without actually turning off the beam; can be used to pulse the final beam current repeatedly on and off, controlled by a TTL signal input.

Beam current: The electron/ion current exiting the gun, usually measured by a Faraday cup at the end of the gun (in mA, μA, or nA); not identical to emission current.

Beam current density: The beam current per unit area reaching the target (typically in $\mu A/cm^2$).

Beam current distribution: The variation in beam current density at different positions in the spot at the target.

Beam divergence: The angular spread of the electron/ion beam as it exits the gun (in degrees º).

Beam pulsing: See Pulsing.

Beam uniformity: A qualitative statement about the beam current distribution, usually Gausian-like.

Cartridge: (1) **Firing unit cartridge:** For electron Guns: An assembly containing cathode and grid which is part of a larger firing unit of some guns and can be replaced separately.
(2) **Ion source cartridge or alkali metal cartridge:** For Ion Guns: A cup containing a solid that is heated to produce alkali metal ions directly by a solid-solid chemical reaction, part of the ion source firing unit.

Cathode: The structure in the electron gun that emits electrons; the first element of the triode; may consist of a sharply-bent wire (hairpin) or of a heating wire and an emitting disc or other configuration.

Centering: See Deflection.

Charged particle: An electron or ion.

CF, ConFlat: A type of vacuum flange with a knife edge on the sealing surface; sized by the approximate diameter:
1⅓ CF ~1.33 inch ~34 mm,
2¾ CF ~2.75 inch ~70 mm,
4½ CF ~4.5 inch ~178 mm.
(The ConFlat flange was invented by Bill Wheeler at Varian; ConFlat is a registered trademark of Varian Associates.)

Cut off (also **Grid cut off**): (1) Shutting off the flow of electrons/ions to the target; for electrons, by making the grid voltage sufficiently negative that the electrons from the cathode are repelled and do not go through the grid, or similarly for positive ions, by making the grid sufficiently positive that the ions in the source region are repelled.
(2) The minimum grid voltage that reduces the beam current to zero.

Deflection, X and Y Deflection: (1) Electrostatic or electromagnetic displacement of the electron/ion beam in a plane (X-Y) perpendicular to the line of travel (Z) of the beam, by means of voltages applied to two pairs of plates (X+,X- and Y+,Y-) , or by currents applied to deflection coils, arranged around the beam; used to position the beam on the target, generally without affecting the focus and energy of the beam.
Also sometimes called **centering or X-Y centering**.
(2) The two power supplies that apply voltage to the deflection plates. Also the potentiometers that control the deflection power supplies.

Differential Pumping: Maintaining a different vacuum pressure in the electron or ion gun and the main vacuum chamber by connecting separate vacuum pumps to the two areas, usually using a Compact Tee differential pumping connector on the gun.

D.V.M., Digital volt meter: A meter that displays in numbers the amount of volts or kilovolts output from a given power supply.

ECC: (1) **Emission Current Control** For Electron Guns: Feedback circuitry that regulates the source power supply that heats the filament; used to maintain a constant emission current from the cathode.
(2) **Emission Current Control** For Alkali metal Ion Guns: Feedback circuitry that regulates the source power supply that heats the alkali metal cartridge; used to maintain a constant ion emission current from the ion source.
(3) **Electron Current Control** For Gas Ion Guns: Feedback circuitry that regulates the source power supply that heats the filament in the ion source, so that a constant flow of electrons is given off; only indirectly controls the production of ions by the ion source.
(4) Also the potentiometer and switch that control the ECC circuitry.

Emission current: (1) For Electron Guns: The total electron current that leaves the cathode and goes to ground (in mA or μA); equivalent to all the current that exits the gun (beam current) plus all the current that lands on grounded elements within the gun.
(2) For Ion Guns: The total ion current produced by the ion source that goes to ground (in mA or μA), directly measured in only some gun; not identical to the electron emission current which causes gas ionization or to the ion beam current which exits from the gun; equivalent to all the current that exits the gun (beam current) plus all the current that lands on grounded elements within the gun.

Energy (1) Kinetic energy of a charged particle emitted from the gun; equal to $\frac{1}{2}mv^2$, where m is the particle mass and v is the particle velocity; this energy is achieved by applying accelerating voltages to elements of the gun. 1 eV is equivalent to the energy obtained by a particle with unit electronic charge (1.6021×10^{-19} coulombs) accelerated by a 1 volt potential difference and is equal to 1.6021×10^{-19} joules.
(2) The energy power supply that provides the electron/ion accelerating voltage; other power supplies can be referenced to this power supply. Also, the potentiometer and switch that control the energy power supply.
(3) For Ion Guns: also called Ion Energy.

Extract (also **G-2**) (1) The second electrostatic lens element in the ion gun, which provides the potential difference that extracts the ions from the ion source region and accelerates them; usually a tube with an aperture (hole); often grounded, but may be referenced to Energy and have a variable voltage.
(2) The power supply that applies voltage to the extract element in some ion guns. Also, the potentiometer that controls this power supply.
(3) For Ion Guns: also called **Ion Energy**

Faraday cup A particle-collecting device consisting of a shielded cup and output wire; usually used with an ammeter in series to ground to measure beam current.

Feedthrough: Electrical, gas, mechanical and other connections (wires, tubing, insulators etc.), usually from vacuum to non-vacuum parts of a system.

Filament, Fil+, Fil-: (1) The wire heating part of the standard cathode or ion source.
(2) Also the positive and negative leads to the cathode or ion source.

Firing Unit: (1). For Electron Guns: The part of the gun that emits the electrons; the assembly that can be replaced as a unit, usually consisting of the complete triode (cathode, grid and anode) or just the cathode and grid; in some guns, only a part of the firing unit called the firing unit cartridge needs to be replaced.
(2) For Ion Guns: The part of the gun that produces the ions; the assembly that can be replaced as a unit, usually consisting of the gas ion source or alkali metal ion cartridge, the grid and sometimes extract elements.

Flange Multiplexer: A vacuum component with one flange surface (usually 2¾ CF) to connect to a vacuum port and five smaller flanges (usually 1a CFs) for various feedthrough and cable connections; used as the mounting system on many electron/ion guns.

Focus (also **Lens**): (1) One or more electrostatic or magnetic lens elements in the electron/ion gun that control the beam spread; usually controls spot size at the target; in some guns, may control beam divergence at points internal to the gun.
(2) The power supply that applies voltage or current to the focus/lens element(s). Also, the potentiometer that controls this power supply.

Gaussian: A normal distribution curve; even if a beam current distribution is not strictly Gaussian, this term is used to describe distributions that are brightest in the center of the spot and fade off at the edges.

G-1, G-2, G-3, G-4.: The series of apertures and electrostatic lens elements in the electron/ion gun labeled by their position (first ,second, third, fourth) instead of by common names.

Grid (also **G-1**)**:** (1) The first electrostatic lens element in the electron/ion gun; the second element of the triode in electron guns; provides the first control and usually focuses the beam to a crossover; usually a tube with an aperture (hole), but may be a mesh (like a screen); can be used to cut-off the beam in most guns.
(2) The power suppl(ies) that apply voltage to the grid element. Also the potentiometer that controls the grid power supply.

H.V.: High Voltage, sometimes used as a label on the Energy switch or to refer to an additional Power Supply unit needed for a high current electron gun.

Insertion length: The length of the gun that is in vacuum, from the vacuum sealing surface to the beam-exit end of the gun.

Ion cage: The part of the ion source where the gas is ionized in some ion guns, consisting of a wire coil that accelerates the ionizing electrons.

Ion emission current: The total ion current produced by the ion source (in mA or μA); not identical to the electron emission current which causes ionization or to the ion beam current which exits from the gun.

Ion source: (1) The structure in the ion gun that produces ions; for gas ions, usually consists of an electron-emitting filament, shields and an ion cage; for alkali metal ions, consists of a chemical cartridge and its heating filament.
(2) Another term for a complete ion gun; the entire unit made up of the ion source which creates the ions, and the electrostatic lens system that controls and focuses the ions to produce the final ion beam.

Ionization: (1). The production of a charged particle (ion) from a neutral atom or molecule by either the loss of one or more electrons (positive ion), or gain of one or more electrons (negative ion).
(2) **Electron impact ionization** Ionization by bombarding a gas with electrons, which collide with and remove electrons from the neutral gas molecules producing positive ions.
(3) **Surface ionization** Ionization by heating a solid alkali metal compound so that ions are produced in a solid-solid chemical reaction.

LaB_6, lanthanum hexaboride: A cathode material with low work function and long lifetime; a single crystal structure cut and mounted on a heating rod; used as a cathode in some electron guns to produce electrons that can be focused to a small spot.

Lens (also **Focus**)**:** (1) One or more electrostatic or magnetic lens elements in the electron/ion gun that control the beam spread; usually controls spot size at the target; in some guns, may control beam divergence at points internal to the gun.
(2) The power supply that applies voltage or current to the focus/lens element(s). Also, the potentiometer that controls this power supply.

MCDU, MCDU-4C, Manual Control Deflection Unit: The group of power supplies, circuitry and controls contained in the main power supply unit that produces and controls the voltages needed for deflection of the beam.

Potentiometer: A dial control knob, usually with numbers 0-10 on the ring, that regulates the output of a given power supply proportionally, typically by a 0 to 10 V signal input.

Plasma: A state of matter in which outer electrons are not held to the rest of the atoms or molecules, so there are free electrons and free ions in a gas-like cloud; used as a source for ions in some guns.

Power Supply: (1) The complete unit containing electronic circuitry, meters and controls, that takes power input from the outside line and converts it to voltages and currents required to run the electron/ion gun.
(2) An individual group of electronic circuits, contained in the larger unit, that produces voltage/current applied to a specific element in the electron/ion gun.

Pulsing (also **Beam pulsing**)**:** Rapidly stopping and starting the flow of electrons/ions, with a variable width (time on/off) and variable repetition rate; usually accomplished by rapidly switching the grid voltage to the cut-off potential; can be controlled in one of several ways: manual control with the grid potentiometer, remote computer control, dual grid power supplies with a TTL switching signal, capacitive pulsing with a pulse junction box and an external pulse generator.

Pulse junction box: A capacitor-containing device that combines input from an external pulse generator and the voltage from the grid power supply to vary the voltage applied to the grid; used to turn the beam current on and off rapidly; can be a separate box or part of a Grid Pulsing Cable.

Rastering: Movement of the electron/ion beam in a synchronized pattern sweeping back and forth (X direction) while simultaneously moving down more slowly (Y direction), then returning to the start position without sweeping back and forth (retrace); used to cover an area of the target region fairly uniformly over time; produced by two synchronized cyclical voltages or currents applied to the X and Y deflection plates or deflection coils in the gun. Rastering may also be non-synchronized, in which case there is no retrace segment.

RGDU, Raster Generator Deflection Unit: A separate unit containing the power supplies, circuitry and controls that produce and control the voltages applied to the deflection plates for either rastering or deflection (centering) of the electron/ion beam.

Rocking (also **Beam rocking**)**:** Movement of the electron/ion beam in an unsynchronized pattern sweeping back and forth (X direction), while simultaneously moving up and down more slowly (Y direction), with no retrace; used to cover an area of the target region fairly uniformly over time; produced by magnetic fields from varying currents in electrical coils around the beam in the gun.

Sine wave driver board: A removable electronic circuit board in the main power supply unit that controls the individual power supply outputs.

Source: (1) For Electron Guns: The power supply that produces the voltage and current that heats the cathode causing it to emit electrons. Also the potentiometer and switch that control the source power supply.
(2) For Ion Guns: The power supply that produces the voltage and current that heats the filament of the ion source, either causing the filament to emit electrons for gas ionization, or heating the alkali metal cartridge for solid ionization, depending on gun. The potentiometer and switch that control the source power supply.
(3) The cable and power supply connector that include the source (filament), grid and other leads, depending on the electron/ion gun; the H.V. Multiconductor Source Cable.
(4) **Ion source** See Ion Source above.

Space charge: The electric field resulting from the presence of a number of charged particles (electrons and ions) in a region of space; can limit the emission of more electrons from a cathode or limit the ions extracted from an ion source; can also affect the path of charged particles through a region.

Spot: The electron/ion beam at the target area; can be seen as a (usually circular) light area on a phosphor screen.

Spot size: The diameter (in mm or μm) of a circle that contains most of the electron/ion beam at a given distance from the gun (working distance); measured either visually on a phosphor screen, or electrically by sampling beam current density across the spot with a Faraday cup; FWHM (full-width-half-max) measurement is the width that includes all beam current densities greater than half the maximum density.

Tantalum: A refractory metal commonly used as the electron emitting material in a cathode.

Target: The place (a plane) at which the electron/ion beam is aimed.

Tetrode: An electron extraction and acceleration unit used in some electron guns, consisting of four elements: cathode, grid, a variable first anode, and a grounded second anode.

Thermionic emission: Emission of electrons or ions from a metal or other coating material by heating the emitter in order to impart enough energy to overcome the work function of the emitting material.

Thoria: A common name for thorium oxide, ThO_2; used as a coating on some cathodes or filaments, because of its relatively low work function.

Triode: The basic electron extraction and acceleration unit of most electron guns, similar to a vacuum tube, consisting of three elements: cathode, grid, and anode.

TTL, transistor-transistor logic: Electronic circuitry that produces a repeated on-off (square wave) signal, usually +5 V and 0 V.

Tungsten: A refractory metal commonly used in cathodes, because of its high melting point, either as the electron emission surface or as the heater leg.

Uniform beam distribution: An even distribution of beam current density over the entire spot area; a flat step-like curve on a graph of beam current density (A/cm^2) vs position in the spot.

Wehnelt: Another term for grid, from the physicist, A. Wehnelt.

Work function: A material-dependent measure of the work per unit charge needed to emit a charged particle (usually an electron) from the emitting material.

Working distance: The distance from the end of the gun where the electron/ion beam exits to the target plane.

X axis, Y axis: Arbitrarily-defined horizontal and vertical lines used as reference for motion of the beam in the target area for deflection, rastering, or alignment; correspond to the position of four deflection plates in the gun.

Z axis: A reference line through the exact center of the electron or ion gun, in the direction of electron or ion travel; the approximate beam line.

Zener limit: The upper limit on the source voltage in ECC mode, pre-set at the factory with a potentiometer and diode in the ECC circuitry.

Zoom lens: A series of electrostatic lens elements in the electron/ion gun (including anode or G-2, focus, and sometimes other lenses) that both focuses and accelerates / decelerates the beam; allows spot size and beam current to remain roughly constant as energy is varied.

8 DRAWINGS

LIST OF DRAWINGS FOR EGG-3101 / EGPS-3101 SYSTEM

EGG-3101B Electron Gun External View (EGG-3101 PROFILE)
EGG-3101B Electron Gun Assembly, Small Spot (EGG-3101B-D--A)
Adjustable Feedthrough Assembly (449A450--A)
EGG-3101 Pinout (429S990--C)
EGG-3101 Block Diagram (429S991--D)
EGPS-3101 Electron Gun Power Supply (Small Spot, Computer Control) (429S904 A)
EGPS-3101 Auxiliary (429S905C)
Sine Wave Driver Board (000S930D)
Source/ECC Driver Board (000S971D)
TTL Relay Board (20-070500B.sch)
MCDU-4C ±300 V (000S940E)
RGDU-3C (000S965C)
Power Supply Auxiliary (for RGDU) (000S906A)

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9 DATA

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10 APPENDIX

LANTHANUM HEXABORIDE CATHODE TECHNICAL BULLETINS

LaB_6 –01	General Guidelines for Operating ES-423E LaB_6 Cathodes
LaB_6 –02	The Relationship Between LaB_6 and Gun Vacuum
LaB_6 –03	Emission Drift LaB_6 and Gun Stability
LaB_6 –04	Oxygen Activation of LaB6 Cathodes-the Double Saturation Effect
LaB_6 –05	Kimball Physics ES-423E LaB_6 Cathode Style 60-06
LaB_6 –06	Kimball Physics ES-423E LaB_6 Cathode Operating Instructions for Leica/Cambridge Steroscan Series SEM's
LaB_6 –07	Recovery of Emission from ES-423E LaB_6 Cathodes Following a Vacuum Dump

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