PLASMA PROCESS GROUP, INC.

IBEAM FC / PBN

Ion Beam Source Power Supply Manual
DC Filament Cathode / Filament Neutralizer

plasma process group

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Date: July 2011 v1.1

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Chapter 1

Introduction

Thank you for purchasing an ion beam source power supply from Plasma Process Group!

This Manual covers the installation and operation of our IBEAM FC/PBN power supply.

Ion beam technology was developed at NASA in the 1960's as a means of producing thrust on spacecraft. Several spacecraft have used ion beam thrusters for station keeping and trajectory control. Recently, the spacecraft Deep Space 1, demonstrated the long duration performance capabilities and propulsion advantages of ion-beam thrusters. There are numerous publications about ion beam thrusters and some are given here for the interested reader [1-3].

Ion beam sources also have numerous terrestrial applications. In the past decade, ion beams have been used for depositing wear resistant diamond-like carbon coatings on mechanical and optical hardware. They have also been used to fabricate the read/write heads used in computer hard-drives and thin-film optical filters for telecommunication applications. A select few publications involving ion beam deposition technology are given here for the interested reader [4-7].

For this manual, it is assumed the operator of the ion beam source has a basic knowledge and/or technical skills with electrical discharge devices. If necessary, we encourage a review of the introductory chapters for the following references [8-10]. A basic physical knowledge of plasma behavior is required, however, the mathematical descriptions will be kept to a minimum. For any technical assistance, please contact us.

We at Plasma Process Group hope that using your new ion beam source will produce rewarding results.

Limited Warranty

Our workmanship warranty:

All equipment manufactured and sold by Plasma Process Group Inc is warranted to be free of defects and workmanship when shipped. The warranty on all equipment is for one year commencing (a) on final acceptance or (b) 30 days from shipping, whichever occurs first. This warranty covers the cost of parts and labor. Expendable and consumable items, such as grid assemblies, RFN collectors and discharge chambers are excluded from this warranty. This warranty supersedes all other warranties, expressed or implied. Plasma Process Group Inc assumes no contingent liability for damages or loss of production.

Expendable items, including, but not limited to, grid assemblies, RFN collectors, discharge chambers, filaments, fuses, o-rings and seals are specifically excluded from the foregoing warranties and are not warranted.

Seller assumes no liability under the above warranties for equipment or system failures resulting from (1) abuse, misuse, modification or mishandling; (2) damage due to forces external to the equipment including, but not limited to, flooding, power surges, power failures, defective electrical work, transportation, foreign equipment/attachments or Buyer-supplied replacement parts or utilities or services such as process gas; (3) improper operation or maintenance or (4) failure to perform preventative maintenance in accordance with Seller's recommendation (including keeping an accurate log of preventative maintenance). In addition, this warranty does not apply if any equipment or part has been modified without the written permission of Seller.

Technical Contact Information

For Service or Repair contact:

Plasma Process Group Inc (PPG)
www.plasmaprocessgroup.com

Please supply the following information:

- Product
- Model and serial number
- Date Purchased
- Detailed description of problem
- Contact person

If the product is to be returned to PPG for repair you will be assigned a **Return Authorization** number (RA), warranty status of the equipment and shipping information to return the product. The RA number should be attached to the outside of the shipping container. A purchase order number should be included should the equipment not be under warranty. After PPG receives the equipment a firm quote and estimated repair time will be given prior to work being started.

Chapter 2

Theory of Operation

The function of an ion beam source is to produce ions and accelerate these ions to high velocities so they are ejected downstream from the source. The ejected ions are directed to form a "beam" in which the ions are mono-energetic with velocities on the order of km/s. An ion beam source consists of four (4) key elements:

Discharge Chamber, Electron Source, Grids, and Neutralizer.

Presented in Figure 1 is a schematic of an ion beam source. Basically, the source is operated by introducing the source gas into the **discharge chamber**. An **electron source** is used to ionize the gas and establish a plasma. Recall, a plasma is an electrically conductive gas where the density of ions and electrons are approximately equal. Ions created in the **discharge chamber** are then accelerated to high velocities with the source **grids**. A **neutralizer** is placed downstream from the source where it emits electrons to balance the number of positive ions which leave the source.

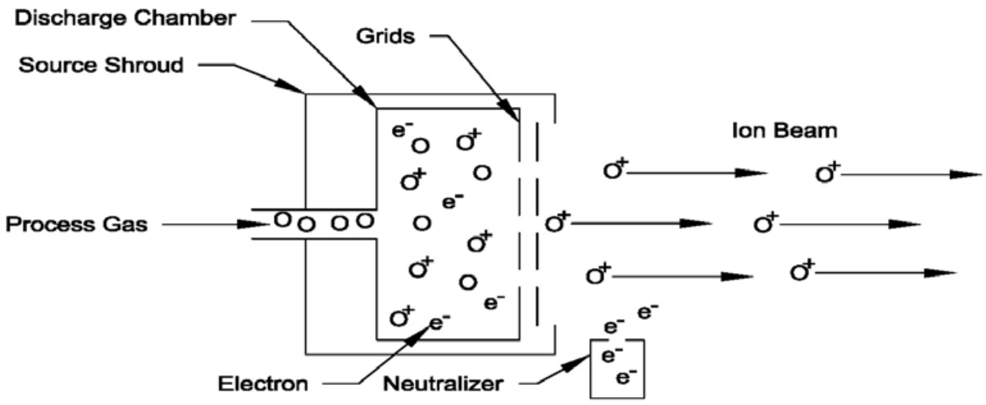

Figure 1. Schematic of an ion beam source.

The different types of ion beam sources are delineated by the specifics of the four (4) key elements. In this introduction, ion beam sources will be classified as either direct current (DC) or radio frequency (RF). A brief, physical description of each of the four elements is presented below.

Discharge Chamber - the discharge chamber is where the source gas is ionized.

For DC sources, the discharge chamber is referred to as the **body**. The body will have a magnetic field produced using permanent magnets. The purpose of the magnetic field is to control the motion of electrons such that they have several ionizing collisions with the source gas occur before being collected on the anode.

For RF sources, the discharge chamber consists of a dielectric material permeable to the RF field produced by the antenna. The RF field ionizes the source gas introduced within the discharge chamber.

Electron Source – mechanism by which electrons are produced to ionize the source gas.

For DC sources, the electron source can be either a hot filament or a hollow cathode. Typically, a filament consists of a tungsten wire which is heated to emit electrons. A hollow cathode is a device which produces electrons by locally ionizing its own feed gas. The electrons from either the filament or hollow cathode are then used to ionize the source gas, which, for the hollow cathode case, may be the same gas it used. The electrons have several ionizing collisions before being collected at the anode surface in a DC source.

For RF sources, the RF field energizes free electrons in the working gas. The energetic electrons have ionizing collisions with the source gas thereby producing ions and additional electrons. As ions leave the discharge chamber, electrons are collected on the screen grid surface.

Grids – the electrostatic apertures by which the ions from the discharge are extracted.

Grids are electrodes separated from each other by a few millimeters. Each grid has several apertures that are aligned and allow for the extraction of ions. The grid closest to the discharge chamber is referred to as the **screen (or S) grid**. Moving downstream, the next grid is referred to the **accelerator (or A) grid**. On some sources, a third grid is used which is the furthest downstream from the discharge chamber and it is referred to as the **decelerator (or D) grid**.

The grid assembly extracts ions from the discharge chamber by applying specific potentials (or voltages) to each grid. A potential (or voltage) diagram of the ion acceleration process is presented in Figure 2. First, the S grid is biased positive (**beam voltage**) with respect to ground and consequently the plasma in the discharge chamber is also biased positive with respect to ground. Next, the A grid is biased negative (**accel voltage**) with respect to ground and establishes an electric field along the source centerline. Positive ions in the discharge chamber that drift close to this electric field are accelerated.

Even if the D grid is not used, the potential downstream from the source is ultimately approximately zero. Depicted in Figure 2 is the electric potential for a 3-grid assembly. The D grid potential is typically held at ground potential (or 0 V). The accelerated ions then decelerate after passing the A grid and exit the aperture with a net, ion energy of approximately **beam voltage**. As depicted in Figure 2, electrons either located in the discharge chamber or downstream from the source are separated due to the established electric field.

Ions extracted through the grid apertures comprise individual beamlets and a typical grid assembly will have numerous apertures. As a result, individual beamlets combine to form a more, broad ion beam.

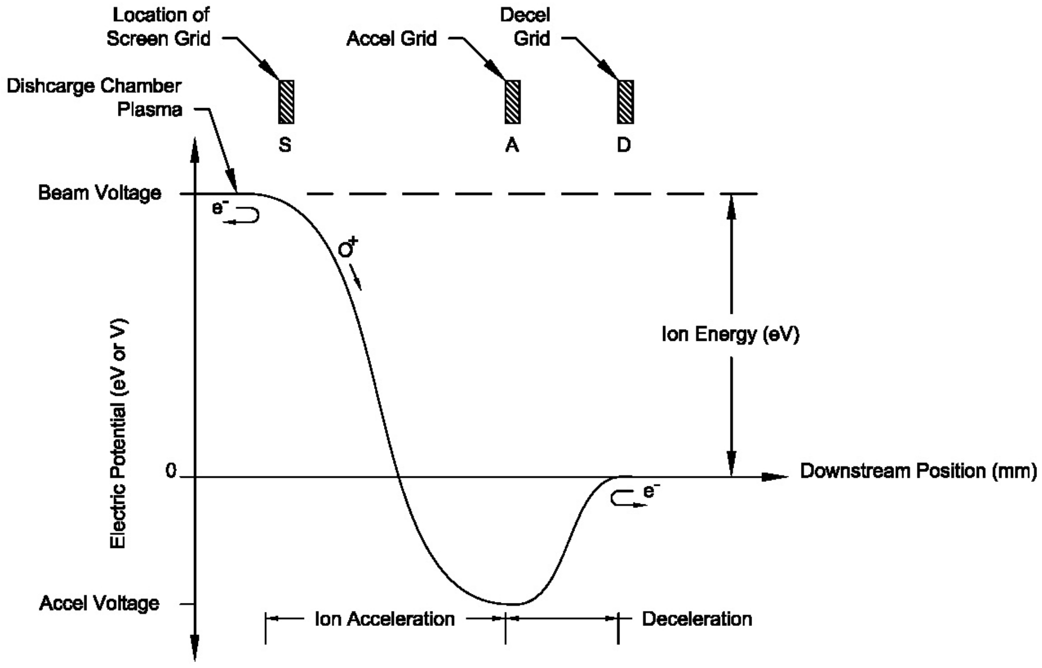

Figure 2. Schematic of the ion acceleration process.

Neutralizer – an electron source downstream from the ion source.

For DC sources, the neutralizer can be a hot filament, hollow cathode, or plasma bridge type. A plasma bridge neutralizer (PBN) is where a hot filament is placed in a smaller discharge chamber through which an inert process gas is supplied. For RF sources, the neutralizer can be either a PBN or RF type. The RF neutralizer (RFN) consists of a small discharge chamber with an RF coil. The RFN utilizes a collector and keeper to emit electrons.

The purpose of the neutralizer is to emit electrons into the environment downstream from the ion beam source. The emitted electrons provide a charge balance for the ions leaving the source. Typically, more electrons are emitted from the neutralizer than ions from the source. This is done to minimize and/or eliminate the space or surface charging that may occur. In most situations, electrons from the neutralizer do not directly combine with the ions in the beam to form high energy neutrals.

Source Parameter Definitions

As electrical devices, ion beam sources require power supplies. Presented in Figures 3 and 4 are the electrical schematics for typical DC and RF sources, respectively.

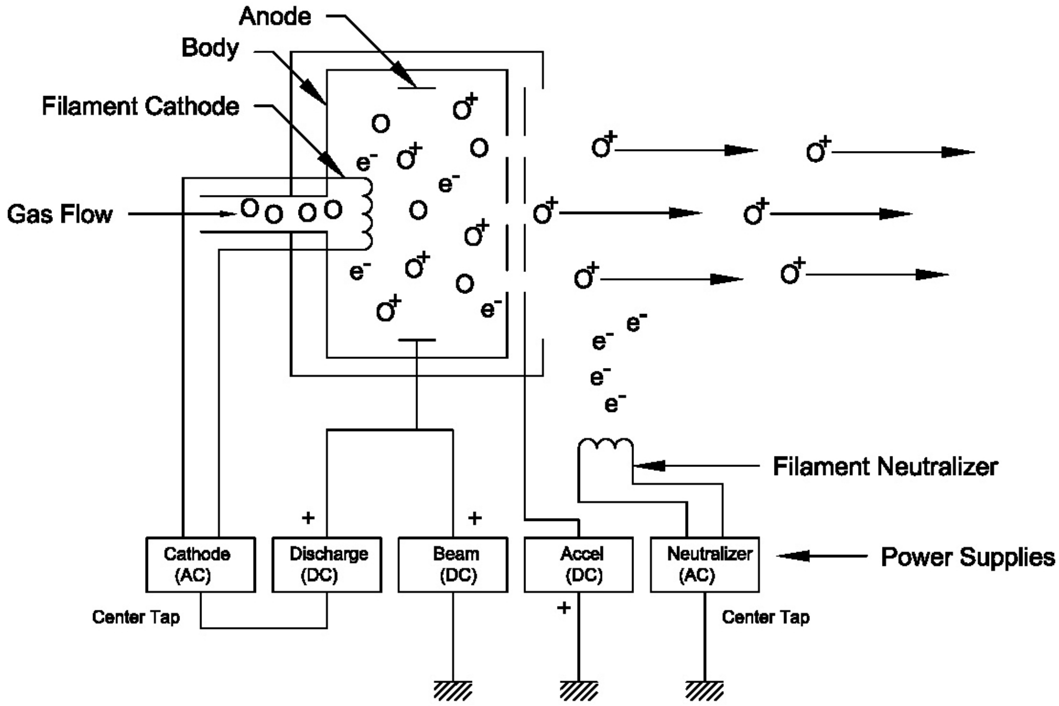

Figure 3. The electrical schematic for a filament DC source.

In Figure 3, the electrical connections for a filament cathode and filament neutralizer DC source are presented. The cathode is heated using an AC power supply. Electrons leaving the filament are collected at the anode with the discharge supply, a DC bias supply. The beam supply, also a DC bias supply, is also connected to the anode and biases the discharge plasma positive with respect to ground. Not illustrated, but commonly used is a resistor placed between the body and anode. The body resistor establishes the proper bias between the anode and body and thereby directs electrons to be collected on the anode surface. The accelerator supply, a DC type supply, biases the accel grid negative with respect to ground. Finally, the neutralizer filament is heated using an AC power supply.

In Figure 4, the electrical connections for a RF source with RF neutralizer are presented. The RF coil for the discharge chamber is energized by the RF supply and is tuned by using a matching network. The beam supply, a DC bias supply, is connected to the screen (S) grid in order to bias the discharge plasma positive with respect to ground. The accelerator supply, a DC type supply, biases the accel grid negative with respect to ground. Finally, the RF neutralizer utilizes an RF supply and matching network for its own discharge and additional DC supplies to emit electrons.

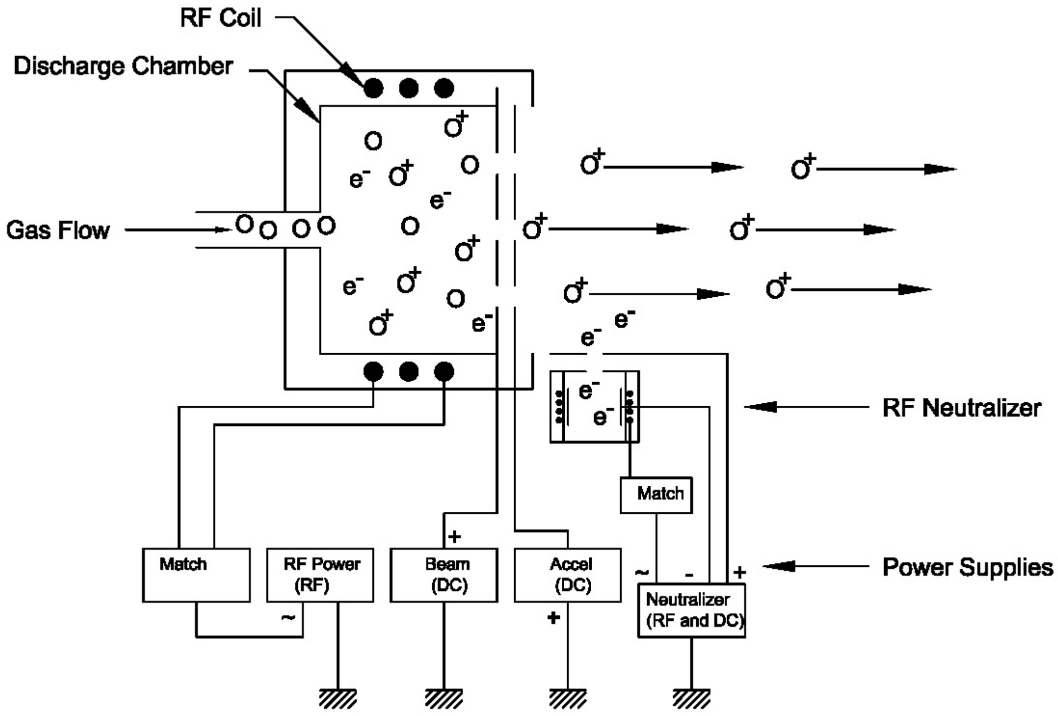

Figure 4. Electrical schematic for a RF source.

Additional power supply details and source parameters are presented in Tables 1 and 2. Ion beam source parameters used by both DC and RF sources are presented in Table 1. Specific parameters that pertain to DC filament, DC hollow cathode, and RF sources are outlined in Table 2. Actual values for these source parameters will be specific to source type, size, grids, and process. Typical values will be given where appropriate.

Table 1. Ion beam parameters for all sources.

Parameter	Definition	Unit
All Sources		
Source Gas Flow	Process gas delivered to the discharge chamber.	sccm
Beam Voltage	Positive voltage applied to the discharge plasma.†	V
Beam Current	The total ion current extracted, or leaving the source.	mA
Accel Voltage	Negative voltage applied to the accelerator (A) grid.	V
Accel Current	Charge-exchange current collected by accelerator (A) grid.	mA
A/B Ratio	Ratio of accel to beam currents. Indicates quality of grid focusing. Typical A/B is < 10%.	%
Neutralizer Emission Current	The electron current emitted by the neutralizer.	mA
E/B Ratio	Ratio of neutralizer emission to beam currents. Typical E/B is >100% to minimize space charging, surface charging and arcing.	%

† For DC sources, beam voltage is applied to the anode. For RF sources, beam voltage is applied to the screen (S) grid.

Table 2. Ion beam parameters for specific types of sources.

Parameter	Definition	Unit
DC Filament Cathode (FC) / Filament Neutralizer (FN or PBN)		
Cathode Filament Current	The electrical current applied to the filament cathode. This current heats the filament so that electrons are emitted from its surface.	A
Discharge Voltage	The voltage established between the filament cathode and anode. This determines the electron energy for ionizing collisions in the discharge chamber.	V
Discharge Current	The electrical current established in the discharge chamber between the filament cathode and the anode. This current controls the ion production rate and to first order, the beam current.	A
Neutralizer Filament Current	The electrical current applied to the filament neutralizer. This current heats the filament so that electrons are emitted from its surface.	A
Body Voltage (PBN)	The voltage applied to the body for an emission current.	V
DC Hollow Cathode (HC) / Hollow Cathode Neutralizer (HCN)		
Cathode Heater Current	The electrical current applied to the HC heater.	A
Cathode Keeper Voltage	The voltage established between the HC body and keeper.	V
Cathode Keeper Current	The electrical current between the HC body and keeper.	mA
Discharge Voltage	The voltage established between the HC body and anode. This determines the electron energy for ionizing collisions in the discharge chamber.	V
Discharge Current	The electrical current established in the discharge chamber between the HC body and the anode. This current controls the ion production rate and to first order, the beam current.	A
Neutralizer Heater Current	The electrical current applied to the HC heater.	A
Neutralizer Keeper Voltage	The voltage established between the HC's body and keeper.	V
Neutralizer Keeper Current	The electrical current between the HC body and keeper.	mA

Table 2. Ion beam parameters for specific types of sources comtinued.

Parameter	Definition	Unit
RF with RF Neutralizer (RFN)		
RF Forward Power	The RF power applied to the matching network. This power controls the ion production rate and therefore, the beam current.	W
RF Reflected Power	The RF power reflected from the matching network. Typically, the reflected power is <1% of the forward power.	W
RFN Forward Power	The RF power applied to the matching network.	W
RFN Reflected Power	The RF power reflected from the matching network	W

Ion Beam Properties

For ion beam deposition applications, it is necessary to know the energy of the ions leaving the source and the dose that they strike a target downstream.

Ion Energy

The ejected ions from an ion beam source are considered mono-energetic and as depicted by Figure 2, the total ion energy is approximately the beam voltage. In order to illustrate the importance of this aspect, plotted in Figure 5 are two types of energy distributions. The ions in a typical electrical discharge device will have a range of energies that form a distribution that is thermalized; also referred to as Maxwellian. A Maxwellian energy distribution is plotted in Figure 5 where the number of ions is plotted for various energies. For comparison purposes, the energy distribution from an ion beam source is also plotted. Ions that leave the source have a limited energy range, selected by the beam voltage, and are referred to as mono-energetic. The significant attribute of the ion beam source is that energies of the ions can be adjusted by selecting different beam voltages, where as, a Maxwellian discharge will have only limited adjustment in its energy distribution. The beam voltage range is typically 100 to 1500 V.

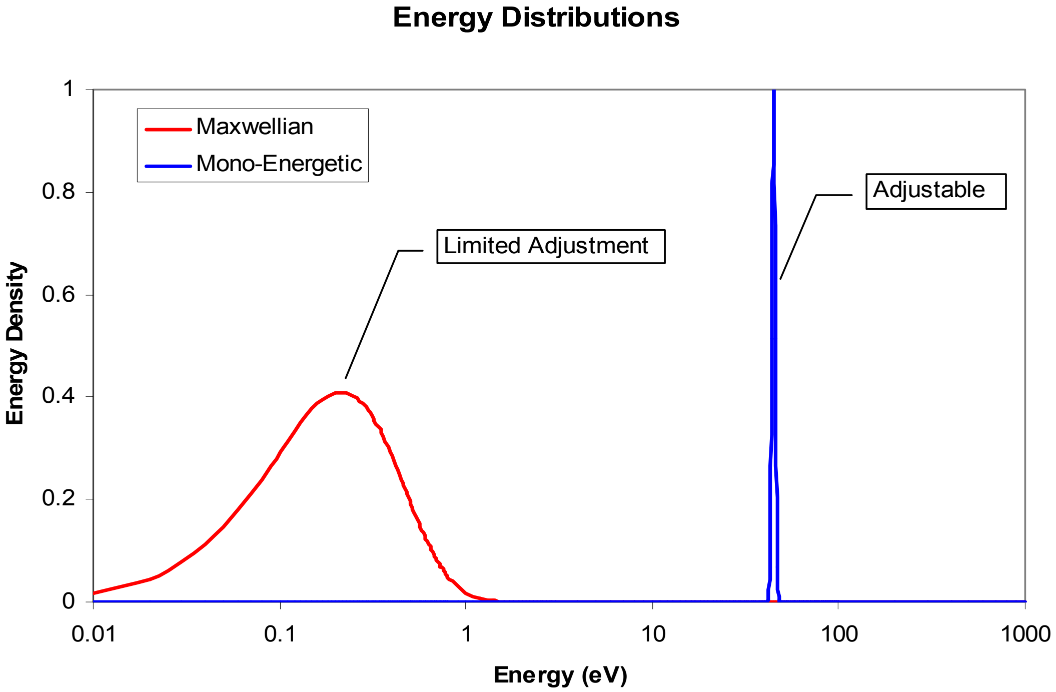

Figure 5. Two types of energy distributions: Maxwellian and Mono-Energetic.

Ion Dose

A measurement of the beam current is also an indication of the number of ions leaving the source. In most applications, it is important to determine the number of ions striking a specific location downstream, such as a target or substrate. This number is also referred to as the dose or flux density. The actual dose downstream from the source is determined by the ion beam focusing characteristics or ion optics.

Ion optics are determined by the beam current and voltage, accel voltage, and grid geometry (i.e. grid thickness, spacing, and shape). In general terms, the ion beam diverges, or spreads out, as it leaves the source. Custom grids can be fabricated to control this divergence and focus the ion beam. Ion optics is a rather detailed subject, and therefore, only brief, general rules of thumb are presented below for a typical grid set.

1) The divergence increases (the beam spreads out) when the accel voltage is increased.
2) The divergence can decrease at higher beam voltages.

Due to the complex nature of ion optics, the beam dose is best determined by measuring it using a Faraday type probe. Recall, a Faraday probe is a small electrode biased negative, usually about 40 V or so, to measure ion current and repel electrons. The probe is typically placed downstream from the source and swept through the beam to measure ion current at locations of interest. The ion current to the probe is divided by the area of the probe to determine the dose of the ion beam in mA/cm^2.

References

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Chapter 3

Set up and Installation Procedures

Installing and operating the IBEAM FC / PBN power supplies requires good safety practice. The power supply must be turned OFF before performing ANY electrical connections. All warnings and cautions must be observed. The power supply should NEVER be operated with ANY of its output connections MISSING or IMPROPERLY attached. READ ALL INSTRUCTIONS before connecting power.

CAUTION

Danger of High Voltage and Personal Injury

WARNING

ALL POWER OUTPUTS CAN BE LETHAL

WARNING

ELECTRICAL SHOCK HAZARD

WARNING

This power supply produces high voltage outputs. Do not operate unit with missing or improper connections. The unit's interlock needs to be incorporated into the facility/system interlock string. There are no serviceable parts inside the unit. Do not remove unit cover.

Electrical connection layout

On the back of the IBEAM FC/PBN are the electrical connections for the source, neutralizer and communication cables. These are depicted in Figure 6.

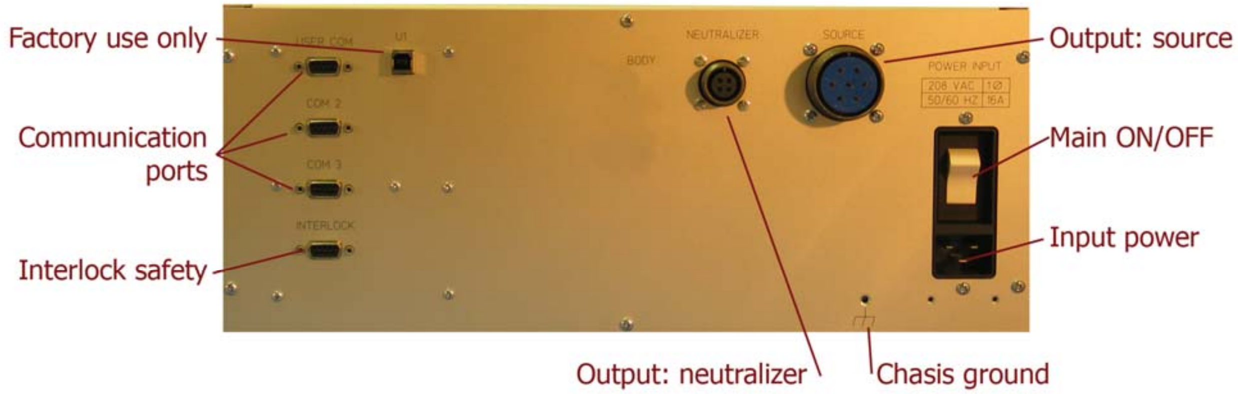


Figure 6. IBEAM FC/PBN rear panel.

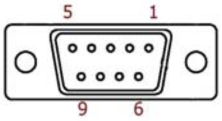
Input power specifications

Input power – 208 VAC, 1 Ø, 50/60 Hz, 16 Amp

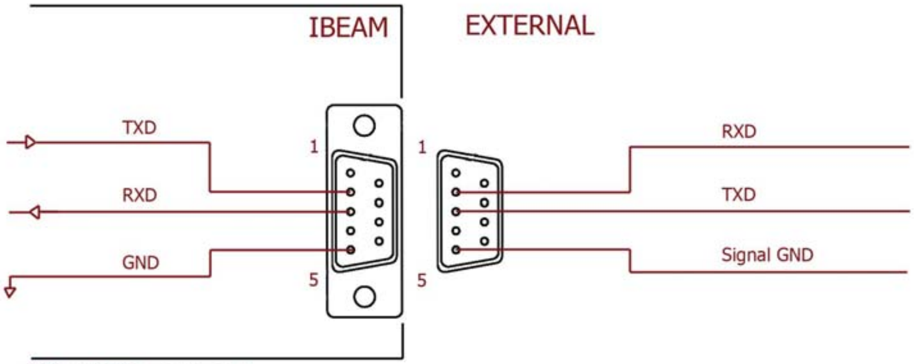
Figure 7. Electrical power connections.

RS232 communications

Figure 8. Pin-outs and electrical connections for USER COM.
Connector style: DB9



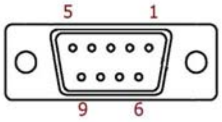
1 - n/c
2 - TXD
3 - RXD
4 - n/c
5 - Signal GND
6 - n/c
7 - n/c
8 - n/c
9 - n/c



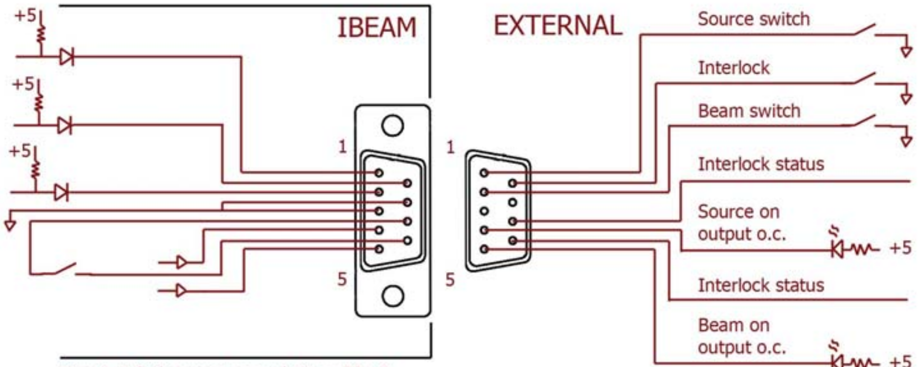
CTS and RTS are not used

Interlock and remote switches

Figure 9. Pin-outs and electrical connections for interlock and remote switches.
Connector style: DB9



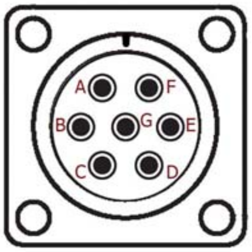
1 - Remote switch for source
2 - Remote switch for beam
3 - GND
4 - Source on output
5 - Beam on output
6 - Interlock
7 - n/c
8 - Interlock status
9 - Interlock status



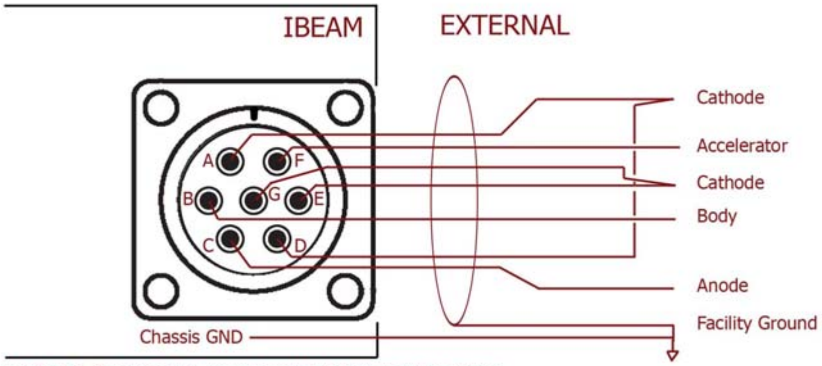
Pins 4, 5 & 6 cannot exceed 5V or 20mA

Output: Source

Figure 10. Source pin-out and electrical connections.
Connector style:
mil spec: 97-3102A-24-2S



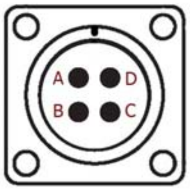
A - (same as D) Cathode lead #1
B - Body
C - Anode
D - (same as A) Cathode lead #1
E - (same as G) Cathode lead #2
F - Accelerator
G - (same as E) Cathode lead #2



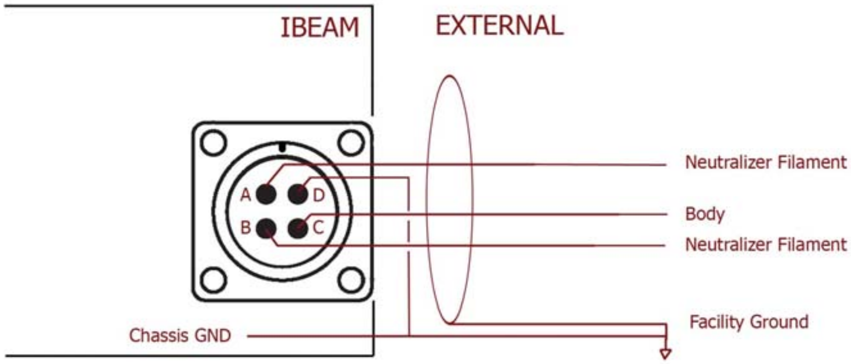
Leads A & D and G & E are connected together at the source.

Output: PBN Neutralizer

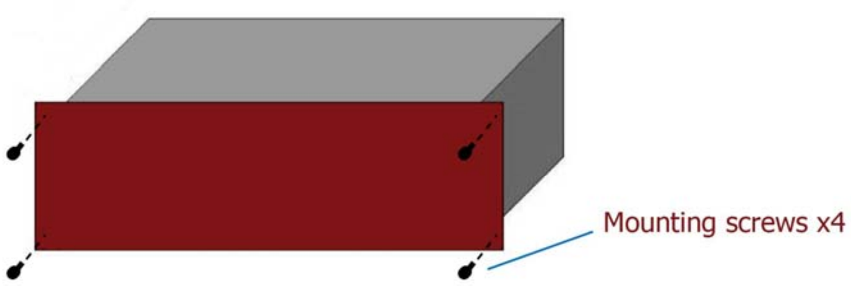
Figure 11. Neutralizer pin-out and electrical connections.
Connector style:
mil spec: 97-3102A-14S-2S



A - Neutralizer Filament lead #1
B - Neutralizer Filament lead #2
C - Body
D - Ground



Mounting the chassis:



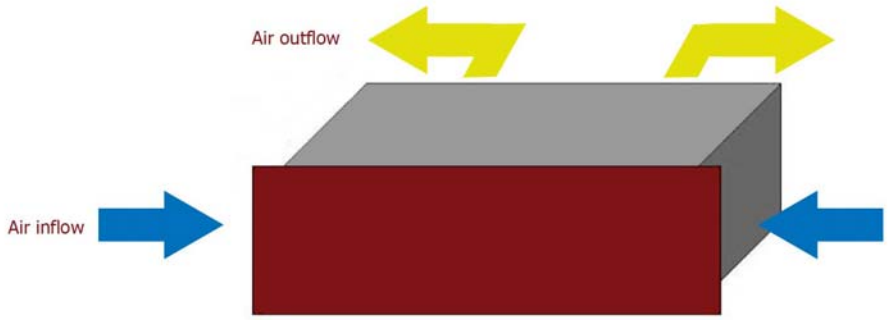
Screw size is 0.5" x 10-32 pan head. Weight of supply is 35 lbs.

Figure 12. Mounting. The power supply is designed to be mounted in a standard 19" equipment rack where the top, bottom, sides and rear are not accessible while the power is ON and operating.

CAUTION

Electrical current. It is important to connect the chassis ground to the facility ground (vacuum tank) (Figs. 10 and 11).

Air cooling:



Ambient air temperature 10 to 30 °C. Air flow is approximate 10 L/s.
At least 1.75" clearance must be maintained around sides and back.

Figure 13. Air flow. The chassis must have adequate air for cooling.

CAUTION

Danger of FIRE. If the power supply does not have proper ventilation, the subcomponents will overheat and may ignite.

Electrical connection setup:

STEP 1. Install the ion beam source and neutralizer in the vacuum system.

STEP 2. Attach the neutralizer and source cables to the output connections (Figs. 10 and 11).

STEP 3. Attach the communications cable, if used, to the USER COM port (Fig. 8).

STEP 4. Connect the input power (Fig. 7).

STEP 5. Connect the interlock (Fig. 9).

STEP 6. Turn the main ON/OFF switch to ON.

STEP 7. The unit is ready for power up and operation (See Chapter 4).

Chapter 4

Operation

This section describes basic operation of the IBEAM supply. Computer control is discussed in Chapter 5. For this chapter, it is assumed the ion beam source is installed in the vacuum chamber and is ready for operation. Also, the IBEAM should be connected to the vacuum facility as described in Chapter 3.

Power supply layout

The IBEAM FC / PBN is a single chassis that contains the 5 individual power supplies described earlier in Figure 3. The user interface is the front panel and its layout is depicted in Figure 14. The output displays are used to provide voltage and current readings on the individual power supplies. Each supply has an indicator light which illuminates when that supply is selected using the module button on the keypad. The emergency power off will disable power. The parameters for each power supply can be entered by the user through the keypad and presented in the main display. In this section, an overview of the key features and how they relate to source operation are introduced. Example values for typical source operation will be provided.

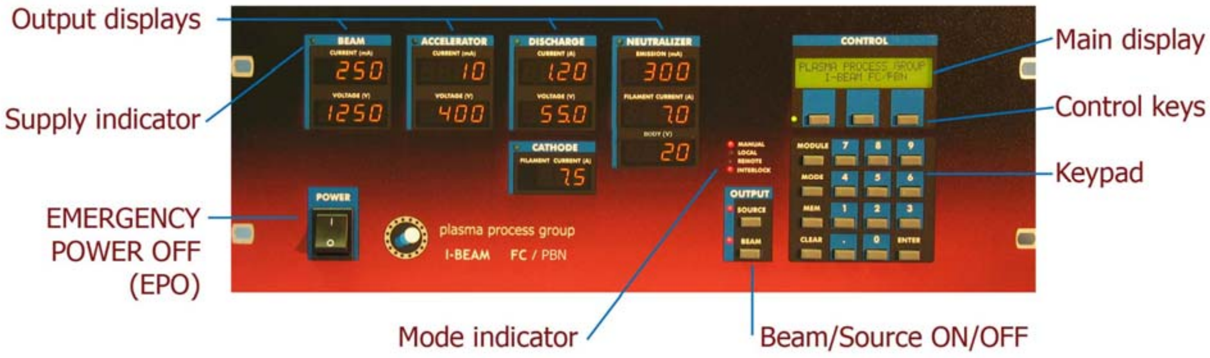


Figure 14. IBEAM FC/PBN front panel.

Keypad entry and power supply adjustments

Adjustments or new target values to the individual power supplies can be input using the keypad. A CLEAR and ENTER key are provided. In order to select a specific power supply, repeatedly press the MODULE button. A green LED (supply indicator) will illuminate near the power supply which indicates parameters for that supply can be entered (see Figure 15).

Figure 15. Select the supply by pressing the MODULE button until the green LED lights.

Other global parameters are entered into the CONTROL module. These can be accessed when the green LED is lighted as shown in Figure 16.

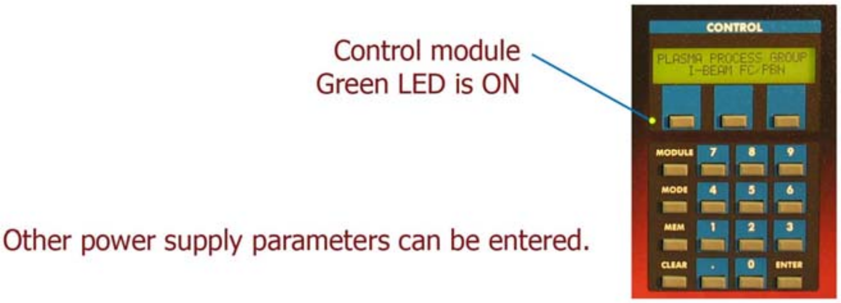


Figure 16. Global parameter entry. To access, press MODULE button until LED lights.

Directly under the main display are 3 control keys. These are used as SELECT buttons for parameters that are presented in the main display directly above (see Figure 17).

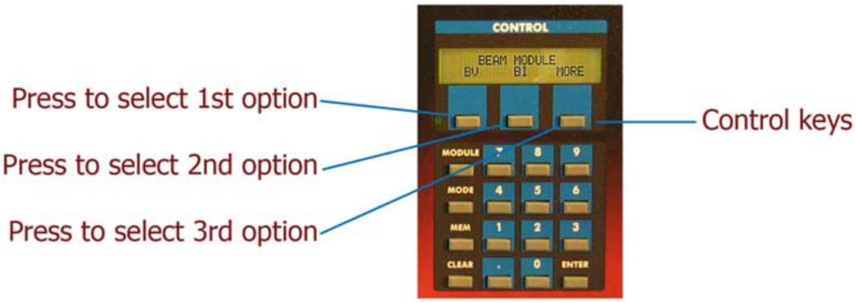


Figure 17. Control keys are used to select options in the main display.

The options for each module in the main display will utilize abbreviations. The following is a listing of these abbreviations, the corresponding parameter and description. The specific module and acceptable range are also provided. The source check-out sheet should be consulted for typical values.

Module	Abbreviation	Parameter and description	Acceptable Range
Beam	BEAM V or BV	**Beam voltage** After the beam is turned on, the power supply will ramp to the beam voltage.	0 to 1500 V
Beam	BI	**Beam current** After the beam is turned on, the power supply will ramp the beam current.	0 to 300 mA
Accelerator	ACCEL	**Accelerator voltage** Below 100 V is not recommended.	0 to 1000 V
Discharge	DISC V	**Discharge voltage** Typical values are 35 to 55 V.	0 to 80 V
Cathode	CATH I	**Cathode filament current**	0.0 to 20.0 A
Neutralizer	NEUT I	**Neutralizer filament current limit**	0.0 to 20.0 A
Control	SETUP	Select to change global parameters listed below	
Control	CATH I LIMIT	**Cathode filament current limit** The limit should be set slightly higher than the maximum expected cathode filament current.	0.0 to 20.0 A
Control	NEUT I LIMIT	**Neutralizer filament current limit** The limit should be set slightly higher than the maximum expected neutralizer filament current	0.0 to 20.0 A
Control	A/B RATIO	**Accelerator to beam current ratio** If the accelerator current exceeds the A/B ratio times the beam current, an alarm is triggered. Default is 10%.	0 to 99%
Control	E/B RATIO	**Emission to beam current ratio** Neutralizer emission will ramp to the E/B ratio times beam current. Recommended is 125%.	0 to 200%
Control	RMT S/B SW	**Remote source / beam switch** This will activate the rear panel remote switch (see Chapter 5).	enable/disable
Control	ALARM	Audio alarm	enable/disable
Control	SECURITY	Factory use	
MEM key	STORE	Store beam parameters into memory	0 to 9
MEM key	RECALL	Recall beam parameters from memory	0 to 9
All	INC	Increase value by 1 or 0.1	
All	DEC	Decrease value by 1 or 0.1	

All values are entered as TARGETS. When the SOURCE and BEAM are ON, the modules will ramp to these target values. If a target value cannot be achieved, an alarm will trigger. See Chapter 6 for a listing of the power supply alarms.

User interface examples

The following are examples of how to set target values and other user interface navigation.

Example 1: Put the IBEAM in LOCAL mode and select the Cathode module.

STEP 1. Press MODE button until LOCAL mode is selected.
STEP 2. Press MODULE button until Cathode supply is selected.
The red LED for LOCAL and green Cathode supply indicator LED should be ON.

Example 2: Set the beam voltage to 1225 V.

STEP 1. Press MODULE button until Beam supply indicator LED is ON.
STEP 2. Use the Control keys to select BV (If IBEAM is in LOCAL mode).
STEP 3. Use keypad to type 1225, then ENTER.

Example 3: Set the beam current to 100 mA (IBEAM must be in LOCAL mode).

STEP 1. Press MODULE button until Beam supply indicator LED is ON.
STEP 2. Use the Control keys to select BI.
STEP 3. Use keypad to type 100, then ENTER.

Example 4: Set the accelerator voltage to 200 V.

STEP 1. Press MODULE button until Accelerator supply indicator LED is ON.
STEP 2. Use keypad to type 200, then ENTER.

Example 5: Set the discharge voltage to 55 V.

STEP 1. Press MODULE button until Discharge supply indicator LED is ON.
STEP 2. Use keypad to type 200, then ENTER.

Example 6: Set the cathode filament current to 2.0 A.

STEP 1. Press MODULE button until Cathode supply indicator LED is ON.
STEP 2. Use keypad to type 2.0, then ENTER.

Example 7: Change the cathode filament current to 2.4 A.

STEP 1. Press MODULE button until Cathode supply indicator LED is ON.

STEP 2. Select INC (increment) in the control keys, and press it 4 times.

Example 8: Set the neutralizer filament current to 4.5 A.

STEP 1. Press MODULE button until Neutralizer supply indicator LED is ON.
STEP 2. Use keypad to type 4.5, then ENTER.

Example 9: Adjust the cathode filament current limit to 6.0 A.

STEP 1. Press MODULE button until Control module indicator LED is ON.
STEP 2. Select SETUP in the control keys. CATH I LIMIT should be displayed.
STEP 3. Use keypad to type 6.0, then ENTER.

Example 10: Adjust the E/B ratio to 150%.

STEP 1. Press MODULE button until Control module indicator LED is ON.
STEP 2. Select SETUP in the control keys. CATH I LIMIT should be displayed.
STEP 3. Select NEXT until E/B RATIO is displayed.
STEP 4. Use keypad to type 150, then ENTER.

If the MEM key is pressed, the STORE or RECALL options are displayed. Each memory location stores beam current, beam voltage, accelerator voltage, discharge voltage, cathode filament current and neutralizer filament current target values. Also stored are the A/B and E/B ratios, cathode and neutralizer filament current limits. Memory location 0 is reserved for the last running condition. There are ten (10) available memory locations.

Example 11: Store all target values into memory location 7.

STEP 1. Press MEM button.
STEP 2. Select STORE in the control keys.
STEP 3. Use keypad to type 7, then ENTER.

Example 12: Recall all target values from memory location 4.

STEP 1. Press MEM button.
STEP 2. Select RECALL in the control keys.
STEP 3. Use keypad to type 4, then ENTER.

Mode indicator and adjustments

The power supply can be operated in one of 3 possible modes. These are MANUAL, LOCAL, and REMOTE. Adjustment of the parameters for the 5 individual power supplies will depend upon which mode is selected. The mode can be selected by pressing the MODE button on the key pad. Below is a table that has the power supply parameters and which of those can be adjusted in the various modes.

Source Parameter, abbreviation	**LOCAL**	**REMOTE**	**MANUAL**
Beam Current, BI (mA)	Adjustable	Adjustable	-
Beam Voltage, BV (V)	Adjustable	Adjustable	Adjustable
Accelerator Current (mA) †	-	-	-
Accelerator Voltage, ACCEL (V)	Adjustable	Adjustable	Adjustable
Discharge Current (A) †	-	-	-
Discharge Voltage, DISC V(V)	Adjustable	Adjustable	Adjustable
Cathode Filament Current, CI (A)	-	-	Adjustable
Neutralizer Emission Current, E/B RATIO (mA)	Adjustable	Adjustable	-
Neutralizer Filament Current Limit, NI (A)	-	-	Adjustable

† These parameters cannot be adjusted using the IBEAM power supply. The accelerator current is induced by charge-exchange ions created in the vicinity of the accelerator grid [see reference 11]. The production of these charge-exchange ions is proportional to the source gas flow rate and chamber pressure. The charge-exchange ions are attracted to the accelerator grid, impinge, and are detected as accelerator current. The impingement process will result in sputtering of the accel grid and excessive accelerator current will reduce the life of the grid. For properly aligned grids and reasonable operating conditions, the accelerator current is typically less than 10% of the beam current. Similarly, the discharge current is dependent upon the source gas and magnetic field strength inside the source body. The discharge current is increased or decreased by changes to the cathode filament current.

In LOCAL mode, the IBEAM allows the user to set a specified beam current (or ion dose). When the source and beam switches are ON, the IBEAM will attempt to run the source at the specified beam current. More specifically, the IBEAM will adjust the cathode filament current to control the beam current. Increasing the cathode filament current will increase the emission of electrons into the discharge chamber. As this is done, the plasma density increases in the discharge chamber, thereby more ions can be extracted and an increased beam current is observed. LOCAL mode is useful for applications requiring a constant beam current (or dose) on a target or substrate. The IBEAM controls the cathode filament current to maintain a steady beam current.

In REMOTE mode, the IBEAM essentially behaves the same as LOCAL mode. REMOTE refers to the interface with the power supply utilizing the RS232 connection. A computer terminal or software program is utilized for parameter adjustment.

In MANUAL mode, the IBEAM allows the user to control the cathode filament current manually from the front panel. The result is the user can increase or decrease the beam current manually. The beam current is not as stable as LOCAL mode. However, MANUAL mode is useful for determining or optimizing other source parameters and troubleshooting source operation. In MANUAL mode the user cannot select a beam current, it is adjusted by increasing or decreasing the cathode filament current.

SUMMARY:

LOCAL – User selects beam current and the IBEAM controls cathode filament current.

REMOTE – Same as LOCAL, IBEAM is controlled using RS232.

MANUAL – User selects cathode filament current which manually controls beam current.

Beam/Source ON/OFF

The power supply has two output ON/OFF buttons labeled SOURCE and BEAM. When the SOURCE button is toggled to ON, power is applied to the cathode and neutralizer filaments. The discharge supply is also turned on. As the cathode filament is heated up to emit electrons, the discharge supply will ramp to about 150 V. As electrons from the cathode make their way to the anode, a discharge is started and will be observed by a drop in discharge voltage to its operating value (typically 55 V). After a discharge has been established, the source has started. The BEAM button can then be toggled to ON.

When the BEAM button is toggled to ON, power is applied to the beam and accelerator supplies. The beam and accelerator voltage will ramp in a steady fashion to their desired settings. The beam can be turned off by pressing either the BEAM or SOURCE button. Turning the beam off by pressing the BEAM button will leave the source ON. Turning the beam off by pressing the SOURCE button will extinguish the beam and source.

Operation example

The following is a step by step example of operating the source.

Step 1) **Pumpdown.**

The ion beam source requires a high vacuum environment for proper operation. As there are several different types of vacuum systems, general guidelines will be presented. Also, the vacuum environment will depend upon the application for the ion beam source. The required pumping speed of the vacuum system will depend upon how much process gas is used by the ion beam source and the vacuum environment required for the process. Problems may arise with operation of the ion beam at higher pressures. Presented in Table 4.1 are general vacuum specifications guidelines.

Table 4.1. Vacuum specifications.

Specification	Value	Comments
Chamber base pressure	10^{-6} Torr	Lower is OK
Chamber operating pressure when the source gas is on.	10^{-5} to 10^{-3} Torr	The discharge may go out at lower pressures. Grid arcing will occur at higher pressures.
Typical pumping speed	1000 l/s (air)	Process dependent.

Step 2) **Turn the process gas on**.

After the vacuum chamber has achieved its base pressure, turn on the process gas. The amount of gas is typically measured in standard cubic centimeters per minute, or sccm. The required amount can be selected based upon the application. It is recommended to wait 5 to 10 minutes after the gas has been turned on in order to purge the gas line. Recommended flow rates for a system using a 1000 l/s pump are presented in Table 4.2.

Table 4.2. Typical source gas flow rates for a 1000 l/s pumping station.

Specification	Value	Comment
3 cm Source gas flow	3 to 6 sccm Argon	Typical flow range.
8 cm Source gas flow	5 to 10 sccm Argon	Typical flow range.

Step 3) **Turn on the water cooling**.

If the source has water cooling, turn it on at this time. The water cooling must have a flow switch connected to the interlock string. If the source cooling stops flowing, the power supply output will shut off.

Step 4) **Turn the source on and allow it to warm-up**.

CAUTION

Make sure all electrical connections have been properly made and that the power supply interlock has been satisfied.

Turn the power supply on.

Set the cathode current and discharge voltage to the recommending starting conditions in Table 4.3. Similarly, adjust the neutralizer starting current.

Table 4.3. Recommending starting cathode current, discharge voltage and neutralizer current.

Source	Cathode filament I (A)	Discharge V (V)	Neutralizer filament I (A)
3 cm Source	3	40	3
8 cm Source	4	55	4

Turn on the source by pressing the SOURCE button. When the SOURCE button is pressed, the power supply will begin to apply power to the cathode, discharge and neutralizer. The cathode and neutralizer heaters will ramp to their respective set point (or last setting). The discharge voltage will ramp to an ignition voltage that is typically higher than 150V. As soon as a discharge starts, the discharge voltage will ramp to its starting set point.

An established plasma discharge is indicated when the discharge current is detected. A reasonable discharge current range for source warm up is 0.5 to 0.7 A. If the discharge current is not within this range, increase or decrease the cathode heater current appropriately.

The recommended warm up period is 10 minutes. If the neutralizer current is sufficient, an emission current will be present. As the source heats it may release trapped water vapor gases which may result in a temporary increase in chamber pressure. Presented in Table 4.4 are typical source warm up conditions. If the discharge current cannot be established, is excessively high, or other starting issues arise, please refer to Chapter 6 - Troubleshooting.

Table 4.4. Typical warm up data.

Source	Gas	Pressure	Cathode	Discharge		Beam		Accelerator		Neutralizer	
		x 10^{-4}	Heater	I	V	I	V	I	V	Heater	Emission
		(Torr)	(A)	(A)	(V)	(mA)	(V)	(mA)	(V)	(A)	(mA)
3 cm	4 sccm Ar	2.2	3.5	0.75	40	0	0	0	0	4.0	50
8 cm	5 sccm Ar	2.6	4.5	0.70	55	0	0	0	0	4.0	30

Step 4) **Set the beam conditions and turn the beam on**.

Set the beam and accelerator voltage for the desired condition. Optimized beam and accelerator voltages will be specific for a given process. Recommended conditions for typical applications are presented in Table 4.5. The comments in Table 4.5 are for standard grids. Grids can be customized for ion beam directional control.

Table 4.5. Typical beam and accelerator voltage settings.

Application	Beam V	Accel V	Comments
Low energy etch or assist beam	300 V	700 V	Beam is spread out.
Low rate sputtering	750 V	300 V	Beam is mid sized.
High rate sputtering	1250 V	250 V	Beam is focused.

Next, select how the beam current will be controlled, that is, either MANUAL, LOCAL or REMOTE. In order to select which mode to run press the MODE button. A description of these modes is listed in Table 4.6. For troubleshooting source problems, MANUAL mode is recommended. For most applications, LOCAL mode is useful for running a process.

Table 4.6. Definition of the power supply operational MODES.

MANUAL	The operator can adjust the cathode current for beam current control.
LOCAL	The operator selects a beam current and the power supply regulates cathode current.
REMOTE	Same as LOCAL, except that a computer is controlling the power supply.

If MANUAL MODE is selected, when the BEAM button is pressed, the extracted beam current is determined by the given discharge conditions. Beam current is increased or decreased by adjusting the cathode heater current.

If the LOCAL mode is selected, a target value for beam current can be set in the BEAM module. When the BEAM button is pressed, the power supply will regulate the discharge current by adjusting the cathode heater to extract the target beam current.

Step 5) **Adjusting the beam conditions**.

The beam current and voltage can be adjusted while the beam is on. However, for some conditions, the beam may need to be turned off while keeping the source on. Also, switching between MANUAL and LOCAL power supply modes may be necessary to achieve desired beam conditions. Some beam currents may not be achievable at various beam voltages (e.g. high beam current at low beam voltage). Please consult the source check out sheet for the nominal range of beam currents and voltages.

Additional recommendations for setting the beam current include start the source with a lower cathode heater current (i.e. lower discharge current) and a higher accelerator voltage. If there are issues with the beam current and voltage please consult Chapter 6 - Troubleshooting.

Step 6) **Optimizing the accelerator voltage.**

For some applications it can be useful to optimize the accelerator voltage. If the application requires low beam voltage (i.e. low ion energy) the accelerator voltage is usually required to be high and the beam spreads out as it leaves the source. On the other hand, if the application requires higher beam voltage (i.e. high ion energy), the accelerator voltage can be optimized to improve the accelerator grid life.

After a beam current and voltage are selected, start with a high accelerator voltage. Put the power supply in MANUAL mode. Decrease the accelerator voltage and examine the accelerator current and discharge current. When the discharge current begins to increase, electrons will begin to back-stream. At this condition, the accelerator voltage is too low. The accelerator voltage is optimized by increasing it above this setting by 50 to 75 V. Illustrated in Table 4.7 is an example of optimizing the accelerator voltage at a given beam condition.

Table 4.7. Electron back-streaming occurs at an accelerator voltage of 50 V. Optimized is 100V.

Source	Gas	Pressure	Cathode	Discharge		Beam		Accelerator		Neutralizer	
		x 10^{-4}	Heater	I	V	I	V	I	V	Heater	Emission
		(Torr)	(A)	(A)	(V)	(mA)	(V)	(mA)	(V)	(A)	(mA)
8 cm	5 sccm Ar	2.6	3.96	0.33	55	100	1250	5	150	3.6	125
	5 sccm Ar	2.6	3.96	0.33	55	100	1250	4	100	3.6	125
	5 sccm Ar	2.6	3.96	0.33	55	100	1250	4	75	3.6	125
	5 sccm Ar	2.6	3.96	0.35	55	110	1250	4	50	3.6	125

The accelerator to beam current (A/B) ratio in the power supply may require adjustment. The ratio is entered into the power supply and will induce an alarm if the A/B ratio is exceeded. A typical A/B ratio is 10% and at this condition, the power supply will alarm if the accelerator current is greater than 10% of the beam current.

Step 8) **Neutralizer operation**.

When the BEAM button is pressed, the neutralizer emission current should increase. If the power supply is in MANUAL mode, the emission current is determined by the given neutralizer heater current. If the power supply is in LOCAL mode, the emission current will adjust to the E/B ratio where the E/B ratio is emission current to beam current ratio. For typical applications, E/B is set to 125% or greater. At this condition, the emission of electrons from the neutralizer is more than the beam current. This will assist with the downstream conditions and minimize surface charging and arcing.

Step 9) **Turning the source off and cool down.**

The beam and source are shut off by pressing the source button. The power supply can be then turned off. It is recommended to leave the process gas running while the source cools for 10 minutes. It is recommended cooling the source about 20 minutes before the vacuum chamber is vented.

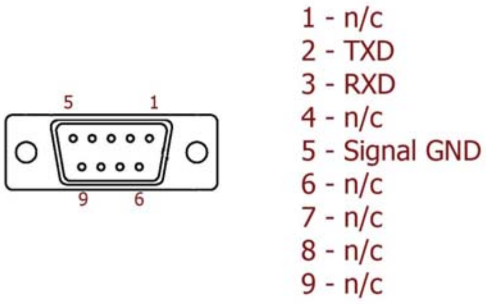
Chapter 5

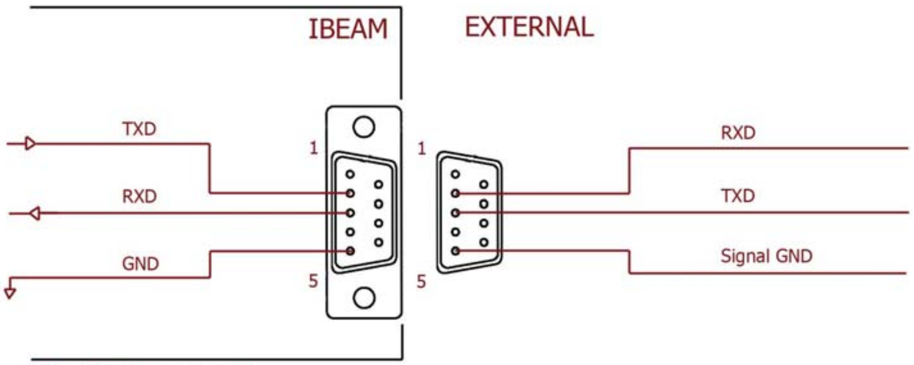
Remote Control

The IBEAM can be controlled with a computer interface via RS232 communication link or using the remote switch feature. The RS232 link is provided at the USER COM port located on the rear of the unit (see Chapter 3). Below is the pin-out and wiring diagram for the connection.

RS232 communications

Figure 8. Pin-outs and
electrical connections for
USER COM.
Connector style: DB9





CTS and RTS are not used

The handshake protocol is:

Baud rate	9600 bps
Data bits	8
Stop bits	1
Parity	none

A quick reference list of standard commands and their description are:

Command	Description
A	Attention, put IBEAM in REMOTE mode
AB	Set A/B ratio
AV	Set accelerator voltage
B	Turn beam on/off
BE	Set beam current tolerance
BI	Set beam current
BV	Set beam voltage
CI	Set the cathode filament current
CL	Set the cathode filament current limit
DV	Set the discharge voltage
M	Set the power supply mode
NI	Set the neutralizer filament current
NL	Set the neutralizer filament current limit
R	Recall conditions from memory
RC	Request running conditions
S	Turn source on/off
ST	Store running conditions to memory

Commands are sent to the IBEAM with carriage return <cr>. The IBEAM will respond with an echo of the command followed by a specific response. If an invalid command is sent, the IBEAM will respond with a <lf><cr>?<lf><cr><eot>, where <lf> is a line feed and <eot> is end of transmission. Certain commands are sent with additional values included before the carriage return <cr>.

The specifics of each command are described in the following section. For these examples, the command contained within the quotes needs to be sent. For example "*command*<cr>" is to send *command* followed by carriage return <cr>. Do not send the quotes.

Command Details

Serial command: **A**

Description: Attention and put IBEAM in REMOTE mode.
Usage: A<cr>
Example: Send “A<cr>”. The IBEAM will switch to REMOTE mode (if not already in REMOTE mode).
Response: <lf><cr>OK<lf><cr><eot>

Serial command: **AB**

Description: Set the accelerator to beam (A/B) ratio.
Usage: AB(0-99)<cr>
Example: Send “AB10<cr>”. The A/B ratio will be set to 10%. If the accelerator current exceeds 10% of the beam current, an error will be displayed. Acceptable range is from 0 to 99%. Default is 10.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: **AV**

Description: Set the accelerator voltage.
Usage: AV(0-1000)<cr>
Example: Send “AV250<cr>”. The accelerator voltage will be set to 250 V. Acceptable range is from 0 to 1000 V. Below 100 V is not recommended.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: **B**

Description: Turn the beam on or off
Usage: B(1 or 0)<cr>
Example: Send “B1<cr>”. The beam will turn on. Send “B0<cr>”. The beam will turn off.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: BE

Description: Set the beam current tolerance limit.
Usage: BE(0-99)<cr>
Example: Send "BE5<cr>". The beam current tolerance limit will be set to 5%. If the beam current, while running, deviates by 5% of the target value, an alarm will trigger. Setting BE to 0 will ignore the alarm. Acceptable range is from 0 to 99%. Default should be 5%.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: BI

Description: Set the beam current.
Usage: BI(0-300)<cr>
Example: Send "BI125<cr>". The beam current target will be set to 125 mA. After the beam is turned on, the power supply will ramp to 125 mA. Acceptable range is from 0 to 300 mA. The source check-out sheet should be consulted for normal ranges.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: BV

Description: Set the beam voltage.
Usage: BV(0-1500)<cr>
Example: Send "BV1250<cr>". The beam voltage target will be set to 1250 V. After the beam is turned on, the power supply will ramp to 1250 V. Acceptable range is from 0 to 1500 V. The source check-out sheet should be consulted for normal ranges.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: CI

Description: Set the cathode filament current.
Usage: CI(0.0-20.0)<cr>
Example: Send "CI4.2<cr>". The cathode filament current will bet set to 4.2 A. After the source is turned on, the power supply will ramp the cathode filament current to 4.2 A. Acceptable range is from 0.0 to 20.0 A. The source check-out sheet should be consulted for normal ranges.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: **CL**

Description: Set the cathode filament current limit.
Usage: CL(0.0-20.0)<cr>
Example: Send "CL8.0<cr>". The cathode filament current limit will be set to 8.0 A. If the cathode current exceeds 8.0 A, an alarm will trigger. Acceptable range is from 0.0 to 20.0 A. The source check-out sheet should be consulted for typical ranges of cathode filament current. The limit should be set slightly higher than the maximum expected cathode filament current.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: **DV**

Description: Set the discharge voltage.
Usage: DV(0-80)<cr>
Example: Send "DV50<cr>". The discharge voltage is set to 50 V. Acceptable range is from 0 to 80 V. Typical values are 35 to 55 V. It is not recommended running at voltages greater than 55 V. The source check-out sheet should be consulted for normal ranges of discharge voltage.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: **M**

Description: Set the power supply mode.
Usage: M(0,1 or 3)<cr>
Example: Send "M0<cr>". The IBEAM will be set to MANUAL mode.
Send "M1<cr>". The IBEAM will be set to LOCAL mode.
Send "M3<cr>". The IBEAM will be set to REMOTE mode.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: **NI**

Description: Set the neutralizer filament current.
Usage: NI(0.0-20.0)<cr>
Example: Send "NI5.1<cr>". The neutralizer filament current will bet set to 5.1 A. After the source is turned on, the power supply will ramp the neutralizer filament current to 5.1 A. Acceptable range is from 0.0 to 20.0 A. The source check-out sheet should be consulted for normal ranges.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: NL

Description: Set the neutralizer filament current limit.
Usage: NL(0.0-20.0)<cr>
Example: Send "NL8.5<cr>". The neutralizer filament current limit will be set to 8.5 A. If the neutralizer current exceeds 8.5 A, an alarm will trigger. Acceptable range is from 0.0 to 20.0 A. The source check-out sheet should be consulted for typical ranges of neutralizer filament current. The limit should be set slightly higher than the maximum expected neutralizer filament current.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: R

Description: Recall conditions from memory.
Usage: R(0-9)<cr>
Example: Send "R2<cr>". The beam conditions stored in memory location 2 will be recalled. Acceptable range is from 0 to 9. Each memory location stores beam current, beam voltage, accelerator voltage, discharge voltage, cathode filament current and neutralizer filament current. Also stored are the A/B and E/B ratios, cathode and neutralizer filament current limits. Memory location 0 is reserved for the last running condition.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: RC

Description: Request running conditions.
Usage: RC<cr>
Example: Send "RC<cr>". The current running conditions will be sent to the buffer. It is recommended this command should not be sent more than 1 time per second.
Response: <lf><cr>AA.A,B.BB,CCC.C,DDD,EEEE,FFF,GGGG,HHHH,II.I,JJJJ<lf><cr><eot>

Where: AA.A is cathode filament current (A)
B.BB is the discharge current (A)
CCC .C is the discharge voltage (V)
DDD is the beam current (mA)
EEEE is the beam voltage (V)
FFF is the accelerator current (mA)
GGGG is the accelerator voltage (V)
HHHH is the emission current (mA)
II.I is the neutralizer filament current (A)
JJJJ is factory use

Serial command: **S**

Description: Turn the source on or off
Usage: S(1 or 0)<cr>
Example: Send “S1<cr>”. The source will turn on.
Send “S0<cr>”. The source and beam will turn off.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: **ST**

Description: Store running conditions to memory.
Usage: ST(0-9)<cr>
Example: Send “ST7<cr>”. The current beam conditions are stored in memory location 7. Acceptable range is from 0 to 9. Each memory location stores beam current, beam voltage, accelerator voltage, discharge voltage, cathode filament current and neutralizer filament current. Memory location 0 is reserved for the last running condition.
Response: <lf><cr>OK<lf><cr><eot>

Operation example

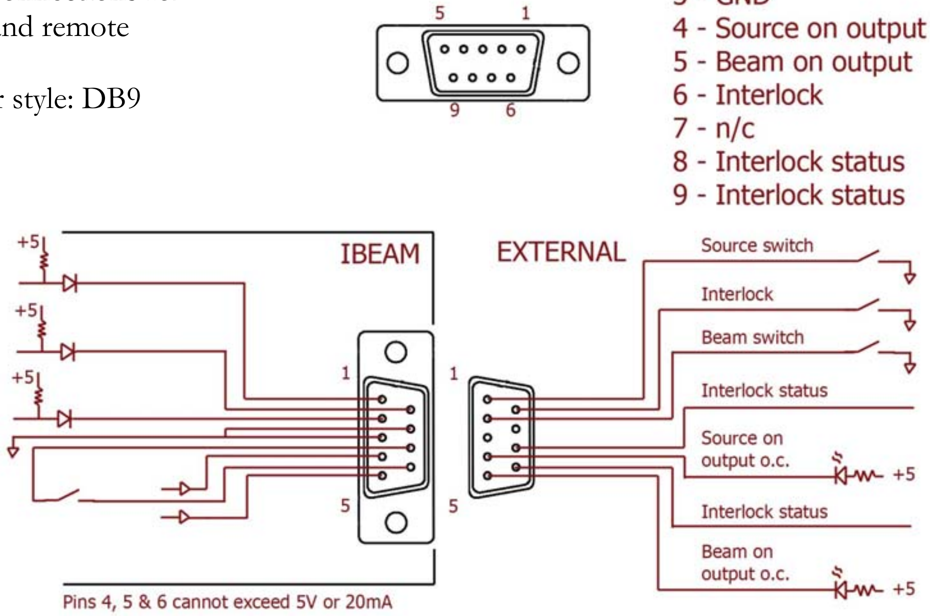
The following is a line-by-line short example of how turn on the beam and monitor its conditions. Each line represents a command sent to the IBEAM. The time duration between each command line should be a least one (1) second. For data logging operations, it is recommended requesting the running conditions should not be performed more than once (1 time) per second. Similarly, setting new target conditions should be limited to once (1 time) per second. If faster response in turning the beam on/off is required, please examine the description on remote switches later in this chapter.

Line	Command	Description
1	A<cr>	Put the IBEAM in remote mode
2	BV1250<cr>	Set the beam voltage to 1250 V.
3	BI100<cr>	Set the beam current to 100 mA.
4	CI3.5<cr>	Set cathode current to 3.5 A.
5	S1<cr>	Turn the source on.
6	*delay*	Wait about 10 minutes before turning on the beam.
7	B1<cr>	Turn the beam on.
8	RC<cr>	Request running conditions.
9	*delay*	Wait at least 1 second before sending next command.
10	*loop to line 8*	Data log beam conditions until event occurs.
11	B0<cr>	Turn beam off.
12	S0<cr>	Turn source off.

Remote switches

For faster control, certain functions of the IBEAM can be performed using remote switches. The remote switch link is provided at the INTERLOCK port located on the rear of the unit (see Chapter 3). Specifically, the source and beam switch can be toggled remotely. For these features to work, the remote switch must be enabled from the CONTROL module (see Chapter 4). Below is the pin-out and wiring diagram for the connection.

Figure 9. Pin-outs and electrical connections for interlock and remote switches.
Connector style: DB9



1 - Remote switch for source
2 - Remote switch for beam
3 - GND
4 - Source on output
5 - Beam on output
6 - Interlock
7 - n/c
8 - Interlock status
9 - Interlock status

Pins 4, 5 & 6 cannot exceed 5V or 20mA

The switch closures work to turn on the source and beam. Their function is identical to the Beam/Source ON/OFF output buttons on the front panel. To turn the source ON, the source switch (pin 1) is shorted to ground. Similarly, to turn the beam ON, the beam switch (pin 2) is shorted to ground. Either can be turned OFF by opening the short. The switch closures are driven by an internal 5 V signal. Additional voltage or power is not required.

The signal timing on the remote switches is about 50 ms. That is, when the state of the remote switches changes, it takes about 50 ms for the power supply to respond. The switch closures have indicators (pins 4 and 5) that can be used for feedback if necessary.

Chapter
6

Troubleshooting

As there are many variables with the ion beam source, the troubleshooting is divided into the various stages of operation. First, common issues with the power supply are presented. It is important to be aware of the electrical nature of the ion beam source. Most issues arise from electrical shorting or openings that disrupt proper operation. These issues may not present themselves easily, say with a multi-meter, as it may be a plasma short or a thermal open that creates the issue.

This chapter is divided into:

Power Supply – Problems that are detected by the power supply.
Starting the source – Cathode, anode and discharge problems.
Turning the beam on – Beam, accelerator, and grid problems.
Neutralizer operation – Neutralizer problems.
Special diagnostics and testing.

Power Supply Error Codes

The IBEAM will display various error codes in the output displays. These are in the form of letter E followed by two numbers (e.g. E##). The errors may pertain to a particular module or the entire unit. Below is a listing of these codes.

Table 6.1 Problems as detected by the power supply.

Error	Description	Possible problems and solutions
03	Output of module is lower than requested.	1. Facility voltage is too low – Check facility voltage. 2. Electrical connection is poor – Check electrical connections 3. Power supply fuse has failed – Check fuses.
04	Output of module is higher than requested.	1. Electrical short – Check electrical connections. 2. Plasma short – Check the source and feedthru for electrical wire proximity problems or coated insulators. 3. Gas flow is too high – Check gas flow level.
05	Module is in current limit.	1. Electrical short – Check electrical connections. 2. Plasma short – Check the source and feedthru for wire proximity problems or coated insulators. 3. Electrical short – Check for flakes or debris.
06	Module is at over temperature.	1. Cooling issue – Make sure fan is operational and unobstructed. 2. Dust buildup – Clean any dust buildup on power supply.
10	Heater current is greater than max heater current set point.	1. Filament is too long – Replace filament or adjust software limit.
20	Interlock is open	1. Water flow – Check water flow. 2. Vacuum – Check vacuum interlock. 3. Interlock cable is not connected – Check cable and connections.
22	Cathode filament error	1. Filament failure (filament open) – Replace filament. 2. Cable is not connected – Check cable and feedthru connections.
23	Neutralizer filament error	1. Filament failure (filament open) – Replace filament. 2. Cable is not connected – Check cable and feedthru connections.
24	E/B Ratio (emission current to beam current ratio)	1. Emission current too low – Check neutralizer filament. 2. Neutralizer location – Neutralizer is too far from beam. 3. Filament is too long – Replace filament. 4. Leakage current on neutralizer insulators – Clean / replace insulators.
25	A / B Ratio (accel current to beam current ratio)	1. Accel current is too high – Check alignment of grids. 2. Accel voltage is too low – Increase accel voltage. 3. Unstable beam condition – Examine data provided with source. 4. Grid spacing incorrect – Check grid spacing. 5. Debris between the grids – Clean and inspect the grids. 6. Leakage current on grid insulators – Clean / replace insulators.

Starting the Source

Table 6.2 Problems with CATHODE, ANODE and DISCHARGE.

Problem description	Possible problems and solutions
Cathode filament current is zero	1. Filament failure – Check and replace filament 2. Faulty connection – Check cable and feedthru connections (Table 6.5). 3. Possible power supply problem – Have power supply serviced.
Cathode filament current lower than normal	1. Faulty connection – Check cable and feedthru connections (Table 6.5). 2. Cathode filament is smaller than standard size. 3. Cathode filament is older than a newer one.
Cathode filament current higher than normal	1. Cathode is electrically shorted – Check electrical connections in cable, feedthru and source. 2. Cathode filament is longer than standard size. 3. Cathode filament is a newer one.
Discharge current is zero.	1. Discharge has not started – Check gas flow rate, make sure flow is OK. 2. Discharge has not started – Check gas flow connection. 3. Discharge has not started – Check status of the cathode operation. 4. Faulty electrical connection – Check cable and feedthru connections. 5. Faulty electrical connection – Check anode electrical connections. 6. Failed body fuse – Check body fuse.
Discharge current lower than normal	1. Anode has a poor connection – Check anode electrical connections. 2. Anode is coated / insulated – Clean anode 3. Cathode is older than a newer one. 4. Gas flow is lower than expected – Check gas flow operation.
Discharge current higher than normal	1. Anode has shorted to the body – Check anode and body connections, look for debris or flakes, clean where necessary. 2. Anode insulator is coated – Check anode insulator and clean / replace. 3. Gas flow is higher than expected – Check gas flow operation.

Turning on the Beam

Table 6.3 Problems with BEAM and ACCEL.

Problem description	Possible problems and solutions
Beam current zero.	1. Discharge is not started or is out – Check discharge operation (Table 6.2) 2. Faulty connection – Check cable and feedthru connections (Table 6.5). 3. Possible power supply problem – Have power supply serviced.
Beam current lower than normal	1. Gas flow is lower than expected – Check gas flow and operation. 2. Discharge current is too low – Check discharge operation (Table 6.2) 3. Cathode is newer than an older one (Manual mode).
Beam current higher than normal	1. Screen grid is electrically shorted – Check body electrical connections. Look for signs of plasma shorts, coated insulators and electrical lead wire proximity issues. 2. If both accel and beam current are high - Check the grid alignment and spacing. Check for accel to screen grid shorting (Table 6.5) 3. Anode is electrically shorted – Check anode connections. Look for signs of plasma shorts inside source, coated insulators and electrical lead wire proximity issues. 4. Screen grid has debris or flakes – Clean screen grid. 5. Discharge current is too high – Check discharge operation (Table 6.2). 6. Gas flow is higher than expected – Check gas flow and operation. 7. Cathode is older than a newer one (Manual mode).
Accel current zero.	1. Discharge not started or is out – Check discharge operation (Table 6.2) 2. Faulty connection – Check cable and feedthru connections (Table 6.5). 3. Possible power supply problem – Have power supply serviced.
Accel current lower than normal	1. Accel grid has a faulty electrical connection – Check connections. 2. Gas flow is lower than expected – Check gas flow operation.
Accel current higher than normal	1. Accel grid is electrically shorted – Check accel electrical connections. Look for signs of plasma shorts inside the source, coated insulators and electrical lead wire proximity issues. 2. If both accel and beam current are high - Check the grid alignment and spacing. Check for accel to screen grid shorting (Table 6.5) 3. Accel grid insulators are coated – Check insulators and clean / replace. 4. Accel grid insulators are coated – Perform high-pot test (Table 6.5). 5. Gas flow is higher than expected – Check gas flow operation. 6. Beam voltage is too low – Examine the source run data.
Arcing	1. Debris or flakes are in proximity to the grids – Check and clean the screen and accel grid. 2. Accel grid is coated with dielectric material – Clean the accel grid. 3. Grids have contamination – Clean grids ultrasonically in Micro-90 and water. Rinse and wipe with alcohol. Bake grids under a heat lamp to remove water vapor. Wipe with alcohol and blow with dry nitrogen. 4. Source was not warmed up long enough – increase warm up time.

Neutralizer Operation

Table 6.5 Problems with the neutralizer.

Problem description	Possible problems and solutions
Neutralizer filament current is zero	1. Filament failure – Check and replace filament 2. Faulty connection – Check cable and feedthru connections (Table 6.5). 3. Possible power supply problem – Have power supply serviced.
Neutralizer filament current lower than normal	1. Faulty connection – Check cable and feedthru connections (Table 6.5). 2. Filament is smaller than standard size. 3. Filament is older than a newer one.
Neutralizer filament current higher than normal	1. Neutralizer is electrically shorted – Check electrical connections in cable, feedthru and source. 2. Filament is longer than standard size. 3. Filament is a newer one.
Emission current is zero	1. Neutralizer filament is not close to beam – move filament. 2. Filament current is too low – Examine run data for the source. 3. Source gas is off or low – check source gas operation. 4. Neutralizer is electrically shorted – Check cable (Table 6.5). 5. Faulty connection – Check cable and feedthru connections (Table 6.5). 6. Failed emission fuse – Check emission fuse.
Emission current is lower than expected	1. Filament current is too low – Increase filament current (Manual mode). 2. E/B ratio is set incorrectly – Check the E/B ratio (Local mode).
Emission current is higher than expected	1. Filament current is too high – Lower filament current (Manual mode). 2. E/B ratio is set incorrectly – Check the E/B ratio (Local mode)
Emission current is unstable	1. Filament cannot effectively couple to the beam – Move filament closer to the beam. 2. Filament is too long.

Special Testing

CAUTION

These test require that the power supply is powered off. Turn the front panel EPO to OFF. Turn the rear panel main switch to OFF.

Table 6.5 Diagnostics and testing procedures.

Problem description	Possible problems and solutions
Cathode filament current is zero or lower than normal.	1. Faulty connection – Check cable and feedthru connections. Note: With the source off, disconnect the source cable from the power supply. Use an ohm meter and measure the resistance between pins A/D and G/E. The reading should be 2 ohms or less to indicate the filament is intact and properly connected.
Beam current zero.	1. Faulty connection – Check cable and feedthru connections. Note: With the source off and at atmosphere, disconnect the source cable from the power supply. Use an ohm meter and measure the resistance between pin C and the anode. The reading should be 2 ohms or less to indicate the anode is properly connected.
Accel current zero.	1. Faulty connection – Check cable and feedthru connections. Note: With the source off and at atmosphere, disconnect the source cable from the power supply. Use an ohm meter and measure the resistance between pin F and the accelerator grid. The reading should be 2 ohms or less to indicate the accel grid is properly connected.
Beam current and Accel current higher than normal	1. Check for accel to screen grid shorting. Note: With the source off and at atmosphere, disconnect the source cable from the power supply. Use an ohm meter and measure the resistance between pin B and pin F. The reading should be open to indicate the body (screen grid) is not shorted to the accel grid.
Neutralizer filament current is zero or lower than normal	1. Faulty connection – Check cable and feedthru connections. Note: With the source off, disconnect the neutralizer cable from the power supply. Use an ohm meter and measure the resistance between pins A/B and C/D. The reading should be 2 ohms or less to indicate the filament is intact and properly connected. Also check between either A/B or C/D to ground. The reading should be open to indicate the neutralizer filament is not in contact with ground. Also check between either A/B or C/D to source cable pin F. The reading should be open to indicate the neutralizer filament is not in contact with the accelerator grid.

Electron Backstreaming

If the accelerator grid voltage is set too low, it is possible for electrons from the neutralizer to migrate into the discharge plasma. This condition is referred to as electron backstreaming. Electron backstreaming will lead to erroneous beam current readings and will result in a lower etch rate on the target (or a lower deposition rate). The source can be quickly tested to determine if electron backstreaming is taking place.

In Table 6.6 are data from an example of electron backstreaming. As the accelerator voltage is decreased from 150 to 50V, the discharge current erroneously increases at 50V. Note the beam current also increases. Similar to these data, testing for backstreaming should be conducted with a fixed cathode current. The power supply is running in manual mode.

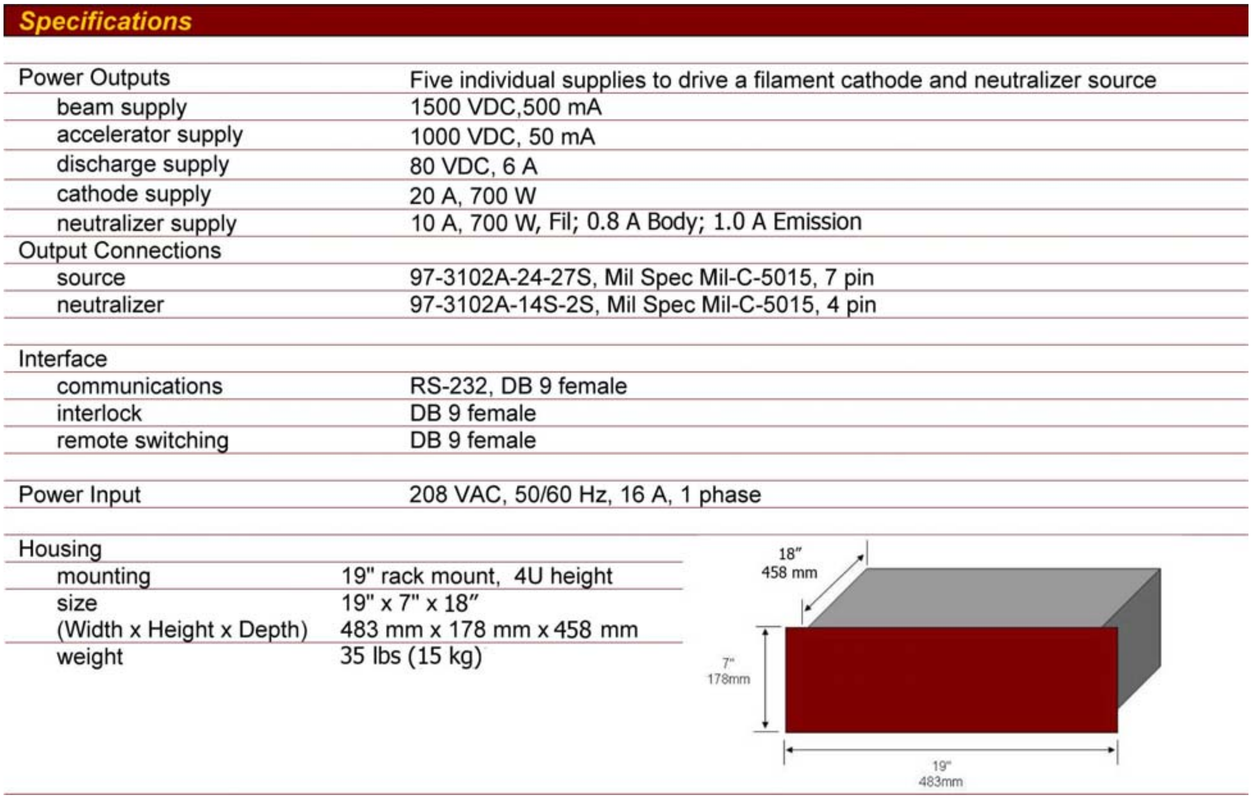
Table 6.6. Electron back-streaming example.

Source	Gas	Pressure	Cathode	Discharge		Beam		Accelerator		Neutralizer	
		x 10^{-4}	Heater	I	V	I	V	I	V	Heater	Emission
		(Torr)	(A)	(A)	(V)	(mA)	(V)	(mA)	(V)	(A)	(mA)
8 cm	5 sccm Ar	2.6	3.96	0.33	55	100	1250	5	150	3.6	125
	5 sccm Ar	2.6	3.96	0.33	55	100	1250	4	100	3.6	125
	5 sccm Ar	2.6	3.96	0.33	55	100	1250	4	75	3.6	125
	5 sccm Ar	2.6	3.96	0.35	55	110	1250	4	50	3.6	125

Chapter 7

Specifications

Below are specifications for the IBEAM FC/PBN power supply.



Specifications	
Power Outputs	Five individual supplies to drive a filament cathode and neutralizer source
beam supply	1500 VDC,500 mA
accelerator supply	1000 VDC, 50 mA
discharge supply	80 VDC, 6 A
cathode supply	20 A, 700 W
neutralizer supply	10 A, 700 W, Fil; 0.8 A Body; 1.0 A Emission
Output Connections	
source	97-3102A-24-27S, Mil Spec Mil-C-5015, 7 pin
neutralizer	97-3102A-14S-2S, Mil Spec Mil-C-5015, 4 pin
Interface	
communications	RS-232, DB 9 female
interlock	DB 9 female
remote switching	DB 9 female
Power Input	208 VAC, 50/60 Hz, 16 A, 1 phase
Housing	
mounting	19" rack mount, 4U height
size (Width x Height x Depth)	19" x 7" x 18" 483 mm x 178 mm x 458 mm
weight	35 lbs (15 kg)