



I-BEAM RF POWER SUPPLY

MANUAL

Safety



WARNING

HAZARDOUS VOLTAGE – ion beam sources are to be serviced and operated by trained personnel only.

Thank you for purchasing an ion beam source power supply from Plasma Process Group! We want your new source to operate safely. Anyone who installs or operates this equipment should read this publication (and any other manuals) before installing or using the ion beam source, neutralizer and power supply.

All applicable local and national codes that regulate the installation and operation of this electronic equipment should be followed. It is your responsibility to determine the codes that apply to your area.

Please follow all applicable sections of the National Fire Code, National Electronic Code, and the codes of the National Electrical Manufacturer’s Association (NEMA). Consult with your local government to help determine which codes are necessary for safe installation. Failure to comply with applicable codes and standards may result in equipment damage or serious injury to personnel.

Our equipment is designed for laboratory or production vacuum environments. The external interlock for the ion beam source power supply should be connected to your facility to ensure maximum safety and prohibit usage of the equipment when unsafe conditions arise. Failure to use the external interlock is considered “High Risk Activities” where personal injury or equipment damage may result. Plasma Process Group specifically disclaims any expressed or implied warranty for High Risk Activities.

The ion beam power supply has been CE certified and the electronic discharges for the source and neutralizer are created using industry standard radio frequency (RF) methods. Improper installation of this equipment may result in disruptions with other sensitive electronic equipment.

If you have any questions regarding the installation and operation of this equipment, please contact us immediately at 970-663-6988 or info@plasmaprocessgroup.com.

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



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Service and Technical Support

For Service or Repair please contact us at 970-663-6988 or send an email to info@plasmaprocessgroup.com.

Before contacting us please have ready the following information about the issue:

- Product type
- Model and serial number
- Date purchased
- List of all the operating parameters
- Error messages on power supply
- Gas flow to the source, neutralizer and background
- Chamber pressure

Many issues can be solved over the phone or email.

In the event hardware needs to be returned, all equipment, including warranty, returned to Plasma Process Group (PPG) requires a return authorization (RA) number. Our support team will provide a return request form with instructions to start the process. This form is also located at our website plasmaprocessgroup.com (see Resources then Terms and Forms). Special instructions will apply to international customers.

Warranty

Our workmanship warranty can be found at our website plasmaprocessgroup.com (see Resources then Terms and Forms).

Warning Statements

This manual uses these symbols to indicate potential hazards.



ALERT - This symbol is used for tips and other pointers.



WARNING

This symbol illustrates a electrical shock hazard.



Warning- Risk of Injury to Persons

This symbol is used to warn of a heavy lift operation.



CAUTION

This symbol is used to alert of a potential risk to person or equipment.

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Chapter 1: Getting Started

Ion beam technology was developed at NASA in the 1960s as a means of producing thrust on spacecraft. Today, ion beam sources are used on vacuum systems for depositing precise thin film coatings of oxides, diamond-like carbon, and other useful materials on optical and mechanical components.

This manual covers the installation and operation of the I-BEAM power supply controller for the radio frequency (RF) ion beam source products we offer.

Section 1.1: Terminology

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 they all have the same energy and can be directed to a target or other substrate. At low energies, the ion beam is useful for etching or cleaning parts. At high energies, the ion beam can be used to sputter target materials.



Ion beam striking a target.

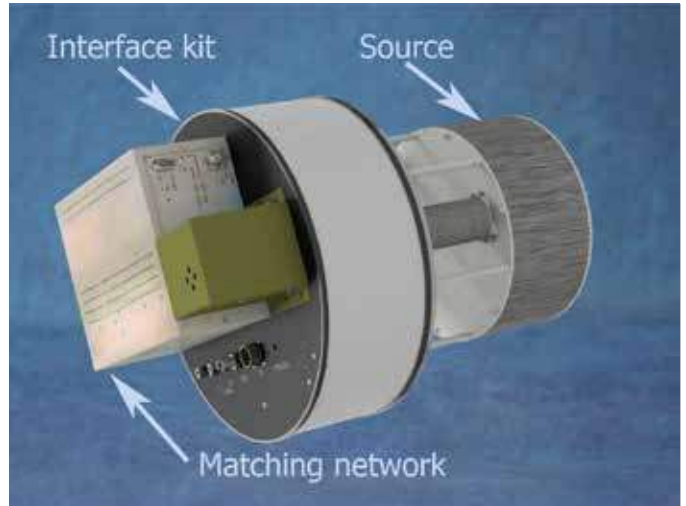
An RF ion source package consists of the ion beam source, an RF neutralizer (RFN), feedthroughs, power supply(s), RF matching network, and cables. To install the source in a vacuum system, feedthroughs are used and these combined with additional hardware form an interface kit.



The hardware unpacked.

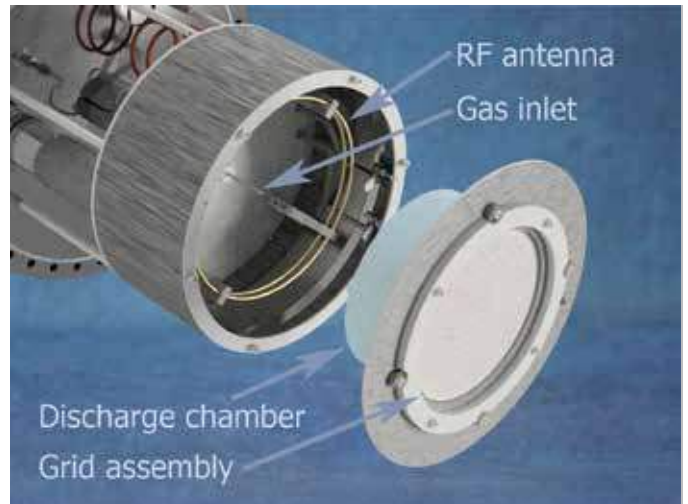
I-BEAM RF POWER SUPPLY MANUAL Chapter 1: Getting Started

Depending upon the configuration, the source may already be attached to the interface kit. This is common for flange mounted sources. For these cases, the matching network is also attached and the entire assembly just requires installation. Internal mount kits will come with individual feedthroughs that require installation into the vacuum system before the source can be attached.



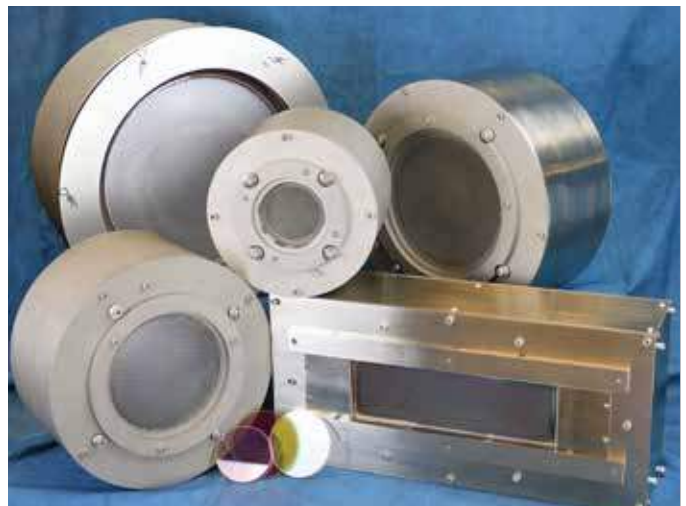
Source and interface kit assembly.

Inside the source are the key elements for operation. These include the gas inlet (also called gas isolator), the RF antenna (also called coil), discharge chamber and grids. Process gas, such as high purity Argon, is fed into the discharge chamber. The RF antenna will then excite free electrons causing ionization of the process gas. A plasma is then created inside the discharge chamber. A plasma is an electrically conductive gas where the density of ions and electrons are approximately equal.



Inside the source.

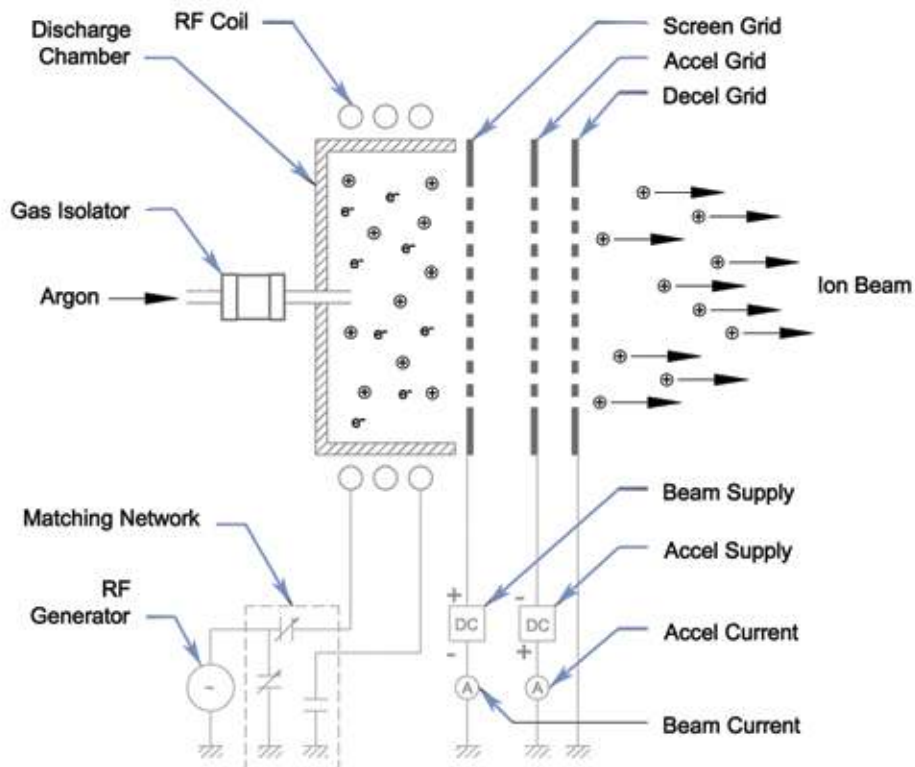
All RF ion beam sources will have these same key elements. Only the sizes and geometries will differ for antennas, grids, and discharge chambers.



The RF ion beam source family.

Section 1.2: Overview

The schematic below illustrates how the key elements work inside the source. Process gas is supplied to the discharge chamber. The RF antenna is tuned using the matching network where its voltages can reach upwards of ± 2500 V. The oscillating field will excite free electrons that can ionize the process gas and sustain a plasma discharge (ions and electrons). Ions created in the discharge chamber that drift towards the grids are then accelerated to high velocities with electrostatic potential applied to the grids. The screen grid is biased positive, the accelerator grid is biased negative and the decelerator grid is grounded.



Electrical schematic for the RF ion beam source.

ION BEAM PARAMETERS		
PARAMETER	DEFINITION	UNIT
Source Gas Flow	Process gas delivered to the discharge chamber.	sccm
RF Forward Power	The RF power applied to the matching network. This controls the ion production rate	W
RF Reflected Power	The RF power returned from the matching network.	W
Beam Voltage	Positive voltage applied to the screen grid (ion energy).	V
Beam Current	The total ion current leaving the source.	mA
Accel Voltage	Negative voltage applied to the accelerator grid.	V
Accel Current	Current collected by accelerator grid (charge-exchange).	mA
A/B Ratio	Ratio of accel to beam current. Typical A/B is < 10%.	%

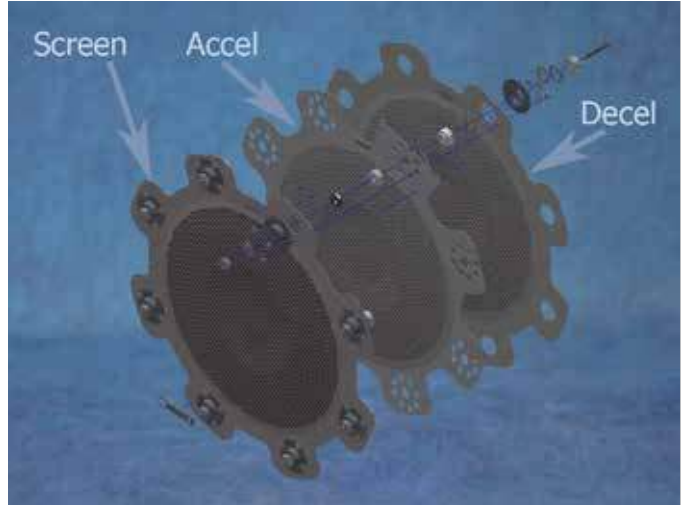
I-BEAM RF POWER SUPPLY MANUAL Chapter 1: Getting Started

The grids, which control the ion optics, will come in different shapes, sizes and materials. They can be flat (i.e. graphite) or dished (i.e. molybdenum) to promote beam shape and trajectories. The inner most grid is called the screen grid (biased positive) and the middle grid is called the accelerator (biased negative). Most grid assemblies will have 3 grids where the decelerator will act as a shield to the other two grids and capture process material coming back to the source. Additional information about the grid operation and design can be found in the *Ion Beam RF Sources Manual*.

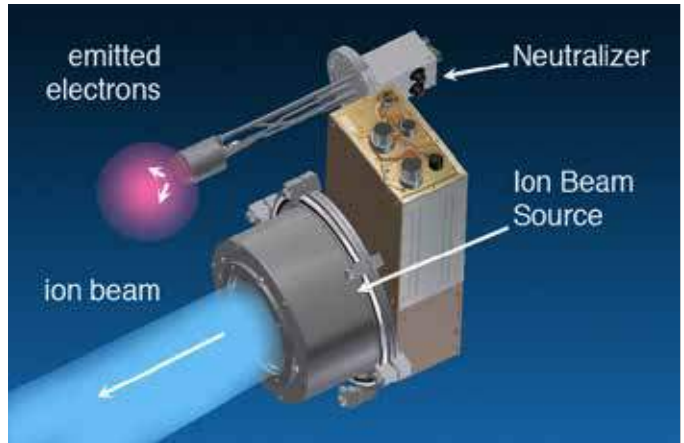
A neutralizer is placed downstream from the source where it emits electrons to balance the number of positive ions which leave the source. The RFN operates in a similar fashion to the source as it requires process gas, has an RF antenna and its own matching network. Please refer to its manual for a detailed description of its operation and additional information.

The RFN needs to be placed so that its electrons can couple (or “see”) the ion beam. It is very important that these electrons have a close (about 150 mm), unobstructed path to the beam to ensure stable, noise free operation. The RFN should also be located away from strong magnets or shielded from magnetic fields using 400 series stainless steel. A common challenge will be to protect the RFN from process material that can coat its keeper - but allow for electrons to couple.

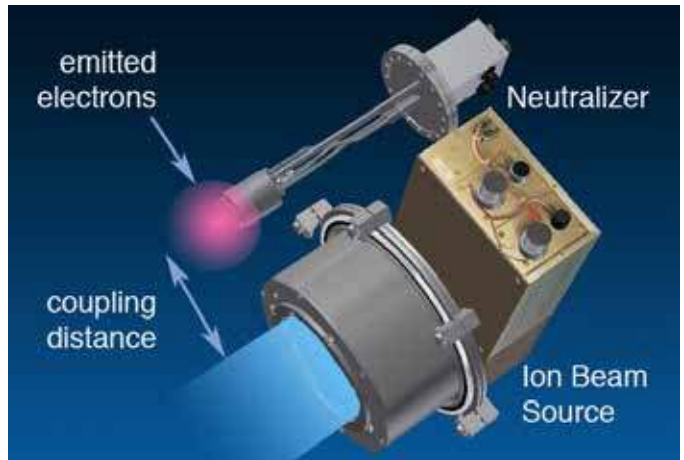
Electrons from the neutralizer do not recombine with source ions, rather they provide space-charge-neutralization for the downstream plasma. Under normal operation, the neutralizer will emit between 125% to 200% of the measured beam current. In this fashion substrates or targets downstream will not suffer damage due to arcing or surface charging.



Typical grids before assembly.



The RFN will emit more electrons than ions from the source.



Place the RFN in close proximity to the ion beam.

I-BEAM RF POWER SUPPLY MANUAL Chapter 1: Getting Started

The source and RFN are both controlled using the I-BEAM power supply. The I-BEAM supply is connected to the source, RFN and it will monitor the source matching network controller. It houses the beam, accel, RF power for the source and power supplies necessary for the RFN. There are three modes of control. These are “Manual” which provides full RF control, “Local” which allows direct beam current control, and “Remote” for system interface.



The I-BEAM ion source controller.

The table below are the critical operating parameters for the RFN.

NEUTRALIZER PARAMETERS		
PARAMETER	DEFINITION	UNIT
RFN Gas Flow	Gas delivered to the neutralizer.	sccm
RFN Forward Power	The RF power applied to the matching network.	W
RFN Reflected Power	The RF power reflected from the matching network.	W
Keeper Current	Discharge current between keeper and collector. Typical is 300 mA.	mA
Keeper Voltage	Voltage applied to keeper. Lower than 30 V is preferred.	V
Neutralizer Emission Current	The electron current emitted by the neutralizer.	mA
E/B Ratio	Ratio of neutralizer emission to beam current. Typical E/B is 125% or greater to minimize surface charging and arcing.	%

Chapter 2: Installation

This chapter will cover the installation of the power supply. Please contact us with any concerns or issues that arise during the installation of the power supply. Please consult the *Ion Beam RF Sources Manual* for a complete description of the source installation procedure.

Section 2.1: General Requirements

Vacuum system

The source will require a modest vacuum system capable of handling some gas flow. Typical pumping stations will have either a diffusion or cryo high vacuum pump. The pumping speed must be appropriate for the ion source selected which will fall within a range from 1500 to 6000 L/s air. The base pressure for the machine should be low 10^{-6} mbar and even a lower water vapor pressure. With the source, RFN and process gases the chamber pressure should not exceed 5×10^{-4} mbar during operation.

Electrical

The vacuum system should have an earth ground. A grounding line should be installed between the I-BEAM and the vacuum chamber earth ground. The I-BEAM supply requires 208 VAC, 50/60 Hz single phase at 16A. The matching network controller will require 110 VAC, 50/60 Hz. Cables between the I-BEAM supply and source (or RFN) should be fully seated. Remaining cable should be looped and secured with tie wraps. The I-BEAM supply and matching network controller need to be mounted to the well ventilated 19" rack.

Safety

The I-BEAM power supply has a switch closure interlock that needs to be interfaced with the facilities. Industry standard is to safe guard the power supply and only allow for the source to be run when the vacuum pumping station is ready, gas and coolant flows are nominal. All facilities should have an emergency power off (EPO) switch that will break the interlock and turn power off to the supply.



WARNING

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


Section 2.2: Unpacking

We take extra care in packaging our equipment for shipment. Please inspect all containers for any shipping damage. Send us a photo of the shipping container if there are any issues. Handle all equipment with care.

Personal protection

Eye protection should always be worn. All equipment should be handled with clean room grade Nitrile™ or Latex™ gloves.

It is recommended to stage the installation away from the shipping container. Care should be taken to minimize particulate contamination such as hair and dust while the source is being assembled and installed.



Warning- Lift hazard

Best practice is to have 2 people lift the source and power supply.

Power Supply

The I-BEAM supply should be lifted with two people and placed on a cart. The matching network controller should also be located and unpacked. All of the cables can be removed from their plastic bags.

Section 2.3: Connection Layout


On the back of the I-BEAM are the electrical connections for the source, neutralizer and communication cables. The I-BEAM 701 will not have the RF output for the source. The I-BEAM 702 will not have RF and DC output for the source. Prepare the location for the power supply with adequate access to these connections



View of the power supply rear panel.

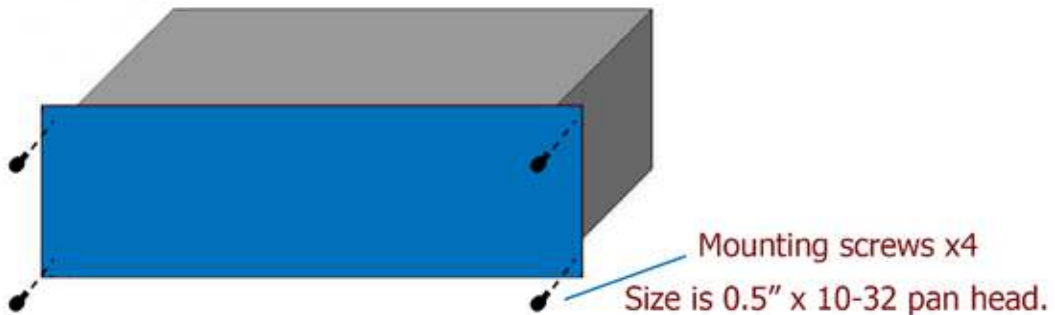
Section 2.4: Mounting and Air Cooling

The power supply is designed to be installed in a standard 19" equipment rack adjacent to the vacuum system. For safety, the top, bottom, sides and rear should not be accessible while the power is ON and operating. When installed in an equipment rack, it must be supported with rails or slides in the cabinet.



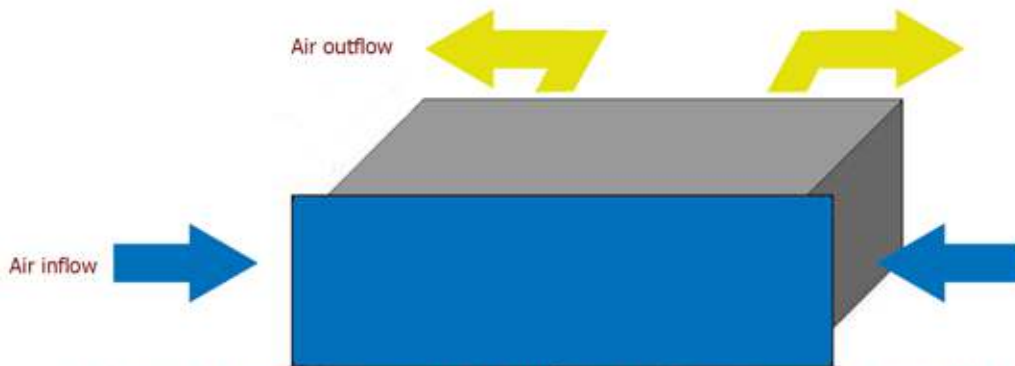
Warning- Risk of Injury to Persons

Use 2 people to lift and move the supply for mounting.




Place the power supply in an equipment rack.

 **TIP** - Do not use the ears to support the weight of the power supply.



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.

Ensure the chassis has adequate air for cooling.

 **TIP** - Leave plenty of access behind the power supply. Do not block the sides of the power supply.

Section 2.5: Source and Neutralizer Connections

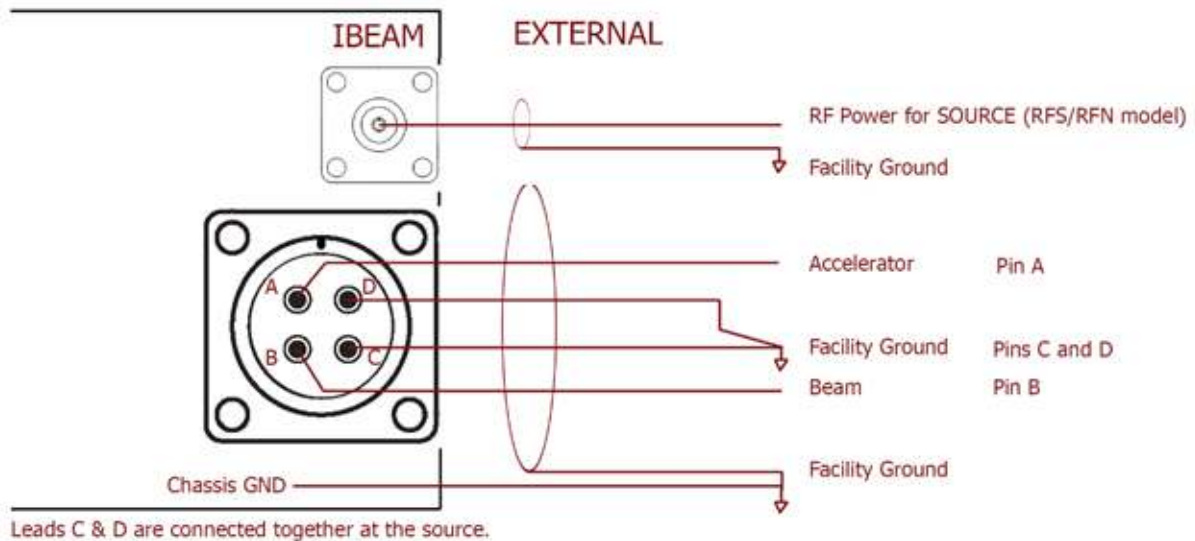
Connect the RED source cable to the I-BEAM 4 pin SOURCE output connector. Connect the other end of the cable to the source interface kit. This cable provides connections to the source screen (beam) and accelerator grids. Connect the RED RF cable to the RFS out on the I-BEAM and the RF in on the source matching network.



Source DC cable.



Source RF cable.



Pin outs for the RED source cables.

I-BEAM RF POWER SUPPLY MANUAL CHAPTER 2: Installation

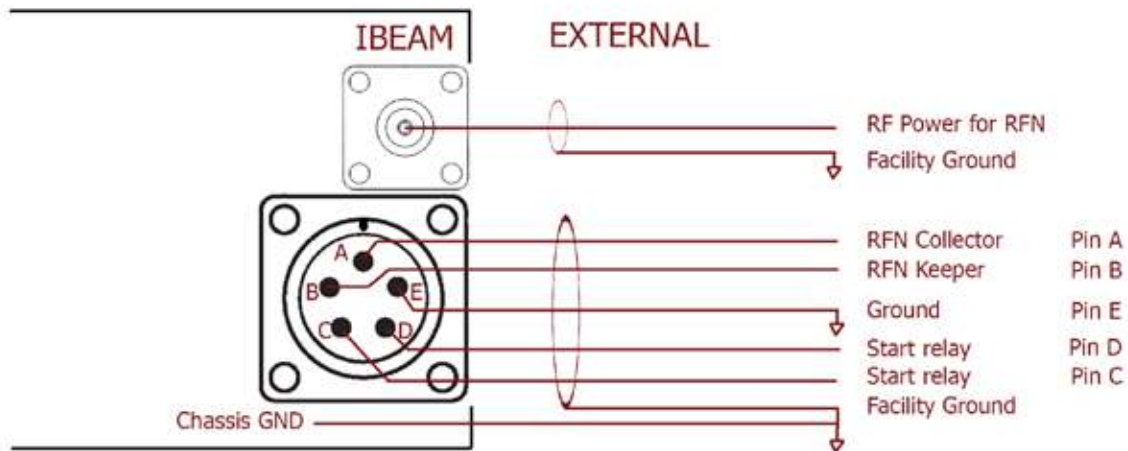
Connect the BLUE neutralizer cable to the I-BEAM 5 pin NEUTRALIZER output connector. Connect the other end of the cable to the RFN matching network. This cable provides the DC bias connections for the RFN's keeper and collector as well as starting relay control. Connect the BLUE RF cable to the RFN out on the I-BEAM and the RF in on the neutralizer matching network.



Neutralizer DC cable.



Neutralizer RF cable.

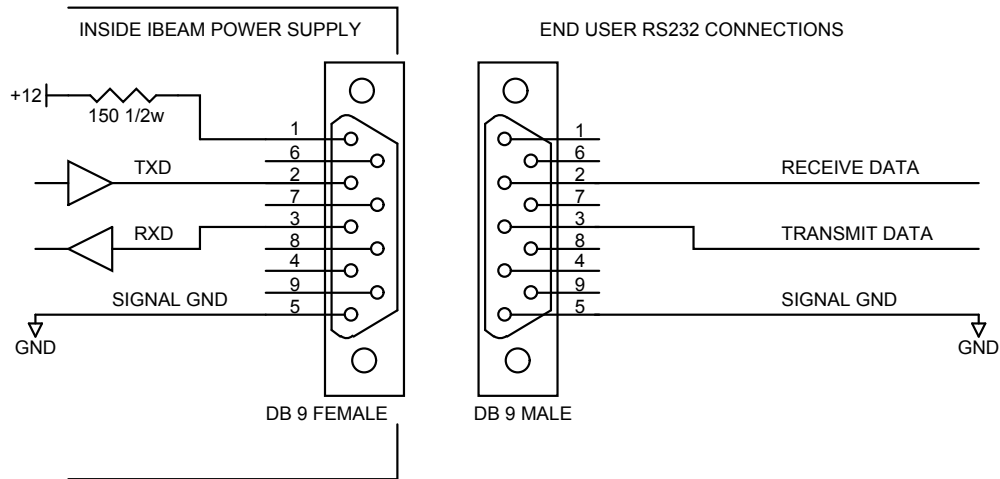


Pin outs for the BLUE neutralizer cables.

Section 2.6: Communication and Switches

User COM port

The USER COM port is designed for remote connections to a RS232 device for remote control and monitoring. Please see *Chapter 5 - Remote Control* for a complete description of the electrical wiring and commands that can be sent to the I-BEAM via RS232 protocol.



Pin outs for the RS232 connections.

COM 2 port

The COM 2 port is used to control and monitor the source matching network and its controller. The I-BEAM will provide presets for the starting position of the matching network capacitors as well as monitor their position.



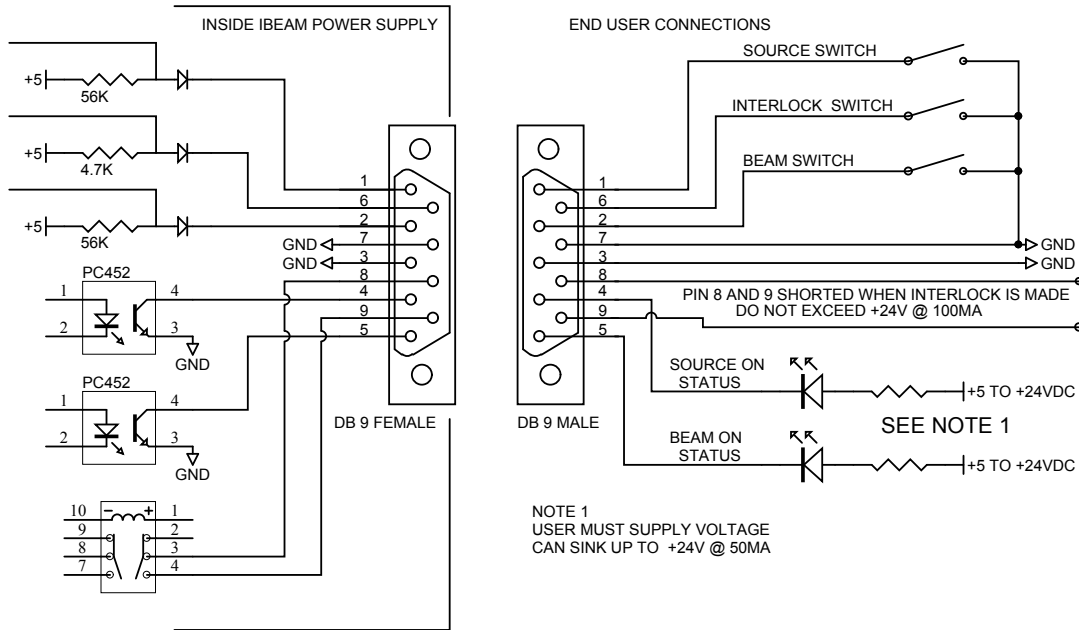
Matching network communication cable.

I-BEAM RF POWER SUPPLY MANUAL CHAPTER 2: Installation

INTERLOCK and REMOTE SWITCH port

The INTERLOCK port is provided so the power supply can be connected into a system for safety. The interlock is satisfied when it is shorted to ground. If needed, pins 8 and 9 can be used to sense interlock status.

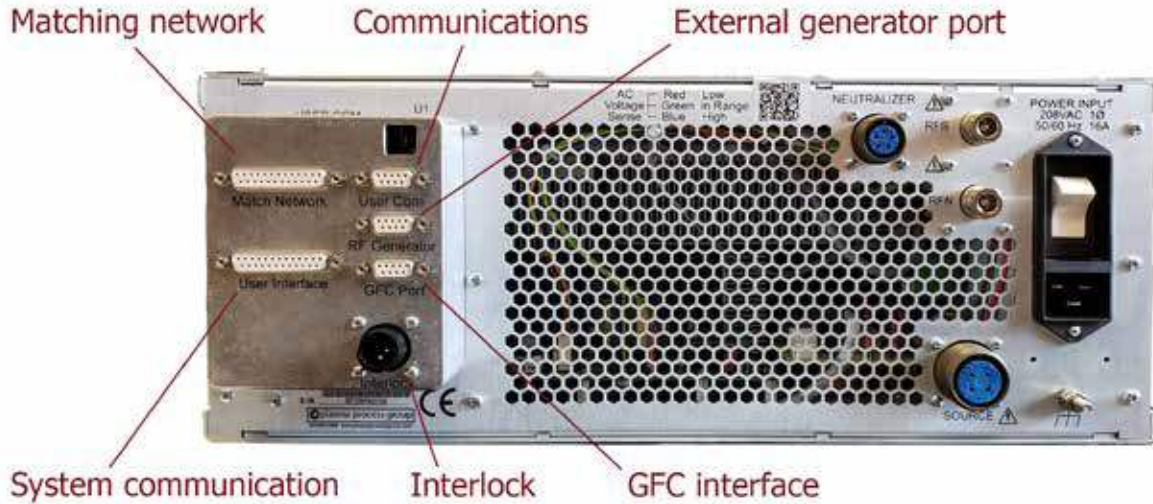
At this same connector, pins are provided for remote switching and sensing for systems that use a programmable logic controller. The source and beam can be turned ON and OFF and their status can be monitored. Please see *Chapter 5 - Remote Control* for a complete description of this feature.



Pin outs for the interlock and remote switch.

Section 2.7: External Generator or Legacy Installation

I-BEAM power supplies which have an interface box (IBOX) are designed for sources that require an external generator (I-BEAM 701 series) or the installation of the supply into older systems. A complete description of the connections is provided in *Appendix A - Legacy Installation*.

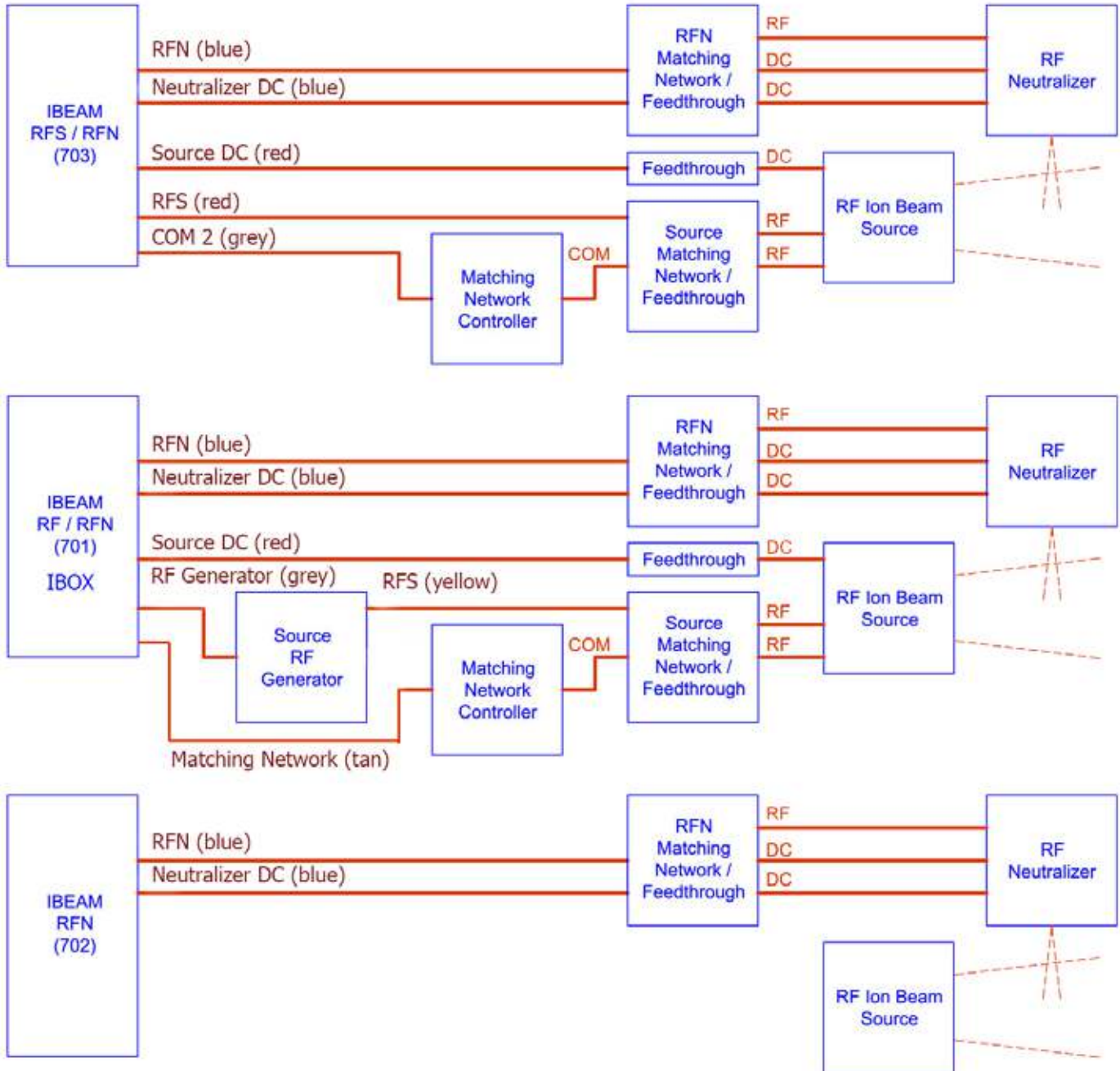


Power supply rear panel with IBOX.

- The USER COM port is designed for remote connections to a RS232 device for remote control and monitoring. Please see *Chapter 5 - Remote Control* for a complete description of the electrical wiring and commands that can be sent to the I-BEAM via RS232 protocol.
- The RF GENERATOR port connects either an external 1 kW RF generator or legacy generator.
- The GFC PORT is designed for systems that use legacy gas flow equipment. Gas is turned ON and OFF through a recall process on the power supply.
- The INTERLOCK connector is standard for the legacy equipment.
- The USER INTERFACE allows direct pin-for-pin connection to legacy system communication cables.
- The MATCHING NETWORK port connects to the matching network controller using the legacy cable.

Section 2.8: Preflight Check

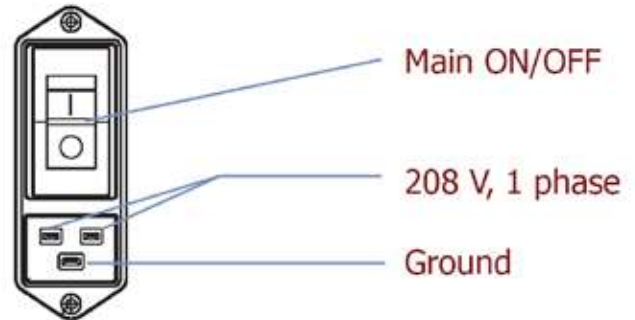
Use the illustration below and confirm the cable connections are in place for all of the items.



Electrical connection setup for I-BEAM RF series power supplies.

Section 2.9: Input Power

The input power requirement is 208VAC, 1 ϕ , 50/60 Hz at 16 Amp. Proper wiring for the power connection is GROUND (green / yellow stripe) and 2 HOT (brown or blue). Use the cable provided to wire the correct plug. Install the plug cover to keep the cable secure.



Electrical power connections.

TIP - The vacuum tank, frame, system electronics and facilities should utilize a single-point-ground scheme.

Connect the power supply chassis ground to the facility ground. Best practice is to ensure the vacuum tank is also connected to the facility ground.



Chassis ground post below plug cover.

After power is connected to the I-BEAM, turn the MAIN breaker ON. Use the AC VOLTAGE SENSE located on the rear panel of the power supply to ensure proper facility voltage is applied.

Facility Voltage	Condition
less than 30VAC	LED is not illuminated
30 to 179VAC	LED is RED or low
180 to 239VAC	LED is GREEN, power is OK
240 to 250VAC	LED is BLUE or high

If the LED is GREEN, the power supply can be powered up safely from the front panel (see *Chapter 4 - Operation*).



LED indicates facility power is OK.

Chapter 3: Specifications

The I-BEAM power supply will have a range of conditions that it can achieve. Some of these conditions might be more than the ion source itself can handle. It is best practice to study the *Ion Beam RF Sources Manual* and understand these limitations. For quick reference, the beam current and voltage ranges for the sources are provided in the table below. The **maximum** beam current will vary with beam voltage.

SOURCE	SPECIFICATIONS	
	BEAM CURRENT	BEAM VOLTAGE
6 cm	25 - 200 mA	50 - 1500 V
12 cm	50 - 400 mA	50 - 1500 V
16 cm	100 - 1000 mA	100 - 1500 V
23 cm	200 - 1500 mA	100 - 1250 V
6 x 22 cm	50 - 500 mA	50 - 1500 V
6 x 30 cm	50 - 500 mA	50 - 1500 V

Section 3.1: Specifications for I-BEAM RF Series



Size (w x h x d): 19" x 7" x 20" weight: 23.1 kg

MODEL	I-BEAM POWER SUPPLY CONFIGURATIONS				
	MAX BEAM CURRENT	MAX BEAM VOLTAGE	RF GENERATOR	NEUTRALIZER CURRENT	IBOX INTERFACE
703-1-0	600 mA	1500 V	500 W	1250 mA	no
703-1-1	600 mA	1500 V	500 W	1250 mA	yes
703-2-0	800 mA	1500 V	500 W	1250 mA	no
703-2-1	800 mA	1500 V	500 W	1250 mA	yes
703-4-0	1000 mA	1500 V	500 W	1250 mA	no
703-4-1	1000 mA	1500 V	500 W	1250 mA	yes
701-6-1-2	1500 mA	1250 V	1000 W external	2250 mA	yes
702	N/A	N/A	N/A	1250 mA	no

Chapter 4: Operation

With the power supply and ion beam source installed it should now be ready for operation. This chapter will describe nominal operation of the power supply. An overview of the key features and how they relate to source operation are introduced. Example values for typical source operation will be provided.



WARNING

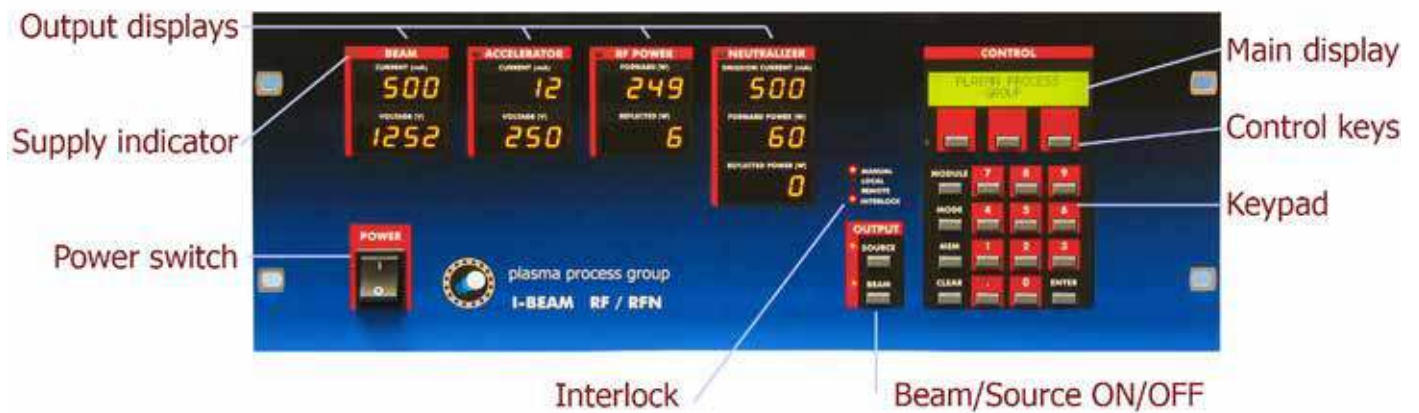
Make sure all electrical connections have been properly made, high voltage covers are installed and that the power supply interlock has been satisfied.

Section 4.1: Power On

Turn the power on by rocking the front panel POWER switch to the ON position. The power supply fans will start up and the processor will start a boot sequence. All LEDs will light momentarily. After a few seconds, the unit will complete the internal checks and be ready for operation.

Section 4.2: Layout

The I-BEAM front panel provides a user interface as well as displaying the set points and current conditions of the power supplies within the unit. Each supply has an indicator light which illuminates when that supply is selected using the module button on the keypad. The parameters for each power supply can be entered by the user through the keypad and are presented in the main display.



Front panel layout.

Section 4.3: Mode of Operation for the Source



Press the **MODE** button to toggle the operational mode.

Excluding special test modes, 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. Study the table below and select the mode of operation by pressing the MODE button on the power supply. In MANUAL mode, the RF source power can be adjusted which is desirable for constant RF power mode. Most applications operate in LOCAL or REMOTE mode where the beam current is set and the RF source power will automatically adjust to control the beam current (constant beam current mode). The modes LOCAL and REMOTE operate the source in the same fashion. REMOTE is used for system or software interface and will lock out some features of the power supply front panel.

POWER SUPPLY OPERATIONAL MODES			
SOURCE PARAMETER	MANUAL	LOCAL	REMOTE
Beam Current, BI (mA)	-	Adjustable	Adjustable
Beam Voltage, BV (V)	Adjustable	Adjustable	Adjustable
Accelerator Current (mA) †	-	-	-
Accelerator Voltage, ACCEL (V)	Adjustable	Adjustable	Adjustable
RF Source Forward Power (W)	Adjustable	-	-
RF Source Reflected Power (W) †	-	-	-
RF Neutralizer Emission Current (mA)	Adjustable	Adjustable E/B ratio	Adjustable E/B ratio
RF Neutralizer Forward Power (W)	Adjustable	-	-
RF Neutralizer Reflected Power (W) †	-	-	-

† These parameters cannot be adjusted using the I-BEAM power supply. Please refer to the *Ion Beam RF Sources Manual* for a complete explanation.



TIP - For troubleshooting source problems, MANUAL mode is recommended. For most applications, LOCAL mode is best for running a process.

Manual Mode

In MANUAL mode, the I-BEAM allows the user to control the RF source forward power manually from the front panel. Since the beam current is not automatically sustained in this mode, 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 power supply will not respond to a beam current change; it is adjusted by increasing or decreasing the RF source forward power.

Local Mode

In LOCAL mode, the I-BEAM allows the user to set a specified beam current (or ion dose). When the source and beam switches are ON, the I-BEAM will attempt to run the source at the specified beam current, adjusting the RF source forward power. Physically, increasing the RF source forward power increases the rate of ion production in the discharge chamber. This causes a plasma density increase in the discharge chamber, thereby allowing more ions to be extracted, and increasing beam current.

LOCAL mode is useful for applications requiring a constant beam current (or dose of ions) on a target or substrate. The I-BEAM controls the RF source forward power to maintain a steady beam current.

Remote Mode

In REMOTE mode, the I-BEAM 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. However, in Remote mode, user input from the key panel is disabled, and process adjustments must come from the controlling computer. The SOURCE and BEAM buttons can still be turned OFF from the front panel.

Takeaway

- MANUAL – User selects RF source forward power which manually controls beam current.
- LOCAL – User selects beam current and the I-BEAM controls RF source forward power.
- REMOTE – Same as LOCAL, I-BEAM is controlled using RS232 and/or remote switches.

Section 4.4: Adjustments using Keypad Entry

To adjust specific parameters, repeatedly press the MODULE button. The supply indicator (green LED) will light for the individual module and its parameters will appear in the MAIN Display. Adjustments or new target values can be input using the keypad, CLEAR and ENTER keys.

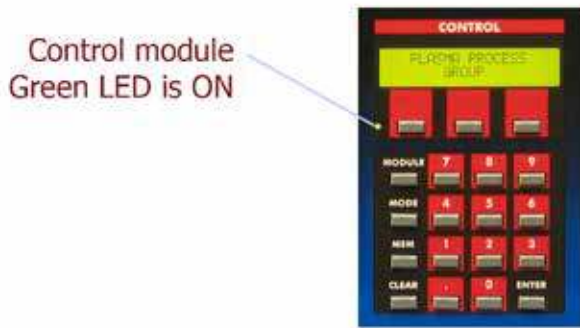


Select the supply by pressing the MODULE button until its LED turns GREEN.

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Pressing the MODULE button again and the CONTROL module LED light will turn green. Global parameters can now be entered. If the MODULE button is pressed again, the LED light will loop back to the BEAM module.


Adjustments to all the modules, including the control module, are performed at the MAIN DISPLAY. 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 or for navigation within the module. The keypad can be used to adjust the parameters.



Adjustment to global parameters.



Use the control keys to select options.




CAUTION

The power supply will accept values that may cause operating issues with the source. Please examine the typical source data in the *Ion Beam RF Sources Manual*.

The control keys will utilize abbreviations for the parameter being adjusted (or navigation selection). If a control key displays MORE, additional options are available. Toggling the MORE option key repeatedly will scroll through the parameters and loop back to the start of the menu.


After the adjustments are completed, the operation conditions can be saved to memory using the MEM key and the STORE and RECALL option keys. There are 10 available memory storage locations on the power supply.

 **TIP** - Use remote control for processes that require more than 10 memory locations.

FRONT PANEL			
ABBREVIATION	PARAMETER	DESCRIPTION	ACCEPTABLE RANGE
INC or DEC	Control key	Increase or decrease value by 1	
STORE	MEM key	Store parameters into memory	0 to 9
RECALL	MEM key	Recall parameters from memory	0 to 9

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The following tables are a listing of the abbreviations for specific modules, the corresponding parameter and description. An acceptable range is provided. The *Ion Beam RF Sources Manual* should be consulted for typical and safe values.



CAUTION

The power supply will accept values that may cause operating issues with the source. Please examine the typical source data in the *Ion Beam RF Sources Manual*.

BEAM MODULE			
ABBREVIATION	PARAMETER	DESCRIPTION	ACCEPTABLE RANGE
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 <i>model specific</i>
BI	Beam current	After the beam is turned on, the power supply will ramp the beam current (LOCAL / REMOTE modes).	10 to 1500 mA <i>model specific</i>
BV PULSE	Pulse voltage	Pulse voltage to start the source. Typical is 1000 V.	0 to 1500 V
BV IDLE	Idle voltage	Idle voltage for the source when beam is off. Higher than 50 V is not recommended.	0 to 75V
START DETECT I	Start detect current	Minimum beam current to determine that the ion source is on. Default is 5 mA.	0 to 50 mA

ACCELERATOR MODULE			
ABBREVIATION	PARAMETER	DESCRIPTION	ACCEPTABLE RANGE
ACCEL	Accelerator voltage	After the beam is turned on, the power supply will ramp to the accelerator voltage. Below 100 V is not recommended.	0 to 1000 V

RF POWER MODULE			
ABBREVIATION	PARAMETER	DESCRIPTION	ACCEPTABLE RANGE
RFS FWD	Source RF forward power	RF power that controls the beam current. MANUAL mode only.	0 to 500 W
START POWER	RF power to start discharge	Recommended is 200 to 250 W.	0 to 500 W
IDLE POWER	RF power at idle condition	Recommended is 150 to 250 W.	0 to 500 W
POWER LIMIT	Software power limit	Recommended is 500 W.	0 to 500 W
LOAD # SET #	Load capacitor position	Current position of load cap in matching network and set point for source startup.	0 to 5000 mV
TUNE # SET #	Tune capacitor position	Current position of tune cap in matching network and set point for source startup.	0 to 5000 mV

(CONTINUED)

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NEUTRALIZER MODULE			
ABBREVIATION	PARAMETER	DESCRIPTION	ACCEPTABLE RANGE
EI	Emission current	The electron emission current from the RFN. Only adjustable in MANUAL mode, or with E/B Ratio.	100 mA to maximum (model specific)
RFN FWD	RF forward power	RF power that controls the emission current. MANUAL Mode only.	30 to 125 W
RFN KPR	Keeper current and voltage	Displays the current and voltage values for the RFN keeper.	100 to 300 mA 20 to 30 V

CONTROL MODULE			
ABBREVIATION	PARAMETER	DESCRIPTION	ACCEPTABLE RANGE
SETUP		Select to change global parameters listed below.	
BEAM I TOL	Beam current tolerance	If the difference between the requested beam current and the measured beam current exceeds the tolerance, an alarm is triggered. Recommended is 20% and 0 will disable alarm.	0 to 100%
A/B RATIO	Accel to beam current ratio	If the ratio between the accelerator current and beam current exceeds the A/B setting, an alarm is triggered. Default is 10%.	0 to 99%
E/B RATIO	Emission to beam current ratio	Neutralizer emission will target the E/B ratio times beam current. Recommended is 125%.	0 to 200%
REMOTE S/B	Remote source and beam settings	This will activate the remote control settings of either RS232, switches or both (see <i>Chapter 5 - Remote Control</i>).	toggle
ALARM		Audio alarm. If disabled, alarms will be silenced.	enable/disable
RFN TUNE UP	Test mode for RFN tuning	Enabling RFN TUNE UP, changes the length of time the RFN start relay is ON to 60 seconds, to ease tuning C1 of matching network. RFN gas should be off.	enable/disable
RFN BURN IN	Test mode for RFN burn in	Allows the user to run just the RFN.	enable/disable
SOURCE TEST	Test mode for beam and accel	Allows the user to immediately turn beam and accelerator voltages on without starting the RFN.	enable/disable
SECURITY		Factory use	

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 - Troubleshooting* for a listing of the power supply alarms.

Section 4.5: Interface Examples

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

Example 1: Put the I-BEAM in LOCAL mode and select the RF Power module.

- STEP 1 Press MODE button until LOCAL mode is selected.
- STEP 2 Press MODULE button until RF Power supply is selected.
The red LED for LOCAL and green LED for RF Power should now 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 I-BEAM is in LOCAL mode).
- STEP 3 Use keypad to type 1225, and then ENTER.

Example 3: Set the beam current to 100 mA (I-BEAM 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, and 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, and then ENTER.

Example 5: Set the source RF power to 200 W (I-BEAM will only react in MANUAL mode).

- STEP 1 Press MODULE button until RF Power indicator LED is ON.
- STEP 2 Use keypad to type 200, and then ENTER.

Example 6: Change the source RF power to 204 W (I-BEAM will only react in MANUAL mode).

- STEP 1 Press MODULE button until RF Power indicator LED is ON.
- STEP 2 Select INC (increment) in the control keys, and press it 4 times.

Example 7: Set the neutralizer emission current to 750 mA (I-BEAM must be in MANUAL mode).

- STEP 1 Press MODULE button until Neutralizer supply indicator LED is ON.
- STEP 2 Use the Control keys to select EI.
- STEP 3 Use keypad to type 750, and then ENTER.

Example 8: Put the I-BEAM into RFN test mode.

- STEP 1 Press MODULE button until Control module indicator LED is ON.
- STEP 2 Select SETUP in the control keys. BEAM I TOL should be displayed.
- STEP 3 Select NEXT until RFN BURN IN is displayed.
- STEP 4 Press any number key on the keypad to toggle to ENABLE, and then ENTER.

Example 9: Take the I-BEAM out of RFN test mode.

- STEP 1 Press MODULE button until Control module indicator LED is ON.
- STEP 2 Select SETUP in the control keys. BEAM I TOL should be displayed.
- STEP 3 Select NEXT until RFN BURN IN is displayed.
- STEP 4 Press any number key on the keypad to toggle to DISABLE, and then ENTER.

(CONTINUED)

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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. BEAM I TOL should be displayed.
- STEP 3 Select NEXT until E/B RATIO is displayed.
- STEP 4 Use keypad to type 150, and then ENTER.

Example 11: To ease initial RFN matching network tuning (enable RFN TUNE UP)

- STEP 1 Press MODULE button until Control module indicator LED is ON.
- STEP 2 Select SETUP in the control keys. BEAM I TOL should be displayed.
- STEP 3 Select NEXT until RFN TUNE UP is displayed.
- STEP 4 Touch any key on the keypad to toggle to ENABLE, and then press ENTER key.

If the MEM key is pressed, the STORE or RECALL options are displayed. Each memory location stores beam current, beam voltage, accelerator voltage, and neutralizer emission current target values. Also stored are the A/B and E/B ratios. Memory location 0 is reserved for the last running condition.

Example 12: 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, and then ENTER.

Example 13: 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, and then ENTER.

Section 4.6: Beam and Source ON/OFF


The power supply has two ON/OFF buttons for output labeled SOURCE and BEAM. When the SOURCE button is toggled to ON, the RFN begins its start-up sequence. The RFN starts by applying RF power while the start / run relay is toggled. Once the RFN establishes a discharge between its keeper and collector, the RFN will go into a 5-minute warm-up period.

As soon as the RFN has started, RF power is applied to the source. When the RF forward power reaches the RF starting power, the BEAM and ACCEL are pulsed to the BV PULSE setting which should start the discharge inside the source. The BEAM and ACCEL are then reduced to the BV IDLE setting. The source has started and should be allowed to warm up for 20 minutes.

When the BEAM button is toggled to ON, power is applied from the beam and accelerator supplies. The beam and accelerator voltage will ramp in a steady fashion to their requested settings. In LOCAL and REMOTE modes, the RF forward power will be adjusted to meet the requested beam current. In MANUAL mode, the RF forward power will be ramped to the target value. The beam can be turned off by pressing either the BEAM or SOURCE button.

Pressing the BEAM button will return the ion source to the IDLE condition. Pressing the SOURCE button will extinguish the beam, ion source, and RFN.

Section 4.7: Quick Start Sequence



CAUTION

Please consult the *Ion Beam RF Sources Manual* for installation instructions and operating limitations for each source. The power supply will accept target values that may damage the source.

Install the source as described in the *Ion Beam RF Sources Manual*.

Step 1: Pump down.

The ion beam source requires a high vacuum environment for proper operation. There are several different types of vacuum systems so only general guidelines will be presented. 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.



TIP - Best practice is to connect the vacuum interlock in series to the power supply interlock.

PARAMETER	VACUUM SPECIFICATIONS	
	VALUE	COMMENTS
Chamber base pressure	10^{-6} mbar	Bake to remove water vapor.
Chamber operating pressure when the source gas is on	10^{-5} to 5×10^{-4} mbar	The discharge may go out at lower pressures. Grid arcing and source failure will occur at higher pressures.
Typical pumping speed	5000 L/s (Argon)	System dependent

Step 2: Turn the process gas on.

After the vacuum chamber has achieved its base pressure, turn on the process gas. The desired amount will vary with source size, but typical values for a system that has a 5000 L/s pump are tabulated below. These flow rates can be scaled with the system pumping speed and watching the overall chamber pressure. Best practice is to allow the gas to flow 5 minutes to purge the gas lines prior to source ignition.

GAS FLOW REQUIREMENTS	
SOURCE	FLOW
6 cm	8 sccm Argon
12 cm	10 sccm Argon
16 cm	18 sccm Argon
23 cm	25 sccm Argon
6 x 22 cm	20 sccm Argon
6 x 30 cm	25 sccm Argon
RFN	5 sccm Argon

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Step 3: Turn on the water cooling.

Turn on the cooling water to the source and test the flow switch interlock. Check the flow rate to ensure 1 L/min is achieved. The flow rate will vary with facilities but should not be less than 0.5 L/min.



TIP - Best practice is to connect the water flow interlock in series to the power supply interlock.

Step 4: Confirm source start up parameters.

Turn on the matching network controller and external RF generator (if used). Place the matching network controller in REM (remote) mode for both LOAD and TUNE.



WARNING

Make sure all electrical connections have been properly made, high voltage covers are installed and that the power supply interlock has been satisfied.

Turn the power supply on and allow it to boot. Confirm the power supply interlock is satisfied. The power supply will have factory default set points for the source startup. However, it is considered best practice to check these startup parameters are set properly.

START PARAMETERS				
SOURCE	RF START POWER	RF IDLE POWER	BV PULSE	BV IDLE
6 cm	200 W	150 W	750 V	30 V
12 cm	200 W	200 W	750 V	50 V
16 cm	250 W	250 W	1000 V	50 V
23 cm	250 W	150 W	1000 V	30 V
6 x 22 cm	200 W	200 W	750 V	50 V
6 x 30 cm	250 W	250 W	1000 V	50 V
RFN	100 W auto	NA	NA	NA

- Start-detect current (I): 5 mA.
- Neutralizer Emission to Beam current ratio (E/B): 150%

Step 5: Select MODE of operation for the source.

Study *Section 4.3* and select a MODE of operation for the source. For this quick test, LOCAL operation will provide constant beam current and provide a good test all of the connections.

Step 6: Select desired beam conditions.

Set the beam and accelerator voltage for the desired condition (see *Ion Beam Sources Manual*). For applications that are ion beam etch or assist, lower beam voltage (250 V) is desired. If the process is high rate sputtering, a higher beam voltage (1250 V) is preferred. Adjust the beam current setting to control the process rate.



TIP - To just test the source, select a beam current of 150 mA, beam voltage of 1000 V and accelerator voltage of 200 V.

Step 7: Turn the source on and allow it to warm-up

Turn on the source by pressing the SOURCE button. When the SOURCE button is pressed, the power supply will begin to start the RFN by applying RF power while the start / run relay is toggled (you may hear a light clicking sound from the RFN Matching Network). Once the RFN establishes a discharge between its keeper and collector, the RFN will go into a 5-minute warm-up period, however, just after the RFN has started, RF power will be applied to the source and the source matching network will adjust itself to maximize the forward power. When the RF power reaches the RF starting power, the BEAM and ACCEL are pulsed to the BV PULSE setting which should ignite the discharge inside the source. The BEAM and ACCEL are then switched to the BV IDLE setting.



TIP - Use the system view port to visually confirm the RFN and source have ignited. Sometimes a Si wafer can be used as a mirror if necessary.

At the BV IDLE condition, the power supply measures the beam current. If the detected beam current at the BV IDLE condition is greater than the START DETECT current, then the power supply considers the source started. If the idle current is less than the START DETECT current, the power supply will continue to pulse the grids until the source either starts or a timeout error is reached. On occasion, if the source has started, but the idle current drops below the START DETECT current, the I-BEAM will indicate the source discharge has extinguished and display an error (E71).



TIP - After the power supply pulses, watch the beam module. The beam will regulate to the idle voltage and display the idle current.

The source should be allowed to warm up for at least 20 minutes. This will allow it to release trapped water vapor and other gases. It is essential the source is warm before the beam is turned on otherwise the grids will arc and the source may extinguish.

Step 8: Turn the beam on

Turn the beam on by pressing the BEAM button. In MANUAL mode, the extracted beam current is determined by the source RF power. In LOCAL (and REMOTE) mode, the beam current should ramp to the target beam current and the source RF power will automatically adjust itself. Beam conditions can be adjusted while the beam is on. However, best practice is to turn the beam off while keeping the source on and adjust the beam current, beam voltage and accelerator voltage. The maximum beam current is dependent on the beam voltage applied. Please refer to *Ion Beam Sources Manual* for the maximum beam currents at various beam voltages.



TIP - Use the system view port to visually confirm the beam is on. Observe the grid assembly for arcing events.

Step 9: Neutralizer operation

When the BEAM button is pressed, the neutralizer emission current will change. If the power supply is in MANUAL mode, the emission current is determined by the settings in the neutralizer module. If the power supply is in LOCAL (or REMOTE) mode, the emission current will adjust to the E/B ratio (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 10: Turn the beam off

When the process run has completed, the beam can be turned off pressing the BEAM button on the power supply. When the BEAM button is toggled, the source will remain on and the source RF power will not change (in MANUAL mode) or ramp to its IDLE conditions (in LOCAL or REMOTE mode). The RFN will ramp to its idle conditions.

For critical applications, the beam can be turned off using an electronic remote switch or via a software command to the power supply. Please refer to *Chapter 5 - Remote Control* for additional information.

Step 11: Turning off the source and cool down.

The source (and beam if on) are shut off by pressing the SOURCE button. The power supply can be then turned off. It is recommended to leave the Argon gas running to the RFN and source while they cool for 30 minutes before the vacuum chamber is vented. Always leave the RFN Argon gas on while venting the vacuum system as this will help prolong RFN life.

Section 4.8: Additional Resources

For additional detail about the source startup sequence, information on how to optimize the accelerator voltage and other useful technical tips, please consult the *Ion Beam Sources Manual*.

If the source did not start, or there were any other issues, please consult *Chapter 6 - Troubleshooting* section of this manual.

Please contact us anytime for guidance and support.

Chapter 5: Remote Control

This chapter will provide a description of how the I-BEAM can be controlled remotely using RS232 communications and switches. The I-BEAM communication mode is toggled in the Control module under REMOTE S/N. The 3 possible modes are:

- REMOTE S/B – RS232: This is used for RS232 serial communication only.
- REMOTE S/B – SW ONLY: This is used for remote switch control only.
- REMOTE S/B – RS232/SW: This is used for both RS232 and switch control.

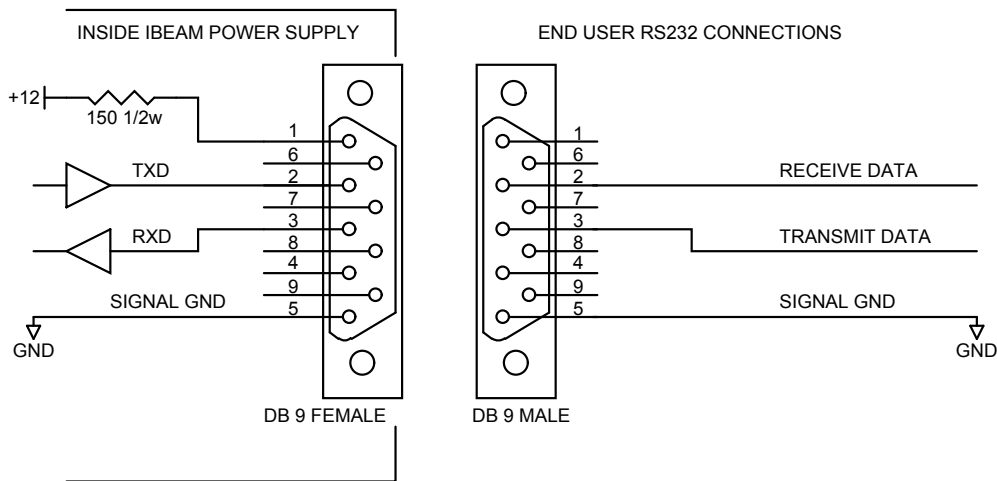
Section 5.1: RS232 Communications

Electrical connections.

The RS232 link is provided at the USER COM port located on the rear of the unit (see *Chapter 2 - Installation*). Below is the pin-out and wiring diagram for the connections.

Handshake protocol for the RS232 connection.

- Baud Rate 9600 BPS
- Data bits 8
- Stop bits 1
- Parity none



Pin outs for the RS232 connections.

RS232 Commands

Commands are sent to the I-BEAM with carriage return <cr>. The I-BEAM will respond with an echo of the command followed by a specific response. If an invalid command is sent, the I-BEAM 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>.

COMMANDS - QUICK REFERENCE	
COMMAND	DESCRIPTION
A	Attention, put I-BEAM in REMOTE mode
AB	Set A/B ratio
AV	Set accelerator voltage
B	Turn beam on/off
BE	Set or disable beam current tolerance
BI	Set beam current
BL	Set beam idle voltage (low)
BP	Set beam high-pulse voltage
BV	Set beam voltage
EB	Set emission to beam current ratio
M	Set the power supply mode
NE	Enable or Disable the E/B ratio error -24-
NI	Set the emission current (manual mode)
NK	Enable or disable front panel switches
PC	Run in RFS Power Control Mode
PF	Set source RF forward power (manual mode)
PI	Set RFS idle power
PL	Set source RF forward power limit
PS	Set RFS start power
R	Recall conditions from memory
RA	Request running conditions (HEX)
RC	Request running conditions (ASCII)
RN	Recall set point (target) conditions
S	Turn source on/off
ST	Store running conditions to memory
V1	Display version (condensed)
VS	Display Software Version



CAUTION

Commands are accepted with values that may cause operating issues with the source. Please examine the typical source data in the *Ion Beam RF Sources Manual*.

Section 5.2: RS232 Command Details

The specifics of each command are described below. 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. Also, <lf> is line feed and <eot> is end of transmission.

- Serial command: A**
Description: Attention and put I-BEAM in REMOTE mode.
Usage: A<cr>
Example: Send "A<cr>". The I-BEAM 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(0-600)<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 maximum beam current (model specific and consult source checkout sheet).
Response: <lf><cr>OK<lf><cr><eot>
- Serial command: BL**
Description: Set the beam low (idle) voltage.
Usage: BL(0-255)<cr>
Example: Send "BL50<cr>". The beam idle voltage will be set to 50 volts
Response: <lf><cr>OK<lf><cr><eot>

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Serial command: BP

Description: Set the beam high-pulse voltage.
Usage: BL(0-1250)<cr>
Example: Send "BP1000<cr>". The beam high-pulse voltage will be set to 1000 volts
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: EB

Description: Set the emission current to beam current ratio (control RFN emission current).
Usage: EB(100-200)<cr>
Example: Send "EB150<cr>". The E/B ratio will be set to 150%. When the beam is turned on, the RFN emission current will ramp to 150% of the beam current when the I-BEAM is in LOCAL or REMOTE mode. Acceptable range is from 100 to 200.
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 I-BEAM will be set to MANUAL mode.
Send "M1<cr>". The I-BEAM will be set to LOCAL mode.
Send "M3<cr>". The I-BEAM will be set to REMOTE mode.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: NE

Description: Enable or disable the E-24 error for E/B ratio.
Usage: NE(0 or 1)<cr>. 0 enables, and is the default. 1 disables.
Example: Send "NE1<cr>". The E-24 error alarm will be disabled. When the emission to beam ratio is not met, the E-24 error will not flash or function.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: NI

Description: Set the neutralizer emission current.
Usage: NI(100-900)<cr>
Example: Send "NI550<cr>". The RFN emission current will ramp to 550 mA if the I-BEAM is in MANUAL mode. Acceptable range is 100 to 900.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: NK

Description: Disable or enables the front panel switches to prevent accidental changes.
Usage: NK(0 or 1)<cr>
Example: Send "NK0<cr>". The I-BEAM will switches act normally.
Send "NK1<cr>". The front panel switches except SOURCE and BEAM will not function to prevent accidental changes during a process.
Response: <lf><cr>OK<lf><cr><eot>

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Serial command: PC

Description: Enable or disable the RFS Power Control Mode.
Usage: PC(0 or 1)<cr>. 1 enables, and is the default. 0 disables.
Example: Send "PE1<cr>". The Power control mode is enabled.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: PF

Description: Set the source RF forward power.
Usage: PF(0-500)<cr>
Example: Send "PF260<cr>". The source RF forward power will ramp to 260 W if the I-BEAM is in MANUAL mode. Acceptable range is 0 to 500 or 1000 (model specific) and will depend upon the power limit setting.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: PI

Description: Set the RFS idle power.
Usage: PI(0-500)<cr>. Sets the RFS wattage at idle condition.
Example: Send "PI100<cr>". The power supply will drop the RF wattage to 100 for idle condition.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: PL

Description: Set the source RF forward power limit.
Usage: PL(0-500)<cr>
Example: Send "PL475<cr>". The source RF forward power limit will be set to 475 W and not allow power settings to exceed this value. Acceptable range is 0 to 500.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: PS

Description: Sets the RFS start power.
Usage: PS(0-500)<cr>.
Example: Send "PS250<cr>". The RF generator will use 250 watts to start the source.
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, and RFS forward power. Also stored are the A/B and E/B ratios. Memory location 0 is reserved for the last running condition.
Response: <lf><cr>OK<lf><cr><eot>

Serial command: RA

Description: Request running conditions (HEX).
 Usage: RA<cr>
 Example: Send "RA<cr>". The current running conditions will be sent back 64 bytes in HEX format for data compression purposes. It is recommended this command should not be sent more than 1 time per second.
 Response: will return in HEX format 64 bytes structured as:
 RA<cr><lf><cr>AABBCCDDEEFFGGHHIIJKL MNOPQRSTTUUVVWWXX
 ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^YZA

Where: RA<cr><lf><cr> is in HEX as 52 41 0D 0A 0D
 AA is the RFS forward power (W)
 BB is the RFS reflected power (W)
 CC is the beam current (mA)
 DD is the beam voltage (V)
 EE is the accelerator current (mA)
 FF is the accelerator voltage (V)
 GG is the RFN emission current (mA)
 HH is the RFN forward power (W)
 II is the RFN reflected power (W)
 J is beam module errors (see module errors below)
 K is accelerator module errors (see module errors below)
 L is RFN module errors (see module errors below)
 M is emission module errors (see module errors below)
 N is RFS module errors (see module errors below)
 O is mode (0>manual, 1=auto, 2=remote)
 P is mode (0=both off, 1=source on, 2=beam on, 3=both on)
 Q is status bit (0: RFS started, 1:RFN started, 2:BI at target, 3:EI at target)
 R is source fatal code (0=no error, 3=RFN out, 4=COM out, 5=RFS out)
 S is beam fatal code (0=no error, 1=BI tolerance, 2=EI error)
 TT is the RFN emission voltage (V)
 UU is the RFN keeper voltage (V)
 VV is the RFN keeper current (mA)
 WW is the LOAD cap position (mV)
 XX is the TUNE cap position (mV)
 ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^ is 21 bytes for future use
 Y is <cr> in HEX as 0D
 Z is <lf> in HEX as 0A
 A is <eot> in HEX as 04

And module errors are:
 0 or '_' is no errors
 1 or 2 is cannot achieve requested target
 4 is module in current limit
 5 is interlock open
 6 or 7 is module in over temperature
 : or 8 is module will not start or went out

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Serial command: RC

Description: Request running conditions (ASCII).
Usage: RC<cr>
Example: Send "RC<cr>". The current running conditions will be sent to the buffer in ASCII format. It is recommended this command should not be sent more than 1 time per second.
Response: <lf><cr>_AAAA,_BBBB,____,_CCCC,_DDDD,_EEEE,_FFFF,_GGGG,
_HHH,_III,_JJJ,KLMNO,P,QRST1,<lf><cr><eot>

Where:

- AAAA is the RFS forward power (W)
- BBBB is the RFS reflected power (W)
- CCCC is the beam current (mA)
- DDDD is the beam voltage (V)
- EEEE is the accelerator current (mA)
- FFFF is the accelerator voltage (V)
- GGGG is the RFN emission current (mA)
- HHH is the RFN forward power (W)
- III is the RFN reflected power (W)
- JJJ is the emission voltage (V)
- K is beam module errors (see module errors below)
- L is accelerator module errors (see module errors below)
- M is RFN module errors (see module errors below)
- N is emission module errors (see module errors below)
- O is RFS module errors (see module errors below)
- P is mode (0>manual, 1=auto, 2=remote)
- Q is mode (0=both off, 1=source on, 2=beam on, 3=both on)
- R is status bit (0: RFS started, 1:RFN started, 2:BI at target, 3:EI at target)
- S is source fatal code (0=no error, 3=RFN out, 4=COM out, 5=RFS out)
- T is beam fatal code (0=no error, 1=BI tolerance, 2=EI error)

And module errors are:

- 0 or '_' is no errors
- 1 or 2 is cannot achieve requested target
- 4 is module in current limit
- 5 is interlock open
- 6 or 7 is module in over temperature
- : or 8 is module will not start or went out

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Serial command: **RN**

Description: Recall set point (or target) conditions.

Usage: RN(0-9)<cr>

Example: Send "RN0<cr>". The current set point (or target) conditions will be returned. Acceptable range is 0 to 9 with 0 as the current conditions and 1 thru 9 as the stored conditions in the I-BEAM memory locations 1 thru 9.

Response: <lf><cr>AAAAA,BBBBB,CCCCC,DDDDD,EEEE,FFFFF,
GGGGG,HHHHH,IIIII,JJJJJ,KKKKK,LLLLL<lf><cr><eot>

Where: AAAAA is the beam voltage set point (V)
BBBBB is the beam current set point (mA)
CCCCC is the accelerator voltage set point (V)
DDDDD is the A/B ratio set point (%)
EEEE is the RF forward power limit set point (W)
FFFFF is the RFN forward power set point (W)
GGGGG is the E/B ratio set point (%)
HHHHH is the beam current tolerance set point (%)
IIIII is not used
JJJJJ is the source RF power set point (W)
KKKKK is the RFN emission current set point (W)
LLLLL is not used

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, RFS forward power, E/B ratio and A/B ratio. Memory location 0 is reserved for the last running condition.

Response: <lf><cr>OK<lf><cr><eot>

Serial command: **V1**

Description: Display the Version in code that is compatible with other company's products.

Usage: V1<cr>

Example: Send "V1<cr>". The display will be "3000000"

Response: <lf><cr>"3000000"<lf><cr><eot>

Serial command: **VS**

Description: Displays the current software version

Usage: VS<cr>

Example: Send "VS<cr>". The software version number will display.

Response: <lf><cr>(Software version number)<lf><cr><eot>

Section 5.3: 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 I-BEAM. 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.

<u>Line</u>	<u>Command</u>	<u>Description</u>
1	A<cr>	Put the I-BEAM in remote mode
2	BV1250<cr>	Set the beam voltage to 1250 V.
3	BI100<cr>	Set the beam current to 100 mA.
4	AV250<cr>	Set accelerator voltage to 250 V.
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.

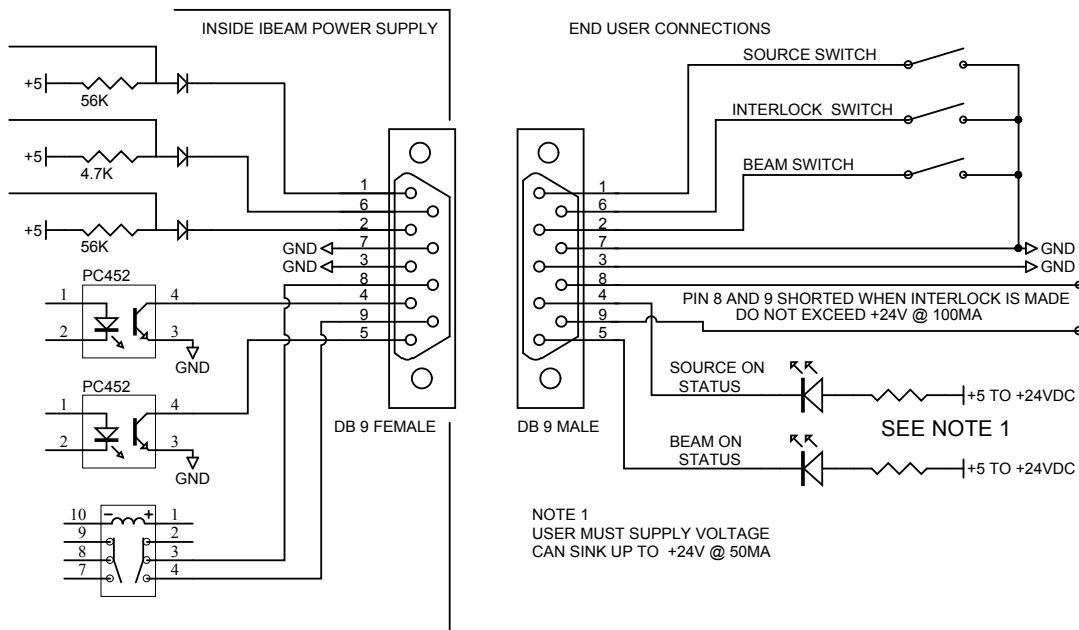
Section 5.4: Remote Switches

For faster control, the source and beam switches can be toggled using remote switches. The remote switch link is provided at the INTERLOCK port located on the rear of the unit (see *Chapter 2 - Installation*). For these features to work, the remote switch must be enabled from the CONTROL module. Below is the pin-out and wiring diagram for the connection.

The switch closures work to turn on the source and beam. Their function is identical to the Beam and 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 (the source would need to be ON). Either can be turned OFF by opening the short.

The switch closures are driven by an internal 5V signal and are edge triggered. 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 source on/off output status signal is on pin 4 and the beam on/off output status signal is on pin 5. When the source or beam are ON, an opto isolator inside the supply turns ON, allowing current to flow (sink) to ground from the status output pin. When the source or beam are OFF, the output status pins 4 and 5 will be open circuit to ground. The switch closures have indicators (pins 4 and 5) that can be used for feedback if necessary. These pins will require an external supply (24 V maximum / 50 mA maximum). In the example below, the LED will light when the source or beam is ON.



Pin outs for the interlock and remote switch.

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 errors are presented as these items are typically overlooked. Next, common alarms as indicated by the power supply are presented. By order of starting, the RFN troubleshooting is covered before source and beam.

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 an open connection that creates the issue.

This chapter is divided into:

- Common Errors are presented first as a quick fix.
- Many errors and alarms are captured by the I-BEAM supply. These error codes are provided next.
- Next, the RFN issues are presented since it needs to start before the source.
- The following section will be covering issues when the source starts.
- Turning on the beam will be the final section.



WARNING

The power supply produces high voltage outputs. For troubleshooting recommendations that require checking electrical connections and continuity **TURN OFF ALL POWER SUPPLIES** before testing.



CAUTION

If a continuity check is performed, the power supply should be disconnected for safety and a proper resistance reading.

Section 6.1: Common Issues and Quick Fixes

This page is a punch list or quick check for common items that may be inhibiting the source from normal operation. They are presented in the order of installation, startup and beam on.

Installation

- RF cables going to the wrong component. The RFN and source use identical cables (with different color coded labels). Make sure these are connected properly.
- Discharge chamber was not installed. Check to ensure the discharge chamber has been installed.
- Grids installed but the spring tab is not making contact or has been bent. Check the electrical continuity of the grids with the power supply disconnected.
- Interlocks are not satisfied. Check and test all interlocks before operations.

Startup

- RFN will not start due to insufficient gas purge. Always purge the gas supply lines for at least 5 minutes prior to operation.
- RFN will not start because the gas lines are not stainless steel.
- RFN tuning was adjusted incorrectly. If tuning is necessary, always tune the RFN matching network when the RFN is cold (at room temperature).
- Source will not tune to START POWER because the matching network controller is turned off or its switches are in MANUAL mode (they need to be in REMOTE mode).
- Facility coolant supplied to the source is conductive which will result in RF losses. The typical RF power will not be sufficient to start the source until the proper coolant is supplied.
- Noise issues, or false readings exist on the beam current reading created by RF noise. The RF antenna has been distorted and is too close to the grid assembly. The antenna should be evenly spaced in proximity to itself, the discharge chamber and source shroud.

Running (beam on)

- Accelerator current reads zero (or 1 mA). The accelerator grid is not connected - probably the spring tab. Check its connection with the power supply disconnected and grids installed.
- Beam and accel currents very high during idle and beam ON modes. The beam and accelerator leads have been accidentally switched at the DC feedthrough connection. Reverse the connection. Verify with the power supply disconnected and grids installed.
- Beam current noise issues or odd behavior. The beaded leads inside the source are too close or touching the RF antenna. Move the leads away from the RF antenna.

Section 6.2: Power Supply Error Codes

The I-BEAM will display various error codes in the output displays in the form of -##-. The errors may pertain to a particular module or the entire unit. The errors are labeled as “fatal” if they will stop a running process, and “non fatal” if the process will continue. Below is a listing of these codes. The possible solutions are presented with the highest probability being first.

POWER SUPPLY ERROR CODES		
ERROR	DESCRIPTION	POSSIBLE PROBLEMS AND SOLUTIONS
01 non fatal	Output of module is lower than requested.	1. The load resistance/impedance connected to the output of the module where the error is displayed is too high or too low. For example: might result from an open circuit to the ion source. 2. Internal electronics failure. Contact us.
02 non fatal	Output of module is higher than requested.	1. Electrical short: Check electrical connections. 2. Plasma short: Check the source and feed-through for electrical wire proximity problems or coated insulators. 3. Gas flow is too high: Check gas flow level.
03 non fatal	RF generator output is at maximum	1. Check RF forward power limit setting 2. Gas flow is too low: Check gas flow setting. 3. Ion source power efficiency problems
04 non fatal	Module is in current or voltage limit.	1. Electrical short: Check electrical connections. 2. Plasma short: Check the source and feed-through for wire proximity problems or coated insulators. 3. Electrical short: Check for flakes or debris.
05 fatal	Interlock is open	1. Water flow: Check water flow. 2. Vacuum: Check vacuum interlock. 3. Interlock cable is not connected: Check cable and connections.
06 fatal	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.
07 fatal	Power line conditioner (PLC) failed to start	1. Line power out of range: check power status indicator light on back of supply. If it is red the incorrect line power is attached. 2. I-BEAM has internal failure (PLC): contact us for assistance.
10 fatal	RFN failed to start after # of attempts exceeded limit	1. RFN gas issue: Run the RFN gas for about 5 minutes and try again. 2. Check the troubleshooting section of RFN manual 3. Internal I-BEAM emission/keeper module issue. Contact us.
13 fatal with beam off	Beam current is out of tolerance.	1. Severe arcing: Clean and inspect the grids. Warm up source longer. 2. Source idle power needs adjustment closer to typical beam on power level 3. Beam tolerance set too tight: increase tolerance setting
24 fatal with beam off	E/B Ratio (emission current to beam current ratio)	1. Emission current too low: Check RFN operation. 2. Beam current jumped up suddenly: Neutralizer can't keep up - possible grid arcing 3. RFN went out: Check RFN operation. 4. I-BEAM is in test mode: Check I-BEAM RFN test settings.

(CONTINUED)

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POWER SUPPLY ERROR CODES		
ERROR	DESCRIPTION	POSSIBLE PROBLEMS AND SOLUTIONS
25 non fatal	Accel current exceeds A/B ratio alarm level setting	<ol style="list-style-type: none"> 1. Accel voltage not optimized: Adjust AV up or down to minimize accel current. See <i>Ion Beam RF Sources Manual</i>. 2. Chamber pressure or gas flow too high: Adjust flow or correct pumping 3. Poorly aligned grids: Check and correct grid alignment 4. Accel short to ground. Resolve electrical short 5. Grid spacing incorrect: Check grid assembly 6. Leakage current on grid insulator: Clean and or replace insulators
26 fatal	RFN Emission I went below plasma detect level (40mA)	<ol style="list-style-type: none"> 1. Open circuit to collector: Check for loose collector hex nut 2. Poor RFN matching network tuning: Check forward and reflected, re-tune if needed 3. Open circuit to keeper: Check for loose keeper thumb nuts 4. Incorrect RFN gas flow: Check flow setting 5. Dirty collector: Clean collector or refurbish RFN
40 fatal	+3.3v Supply Fault	<ol style="list-style-type: none"> 1. Internal +3.3 volt power supply has failed.
70 non fatal	Communication	<ol style="list-style-type: none"> 1. Cannot communicate with external RF generator (I-BEAM 701). This is only checked at power up.
71 fatal	Failure mode A: Beam I dropped below start-detect setting	<ol style="list-style-type: none"> 1. Excessive arcing: Check grid condition and proper assembly, observe beam during operation. 2. Momentary RF circuit disturbance - probably a plasma leak: Check for gaps between grid assembly and mounting hardware. 3. Tuning Issues: RF power ramped down too far during idle mode (overshot). Check matching network for correct operation (are motors working?), damaged connections, and verify gauge position on matching network controller (is the red LIMIT light on?). 4. RF circuit tuning disturbance. Check RF path from matching network, feedthrough, vacuum leads, and antenna. 5. Sudden or momentary open circuit to grids. 6. Gas Flow Interruption: Check Mass Flow Meters and chamber pressure to verify gas flow rates and stability.
71 fatal	Failure mode B: Accelerator current exceeded 150 mA limit for over 10 seconds	<ol style="list-style-type: none"> 1. Accelerator short to ground or beam - Ohm out the source from atmospheric side of feedthrough. Inspect grids, accelerator connections, and feedthrough for conductive flakes, out of place electrical connection, conductive deposition on insulators. 2. High current plasma short: Check pressure, check for leaks, inspect grids discharge chamber and bias leads. 3. High current direct impingement: Incorrect beam operating point, contact us for assistance with operating point (See <i>Ion Beam RF Sources Manual</i>).
80 fatal	Max RF reflected	<ol style="list-style-type: none"> 1. Reflected power is too high: Check RF matching network, controller.
81 fatal	Max RF power	<ol style="list-style-type: none"> 1. RF power too high: Check RF circuit, matching network, and antenna. 2. Source gas too low: Check source gas flow rate and pressure. 3. Obstructed RF power: Clean quartz Discharge Chamber
82 fatal	RF amplifier out	<ol style="list-style-type: none"> 1. RF supply (for source or RFN) exceeded 10 amps for 5 seconds.
8888 fatal	Internal I-beam processor lockup	<ol style="list-style-type: none"> 1. The I-BEAM keypad was over worked. Simultaneous multiple keys pressed may lock up the processor. Cycle I-BEAM power to reboot the supply.

Power Supply Error code -71-

Error -71- occurs if the source is on and the beam current drops below the plasma sense detect threshold (START DETECT I). The power supply monitors the beam current (with the beam on or off) to determine whether plasma is present inside the ion source. The detect threshold value (START DETECT I) is usually set to 5mA. This means if the beam current drops below 5 mA, error -71- is activated, indicating plasma is no longer present. It is a Fatal alarm, so it turns the ion source off and stops process.

There are a large number of possible causes which might initiate the -71- alarm and many of those problems are momentary, such that after the alarm happens the ion source may work again normally for a period of time until the problem recurs tripping the alarm again. As a result, troubleshooting this alarm scenario may sometimes be challenging. It is recommended to examine these issues first and then call us if the error cannot be cleared. In order of relevance:

- Excessive arcing – Visually observe operation of the beam for any arcing or unusual behavior. Check grid condition and proper assembly. Check for signs of arcing behind the discharge chamber (plasma shorts). Check for water leak or other high pressure.
- Plasma short – There might be a gap between the grid assembly and the mounting hardware. A plasma leak may impinge on the RF antenna and create a momentary tuning disturbance which will extinguish the discharge. Look for gaps in the grid assembly that plasma can escape.
- Tuning issues – Test the matching network and controller by ramping the RF power between 150 W and 450 W with the beam off. Check matching network for correct operation (i.e. are motors working?) and verify load and tune analog meter positions on matching network controller (is a red LIMIT light on?). Please refer to *Appendix B - Matching Network Tuning* as the matching network may need to be re-tuned.
- Accelerator current exceeds 150mA for 10 seconds or more. Accel grid is shorted.
- Improper grid assembly / connection – Before removing grids, ohm out grid connections to the atmosphere side of feedthrough. Then remove grids and check the electrical connections to the grids. Also check the grid spacing and mount assembly against drawings.
- Momentary RF interrupt – Do a careful visual and olfactory (sniff test) inspection of the entire RF circuit near the feedthrough, the matching network, atmosphere and vacuum sides of the feedthrough, the RF beaded and shielded vacuum leads, and RF antenna. Look for signs of excessive heat, loose connections, oxidation, or failed capacitors.
- Gas Flow Interruption – Check mass flow controller to verify gas flow rates and stability.

Contact our technical support for assistance if these steps do not produce any substantial clues suggesting a root cause. Run data at 1 second sampling rate, or video capture of the display of the power supply during a -71- alarm occurrence will sometimes be very helpful to analyze the problem, as well as pictures of the ion source equipment.

Section 6.3: RF Neutralizer (RFN) Errors

It can be advantageous to view the RFN as it attempts to start. Use a silicon wafer as a mirror if necessary. The table below covers the tuning and starting of the RFN. The possible solutions are presented with the highest probability being first.

RFN TROUBLESHOOTING TABLE	
PROBLEM DESCRIPTION	POSSIBLE PROBLEMS AND SOLUTIONS
RF power cannot rise above 80 watts within several cycles. RFN fails to start. TUNING issues during start.	<ol style="list-style-type: none"> 1. Adjust match network cap C1 with gas off. See <i>RFN manual</i> for tuning instructions. 2. Vacuum side of RF lead connection to feedthrough not centered or not mated. RF lead is shorted at the feedthrough. NOTE: The RF lead does short to ground but at the RFN body. Disconnect and carefully reconnect RF lead to feedthrough. 3. RFN RF cable is disconnected, or cross connected with source RF cable. Check RF cables leaving I-BEAM power supply. 4. RFN antenna assembly issue. Repair antenna or replace RFN. 5. RFN match network inductor coil mis-shaped. Service match network. 6. Damaged RF lead braided shield. Inspect braid for loose/broken strands, replace RFN or repair RFN if needed. 7. RFN match network relays failure or relay controls failure. Listen for relay toggle. If relay does not toggle replace match network. 8. RFN match network capacitor damage due to over tightening. Service match network.
RF rises above 80 W, no light ever emitted from the RFN, or only a dim intermittent glow is seen in RFN. RFN fails to start. IGNITION issues during start.	<ol style="list-style-type: none"> 1. Process gas is slightly contaminated (water vapor or air). Close bottle, pump line to low pressure, flow new fresh gas from bottle and retest. 2. Process gas is contaminated because process gas line is not electropolished stainless steel between bottle and chamber. Correct gas line material. 3. RFN gas flow incorrect level. Check MFC setup and compare flow to chamber pressure ratio. Also inspect for vacuum side gas line damage. 4. Collector is poisoned, damaged, or assembly issue. Service or replace RFN. 5. Conductive coating inside ceramic discharge chamber due to excessive keeper voltage. Service RFN and check for low flow conditions. 6. Bottle pressure < 100 psig, gas contamination in bottle. Replace bottle.
Bright light emitted while match network start relay on, but dark or very dim when start relay off. RFN fails to start. Starting issues.	<ol style="list-style-type: none"> 1. Gas contamination issue. Flow gas for 5 minutes and retry. 2. Adjust match network cap C2 while start attempt is cycling. Once started, warm up well, then further adjust C2 for low operating reflected power, then retest starting. 3. Keeper is not connected properly. Check keeper plate connections. 4. RFN match network damage or failure. Service match network.
Bright light emitted during entire start cycles, emission current never rises. RFN fails to start. Starting issues.	<ol style="list-style-type: none"> 1. Vacuum side collector lead not correctly mated to feedthrough. Remove leads, inspect and re-install. First, mate the pins. Then inspect. Then assemble the threaded connection cover. 2. Collector is poisoned, damaged, or assembly issue. Service or replace RFN.
RFN emission plume is a narrow beam (pencil beam mode). This is a starting/running issue.	<ol style="list-style-type: none"> 1. Keeper plate is loose or not connected. 2. Keeper lead incorrectly connected at vacuum side of feedthrough. Remove leads, inspect and re-install. First mate the pins, then inspect. Then assemble the threaded connection cover. 3. Keeper has been heavily coated with insulative material. Clean the keeper. 4. Bias supply electronics failure. Test with spare RFN before servicing I-BEAM power supply.

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I-BEAM RF POWER SUPPLY MANUAL Chapter 6: Troubleshooting

The table below covers the starting and running of the RFN. The possible solutions are presented with the highest probability being first.

RFN TROUBLESHOOTING TABLE	
PROBLEM DESCRIPTION	POSSIBLE PROBLEMS AND SOLUTIONS
Emission current normal, but RFN does not emit light, and source won't start. False start.	1. Vacuum side Collector bias lead not correctly mated to feedthrough and is shorted to ground. Disconnect atmospheric side cable and ohm-out collector lead. Remove bias leads, inspect and re-install. Mate the pins first, then inspect. Then assemble the threaded connection cover.
Emission current unstable during 5 minute warm up period. Initial stability.	This is normal behavior and typical for a clean collector. It does not occur for every RFN. No action required.
Emission current gradually becomes more unstable over an extended period of time. Unstable operation.	1. This may not be an issue as a clean collector will exhibit this. 2. Discharge chamber orifice has worn beyond a 0.050" diameter. Inspect hole size and service if necessary.
Emission current instability greater than +/- 50 mA only when beam is off, source idling. Running issue.	1. Over neutralization, negative space charge buildup in chamber. RFN may be positioned in a poor location. See <i>Ion Beam RF Sources Manual</i> or contact us for guidance.
After 20 to 60 minutes normal operation, emission becomes unstable or can't reach request, or goes out. Running issues.	1. Collector is loose. Service the RFN and use extreme care to ensure no rotation of gas isolator during RFN installation as rotation will loosen collector nut. 2. Poor RF efficiency due to RF antenna is loose or has become mis-shaped with age and thermal cycling. Service the RFN. 3. Poor RF efficiency due to RF antenna lead connector and feedthrough pin not centered in shield tube. Disconnect, re-center, and carefully reconnect RF lead to feedthrough.
Emission current unstable only at specific emission levels, but not others. Running issue.	1. Emission operating point coincides with RF power table break (usually 200mA and 600mA), RF jumps at this break. Select a higher E/B ratio to avoid this emission level request. 2. Poor RF efficiency (RF power too high or too low for emission operating point. Adjust the E/B ratio or increase gas flow to RFN by 1 sccm Argon.
RFN fails to start when RFN is hot, successfully starts after 20-50 minutes cool down. Running issue.	1. RFN antenna may have moved when hot, affecting tuning. Service RFN. 2. RFN match network was tuned when RFN was hot. Re-tune the matching network when the RFN is cold (room temperature).

Section 6.4: Starting the Source

For reference, the source startup sequence summary is:

- Step 1. The RFN will start.
- Step 2. The RF power supply ramps to the START POWER setting. The match network adjusts to minimize reflected power, allowing forward to rise to request.
- Step 3. Once START POWER is achieved, the power supply will pulse the beam and accel grids to the BV PULSE setting, and cycle between BV PULSE and BV IDLE.
- Step 4. The pulse draws free electrons from the RFN in through the grids, to help start plasma in the discharge chamber.
- Step 5. Plasma is initiated in the discharge chamber and a small amount of beam current occurs.
- Step 6. When beam current rises above the START DETECT CURRENT setting the pulsing cycle stops and RF power ramps to the RF IDLE POWER setting.

The possible solutions are presented with the highest probability being first.

SOURCE STARTUP TROUBLESHOOTING GUIDE	
PROBLEM DESCRIPTION	POSSIBLE PROBLEMS AND SOLUTIONS
RF power does not turn ON. Source fails to start (step 2)	<ol style="list-style-type: none"> 1. Interlock not satisfied. Examine interlock connections 2. Power supply in a test mode. Reboot supply.
RF forward power fails to rise to starting power. Source fails to start (step 2).	<ol style="list-style-type: none"> 1. Source matching network tuning issues: Check matching network electrical and communication connections. Check match controller power is turned on. See <i>Appendix B - Matching Network Tuning</i>. 2. Antenna issues. Check source antenna for proper alignment, spacing and positioning. Check to ensure antenna is not electrically connected to ground. 3. Failing RF circuit connection: Visually inspect RF circuit between matching network and the source. Look for loose connections, oxidized hardware or failed capacitors. 4. RF generator issues. Check RF generator for alarms.
Beam voltage does not pulse to high voltage value. Source fails to start (step 3).	<ol style="list-style-type: none"> 1. Check BV PULSE setting and retest (see <i>Chapter 4 - Operation</i>) 2. START DETECT I is set to zero. Correct setting (usually 5mA) and retest. 3. Power supply in a test mode. Reboot supply.
RF reaches request start power (step 3) but pulsing continues with no light emitted from ion source	<ol style="list-style-type: none"> 1. Source gas is off or low flow. Check source gas flow rate, and chamber pressure. 2. Accel and/or beam grid are not connected. Check connections, vent and ohm-test the source. 3. BV PULSE setting is low or 0 V. Correct setting (see <i>Chapter 4 - Operation</i>) 4. Insufficient RFN emitted electrons near ion source. Check RFN performance, review RFN position, aim, and chamber conditions etc. Possible RFN mounting adjustment aim, or shielding change may be required. 5. Beam Relay (switch) failure. Send us a video of the startup sequence. 6. RFN extinguished. Check RFN emission current.
High BV IDLE current (greater than 60 mA) (step 6).	<ol style="list-style-type: none"> 1. Beam and/or accel grids are shorted to ground. Check spring tab connections. 2. Gas flow is higher than expected. Check gas flow operation and chamber pressure. 3. RF IDLE power is higher than expected. Check setting.
Source fails to start unless excessive gas is flowing.	<ol style="list-style-type: none"> 1. Poor gas connection to the source. Check gas connections to the source and gas isolator. 2. Wrong type gas flowing. Check MFC gas type and setup.

Section 6.5: Turning on the Beam

The possible solutions are presented with the highest probability being first.

BEAM TROUBLESHOOTING GUIDE	
PROBLEM DESCRIPTION	POSSIBLE PROBLEMS AND SOLUTIONS
Beam ON request immediately canceled or ignored.	<ol style="list-style-type: none"> 1. Source had not reached normal idle RF power before beam button pressed or command received. Wait for idle RF power to be reached before turning on beam. 2. RFN TUNE UP or RFN BURN IN mode is enabled. Disable special mode.
Beam current drops to zero immediately after accel voltage rises. Source discharge is dark after beam is on.	<ol style="list-style-type: none"> 1. Backstreaming electrons gave false plasma detection indication. Increase START DETECT CURRENT setting. 2. Discharge chamber not installed or plasma ignition was near RF antenna. Inspect source interior for plasma short. 3. RF noise is on the beam or accel leads. Move beaded leads away from RF antenna.
Beam turns ON but beam current does not rise as expected.	<ol style="list-style-type: none"> 1. Power supply is in MANUAL mode. Change to LOCAL mode and try again. 2. RF match network not tuning, prevents RF power from rising. Check match network (and controller limit) for proper function and capacitor motion. 3. RF power rises to limit and efficiency problem has degraded performance, preventing BI request from being reached. Discharge chamber is coated or RF loss exists in matching network circuit (polyethylene tubing is coated or facility coolant is conductive).
Color of beam abnormal. Argon beam will be light purple.	<ol style="list-style-type: none"> 1. Incorrect gas flow species. Air, or Nitrogen will produce a red beam. Check gas line for leaks. 2. Water leak. Check system for water leaks.
RF power abnormally low, deposition rate abnormally low, and accelerator current abnormally low or zero.	<ol style="list-style-type: none"> 1. Open circuit to accel grid - accelerator voltage not reaching grid. Check accel tab position and ohm-out atmosphere-side feedthrough to grids. *Note: grids may be catastrophically damaged within a few hours if beam is operated with open accelerator. 2. Discharge chamber not installed or plasma ignition was near RF antenna. Inspect source interior for plasma short.
Beam current lower than normal (BI tolerance alarm E13 may trip).	<ol style="list-style-type: none"> 1. Excessive grid arcing. Visually observe operation of the beam to check for arcing. Check for excessive particulates falling on or peeling from ion source, insufficient source warm up to remove moisture, insufficient conditioning to resolve loose particulates after grid cleaning 2. Applied RF power is too low. Power supply is in MANUAL mode. Change to LOCAL mode. 3. Drop in gas flow. Check gas flow (and bottle) and chamber pressure data log, correct gas flow problem. 4. Change in RF impedance and RF power. Check RF circuit for problems.
Beam current higher than normal (BI tolerance alarm E13 may trip).	<ol style="list-style-type: none"> 1. Screen grid is electrically shorted. Check electrical connections including spring tab in contact with grid mount stack. 2. Beam and accel connections have been reversed at the feedthrough. Perform a continuity check with I-BEAM disconnected. 3. Excessive grid arcing. Visually observe operation of the beam to check for arcing. Check for excessive particulates falling on or peeling from ion source, insufficient source warm up to remove moisture, insufficient conditioning to resolve loose particulates after grid cleaning. 4. Discharge chamber not installed or plasma ignition was near RF antenna. Inspect source interior for plasma short.

(CONTINUED)

I-BEAM RF POWER SUPPLY MANUAL Chapter 6: Troubleshooting

The possible solutions are presented with the highest probability being first.

BEAM TROUBLESHOOTING GUIDE	
PROBLEM DESCRIPTION	POSSIBLE PROBLEMS AND SOLUTIONS
Accel current is zero.	<ol style="list-style-type: none"> 1. Discharge not started or is out. Check discharge. 2. Faulty accelerator grid connection. Check spring tab connection to accel grid. 3. Faulty connection between I-BEAM and grid. Check feedthrough. 4. Possible I-BEAM problem. Video record the event and send it to us for assistance.
Accel current is higher than normal.	<ol style="list-style-type: none"> 1. Accel grid is electrically shorted. Check accelerator connections. Look for signs of plasma shorts inside the source, coated insulators and electrical lead wire proximity issues. Spring tab may be bent. 2. Damaged accelerator grid. Inspect accelerator grid for delamination or proximity issues to the screen or decel grids. 3. Grid alignment is not sufficient. Check grid alignment. 4. Chamber pressure or gas flow is abnormally high. Check vacuum system for leaks or excessive gas flow.
Excessive arcing when beam is ON.	<ol style="list-style-type: none"> 1. Source was not warmed up properly. Increase warm up time. 2. Accel grid is coated with dielectric material. Clean the accel grid. 3. Debris or flakes are in proximity to the grids or peeling and falling onto the grids. Check and clean the screen and accel grid, or source of peeling. May need to clean vacuum chamber near source. 4. 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.

Section 6.6: Additional Resources

Please consult the *RFN Manual* for guidance with the RFN service, tuning and installation procedures. The *Ion Beam RF Sources Manual* also provides more information on installation and operation of the source and its hardware. See *Appendix B - Matching Network Tuning* for a description of the source matching network tuning procedures.

Also have a look at our web site plasmaprocessgroup.com as there are a number of technical notes published that pertain to using the ion beam source for different applications.

If the problem encountered was not listed in the previous sections, please contact us for assistance. Send us a short video clip, photos and run data so that we can assist with the troubleshooting.

Appendix A: Legacy Installation

The I-BEAM RF utilizes industry standard electrical connections and software control commands. As a result, it can replace existing power supplies in many systems. More specifically, the I-BEAM RF is a replacement for the RF2001, RF2051, RF2070 and RF5S generator offered by Veeco Instruments, Inc. This section describes how to interface the I-BEAM RF on older systems.

I-BEAM 703 replaces RF2001, RF2051, RF2070 and RF5S

I-BEAM 701 replaces RF2001, RF2051 and RF2070

I-BEAM 702 replaces RF2001 and RF2070

Section A.1: Hardware Kit

Main Kit

The IBOX hardware kit required to interface an I-BEAM 703 or 701 to an existing system is shown below. The kit includes an interface box, DB25 pin cable extensions, an interlock extension and a GFC adaptor. Individual part numbers are listed with each item.



IBOX interface kit for legacy systems.

Other Cables

Depending upon the installation, some of the existing cables can be used. However, the I-BEAM has been optimized and will require 18 foot RF cables (505348A for source and 505410A for RFN).

Section A.2: Installation Location

The I-BEAM RF can be installed in any rack mount location. Depicted in below is a recommended location. In addition, the position of the existing user interface cable is provided for reference.



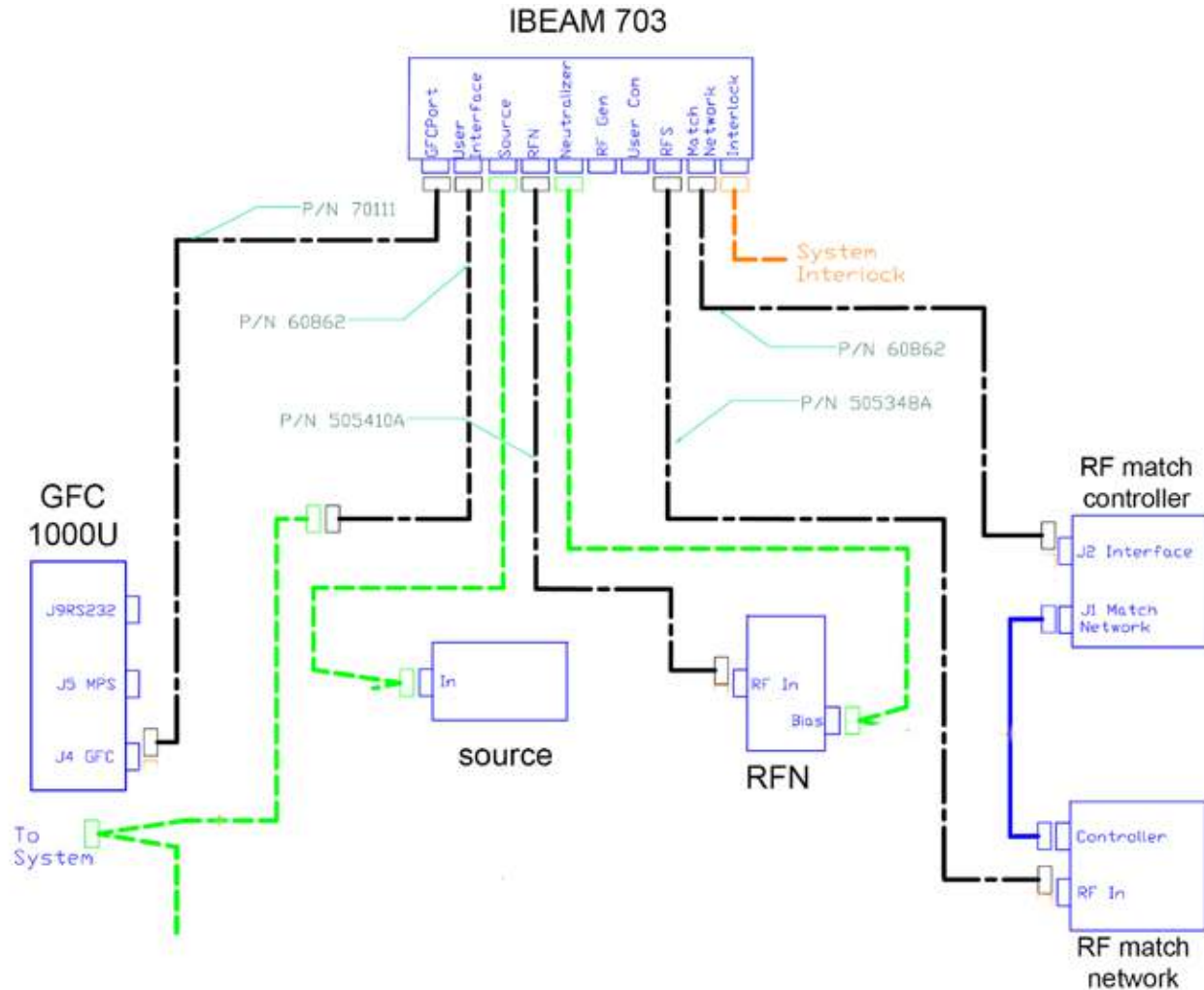
Recommended location for the I-BEAM supply.

Please consult the factory if:

- The system configuration is not shown or different.
- Installation of an I-BEAM 702 is required.
- Interface issues are encountered.

Section A.3: Installation of an I-BEAM 703 with IBOX

The I-BEAM 703 comes with its own RF generator for the source. The figure below show the wiring diagram for installing the I-BEAM onto an existing system.

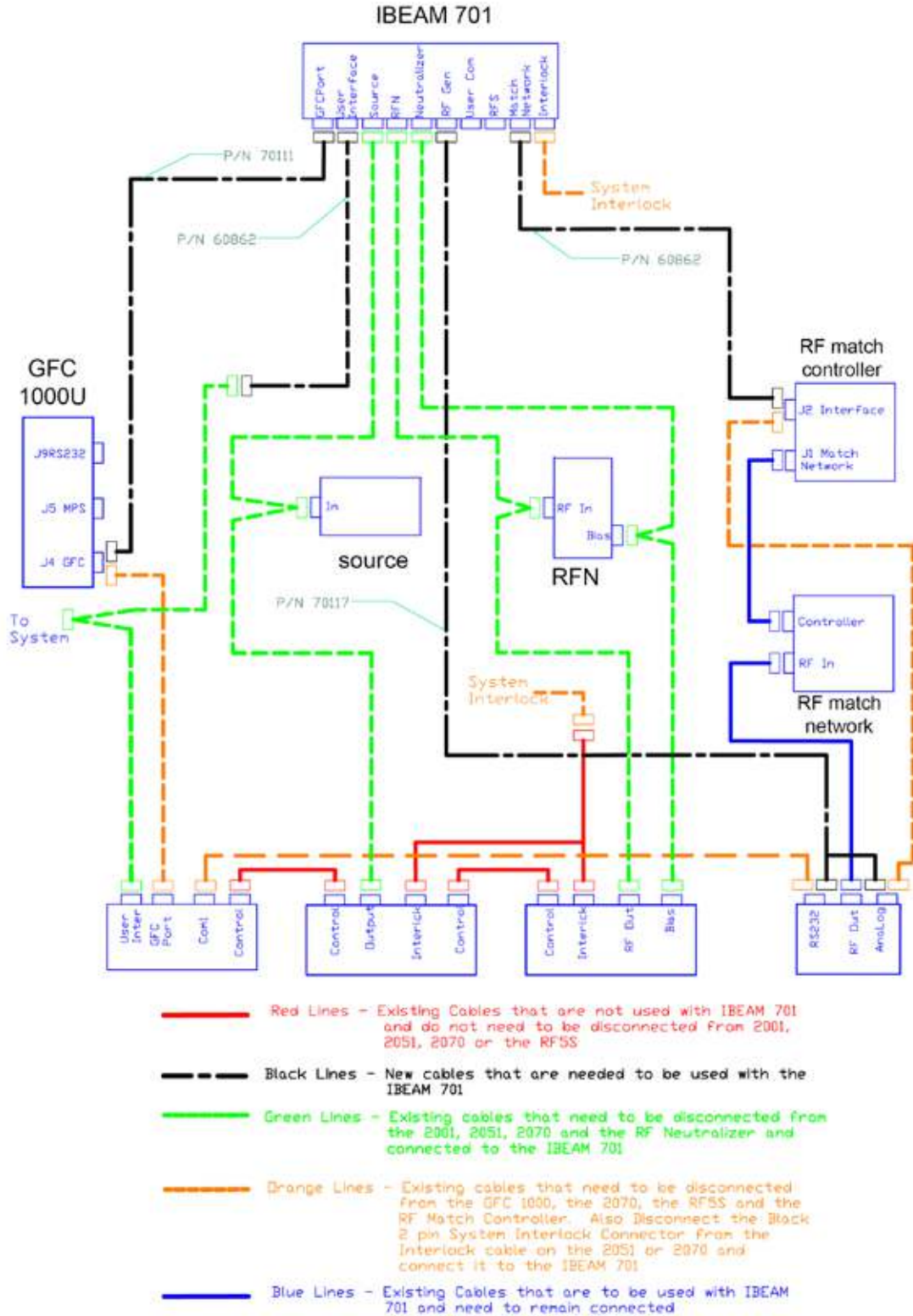


- Black Lines** - New cables that are needed to be used with the IBEAM 703 The RF Cables need to be 18ft long
- Green Lines** - Existing cables that need to be disconnected from the 2001, 2051 and the 2070 and connected to the IBEAM 703
- Orange Lines** - Existing cables that need to be disconnected from the GFC 1000, the RF Neutralizer and the RF Match Controller. Also Disconnect the Black 2 pin System Interlock Connector from the Interlock cable on the 2051 or 2070 and connect it to the IBEAM 703
- Blue Lines** - Existing Cables that are to be used with IBEAM 703 and need to remain connected

Electrical schematic for interfacing the I-BEAM 703.

Section A.4: Installation of an I-BEAM 701 with IBOX

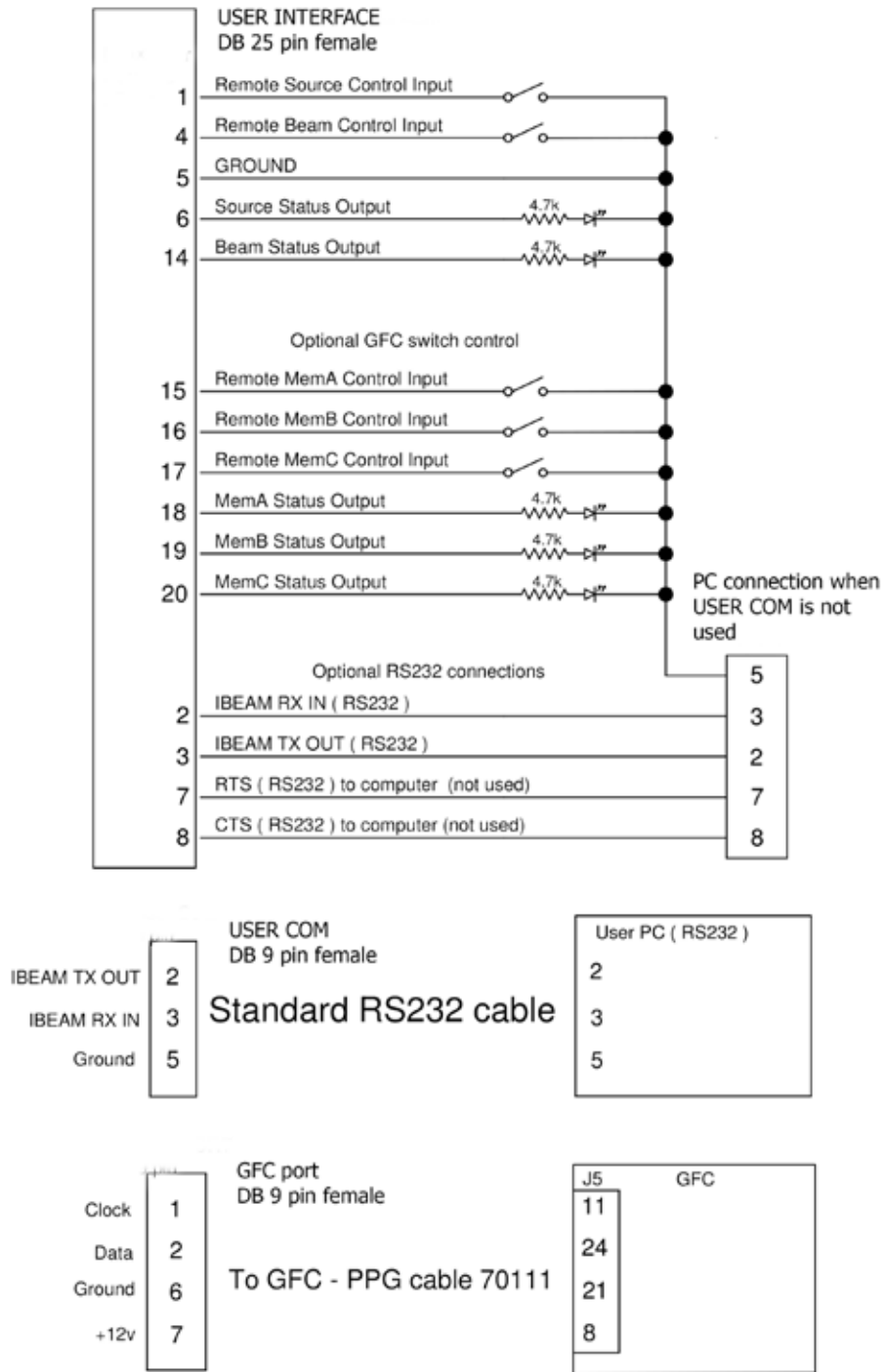
The I-BEAM 701 will require an external generator. If the generator is our 1kW it will require a 24' RF cable. The figure below show the wiring diagram for installing the I-BEAM onto an existing system.



Electrical schematic for interfacing the I-BEAM 701.

Section A.5: Pin Outs for the IBOX

The pin outs for the IBOX are provided for reference. Best practice is to connect the USER INTERFACE or USER COM to the PC but not both. Please contact us if you have any questions.



Pin connections for the IBOX.

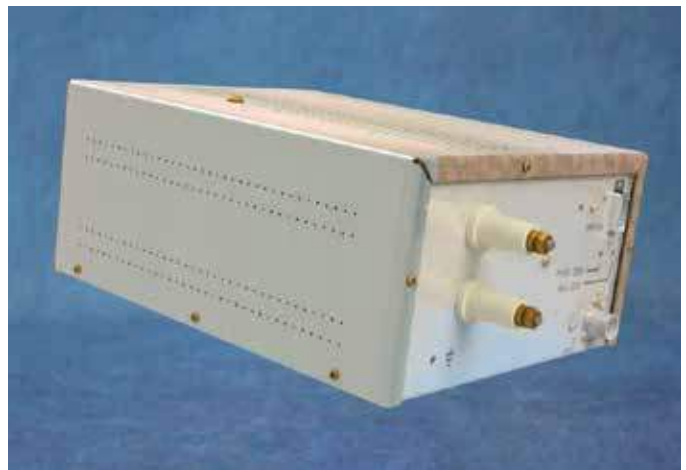
Appendix B: Match Network Tuning

Occasionally, after servicing or as the source ages, the source matching network may require re-calibration. This appendix describes the tuning procedure.

Section B.1: Definitions

Matching Network

The matching network is a gold-colored box mounted close to the ion source flange. The front of the matching network has the RF power connector (RF IN input power), controller cable connector (DB 15 male), and two RF ceramic insulator posts (output power). Inside the matching network are the load and tune variable capacitors.



Matching network for the source.

Beehive Insulators

Two ceramic insulator posts on the front of the matching network provide RF power connections to the source RF feedthrough. The power connections to the RF feedthrough are silver plated copper strap and are protected with a high voltage cover.

Older equipment may have paper gaskets between the beehive insulators and this should be removed.



Connections to the feedthrough.

Phase and Mag adjustments

The magnitude (M or MAG) sensor and phase (P or PHASE) sensor zero adjustments are potentiometers located just inside the matching network. The potentiometers appear as small brass screws visible when looking into the opening. If either sensor requires calibration, an insulated screwdriver should be used. Adjustments to either potentiometer should be performed slowly as small turns have large effects.



Location for the ZERO potentiometers.

Matching Network Controller

The PT-II matching network controller is a gray box which adjusts the matching network capacitors. The controller is typically mounted into the instrumentation panel near the source power supply.

The position indicator meters for the load and tune capacitors are on the front of the controller. The back of the controller has the power plug, two communications cable connectors, and two BNC connectors.



Matching network controller.

Switches

The switch labeled with the words AUTO, MAN, and REM is referred to as Toggle switch, and adjusts the mode of the matching network. The second switch labeled with a plus (+) and minus (-) is called the Manual switch and does not work when the toggle switch is set to AUTO or REM.



Toggle switches.

Gages

On the front of the Controller are two position indicator gages, marked LOAD and TUNE. Capacitor position is indicated from 0 to 1. Each gauge has two LEDs to indicate minimum or maximum position has been reached.



Capacitor position indicators.

Controller backside

On the back of the controller are two potentiometers for gain adjustments for the Phase and Mag. These are typically adjusted at the factory. Please contact us for guidance on adjusting these.

Two BNC connectors labeled J3 and J4 are the readouts for the matching network phase and magnitude zero control signals. These will be monitored during the tuning process.



Controller layout on the backside.

Section B.2: Setup

1. A voltmeter with a coaxial cable adapter and a small, insulating screw driver for adjusting potentiometers will be required to calibrate your matching network.
2. Make sure the communications cable from the I-BEAM power supply to the matching network controller is connected. Make sure the control cable from the matching network to its controller is connected. Also verify the RF Power cable from the I-BEAM source RF (or a stand alone RF generator) to the matching network RF input is connected.
3. Set both toggle switches on the controller to AUTO.
4. On the I-BEAM supply press the mode button to place the power supply in MANUAL mode. Then press the Source button to try to start the source under normal gas conditions. If it starts, let it warm up at its idle power. The source IDLE power should be within the range 200 to 250 W. If the source successfully reaches the idle condition, skip to step 9, otherwise continue with step 5.
5. If the source cannot tune to the idle condition, turn SOURCE button OFF and set both toggle switches on the controller to MAN.
6. Use the Manual switches on the controller to adjust the LOAD and TUNE cap positions to about 0.75 (3/4 of the way across the analog meter). Turn on the source (press SOURCE button ON).
7. After the RFN has started, the RF starting power is applied to the source. Use the Manual switches on the controller to maximize the RF forward power. Monitor the forward power while making small adjustments in the load and tune capacitor positions. Small adjustments are made by pressing and releasing the switch in rapid succession ("clicking" the switch).



TIP - Make small adjustments to the load capacitor and maximize the forward power and minimize reflected power with the tune capacitor.

The Manual switch for the LOAD capacitor is more sensitive than the Manual switch for the TUNE capacitor. Fatal -80- alarm for too high reflected power occurs every 20-30 seconds of attempted tuning. This will make it difficult to manually tune the matching network, requiring frequent restarting of the RFN and source. Just leave the capacitor positions alone and try again.

8. When the forward power reaches the starting power and reflected power is minimized, the power supply will apply the pulse voltage to the grids to start the source. When a plasma is ignited in the source (source starts), the RF forward power will drop again and reflected power will increase. Repeat step 7 to maximize the RF forward power (now the idle power) and minimize the reflected power. If the plasma extinguishes (source goes out) return to step 6.
9. Once the ion source has reached the idle condition with a reflected power of about 0 Watts, warm up the source for 30 minutes. This warm up will minimize thermal drift issues for the tuning process. Set the matching network controller toggle switches to MAN during the warm up period. If reflected power rises more than a few watts, make small adjustments to the Manual switch on the TUNE side to minimize reflected power (0 Watts).

Section B.3: Tuning Procedure

1. Press MODULE button until RF Power indicator LED is ON. Select the control key marked MORE four (4) times to reach the LOAD values. This displayed number is equal to the reading on the matching network controller analog meter x 5000, allowing for a greater accuracy reading. Pressing MORE again will display the TUNE values. Use these menus for STEPS 2 and 3 below.



RF module sub menu.

2. Determine the LOAD middle position (L_0). Restart the source if it goes out during this step. To complete this step do the following:
 - a. Note: for all of these steps the reflected power should be 0 W
 - b. Carefully tap the TUNE capacitor manual switch to adjust the reflected power to 0 W.
 - c. Note the position of the load cap in the I-BEAM window (e.g. LOAD 2833 mV).
 - d. Carefully tap the LOAD (-) manual tune switch to decrease its position and note its value in the I-BEAM window (e.g. LOAD 2750 mV).
 - e. Carefully tap the TUNE manual tune switch to adjust the reflected power to 0 W.
 - i. If the reflected power can be adjusted to 0 W repeat step D again.
 - ii. If the reflected power cannot be adjusted to 0 W, the last LOAD position where 0 W reflected power was observed is the LOAD lower position (L_1) (e.g. LOAD 2600 mV). Move on to step F.
 - f. Carefully tap the LOAD (+) manual switch to increase its position and note its value in the I-BEAM window (e.g. LOAD 2850 mV).
 - g. Carefully tap the TUNE manual switch to adjust the reflected power to 0 W.
 - i. If the reflected power can be adjusted to 0 W repeat step F again.
 - ii. If the reflected power cannot be adjusted to 0 W, the last LOAD position where 0 W reflected power was observed is the LOAD upper position (L_2) (e.g. LOAD 3000 mV). Move on to step H.
 - h. Calculate L_0 , the LOAD middle position. L_0 is the average of L_1 and L_2 or $L_0=(L_1+L_2)/2$.

3. Determine Tune Middle Position T_0
 - a. Place the LOAD cap in the middle position (L_0) by adjusting the LOAD manual switch (e.g. LOAD 2800 mV) until the value on the I-BEAM screen matches within ± 10 mV .
 - b. Carefully tap the TUNE manual switch to adjust the reflected power to 0 W. Manually adjust the TUNE cap upward to determine the highest TUNE value which results in 0 reflected power. Record this upper value as T_1 .
 - c. Then manually adjust TUNE cap downward to determine the lowest TUNE value which results in zero reflected power. Record this lower value as T_2 .
 - d. Calculate TUNE midpoint T_0 similarly where $T_0=(T_1+T_2)/2$.
 - e. Move the tune cap to the T_0 Position within ± 10 mV.

I-BEAM RF POWER SUPPLY MANUAL Appendix B: Match Network Tuning

4. Connect a coaxial cable adapter to the J4 connector on the back of the controller. Take the positive lead from the digital voltmeter and connect it to the positive side of the coaxial cable adapter. Take the negative/ground lead from the voltmeter and connect it to the ground side of the coaxial adapter. Set the voltmeter to read DC millivolts (mV).
5. Using a small insulated screwdriver, adjust the MAG ZERO potentiometer on the matching network until the voltmeter reads 0 mV (it may fluctuate to within ± 2 mV).
6. Connect a coaxial adapter to the J3 connector on the back of the controller. Using a small insulated screwdriver, adjust the PHASE ZERO potentiometer on the matching network until the voltmeter reads 0 mV (it may fluctuate to within ± 2 mV).
7. Set the LOAD and TUNE toggle switches back to REM on the matching network controller. Manually increase the RF idle power to 400 W (with the beam off) then decrease to 150 W several times to ensure the matching network will automatically adjust for different RF powers. Pause a few seconds at each extreme to monitor the maximum reflected power which should be less than 4 W at higher RF powers.
8. If the source does not maintain low reflected power or the LOAD cap position drifts, check all antenna connections for corrosion. Repeat all tuning steps if significant changes to the antenna or matching network are performed.

Section B.4: Setting the Presets

1. After matching network tuning is complete, determine the LOAD and TUNE presets by first turning off the source (press SOURCE button OFF). Turn the source gas OFF. Then, press the source button (press SOURCE button ON).
 - a. Observe the I-BEAM window (in RF module) which should display "LOAD ####" or "TUNE ####". Just after the RFN starts and before the beam is pulsed, note the values for the LOAD and TUNE (e.g. LOAD 3050 and TUNE 1650).
 - b. Turn the source OFF.
2. Return to the RF module window that displays the LOAD ####.
 - a. Select SET. Use the keypad to enter a LOAD value 200 mV higher than that observed in step 1 above (e.g. 3250).
 - b. Select MORE. Use the keypad to enter a TUNE value 200 mV higher than that observed in step 1 above (e.g. 1850).
3. When the source is turned OFF, the LOAD and TUNE capacitors should move to these positions if the controller is in remote (REM) mode. By setting the presets, the source typically starts slightly faster and there is less wear on the matching network.



Plasma Process Group

Since its founding in 2003, Plasma Process Group has consistently provided the highest quality service and equipment to the ion beam industry. We offer innovative new designs and industry standard products compatible with legacy equipment.

EQUIPMENT

We provide a wide array of ion beam products ranging from stand alone ion beam source and power supply packages. The ion beam sources we offer include both radio frequency RF and filament-driven DC styles. Our I-BEAM Power Supply family provides reliable operation for the most demanding production environments. Our ion beam grid assemblies, or ion optics, are constructed from molybdenum, graphite, or titanium and are available in a variety of shapes and sizes. We also carry a healthy assortment of spare parts including discharge chambers, insulators and many other items to keep your source running.

CUSTOMER SERVICE & SUPPORT

Whether in research or production, Plasma Process Group is committed to providing the best support in the industry. Help is always just a call or email away. Our staff has decades of hands on experience using ion beam sources and sputter deposition systems. We are happy to share our expertise and assist you with your application.

CONTACT US

Contact us today for all of your ion beam needs — *simple ion beam solutions.*



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