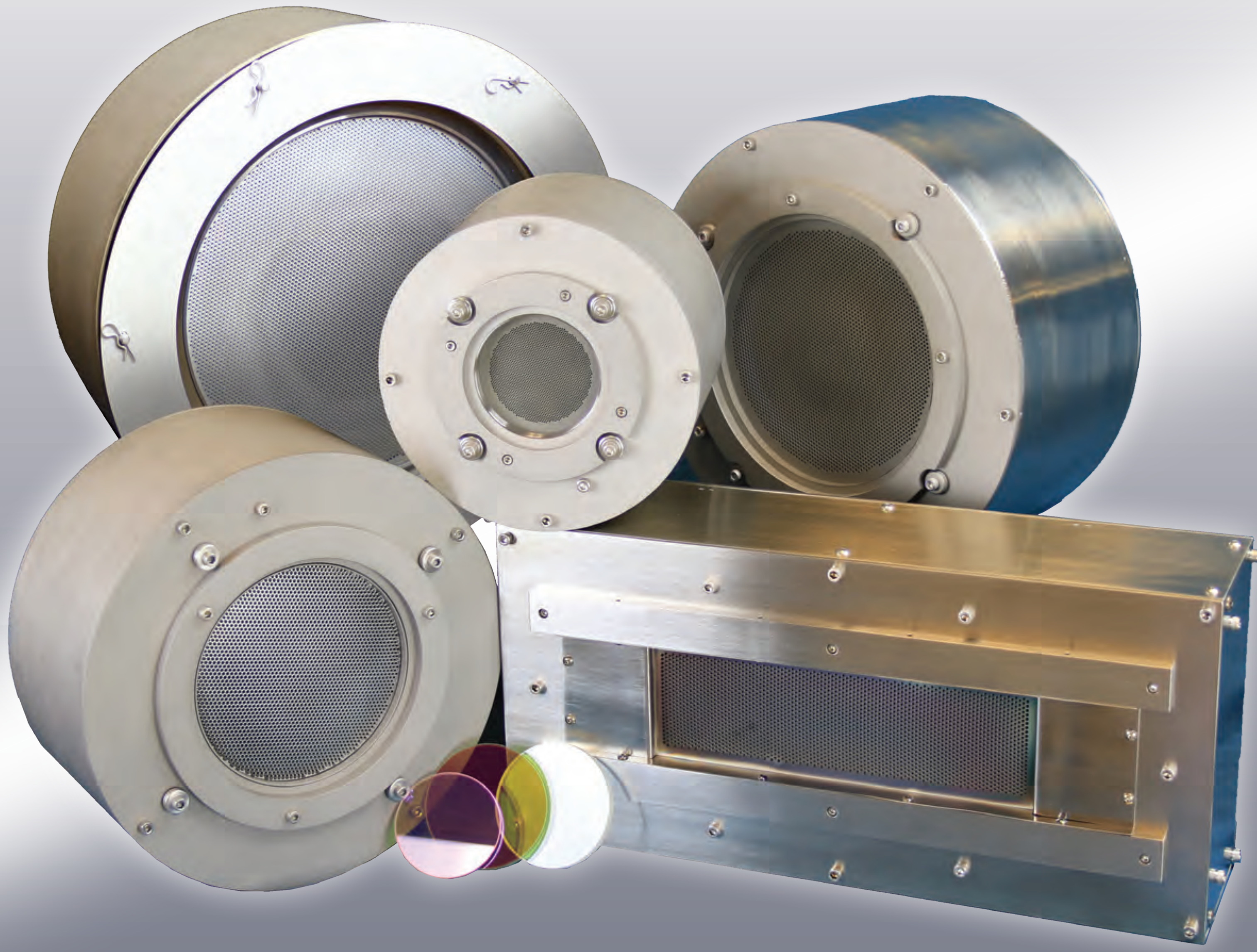


ION BEAM RF SOURCES

MANUAL

plasma process group

ESTABLISHED 2003

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 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.

7330 Greendale Road, Windsor, CO 80550 USA
Phone 970-663-6988 • Fax 970-669-2312

Date: October 2023 REV P2

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.

Table of Contents

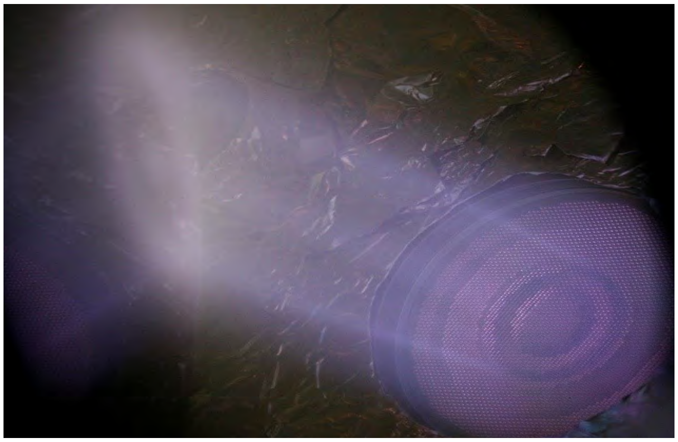
Chapter 1: Getting Started

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 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.

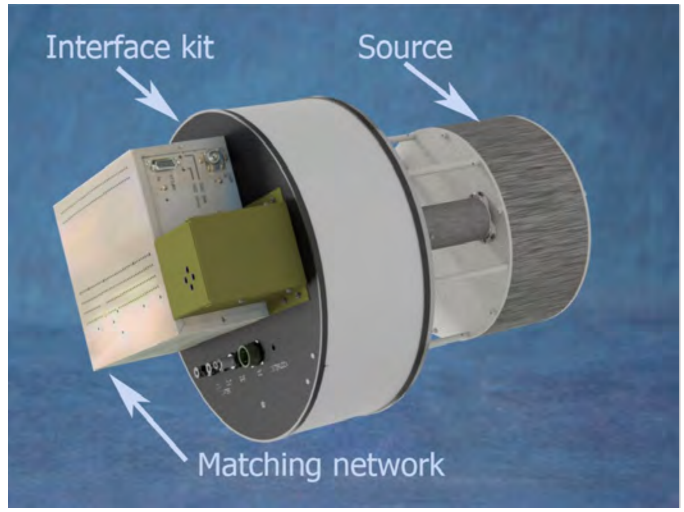


Ion beam striking a target.

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.

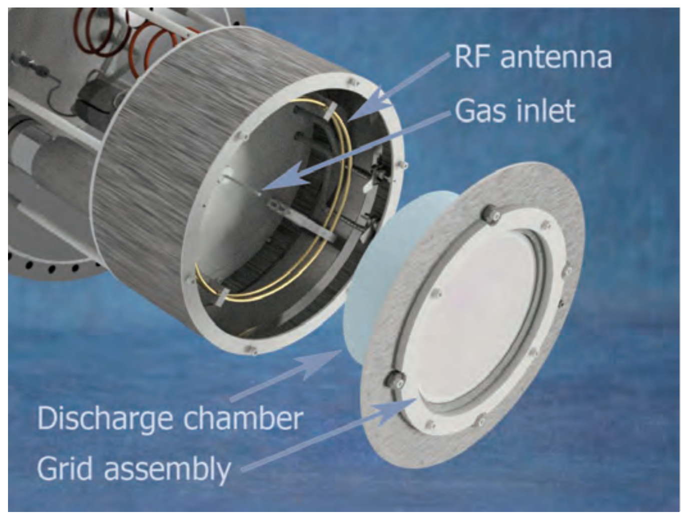
The hardware unpacked.

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.



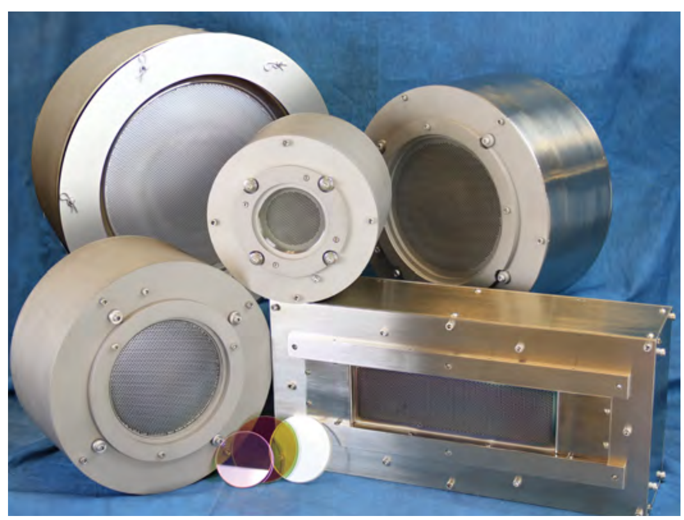
Source and interface kit assembly

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

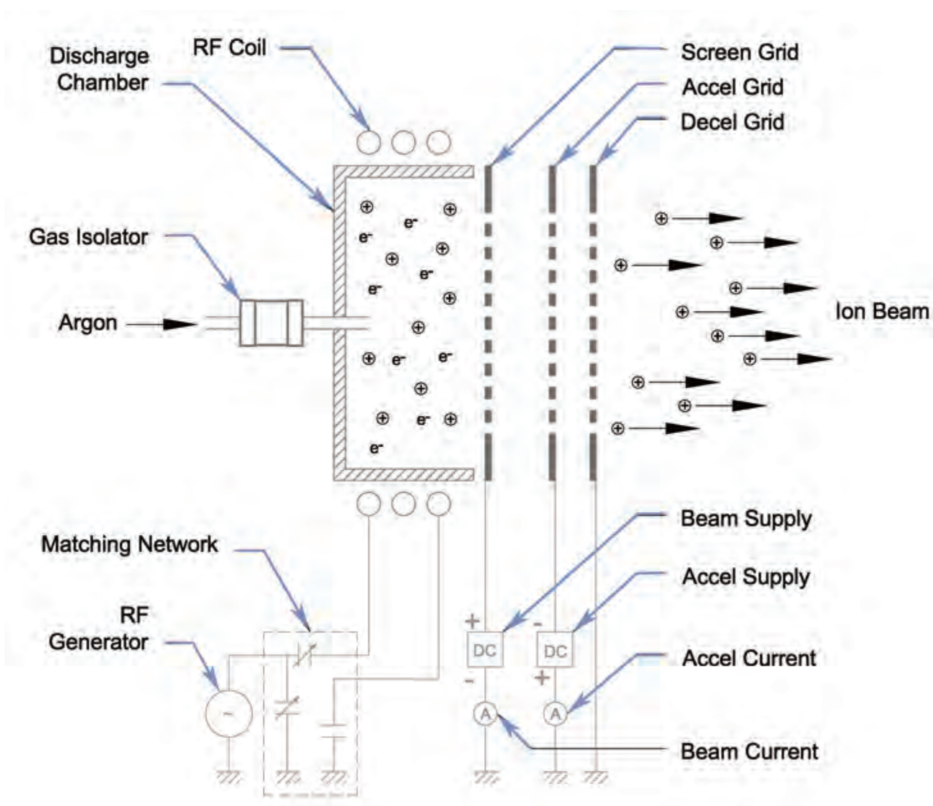
All RF ion beam sources will have these same key elements. Only the sizes and geometries will differ for antennas, grids, and discharge chambers.



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

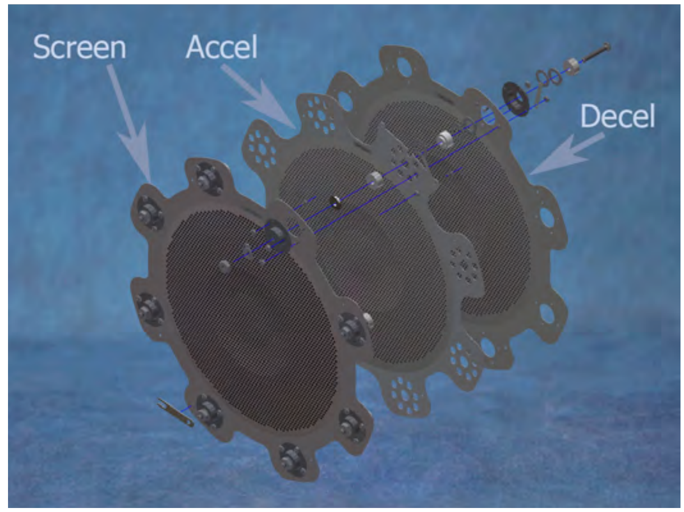
ION BEAM PARAMETERS		
PARAMETER	**DEFINITION**	**UNIT**
Source Gas Flow	Process gas delivered to the discharge chamber.	sccm
RF Forward Power	The RF power applied to the matching network. This controls the ion production rate	W
RF Reflected Power	The RF power returned from the matching network.	W
Beam 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%.	%

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 Chapter 5.

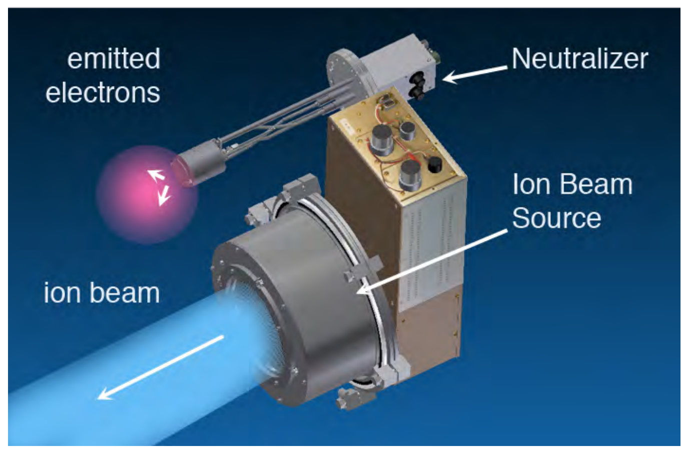
A neutralizer is placed downstream from the source where it emits electrons to balance the number of positive ions which leave the source. The RFN operates in a similar fashion to the source as it requires process gas, has an RF antenna and its own matching network. Please refer to its manual for a detailed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

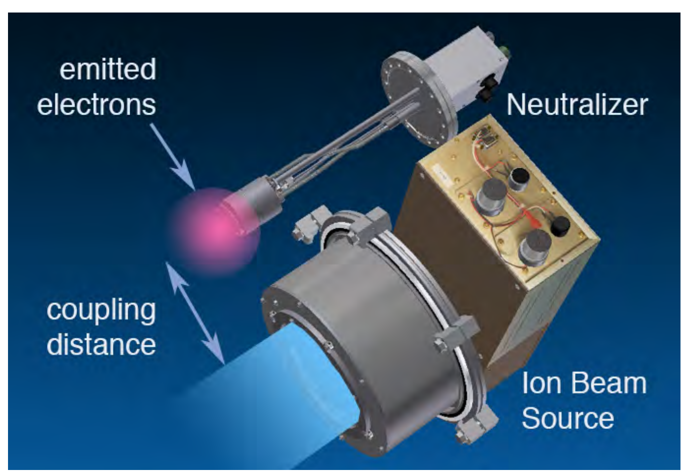
Electrons from the neutralizer do not recombine with source ions, rather they provide space-charge-neutralization for the downstream plasma. Under normal operation, the neutralizer will emit between 125% to 200% of the measured beam current. In this fashion substrates or targets downstream will not suffer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

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. 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. Please refer to its manual for a complete description and additional information. Specifics on the power supply operational features will be discussed in Chapters 4 and 5 of this manual. Chapter 5 also has tech tips for the source, RFN, and I-BEAM.

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

The I-BEAM ion source controller

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

Please contact us with any concerns or issues that arise during the installation of the source. Each source and vacuum system are unique and present challenges.

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 $5x10^{-4}$ mbar during operation.

Gas supply

The source and RFN require accurate and stable flow. We recommend and use Alicat™ mass flow controllers (MFC) or equivalent. Mass flow control should be accurate to .1 sccm levels. The RFN does require high purity (5N) Argon and can be operated on Xenon if necessary. The source also uses high purity Argon, but will operate using Oxygen or Nitrogen. Please give us a call if you have specific questions about the gas type.

The gas bottle should have a 2 stage regulator to provide minimal pressure fluctuations. The facilities should run electropolished stainless steel gas lines between the bottle and MFC and between the MFC and source (or RFN).

Cooling

The RF sources will require water cooling for the RF antenna. This promotes RF power stability. Some of the RF sources also have a water cooled shroud. Treated drinking water at 25°C and no more that 300 kPa (50 psi) is recommended. Care should be taken for recirculating systems with additives that may change the electrical conductivity of the water as RF power is susceptible to these coolants. The water should be pH neutral and deionized water should be avoided. The typical flow rate for the source and shroud will be 1 L/min and the water manifold should have a flow interlock.

Electrical

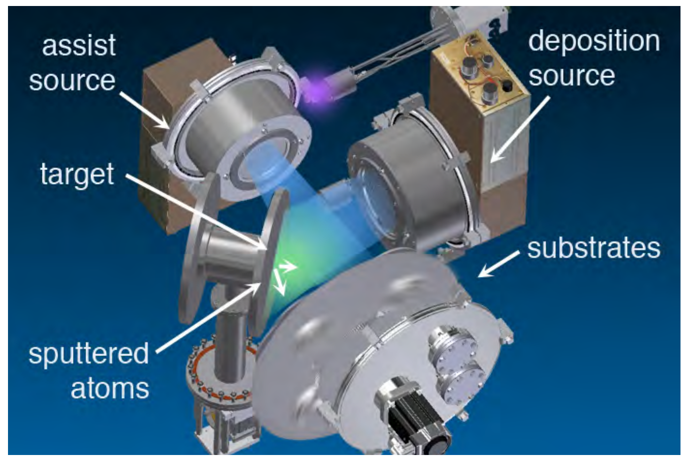
The vacuum system should have an earth ground. A grounding line should be installed between the I-BEAM and the vacuum chamber earth ground. The I-BEAM supply requires 208 VAC, 50/60 Hz single phase at 16A. The matching network controller will require 110 VAC, 50/60 Hz. Cables between the I-BEAM supply 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. Additional installation information is provided in the I-BEAM manual.

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.

Section 2.2: Layout

When installing a source, careful consideration must be given to the final geometry. A starting point is to define where the ion beam is needed and work backwards from there. Source to target distance is important for sputtering applications where source to substrate distance is important for assist applications.

All ion beams will spread out downstream and the source grid design will control the degree of focus. Beam over-spray should also be considered when designing a system. In the Learning Center of our website we have beam coverage diagrams. These illustrate how the beam shape is changing downstream with different sources and grid assemblies.

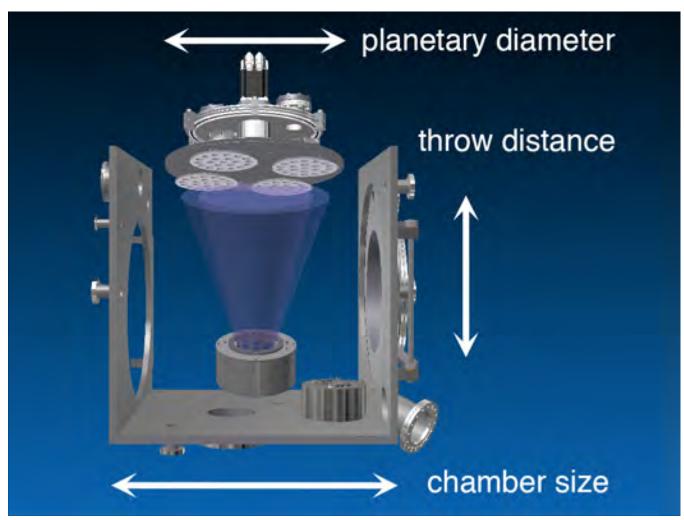


Source locations for a Ion Beam Assisted Deposition tool.

Ion Current Density
For some applications, it can be useful to determine the expected ion current density distribution on the target or substrate. We have a calculator on our website in the Learning Center that estimates beam cross section current density at different distances downstream.

Neutralizer
The neutralizer should be placed in close proximity to the grids on the source. This helps the electrons couple to the beam and minimizes emission noise and arcing issues.

Consultation
Please reach out to us for assistance with your system needs. There are a few guides in the Learning Center of our website that assist with the design process, but we are here to make sure your project is successful and your machine is profitable.



Source installation in a evaporator coating system

Section 2.3: 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.

Source and RFN
All the ion beam source and sub-assemblies have been rigorously cleaned. Common vacuum practice is recommended while handling the source components. This requires that the operator use latex or non-latex type gloves to prevent finger oil from contaminating the surfaces of the ion source. Some of the items will be wrapped in vacuum grade aluminum foil for shipment protection. Remove all foil and other plastic bag materials.

Power Supply
The I-BEAM supply should be unpacked on a cart and should be lifted with 2 people. The matching network controller should also be located and unpacked. All of the cables can be removed from their plastic bags.

Extras
For complete source packages we will also include a spare set of tools, an alignment jig for the grid assembly, and a spare parts kit.

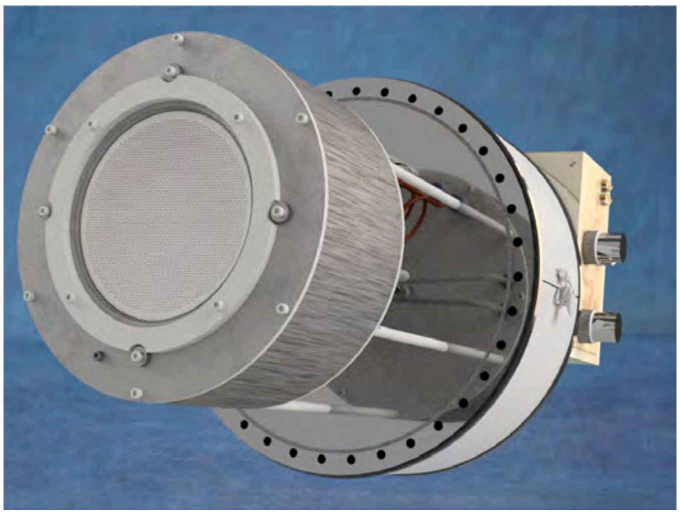
Section 2.4: Source Installation

The installation of a flange mount or extension mount source styles are straightforward, as the source body is mounted to the vacuum flange. An internal mount source differs from the flange mount sources in a few respects; feedthroughs come in diverse sizes, the matching network has to be creatively mounted if smaller feedthroughs are used, and there are more connections involved.

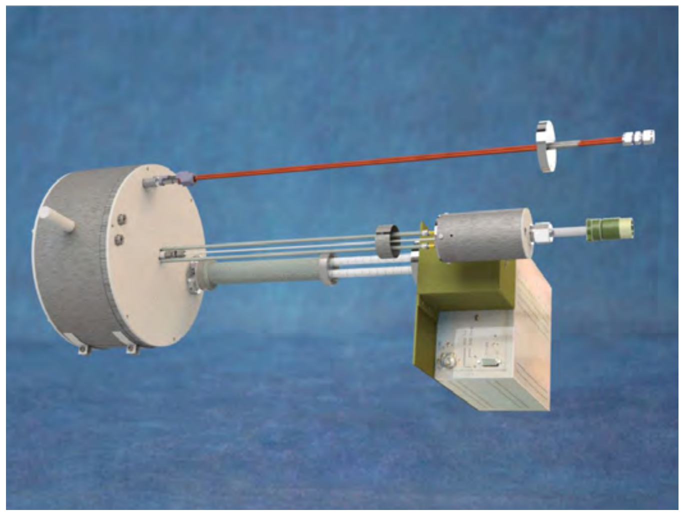
⚠ **TIP:** Install the source first - then the grid assembly. Consult our website for assembly drawings and videos pertaining to the installation of the source grid assembly and discharge chamber.

⚠ **TIP:** Please consult the I-BEAM power supply manual for its proper installation. Our website also has a power supply installation video.

⚠ **TIP**: Please consult the RFN manual for its proper installation.



Flange mount - 16 cm source on 16.5" conflat flange



Internal mount - 16 cm source with 2.75" flanges

The internal mount source allows the user to aim the source in a specific direction. The flange mount source bolts directly to a vacuum system and its orientation cannot be adjusted.

Internal and Flange mount

Step 1: Vent the system. Remove the flange to be replaced by the flange mount source or remove the feed-through blanks to be replaced by the feedthroughs for the internal mount source.

Step 2: Prepare the flanges and feedthroughs. Wipe all debris from open port on the vacuum system. For o-ring type, apply a thin coating of vacuum grease to the supplied o-ring, and install the o-ring on the chamber orifice. For metal seal type, clean and install the metal gasket.

Flange mount

Step 3A: Use appropriate lift assistance to pilot the source assembly into position on the chamber. The assembly is quite heavy. Make sure the o-ring or gasket retains its position.

Step 3B: Bolt it to the chamber gradually, using a star pattern and tightening each bolt, each pass. Install the high voltage cover when finished.

Internal mount

Step 3A: Place the source body inside the chamber and position it to line up with the feed-through connections. Secure it loosely for now.

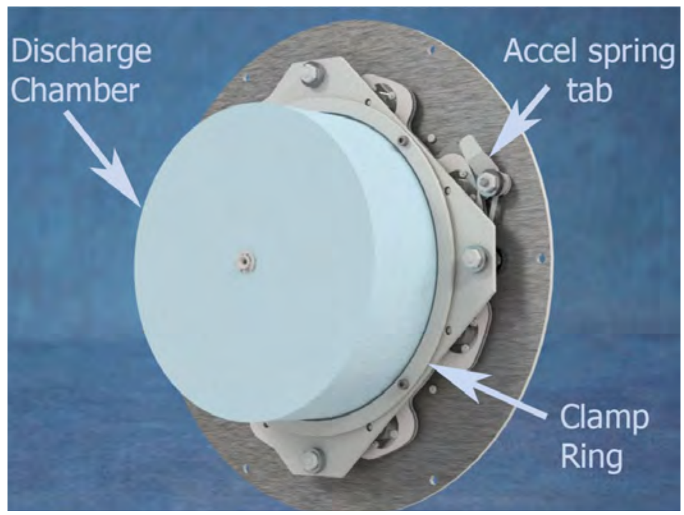
Step 3B: Connect the gas line from the feed-through to the source.

Step 3C: Connect the DC power leads from the feed-through to the source.

Step 3D: Connect the antenna feed-through to the antenna inside the source body.

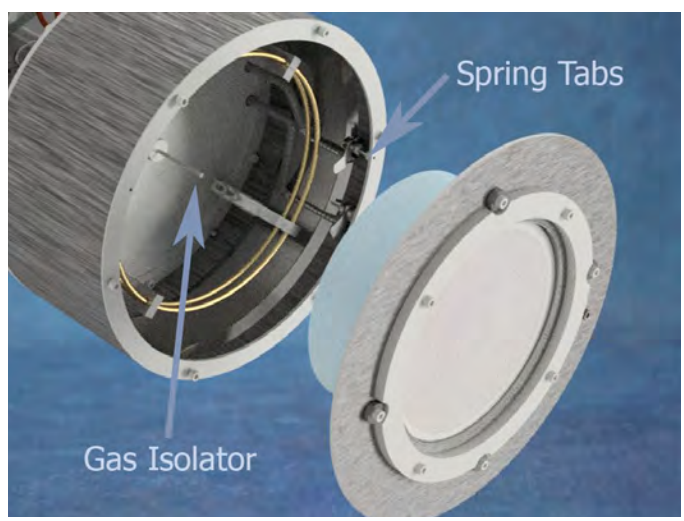
Internal and Flange mount

Step 4: Prepare the grid assembly for installation by first removing the clamp ring. Install the quartz discharge chamber onto the grid assembly. The discharge chamber should have some movement freedom when installed properly. Be careful - the quartz discharge chamber is fragile!



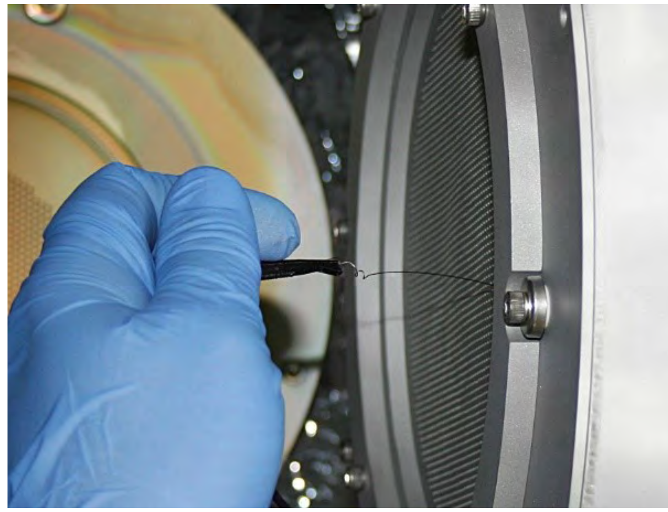
Attach discharge chamber

Step 5: Mount the grid assembly to the source by lining up the spring tabs between the source and grid assembly first. Then slowly insert the gas isolator into the discharge chamber. Secure finger tight using a star pattern.



Align grids with spring tabs and install gently.

Step 6: It is good practice to ensure the spring tabs are connected. For sources with molybdenum grids, perform a continuity test between the pins of the feed-through and each grid. Use a multimeter (preferably with an audible continuity test tone) with a fine wire probe. Do NOT perform this test with graphite grids as they are fragile.



Checking electrical continuity on molybdenum grids.

Continuity at the feedthrough should be as follows:

o **Feedthrough Pin A** to Accel grid (and not conductive to Ground or other pins)

o **Feedthrough Pin B** to Screen grid (and not conductive to Ground or other pins)

o **Feedthrough Pins C & D** to Decel grid (and should be to Ground only)

Internal mount

Step 7A: Mount the RF matching network to your chamber and connect it to the antenna feed-through.

Step 7B: Install the high voltage covers over the antenna connections and the DC feedthrough.

Step 7C: Connect a cooling water supply to one end of the supplied 7-foot antenna poly tubes. Connect the other 7-foot poly tube from the other antenna connection to one end of the shroud water feedthrough. Connect the drain line to the other shroud water connection. The source shroud and antenna will now be cooled in series.

Flange mount

Step 7: Connect a water supply and drain line to the respective In and Out water connections on the flange feed-throughs.

Internal and Flange mount

Step 8: Connect the gas supply line from the mass flow controller to the source.

Step 9: Install the RFN and its matching network to the desired vacuum port. Connect its gas line from the mass flow controller.

Step 10: Connect the RF cables from the source and RFN to their appropriate connectors on the power supply. The red-colored RF cable is for the source connection, the blue colored cable is for the RFN connection. **NOTE: Incorrect connections can damage the ion source.**

Step 11: Follow the I-BEAM power supply manual to complete installation of the power supply and its connections. Connect the interlocks as required.

Step 12: Pump down the vacuum chamber. Leak check all vacuum ports that have been affected.

Step 13: Slowly open the coolant water valve. Watch for a rise in chamber pressure from an internal leak, and look for any external leaks (potentially introduced during shipping).

Step 14: Check proper operation of the gas supply to the source and RFN.

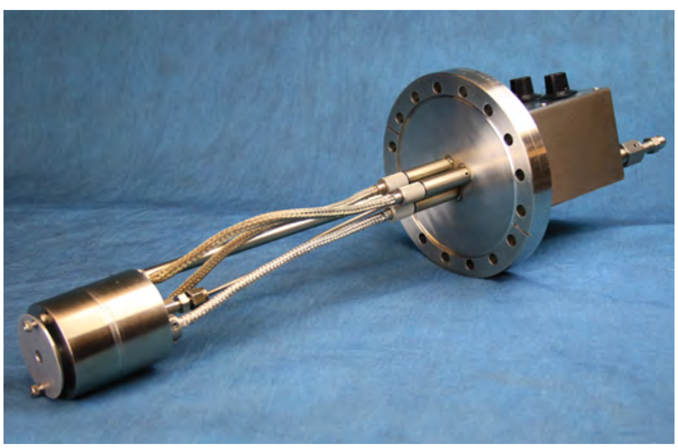
Step 15: The source should now be ready for operation. If you are unsure of any item, please contact us for assistance.

Chapter 3: Specifications

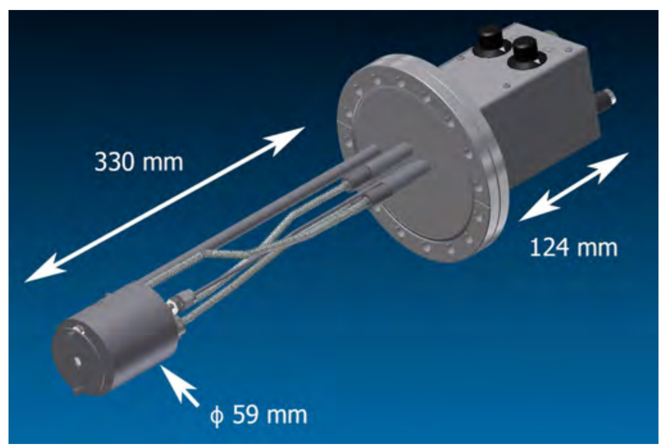
Each ion beam source will have a range of operating conditions that it can achieve under typical running conditions. The data in this chapter are typical and have been optimized for proper operation. Critical parameters for the source will be the beam current (number of ions leaving the source), beam voltage (ion energy) and accelerator voltage. The **maximum** beam current will vary with beam voltage. Grid material may play a role in the process and please consult our *Grid Selection Guide* on-line or call for assistance.

SPECIFICATIONS				
SOURCE	BEAM CURRENT	BEAM VOLTAGE	GRIDS	COOLING
6 cm	25 - 200 mA	50 - 1500 V	molybdenum or graphite	antenna
12 cm	50 - 400 mA	50 - 1500 V	molybdenum or graphite	antenna and shroud
16 cm	100 - 1000 mA	100 - 1500 V	molybdenum or graphite	antenna and shroud
23 cm	200 - 1500 mA	100 - 1250 V	molybdenum	antenna
6 x 22 cm	50 - 500 mA	50 - 1500 V	molybdenum	antenna
6 x 30 cm	50 - 500 mA	50 - 1500 V	graphite	antenna

Section 3.1: Specifications for RF Neutralizer (RFN)



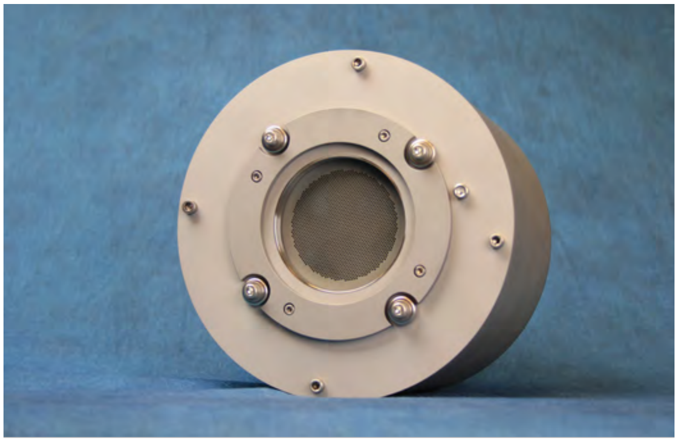
RFN and match network on a 6" CF flange



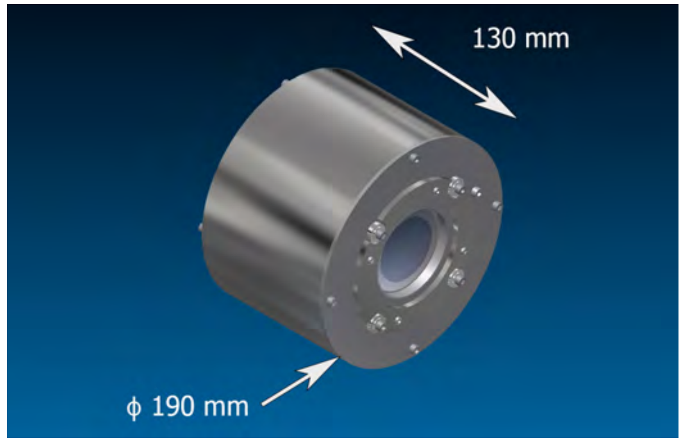
Dimensions and weight: 4.4 kg

NOMINAL PERFORMANCE DATA - USING ARGON @ 5 SCCM				
NEUTRALIZER	RF POWER		KEEPER	
Emission (mA)	Forward (W)	Reflected (W)	Voltage (V)	Current (mA)
100	40	0	24	300
500	50	0	25	300
900	60	0	22	300
1500	90	2	40	200
1750	90	2	45	200
500 idle	65 warm up	1	27	300

Section 3.2: Specifications for 6 cm RF



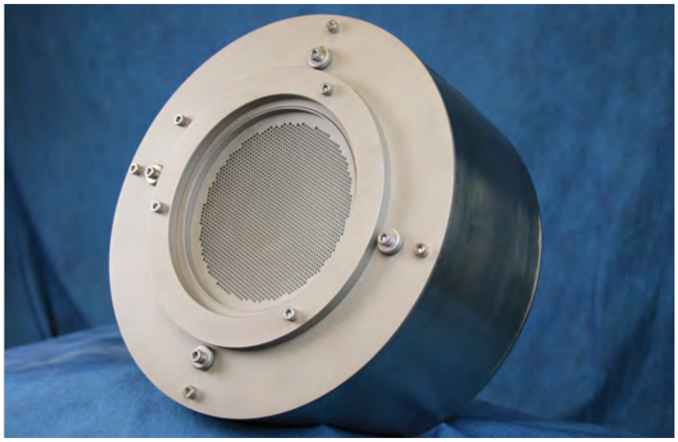
6 cm RF ion beam source



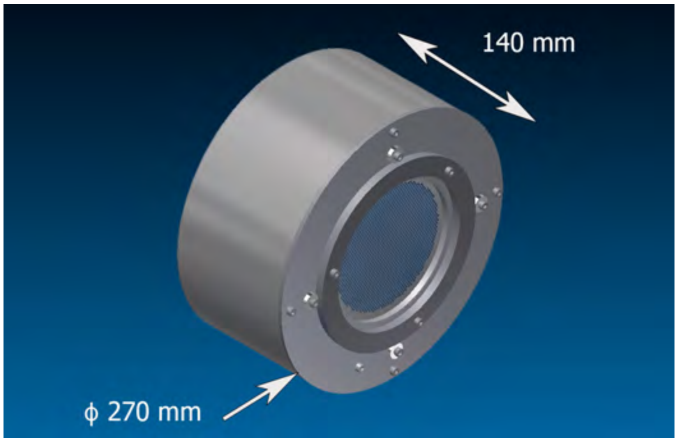
Dimensions and weight: 3.6kg

NOMINAL PERFORMANCE DATA - USING ARGON @ 8 SCCM						
BEAM		ACCELERATOR		RF POWER		NEUTRALIZER
Voltage (V)	Current (mA)	Voltage (V)	Current (mA)	Forward (W)	Reflected (W)	Emission (mA)
100	100	500	14	258	1	150
250	100	350	14	256	0	150
500	150	300	12	373	1	225
1000	200	250	2	446	2	300
1250	200	150	2	412	2	300
1500	200	150	2	391	2	300
100-1500	50 floor	100	~1	~80	1	75
50 idle	~50 typical			150 idle		500

Section 3.3: Specifications for 12 cm RF



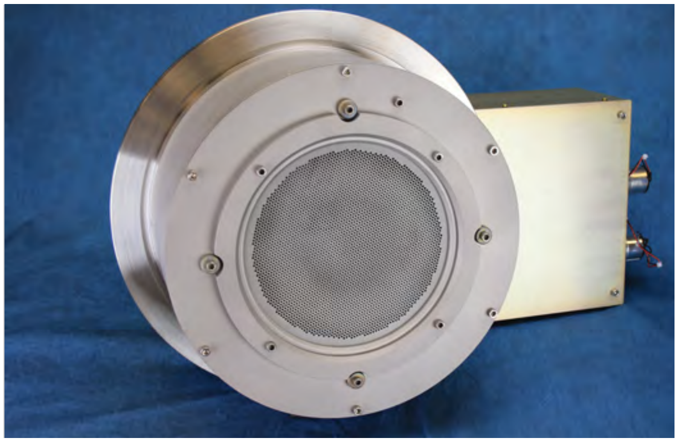
12 cm RF ion beam source



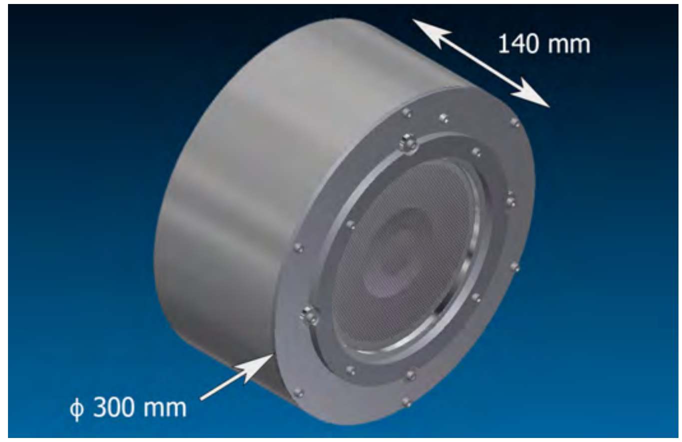
Dimensions and weight: 6.8 kg

NOMINAL PERFORMANCE DATA - USING ARGON @ 10 SCCM						
BEAM		ACCELERATOR		RF POWER		NEUTRALIZER
Voltage (V)	Current (mA)	Voltage (V)	Current (mA)	Forward (W)	Reflected (W)	Emission (mA)
250	150	300	3	143	0	225
500	150	300	4	139	0	225
750	200	250	5	163	0	300
1000	400	250	9	280	0	300
1250	400	200	8	270	0	600
1500	400	200	7	260	0	600
250-1500	50 floor	250	~1	~91	0	75
50 idle	~60 typical			200 idle		500

Section 3.4: Specifications for 16 cm RF



16 cm RF ion beam source



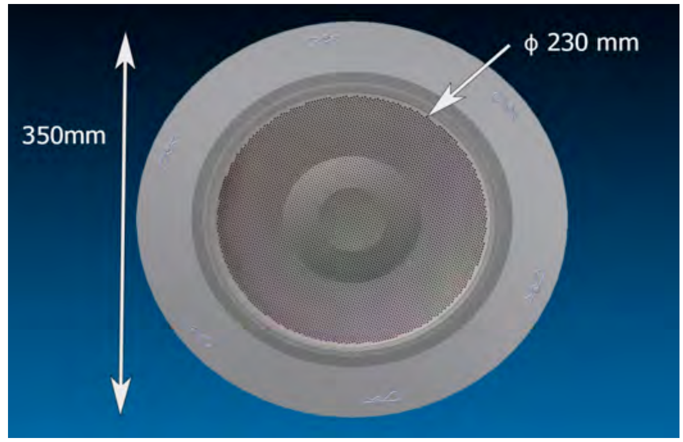
Dimensions and weight: 7.7 kg

NOMINAL PERFORMANCE DATA - USING ARGON @ 18 SCCM

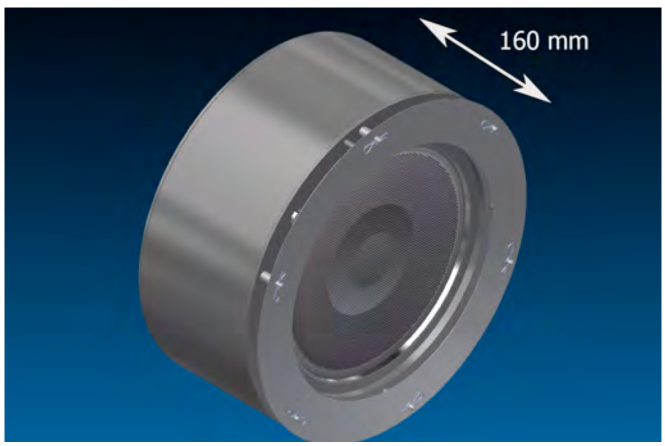
BEAM		ACCELERATOR		RF POWER		NEUTRALIZER
Voltage (V)	**Current (mA)**	**Voltage (V)**	**Current (mA)**	**Forward (W)**	**Reflected (W)**	**Emission (mA)**
250	300	550	11	199	0	450
500	300	400	8	193	0	450
750	450	300	17	266	0	675
1000	600	350	18	347	1	900
1250	600	250	15	352	2	900
1250	800	400	24	485	4	1200
1500	800	250	20	475	3	1200
250-1500	100 floor	200	~3	~94	1	150
50 idle	~40 typical			250 idle		500

Section 3.5: Specifications for 23 cm RF

23 cm RF ion beam source

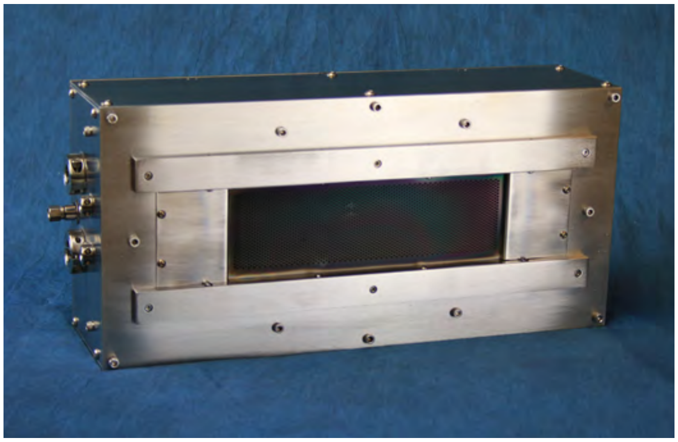


Dimensions and weight: 22 kg

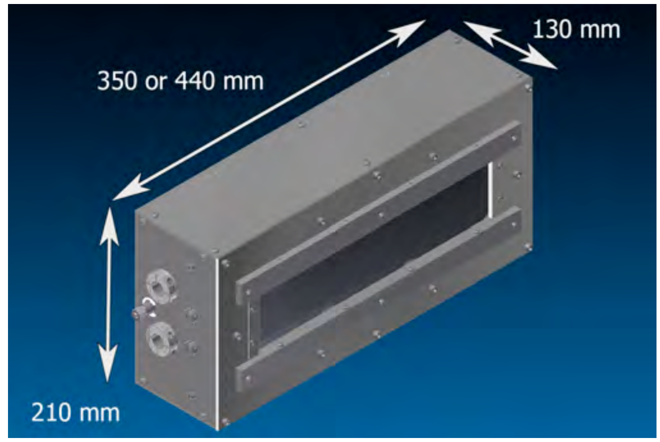


NOMINAL PERFORMANCE DATA - USING ARGON @ 20 SCCM						
BEAM		ACCELERATOR		RF POWER		NEUTRALIZER
Voltage (V)	Current (mA)	Voltage (V)	Current (mA)	Forward (W)	Reflected (W)	Emission (mA)
100	1000	1000	58	510	0	1500
250	1000	750	64	460	0	1500
500	1100	500	62	450	0	1650
750	1250	300	55	520	0	1562
1000	1500	250	59	640	0	2000
1250	1500	250	60	630	1	2000
100-1500	300 floor	200	~16	~125	1	450
30 idle	~90 typical			150 idle		500

Section 3.6: Specifications for Linear RF



6x22 and 6x30 cm RF ion beam source

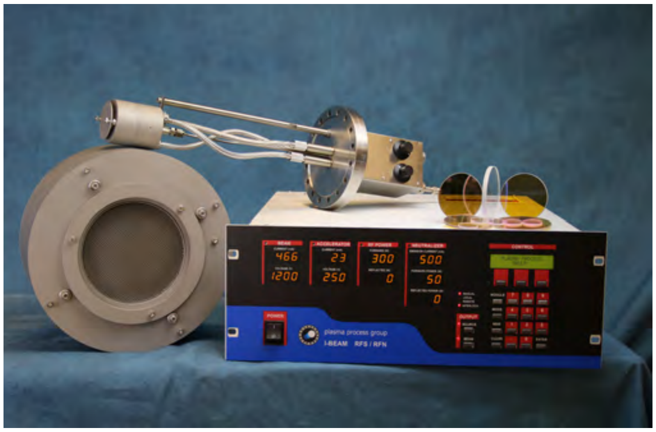


Dimensions and weight: 11.9 kg

NOMINAL PERFORMANCE DATA - USING ARGON @ 20 SCCM						
BEAM		ACCELERATOR		RF POWER		NEUTRALIZER
Voltage (V)	Current (mA)	Voltage (V)	Current (mA)	Forward (W)	Reflected (W)	Emission (mA)
100	250	600	11	387	3	375
250	300	500	15	435	4	450
500	300	400	13	485	3	525
1000	450	200	12	464	4	525
1250	500	200	12	453	4	525
1500	500	200	12	450	4	600
100-1500	100 floor	200	3	210	3	150
50 idle	~20 typical			200 idle		500

The 6x22 cm source can only use 6x22 grid assemblies (molybdenum).
The 6x30 cm source can use 6x22 cm grid assemblies (molybdenum) or 6x30 cm grids (graphite).

Section 3.7: Power Supply Specifications



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

I-BEAM POWER SUPPLY CONFIGURATIONS				
MODEL	**BEAM CURRENT**	**BEAM VOLTAGE**	**RF GENERATOR**	**interface box IBOX**
703-1-0	600 mA	1500 V	500 W	no
703-1-1	600 mA	1500 V	500 W	yes
703-2-0	800 mA	1500 V	500 W	no
703-2-1	800 mA	1500 V	500 W	yes
703-4-0	1000 mA	1500 V	500 W	no
703-4-1	1000 mA	1500 V	500 W	yes
701-6-1-2	1500 mA	1250 V	1000 W external	yes

Chapter 4: Operation

With the ion beam source installed in the vacuum chamber as described in the previous chapters, it is now ready for operation. This chapter will describe nominal operation of the source.

Section 4.1: Quick Start Sequence

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. Please check the power supply manual for proper interlock specifications.

VACUUM SPECIFICATIONS		
PARAMETER	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 $5x10^{-4}$ 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

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. Please check the power supply manual for proper interlock specifications.

TIP - Under base pressure conditions (with source gas off) turn the water flow ON and close its drain. This will test the water line at maximum water pressure and check if there are any leaks in the vacuum system.

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.

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. Consult the power supply manual for menu navigation and the location of these parameters.

		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%

WARNING

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

CAUTION

The power supply will accept commands that may cause operating issues with the source. Please examine the typical source data in the *Chapter 3 - Specifications* of this manual.

Step 5: Select MODE of operation for the source.

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.

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

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. The accelerator current is induced by charge-exchange ions created in the vicinity of the accelerator grid. The production of these charge-exchange ions is proportional to the source gas flow rate and chamber pressure. The charge-exchange ions are attracted to the accelerator grid, impinge, and are detected as accelerator current. The impingement process will result in sputtering of the accel grid and excessive accelerator current will reduce the life of the grid. For properly aligned grids and reasonable operating conditions, the accelerator current is typically less than 10% of the beam current. The RF Source and RF Neutralizer reflected power is dependent upon the matching networks and how well they are tuned.

Step 6: Select desired beam conditions.

Set the beam and accelerator voltage for the desired condition. Study the data in *Chapter 3 - Specifications* to select the appropriate beam current, beam voltage and accelerator voltage. 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. *Chapter 3 - Specifications* has typical idle currents for sources with clean grids.

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 *Chapter 3 - Specifications* to see the maximum beam currents for various beam voltages. Also, please refer to *Chapter 5 - Advanced Operation* for a detailed description on how to optimize the accelerator voltage.

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 the power supply manual 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 4.2: 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 *Chapter 5 - Advanced Operation* in this manual.

If the source did not start, or there were any other issues, please consult *Chapter 7 - Troubleshooting* section of this manual.

Please contact us anytime for guidance and support.

Chapter 5: Advanced Operation

This chapter will provide a more in depth description of the source operation. It is designed to add more detail to the previous chapters and is divided into 3 main sections. These are grid theory, source ignition, and technical tips.

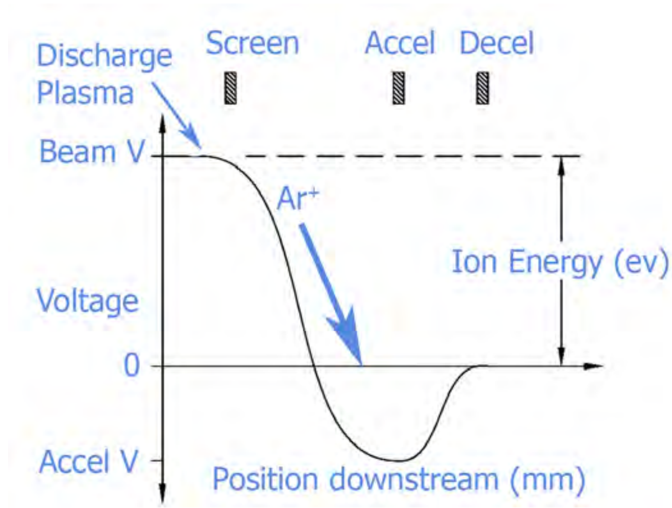
Section 5.1: Grid Theory

Extraction and acceleration of plasma ions.

The plasma created in the discharge chamber will contain ions and electrons. To extract just the ions, a grid assembly is connected and exposed to the plasma. The grids are electrodes separated from each other by roughly one millimeter. The grid closest to the discharge chamber is referred to as the screen (S) grid and is also sometimes called the “beam grid” since beam voltage is normally applied to it. Moving downstream – that is, following the path of an ion out from the source - the next grid is referred to as the accelerator (A) grid, and is also sometimes called the “suppressor grid”. On many sources a third grid is used and is the furthest downstream from the discharge chamber. This is referred to as the decelerator (D) grid and is also sometimes called the “ground grid” since it is normally at ground potential.

The grid assembly extracts ions from the discharge chamber by applying specific potentials (voltages) to each grid. A potential (or voltage) diagram of the ion acceleration process illustrates this ion acceleration process.

First, the screen grid is biased positive (beam voltage) with respect to ground. The plasma is conductive and will naturally bias itself slightly more positive than the screen grid potential. Next, the accelerator grid is biased negative (accel voltage) with respect to ground. Positive ions in the discharge chamber that drift near the hole in the screen grid will be electrostatically attracted by the negative potential on the accelerator grid. The power supply **does not** display the negative sign on the accelerator module.



Electrostatic potential hill within a grid assembly

The size of the holes in the grids, the spacing between the grids, and the voltages applied to the grids are carefully chosen to insure the accelerated ions are moving on a directional path such that they pass through the holes in the accelerator grid rather than hitting it.

Ion energy - conversion of potential to kinetic energy

The decelerator grid potential is held at ground (0 V). If the decelerator grid was removed, the electrostatic potential in the downstream plasma environment (within a few mm of the accel grid) is approximately zero because this downstream plasma is in contact with the grounded vacuum chamber. After passing the accelerator grid, the ions are then slowed down (decelerated) by the potential difference between the accel and decel grids (which is just the accelerator voltage). The ion has sufficient momentum to carry it through the aligned hole in the decelerator grid. Ions then exit the decelerator grid hole with a net kinetic ion energy approximately equal to the potential energy applied by the screen grid. Therefore, the kinetic energy of the ion after it has been extracted through the grids is expressed in electron volts, or eV, and is equal to the beam voltage (multiplied by 1 eV / V).

Conceptually, as an ion passes through the grids and into the vacuum chamber one can think of a roller coaster which starts at the top of the biggest hill (potential energy), screams to the lowest point, then slows a little as it comes back up a medium sized hill, then continues at constant velocity (kinetic energy) across a flat region. A roller coaster that is traveling at velocities reaching km/s.

Grids - the takeaway

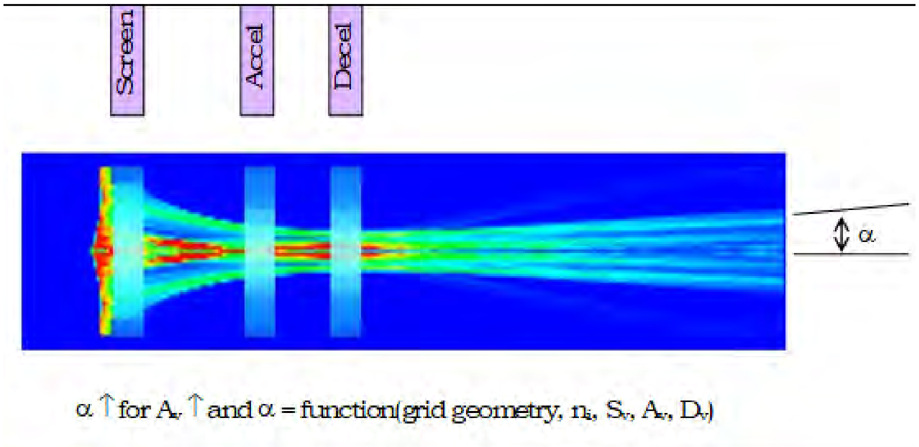
The Screen grid will:
- Apply potential to the plasma in the discharge chamber.
- Starts the process for ion acceleration and sets up the ion trajectories.

The Accelerator grid will:
- Accelerate the ions and focus them to create a beam.
- Prevent electrons in the plasma from escaping the discharge chamber via any path other than hitting and conducting through the screen grid.
- Prevent electrons downstream (e.g. from the neutralizer) from entering the ion source through the grid holes.

The Decelerator grid will:
- Prevent sputtered material from accumulating on the accelerator and screen grids.
- Give additional structural support to the grid set, minimizing warping and shape changes of the other grids.

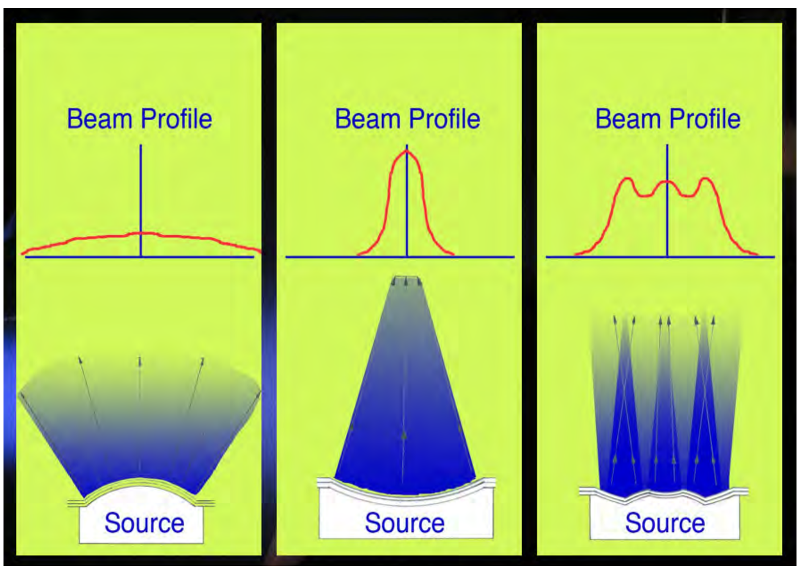
The beamlet

When run properly, ions extracted through grid apertures will focus into a beamlet. The beamlet will start to diverge immediately downstream from the source and this is called the divergence half angle (α). This divergence depends on many factors, including grid geometry, plasma density inside the discharge chamber, and voltages on the grids. This subject is generally called *ion optics* and it is important to be aware that a change of any of these parameters may result in a change of beamlet divergence and ion distribution in the beam.



Beamlet focusing example

The beamlets will combine and form a larger broad beam. The broad beam can then be shaped by the grid assembly and its geometry. For flat grids, such as graphite, the broad beam will diverge at the half angle (α). However, if the grid assembly is dished, such as molybdenum, the beam shape can be tailored for a specific application. To quantify these changes, the beam current density (in mA/cm^2) is measured along a "slice" through the middle of the beam to obtain a beam profile. The figure below illustrates this concept.



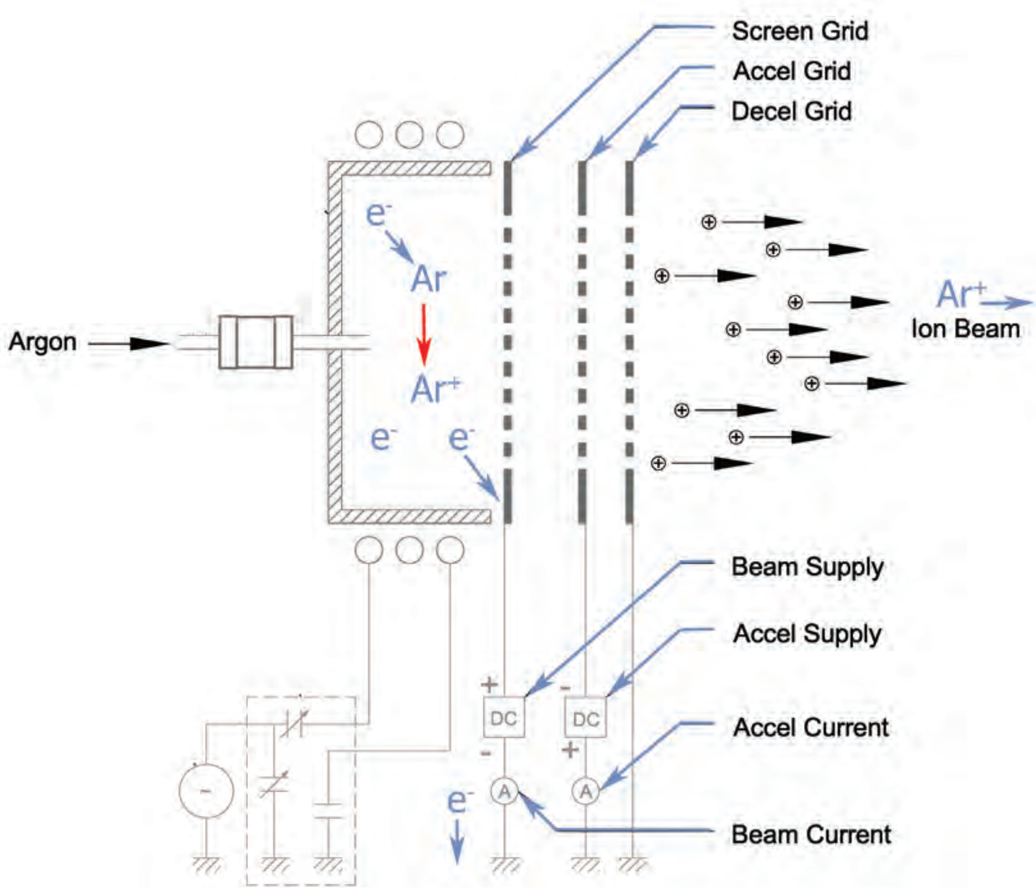
Adjusting grid shape to change current density

Best practice is to select the grid style as the first priority. Please see our *Grid Selection Guide* on our website and call for assistance. Once grids are selected, there will be very limited adjustment to the individual beamlet focusing.

Beam takeaway

Ion distribution (energy, dose, incidence angle) all have strong effects on the process result.

- The ion energy is adjusted with the beam voltage.
- The dose is controlled with the beam current.
- The incidence angle is controlled by the grid shape, divergence half angle (α), and system geometry.



Ionization process and detection of beam current

Beam Current Measurement

As ions are created and exit the ion source through the grids, extra electrons are also produced inside the discharge chamber. These electrons can create additional ions or be collected at the screen grid (or any surface in contact with the screen grid). Unless there is a plasma leak, discharge electrons will stay confined in the discharge chamber. These electrons will be repelled by the negative potential on the accelerator grid and cannot escape as the gas isolator and discharge chamber are non conductive. The ion leaving the source will eventually pickup an electron from the vacuum tank environment which is ground. So for every ion that leaves the source, an electron will be collected at the screen grid and will be detected as beam current.

However...

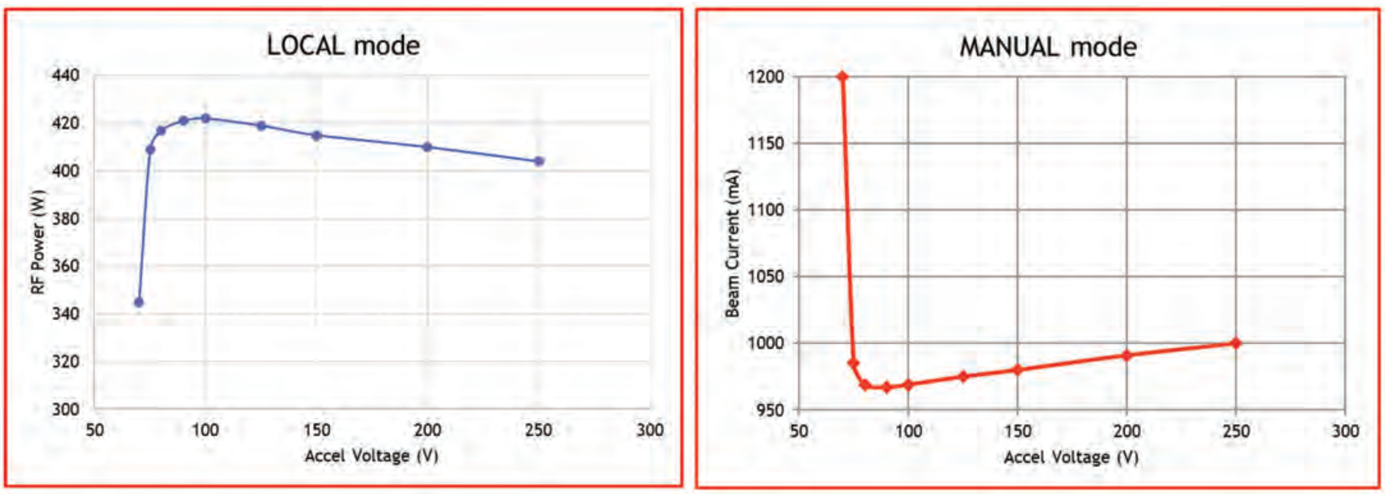
Electron Backstreaming

If the accelerator grid voltage is set too low, it is possible for downstream electrons from the neutralizer to migrate into the discharge plasma inside the ion source. This condition is referred to as electron backstreaming. Electron backstreaming will lead to erroneous beam current readings as the backstreaming electron will look the same to the power supply as ions going out through the grids. The end result will be a lower etch rate on the target and a lower deposition rate.

Electron Backstreaming continued

In the example graph below the accelerator voltage of a 23 cm RF ion source was systematically lowered while the power supply is in LOCAL mode. The power supply adjusts the RF power as needed to keep the beam current at the requested level (in this case, 1000 mA). At some point below 100V electrons begin to enter the ion source through the grids. Since some fraction of the beam current is a measurement error the I-Beam power supply thinks less RF power is needed to achieve the request, and we see a non-linear drop in RF power. At the last captured data point (70V) the level of electron backstreaming is very high, causing the beam voltage and current as well as the accelerator voltage and current to become unstable.

This behavior is different if the power supply is in MANUAL mode whereby the beam current sharply rises when backstreaming starts to occur.



Detection of electron backstreaming

The most common cause of backstreaming occurs when the accelerator grid is not connected (i.e. spring tab misalignment). In this circumstance, the accelerator grid does not have an electrical connection (or potential) and downstream electrons can freely see the positive potential of the screen grid. In LOCAL mode, the RF power will start to drop as the power supply thinks there is sufficient beam current. If the source is left unattended, this type of backstreaming can damage the accelerator grid and power supply. The symptoms of an open circuit on the accelerator grid are A) little or no measured accelerator current, B) abnormally low RF power, and C) abnormally low etch or deposition rate.

Another cause for backstreaming is when non-conductive material accumulates on the accelerator grid. The insulative coating will reduce the effective accelerator voltage and its potential will start to drop. The mechanism for this effect are charge exchange ions that accumulate on the coating. The behavior is similar to a capacitor where the charge cannot pass through the coating. The accelerator voltage can be increased to compensate for any backstreaming or the accel grid requires cleaning.

Backstreaming takeaway

Backstreaming will induce errors in the measured beam current.

- Make sure the accelerator grid is connected, has a detectable current, and is clean.
- Keep an eye on RF power required and deposition rates.

Accel Current, Voltage and Charge Exchange

$$Ar_{slow} + Ar^{+}_{fast} \rightarrow Ar^{+}_{slow} + Ar_{fast}$$

Charge exchange reaction

Charge exchange reaction is the process whereby a fast moving ion (created by the source) will encounter a slow moving neutral (unused source gas). The slow moving neutral will pick up the positive charge and the ion will become a fast moving neutral. This natural process becomes important when it occurs near the grid region of the source. When slow moving ions are created in the vicinity of the accel grid, they will be attracted to its negative potential and impinge with the charge collected. The accelerator power supply will detect this charge and it is defined as accelerator current. It is worth noting the accelerator current is only detected and not adjustable.

The charge exchange reaction will increase when there are more neutrals present. Excessive source gas flow or high pressure in the vacuum chamber will promote the reaction. As a result, the detected accelerator current will increase.

Most of the time and under typical source conditions, the accelerator current is due to the charge exchange reaction. Accelerator current can also arise from direct impingement of the beam ions (i.e. a severe backstreaming case). Both situations will induce accel grid erosion and reduce grid life. The grid erosion from charge exchange is proportional to the accelerator voltage as this sets the ion energy. The sputtering of the accelerator grid may induce unwanted contamination for some processes.

Accel voltage optimization

For some applications it can be useful to optimize the accelerator voltage. For low ion energy applications (i.e. etch) a higher accelerator voltage (i.e. 750 V) will help spread the beam out. For high ion energy applications (i.e. sputtering) an accelerator voltage just above the backstreaming limit (i.e. 150V above limit) will promote a focused beam with limited backstreaming and minimized grid erosion due to charge exchange. The data in *Chapter 3 - Specifications* are for optimized accelerator voltages. Please contact us for guidance if different voltages are necessary.

Takeaway

The critical aspects of the accelerator current and voltage are:

- Normal accelerator current is due to charge exchange ions.
- Accel grid erosion is due to the charge exchange ions impinging at an energy near the accelerator voltage.

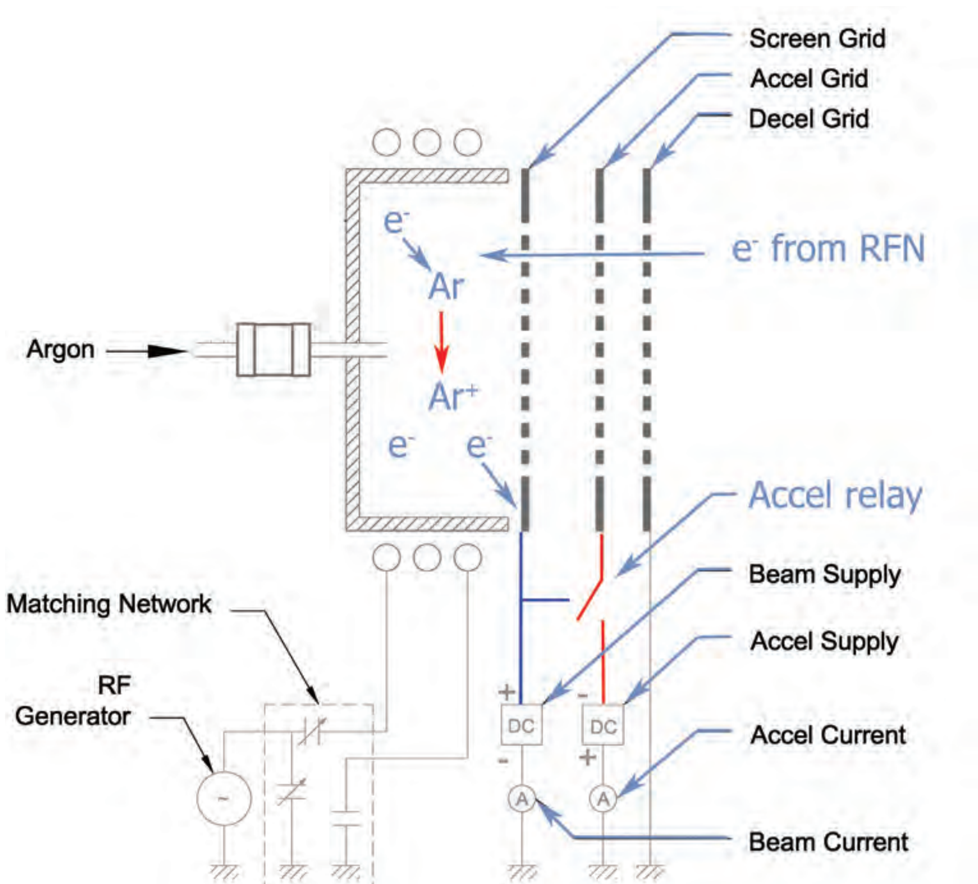
Section 5.2: Source Ignition

RFN and Source Ignition

The ionization process inside the RFN or discharge chamber of the source may begin immediately when RF power is applied to the its RF coil. For these situations, the RFN or source has self started by using free electrons in the gas and oscillating these electrons in the RF field to create ions. For the RFN, it will toggle its START / RUN relay checking to see if a discharge has started between its collector and keeper. Unless there are issues, the RFN will ignite after a few cycles as it has been designed for this self starting characteristic. For additional information about the RFN please refer to the *RFN manual*.

BV Pulse

Regardless if the source self starts, it utilizes electrons from the RFN as an ignition source. After the RFN has started, the source will apply the RF power to its antenna and when the RF power level reaches the RF START power, a relay on the accelerator power supply is used to connect the screen and accel grids together electronically. The beam power supply then pulses both grids positive simultaneously to the BV PULSE setting. This event is designed to pull electrons created by the RFN into the source discharge chamber to start the ionization process.



Source ignition by pulsing the grids and relay.

The screen and accel grids remain connected to the beam supply as it will pulse and then drop back to an idle condition set by the BV IDLE. In the idle condition, the power supply will check to see if there is any ion current leaving the source by monitoring the beam current meter. If the current detected on the beam current meter is less than the start detect current (START DETECT I), the pulse process is repeated until the source ignites or a time out occurs.

BV IDLE

Once plasma has started inside the source, the discharge is sustained by applying a low voltage (BV IDLE) simultaneously to the screen and accel grid. During this process, a small number of ions will exit the ion source through the grids because the screen and accel grid are held at this idle voltage (usually 50V positive). These ions are low energy (50 eV) and are non-isotropic in direction. The screen and accel grids remain connected to each other when the source is ON and beam is OFF. When the beam is turned ON the accel relay releases so the accelerator grid is biased using its own supply.

START DETECT I

The mechanism by which the power supply recognizes a discharge has started is the monitoring of the beam current during the idle setting. In idle mode, if the beam current is greater than the start detect current (START DETECT I), the source is considered to be started and a plasma exists. This parameter is usually set to 5 mA and represents a threshold whereby if the detected current on the beam supply is greater than this value, the source is considered to be started and a plasma exists. If at any time this detected current drops below the threshold, the power supply considers that event as the discharge extinguishing. If the beam current drops below the start detect current setting for longer than one second, an alarm is initiated which turns off the ion source (even though it might already be off). The error code displayed on the I-BEAM supply is “-71-”, referred to as the “E-71” alarm and the source discharge has extinguished.

Section 5.3: Source Ignition Sequence

In this section, the RFN and source startup sequence is described in greater detail than the quick start guide presented in *Chapter 4 - Operation*. Our goal for this chapter is to provide detail that may be useful for troubleshooting RFN and source issues. This section will hopefully provide further insight to rectify potential issues in the field.

Please prepare the vacuum system, gas, water flow and source as described in the quick start guide within *Chapter 4 - Operation* before continuing. The source and RFN should be ready to turn on.

Pressing the SOURCE BUTTON on the I-BEAM

Pressing the SOURCE BUTTON can also be performed using the software command "S1" or using a remote switch. Please consult the I-BEAM power supply on the different methods for turning on the source.

Start the RFN first

1) When the SOURCE is turned ON, the supply turns on the RFN RF output and begins to ramp up to the programmed RFN start power of 100 W. Additionally, the keeper and emission DC bias circuits are activated. Switching of the RFN Matching Network relay begins with 10 second cycle where 8 seconds are used to start the RFN and 2 seconds are used to check to see if ignition has occurred.

2) During the RFN start cycle, the I-BEAM checks for RFN emission current. If the emission current is greater than 40 mA for one cycle, the I-Beam considers the RFN started. The power supply will attempt 10 start cycles and post an alarm if the RFN did not start. Otherwise, the power supply will adjust the RFN RF power to the warm up power setting of 65 W and idle emission current of 500 mA. A feedback control loop monitors the emission current and adjusts the bias voltage on the collector supply up or down as needed to keep the emission current at target.

3) After the RFN has started, the RFN RF power will remain at an elevated “warm up” power level for 5 minutes. During this time the RF power is higher than appropriate for the 500 mA emission level, so the emission may be slightly unstable until the warm up period ends. There are special cases where the warm up period will be skipped (e.g. restarted after an error). When the warm up is complete, the RFN will adjust to its normal idle condition of 50 W, and 500 mA emission.

Start the source next

4) Once the RFN has started, the RF generator will begin to apply the RF power to the source, attempting to reach the programmed START POWER setting. Consult section *4.1 Quick Start Sequence* for START POWER values for different source sizes. The matching network will automatically adjust to tune the applied power, maintaining a low reflected power as best it can. If there are tuning issues, the two capacitors in the matching network may travel to their limits which may induce E-80 alarm.

5) When the source RF power has reached the START POWER setting, the power supply begins to pulse the screen and accel grids using the BV PULSE and BV IDLE settings. This process is described in the previous section and in section *4.1 Quick Start Sequence* are typical values for these settings.

6) During any time while the beam voltage is at the BV IDLE setting, if the beam current is above the “Start Detect” level (default value is 5 mA), the I-Beam considers the plasma in the source to be started and will

proceed to adjust the RF power to the IDLE POWER setting.

7) The source should be allowed to warm up for 20 minutes prior to turning the beam on.

Turning on the beam - too early
8) If the beam button is pressed when the I-Beam believes the source has NOT yet started, an alarm will occur, and the beam switch will turn back off. If the beam button is pressed immediately after source started, and before RF power ramps down to the idle level, the beam on command will be ignored.

Pressing the BEAM BUTTON on the I-BEAM

Pressing the BEAM BUTTON can also be performed using the software command "B1" or using a remote switch. Please consult the I-BEAM power supply on the different methods for turning on the beam.

Turning on the beam
9) When the beam is turned ON, the accel relay will reconnect the accelerator grid to its power supply. Next, the I-BEAM ramps the beam voltage to the BV setting, and about 1.5 second later ramps the accelerator voltage to the AV setting. Note that before the beam is turned ON the accelerator display screen on the I-BEAM will show the accelerator request value, but accelerator voltage is not applied to the accelerator grid. The accelerator grid will be at idle voltage potential (BV IDLE) as described in the previous section.

10) When both power supplies are ramping to the target settings, the beam current will rise. In LOCAL or REMOTE modes, the I-BEAM enables a control loop which will attempt to adjust the RF power as needed to reach the beam current setting (BI). In MANUAL mode, the I-BEAM will ramp the RF power to reach the RF power setting (RFS FWD POWER) and the beam current is not automatically controlled.

11) Simultaneous with step 10, 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.

Section 5.4: Technical Tips

Gas Flow Selection

In most cases, operating the ion source at the factory-recommended Argon gas flow level is best. If running the source on oxygen, or nitrogen, or a mixture of argon with those gases, additional gas flow may be required as these gases ionize differently. The RF source is also compatible with many other gas. Contact us to discuss your process needs and for help selecting gas flow level of alternative gases.

Occasionally, the pumping speed of a system may be unusually slow or fast. If you suspect your high vacuum pump falls into either category, additional testing may be needed to help select an optimal gas flow. Choose an upper mid-range ion source parameter set. For example these beam settings for a 16cm source: BI=600 mA, BV=1250V, AV=250V. With the beam ON and the power supply in LOCAL mode adjust the gas to the source from 50% to 150% of the nominal flow condition in increments of 2 sccm.

At each gas flow setting, record the RF power required to produce the desired beam current (e.g. 600 mA). If the source can run at 50% of the flow, the RF power will be at a high setting. As the gas flow increases, the RF power will start to drop and the accelerator current will increase. When the gas flow is increased but the RF power does not drop with much change (compared to the previous drop) - saturation in source efficiency has started. Further increase of gas flow has little or no effect on the efficiency of the source and accelerator current continues to climb. Generally, the recommended gas flow is near the saturation point for optimized RF power.

Heat generated

The kinetic energy of an ion is deposited in the surface which the ion strikes through collisions with surface atoms. Any energy which does not result in emitted (sputtered) particles is retained as heat. In some cases excessive ion beam heat may damage a target or substrate. The heat flux (in W/cm^2) delivered by the beam is proportional to the product of the ion dose per unit time at a given location (mA/cm^2) and the ion energy (V). Ultimate temperature will be a function of rate and method of cooling and the rate of heat delivery by the beam.

Heat is also generated inside the ion source from the application of RF power and creating a discharge. To combat this, the RF antenna is water-cooled, as is the source shroud for most ion sources. Heat is also eliminated radiatively to the chamber, however radiant heat is negligible compared to conductive transfer by water cooling.

Grid life

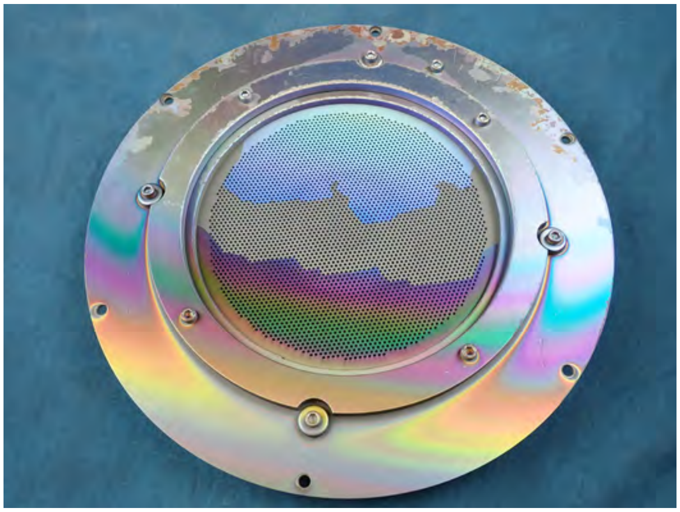
In most cases, process material will distort the grid assembly. The beam direction can then change and this will induce process variations such as deposition rate and uniformity drift.

Refurbishment at regular intervals is recommended to extend grid life. Keeping a spare grid assembly on hand is also recommended. The refurbishment process is described in *Chapter 6 - Maintenance* and *Appendix A* of this manual.

If the grid assembly is heavily coated and distorted, permanent grid damage may occur.

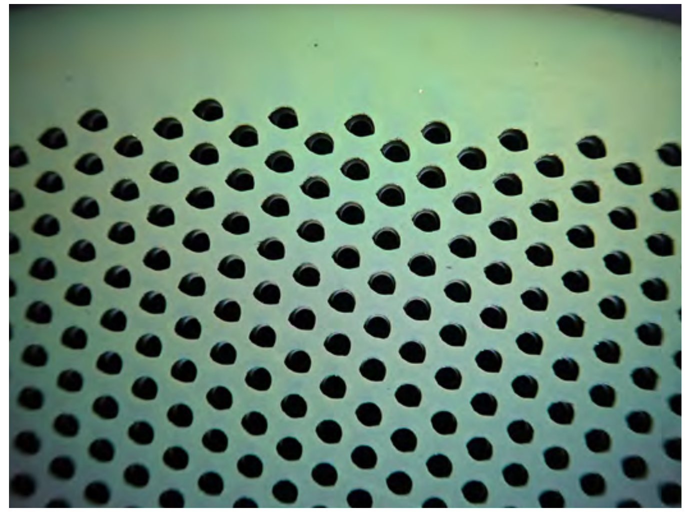
Grids will require replacement when they are worn beyond repair, usually discovered during a maintenance cycle.

The more common ways that grids deteriorate are wearing of the decelerator holes, direct impingement and delamination.



16 cm grids coated with oxide materials.

Impingement damage can occur when ions strike a grid directly. The most common mechanism for this is when the accelerator grid holes become unevenly coated near the edge of the grid. The beamlets will then steer and strike the decelerator grid. Impingement will also occur when grids are distorted, misaligned, or have uneven spacing. A coating flake can also create a temporary impingement situation. The damage to the grid will be holes that are shaped like teardrops or ovals. It is normal to have some of these holes, especially near the edge of the grid. Grids are usually replaced when this type of wear becomes excessive.



Impingement wear due to coating of the accelerator grid.

Delamination can occur when the molybdenum is nearing its end-of-life. Layers of material begin to separate between grid holes. The layers will distort and can peal back. Delamination will occur when grids have been cleaned numerous times. It can also be triggered when grids have been cleaned too aggressively (i.e. media blast at too high of pressure). The delaminated sections of the grid can trap water vapor and will promote grid arcing. When this condition is first noticed, consider it an alert the grids will need to be replaced soon.

Delamination is where the molybdenum starts to peal back, bubble, and separate between holes.

Chapter 6: Maintenance

General guidelines are provided here for the more common items that will require service on the ion source. The time between maintenance will vary as this can be system or process specific. The most common item that will require service are the molybdenum grids. *Appendix A* of this manual describes the cleaning procedure for grids but this process can be used to clean other source hardware. We also have videos on our website to assist with the maintenance process.

Section 6.1: Maintenance Work Station

Most items on the source require these basic tools for maintenance including cleaning and inspection. We recommend setting up a work center dedicated for this task. The location of this work center should be away from the clean environment of the vacuum system and large enough to provide a staging area for disassembly, cleaning and inspection.

Tools

- Clean room approved gloves for handling all exposed source and RFN parts.
- Tools for disassembly and assembly, (clean and oil free)
- Torque wrench (to 30 in-lbs)

Cleaning equipment

- Media blaster with 150 grit Aluminum Oxide media
- Hot water filtered to 3 microns
- Ultrasonic tank for final detergent cleaning
- Micro90 brand detergent for final cleaning (125 mL per 5 gallon of water)
- Distilled water for final rinse (2 gallons)
- Isopropyl alcohol for vacuum preparation
- Lab grade, dry nitrogen
- Heat lamp
- Clean room quality, lint free wipes
- Anti-static plastic bag for clean parts containment

Inspection equipment

- Standard micrometer for parts and grid measurement
- Microscope for inspection before and after media blasting
- High flatness granite block with dial indicator for surface to dome height measurement
- Insulation tester

Additional supplies

- Assembly drawings
- Acrylic grid assembly jig for alignment and re-assembly of the grids.

We recommend setting up processes and procedures for proper logging of the maintenance and documentation of measurements performed. It is important to keep track of the following information.

- Grid hours as determined by the time with the beam on.
- RFN hours as determined by the time the RFN is running.
- Source Discharge chamber hours as determined by the time with the beam on.
- Mounting hardware hours as determined by the time with the beam on.

Before and after cleaning, we recommend capturing the dome heights for molybdenum grids. These grids will change shape over several cleaning cycles and it can be useful to record the dome height history as this will provide guidance for when the grids need to be replaced.

Section 6.2: Schedule

The time for maintenance will be determined by the specifics of the process and how the ion beam source was used. The more common maintenance issues for a source in a sputter deposition system (i.e. worst case scenario) are presented in the table below. Please contact us for assistance with setting up the maintenance schedule.

SCHEDULE			
ITEM	**HOURS**	**ISSUE**	**REMEDY**
grid assembly	250 hours	grid distortion	clean grids
source discharge chamber	500-1000 hours	RF power drift	clean discharge chamber
mounting hardware	750 hours	particulate generation	clean hardware
RFN	2500 hours	cannot achieve emission current	replace collector and clean RFN assembly

END OF LIFE	
ITEM	**ISSUE**
grid assembly	excessive hole wear on decel grid, grid shape change, delamination from cleaning
RFN gas isolator	leaking between metal and ceramic bonding
RFN discharge chamber	orifice opening up due to excessive wear (cleanings and usage)
RFN	cannot achieve emission current, tuning issue

Section 6.3: Common Wear and Tear

Common issues with grids

For applications sensitive to uniformity and rate, grid distortion can create yield issues. Grids can distort when they become heavily coated with insulative materials (i.e. optical coatings) as these tend to be highly compressive in nature. Usually ion beam sources used for sputter deposition receive the heaviest of coatings. When these grids distort, the overall beam shape changes thereby influencing the sputtering plume. This beam steering will change the sputtering and etching processes such as rate or uniformity.

When grids become heavily coated with conductive materials, small flakes may detach from the grids creating grid shorts and arcing.

Best practice is to monitor the process behavior and schedule grid maintenance appropriately.

Molybdenum grids are easily cleaned. *Appendix A* of this manual describes the cleaning procedure and we have videos on our website to assist with this process. Graphite grids are not typically cleaned due to their fragile nature, but they can be lightly sanded in some cases.

Common issues with source discharge chamber

The source discharge chamber will slowly coat with process material that can reduce the efficiency of the RF discharge. When the discharge chamber becomes coated with a conductive (or partially conductive) coating, the coating will act as a Faraday shield and block the RF from penetrating the discharge chamber. The RF power on the source may slowly rise so it is important to clean this occasionally.

Common issues with mounting hardware

The hardware that supports the grids and discharge chamber will slowly become coated with the process materials. If this coating becomes too thick, it can detach and create unwanted particulates. This group of hardware can be cleaned using the same procedures for molybdenum grids (see *Appendix A*).

Common issues with the RFN

As the collector in the RFN oxidizes, it will become more difficult for the RFN to start or achieve target emission currents. Other RFN components such as the gas isolator and discharge chamber will wear. It is good practice to replace the collector during routine maintenance and check the gas isolator for leaks and inspect the orifice size of the discharge chamber. The fasteners inside the RFN should also be replaced during maintenance as they tend to gall due to the heat loading. Additional detail on the RFN cleaning and assembly are found in the *RFN manual*.

Unexpected events

Occasionally the source might experience an unexpected event such as ignition of a plasma near the RF antenna and behind the discharge chamber (i.e. under high pressure environment). In most cases, this event will produce a flash coating that is electrically conductive onto the backside of the discharge chamber and other source insulators (i.e. RFN antenna insulators or feedthrough). After the event, the source should be throughly cleaned and rebuilt to remove the conductive coating on all insulative surfaces. The source should then be fully tested to ensure its operation is stable.

Standard cleaning procedure

Most items can be cleaned using a media blast cabinet with 150 grit alumina media. Media blast is the most common technique for cleaning. This will texture the surfaces of grids and other hardware which promotes adhesion of process materials in the vacuum system and minimizes coating flakes. All of the media blast parts need to be cleaned in an ultrasonic bath, rinsed and dried as described in *Appendix A*. Even though *Appendix A* describes grid cleaning specifically, it does provide an outline for the standard procedure for cleaning other source hardware, such as discharge chambers, insulators and grid mounting hardware.

Long term care

Proper care of the source and its sub-assemblies should provide several years of stable operation. There are items that do wear out over periods of use and should be monitored from time to time.

Water connections to the RF antenna have been known to fail slowly after years of operation. It is considered good practice to monitor the vacuum system base pressure weekly to catch any unforeseen water leak.

Long term monitoring of the RF power for a given process condition should also be performed. The RF power will start to increase when the polyethylene tubing used to cool the antenna becomes electrically conductive. Best practice is to replace the cooling lines with new pieces of equal material and length (2.5 m). The RF power will also climb, sometimes rapidly, if there is a connection issue with the RF strap between the matching network and feedthrough. After many years of service, the strap can oxidize with a black tarnish and become loose. In addition to monitoring RF power, visual inspection every 6 months for both these items is recommended.

The RF antenna in the source is silver plated and this will oxidize and turn black in an oxygen environment. Silver oxide is actually OK for RF power and should not create any issues. However, if this oxide is wiped and accidentally transferred to the RF support insulators, this may create tuning issues. When this oxide is rather old, it may appear as a dust with large flakes. When left unattended for years, the flakes can create unpredictable arcs and extinguish the discharge. Best practice is to remove these larger flakes from time to time using a lint free wipe soaked in alcohol - but with care not to transfer the conductive coating to the antenna mounting insulators.

Section 6.4: Recommended Spare Parts

These parts are recommended as spare parts. When maintenance is performed on the source, these parts can be swapped as to keep the system running smoothly. They are also useful for troubleshooting source issues.

- Additional grid assembly - to be run while the other grid assembly is serviced.
- Discharge chamber - in case the primary one breaks as these are fragile
- RFN - to be run while the other RFN is serviced

Chapter 7: 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 7.1: 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 7.2: 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.

ERROR	DESCRIPTION	POWER SUPPLY ERROR CODES 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)

POWER SUPPLY ERROR CODES		
ERROR	**DESCRIPTION**	**POSSIBLE PROBLEMS AND SOLUTIONS**
25 non fatal	Accel current exceeds A/B ratio alarm level setting	1. Accel voltage not optimized: Adjust AV up or down to minimize accel current. Examine *Chapter 4 - Specifications*. 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)	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	1. Internal +3.3 volt power supply has failed.
70 non fatal	Communication	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	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	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 *Chapter 3 - Specifications*).
80 **fatal**	Max RF reflected	1. Reflected power is too high: Check RF matching network, controller.
81 **fatal**	Max RF power	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	1. RF supply (for source or RFN) exceeded 10 amps for 5 seconds.
8888 **fatal**	Internal I-beam processor lockup	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 the *I-BEAM manual* 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 7.3: 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.**	1. Adjust match network cap C1 with gas off. See *RFN manual* 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.**	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.**	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.**	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.**	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.

(CONTINUED)

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. Consult *Chapter 2 - Installation* 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 7.4: 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**)	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**).	1. Source matching network tuning issues: Check matching network electrical and communication connections. Check match controller power is turned on. See match network tuning instructions in the *I-BEAM manual*. 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**).	1. Check BV PULSE setting and retest (see *Chapter 4 - Operation*) 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	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 *Chapter 4 - Operation*) 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**).	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.	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 7.5: 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.	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.	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.	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.	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.	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).	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).	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)

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

PROBLEM DESCRIPTION	BEAM TROUBLESHOOTING GUIDE POSSIBLE PROBLEMS AND SOLUTIONS
Accel current is zero.	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.	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.	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 7.6: Additional Resources

Please consult the *RFN Manual* for guidance with the RFN service, tuning and installation procedures. The *I-BEAM Manual* also provides more information on installation and operation of the power supply. Within the *I-BEAM Manual* is 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.

Chapter 8: Parts and Drawings

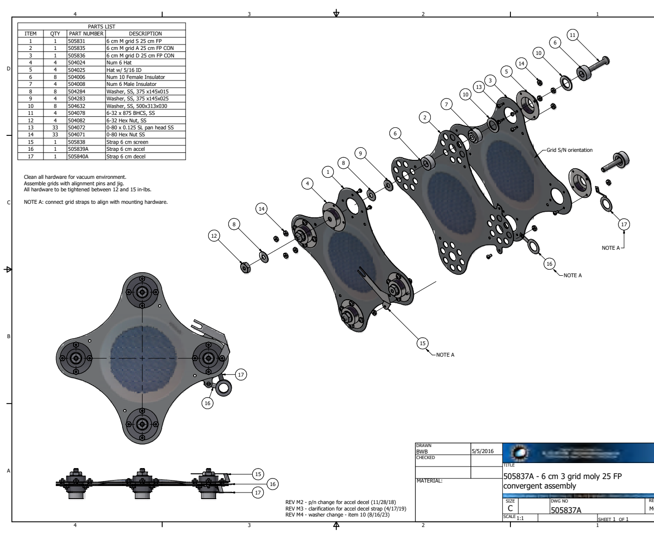
Please see our website for spare parts and the latest mechanical drawings. Complete assembly drawings are provided to customers (through our website). The drawings provided in this chapter are for a quick reference only.

CAUTION

If the source or its associated hardware are incorrectly assembled, permanent damage may result to the source hardware including the power supply. Please contact us for service questions.

Section 8.1: Navigating Grid Assembly Drawings

Since grids are serviced frequently, it is important to utilize the grid assembly drawing during the cleaning process. This section covers how to use and understand this type of drawing.



Typical grid assembly drawing.

Part number
The grid assembly part number will be located in the title block on the lower right hand corner. Additional information, such as revision number, is also located in the same area.

Parts list
The bill of materials (BOM) or parts list will usually be in the upper left hand corner. This list contains all of the parts utilized within the grid assembly.

Exploded view
Most of the drawing will show a typical insulator stack in an isometric view. Each item from the BOM and its location are identified. Usually just one stack is exploded and the others are shown assembled. The spring tab locations and serial number orientation are shown.

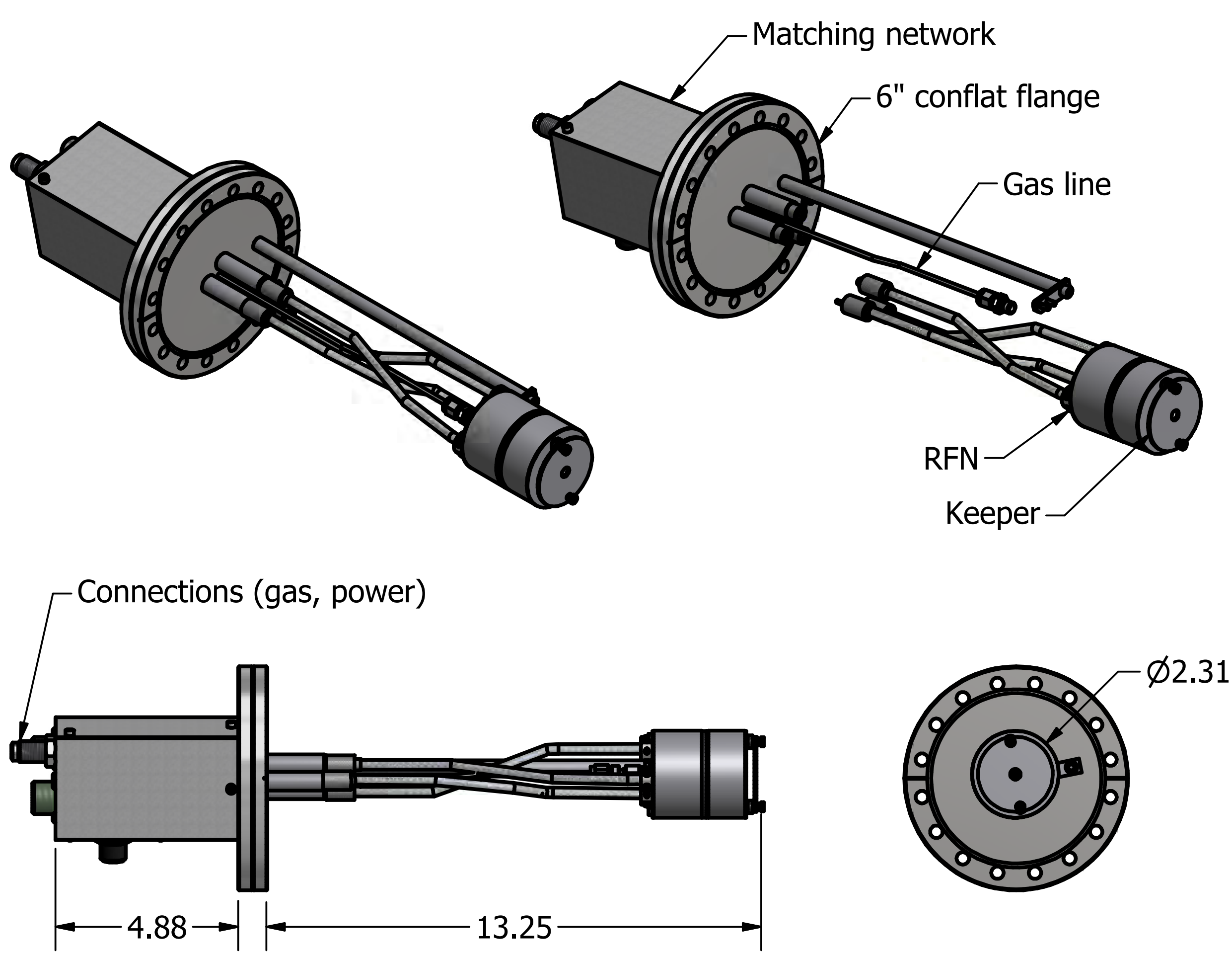
Plan and side view
Occasionally other views are presented to show orientation or other important assembly notes.

Multiple sheets
Most grid assemblies utilize just one sheet, but check the title block if there are more pages.

Section 8.2: Part Numbers for RFN

This section contains part numbers and drawings for the RF neutralizer. Dimensions are in inches.

RFN PARTS	
PART NUMBER	**DESCRIPTION**
504424B	RFN assembly
504425B	Gas isolator assembly for RFN
504687A	RFN refurbish kit - includes collector
504136	RFN discharge chamber
Refurbish service	Please contact us if you would like us to service the RFN

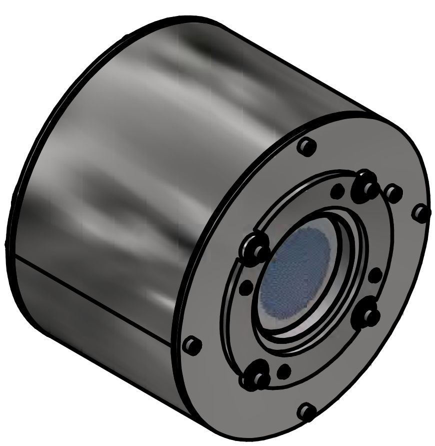


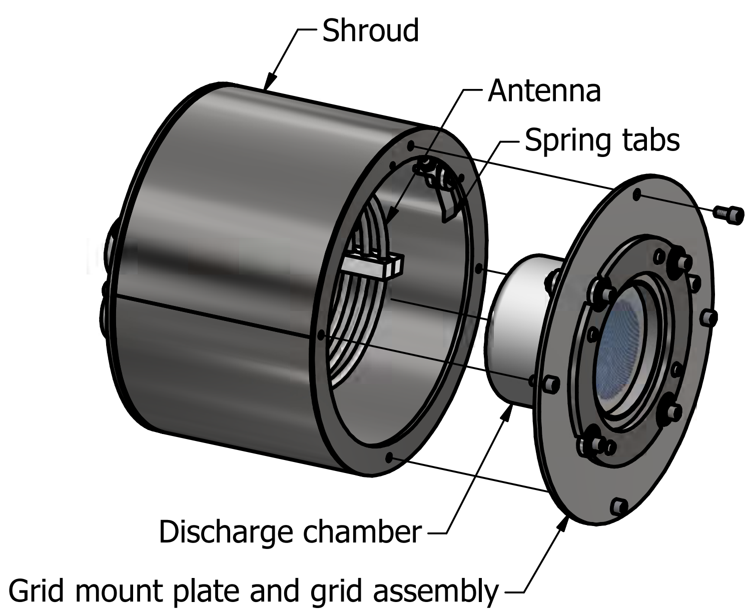
504855A - RFN Flange with match network ITI style, 6 inch, CF.

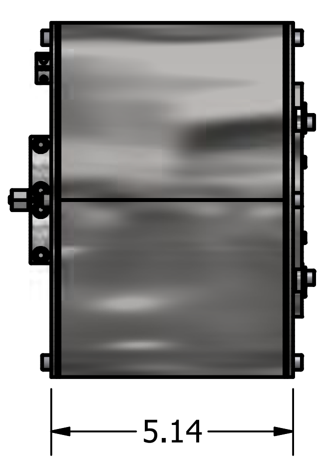
Section 8.3: Part Numbers for 6 cm RF Source

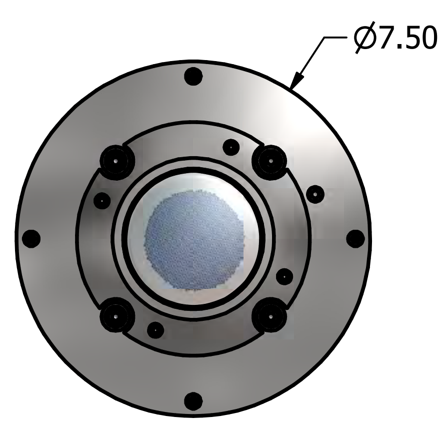
This section contains part numbers and drawings for the 6 cm RF source. Dimensions are in inches.

6 CM RF SOURCE PARTS	
PART NUMBER	**DESCRIPTION**
06RF	6 cm source. Includes shroud, antenna, grid mount plate and discharge chamber.
507042A	6 cm grid mount hardware kit (includes discharge chamber)
505830A	6 cm RF discharge chamber assembly
504330	RF antenna insulator
505856A	6 cm RF antenna assembly
grid assemblies	please visit our website for a complete listing

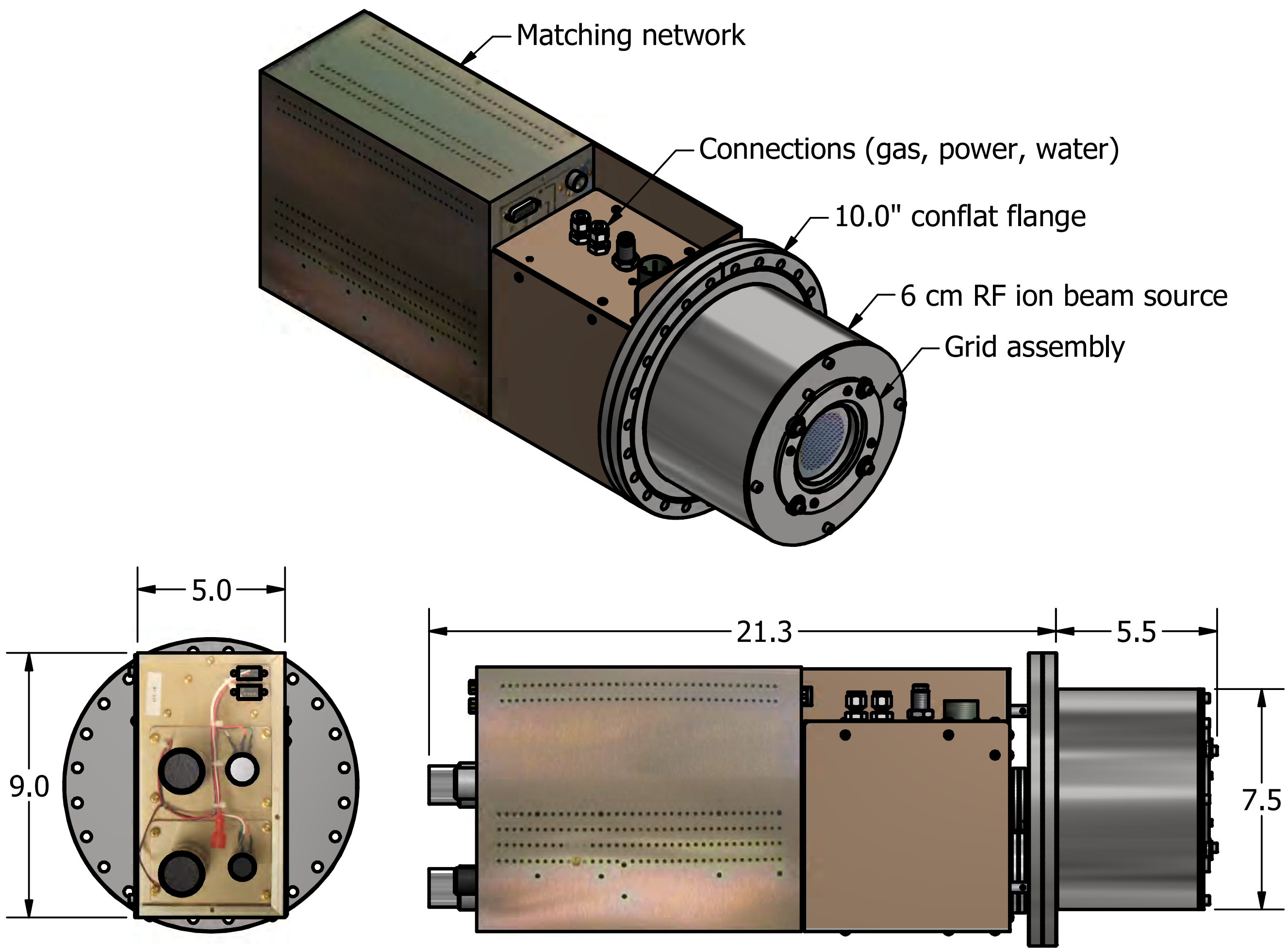






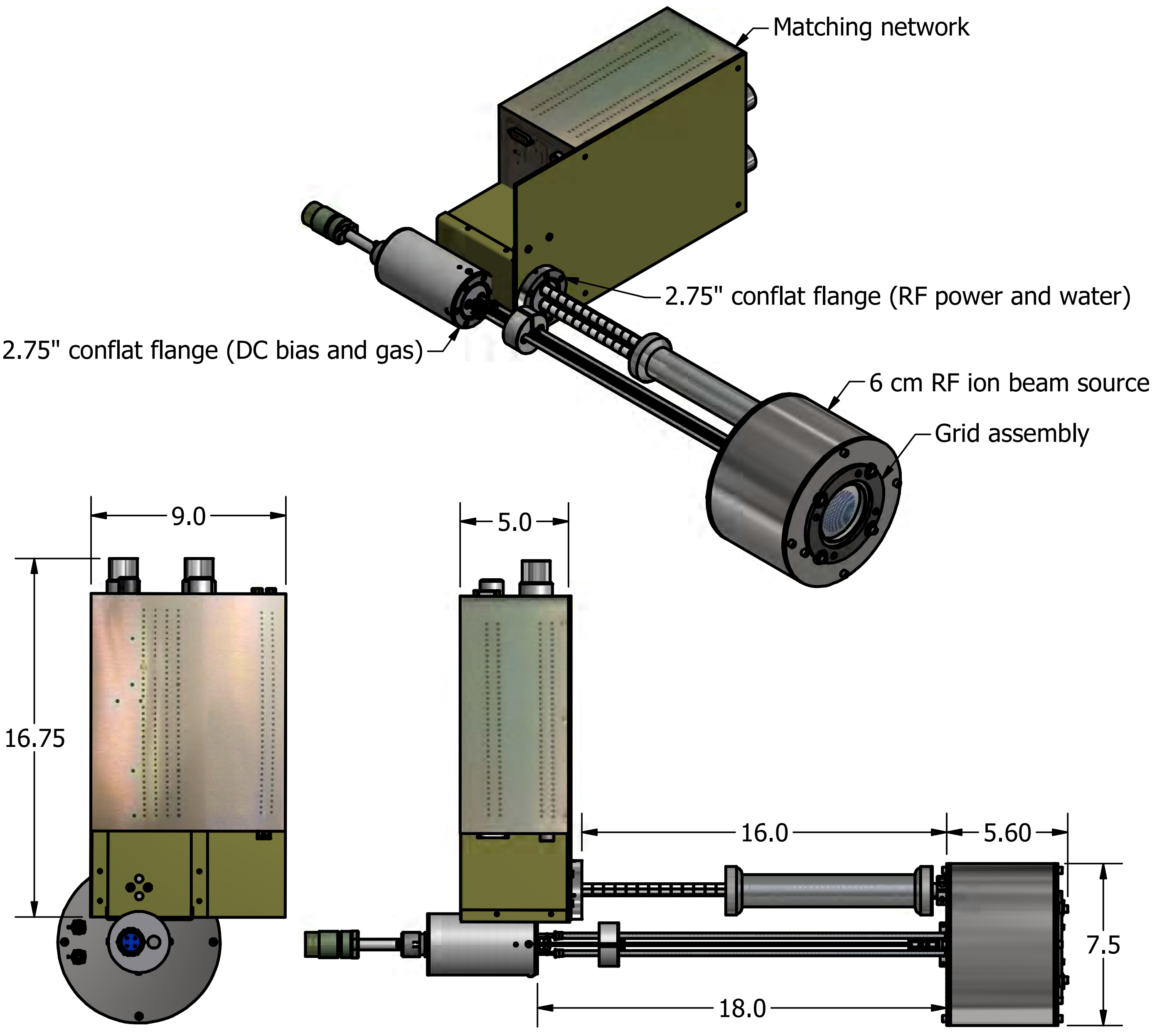


Flange mount interface kit part number 505865A.



505865A - 10.0" conflat flange mount (with source, grids and matching network)

Internal mount interface kit part number 505864A.

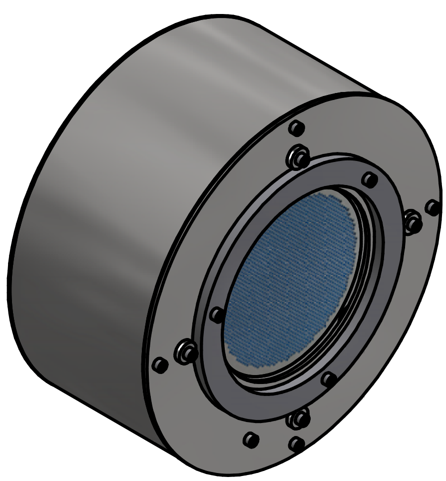


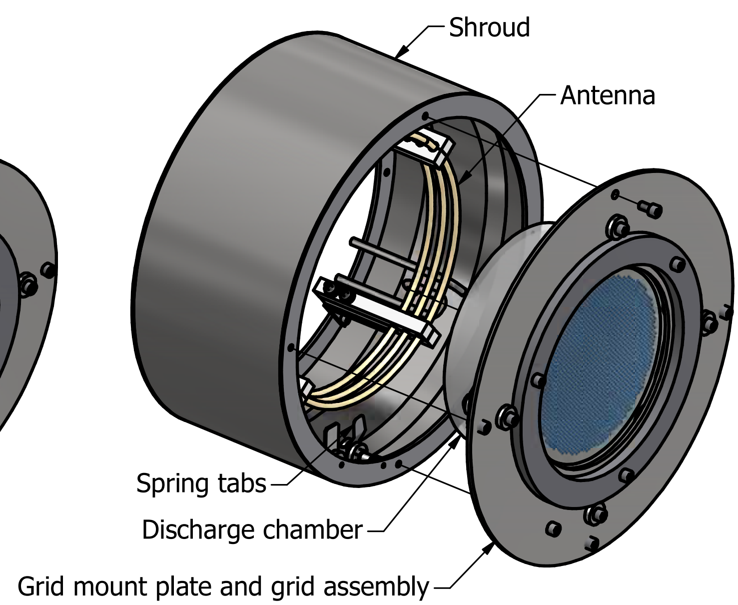
505864A - internal mount 2.75" CF flanges x2 (with source, grids and matching network)

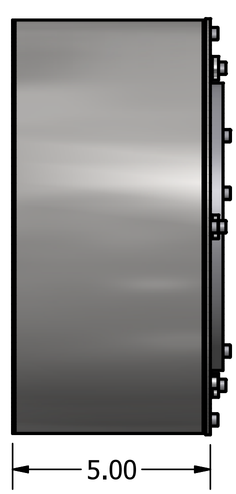
Section 8.4: Part Numbers for 12 cm RF Source

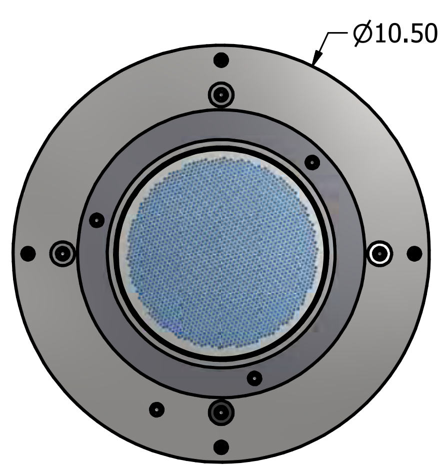
This section contains part numbers and drawings for the 12 cm RF source. Dimensions are in inches.

12 CM RF SOURCE PARTS	
PART NUMBER	**DESCRIPTION**
12RF08	12 cm source. Includes shroud, antenna, grid mount plate and discharge chamber.
505190A	12 cm grid mount hardware kit (does not include discharge chamber)
504211A	12 cm RF discharge chamber assembly
504330	RF antenna insulator
504320A	12 cm RF antenna assembly
grid assemblies	please visit our website for a complete listing

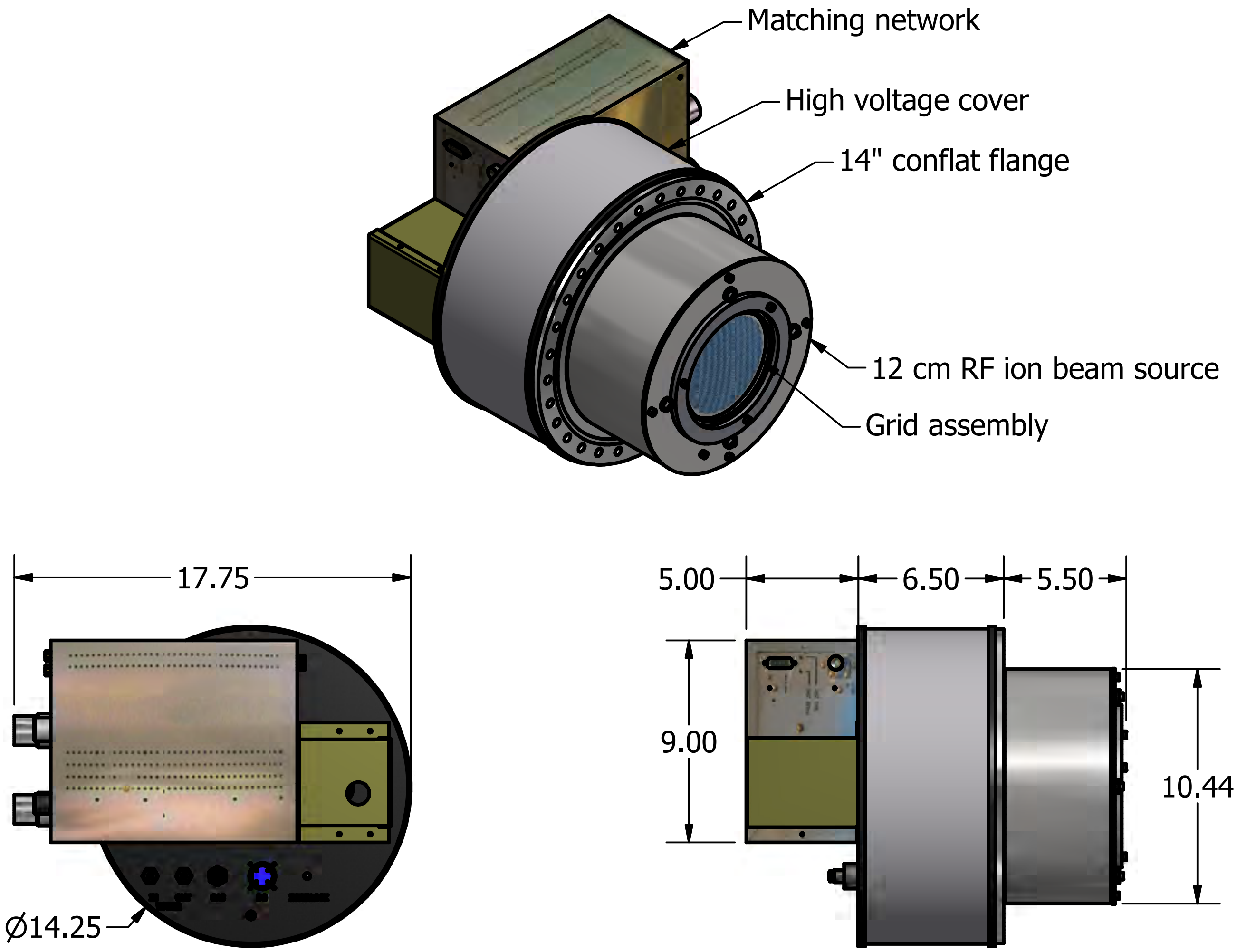






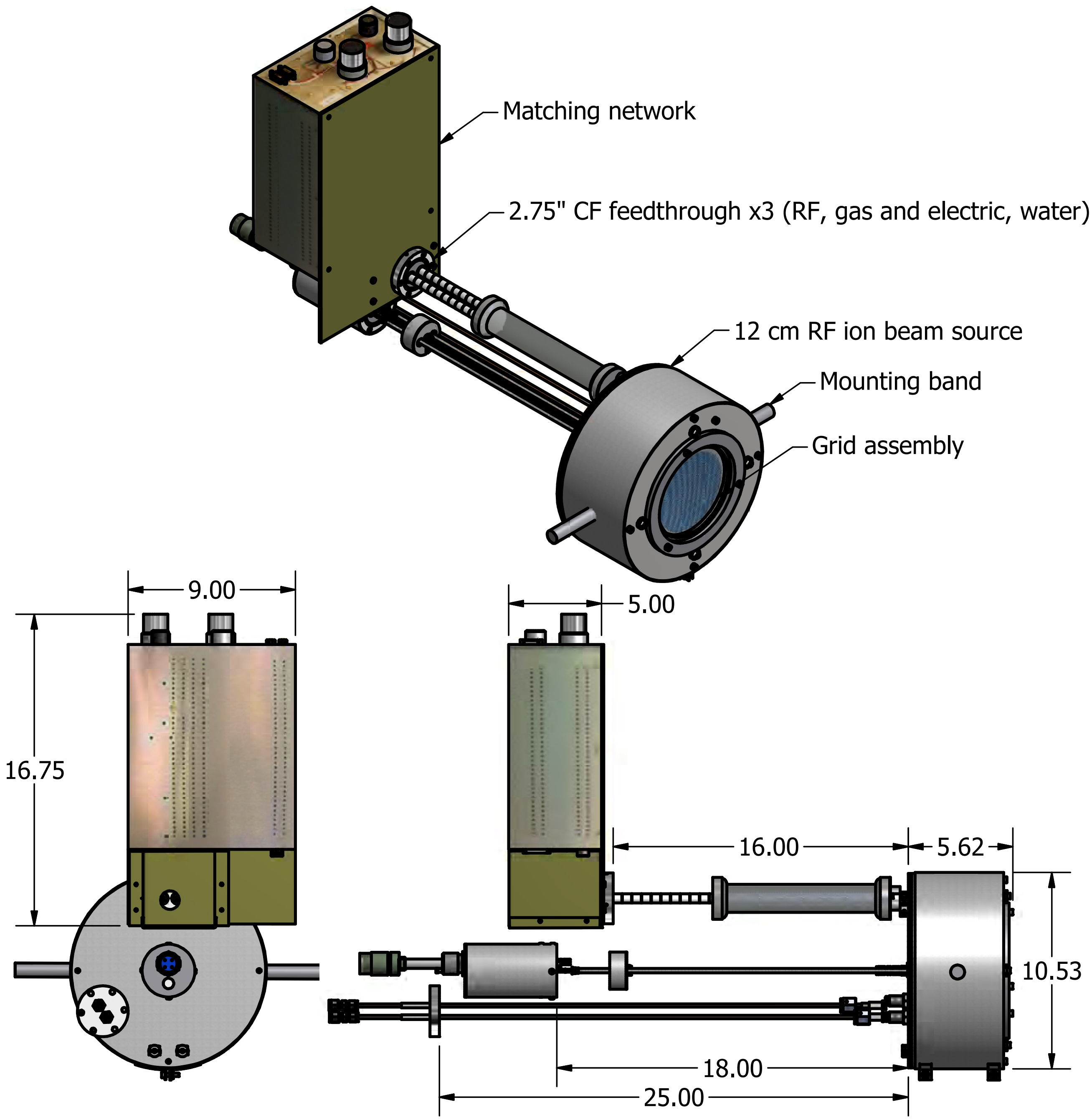


Flange mount interface kit part number 504904A.



504904A - 14" conflat flange mount (with source, grids and matching network).

Internal mount interface kit part number 504905A.

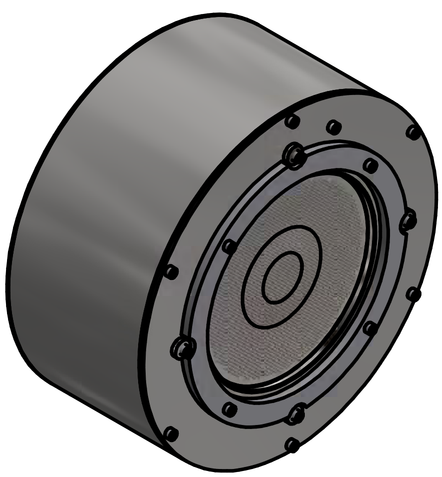


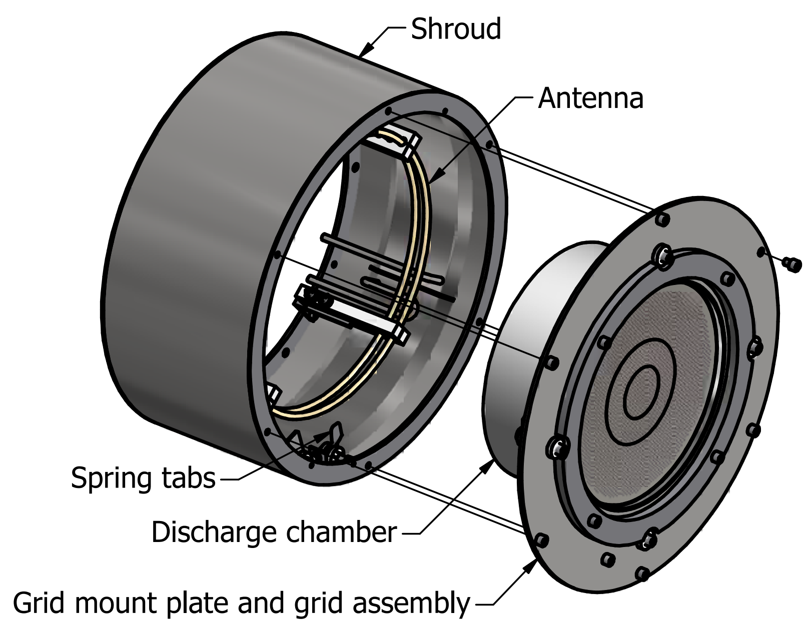
504905A - internal mount 2.75" CF flanges x3 (with source, grids and matching network).

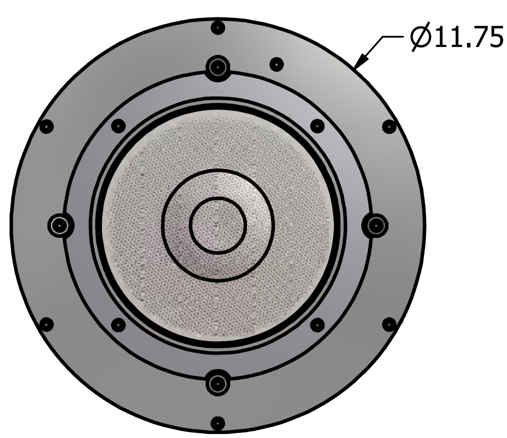
Section 8.5: Part Numbers for 16 cm RF Source

This section contains part numbers and drawings for the 16 cm RF source. Dimensions are in inches.

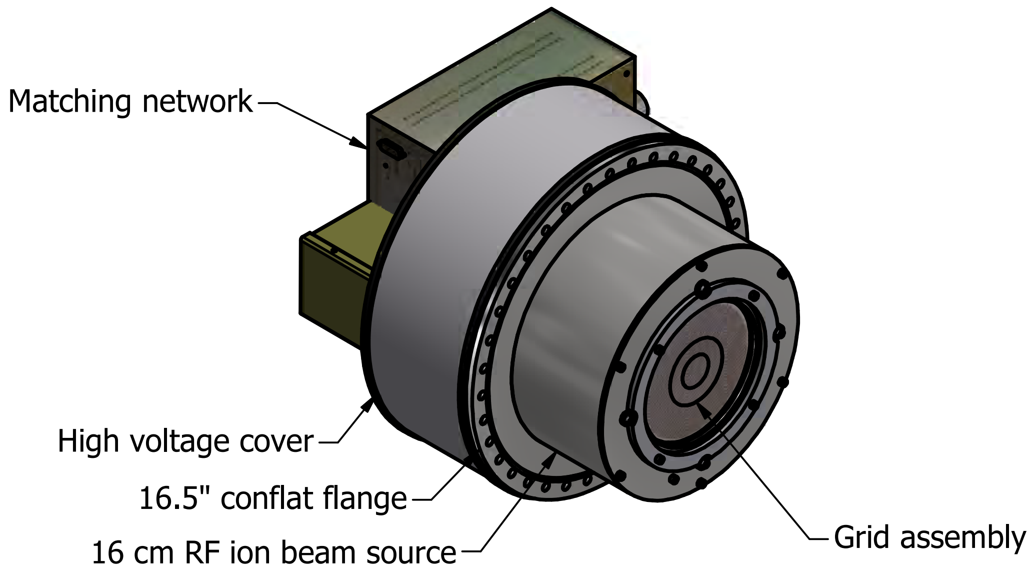
16 CM RF SOURCE PARTS	
PART NUMBER	**DESCRIPTION**
16RF08	16 cm source. Includes shroud, antenna, grid mount plate and discharge chamber.
505161A	16 cm grid mount hardware kit (does not include discharge chamber)
504210A	16 cm RF discharge chamber assembly
504330	RF antenna insulator
504370A	16 cm RF antenna assembly
grid assemblies	please visit our website for a complete listing

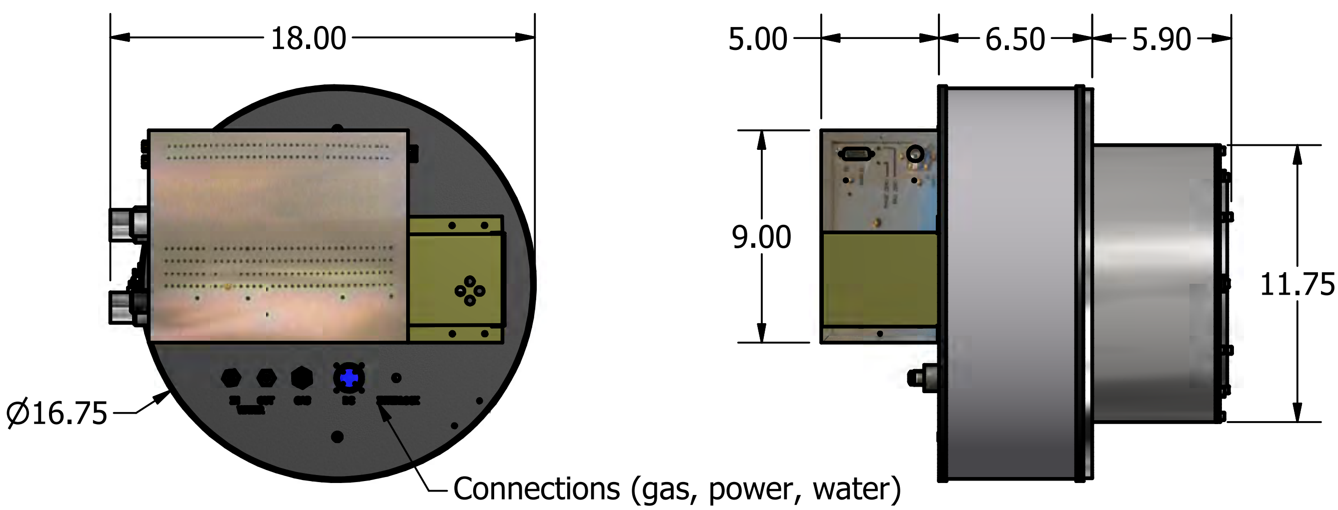






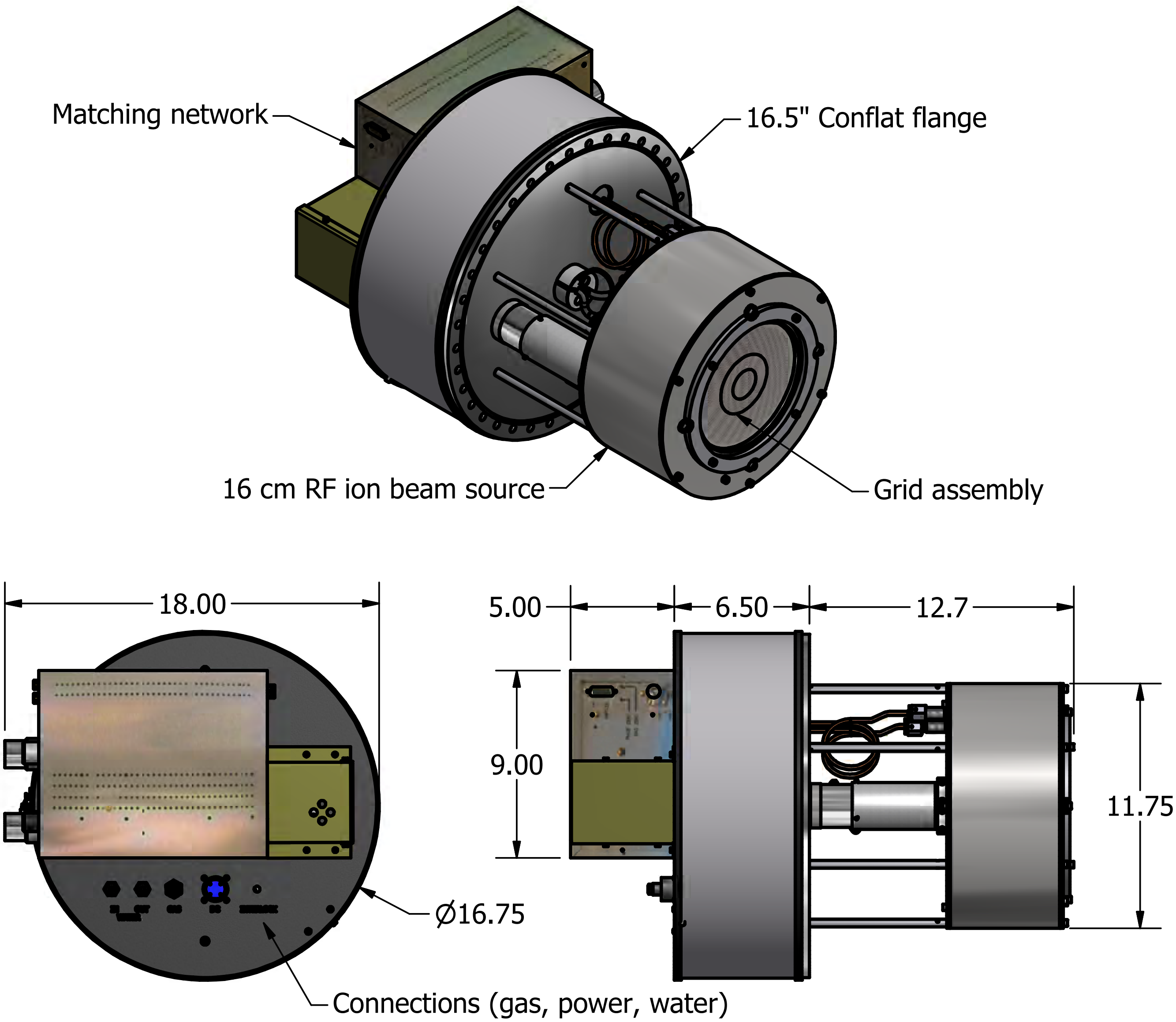
Flange mount interface kit part number 504901A.





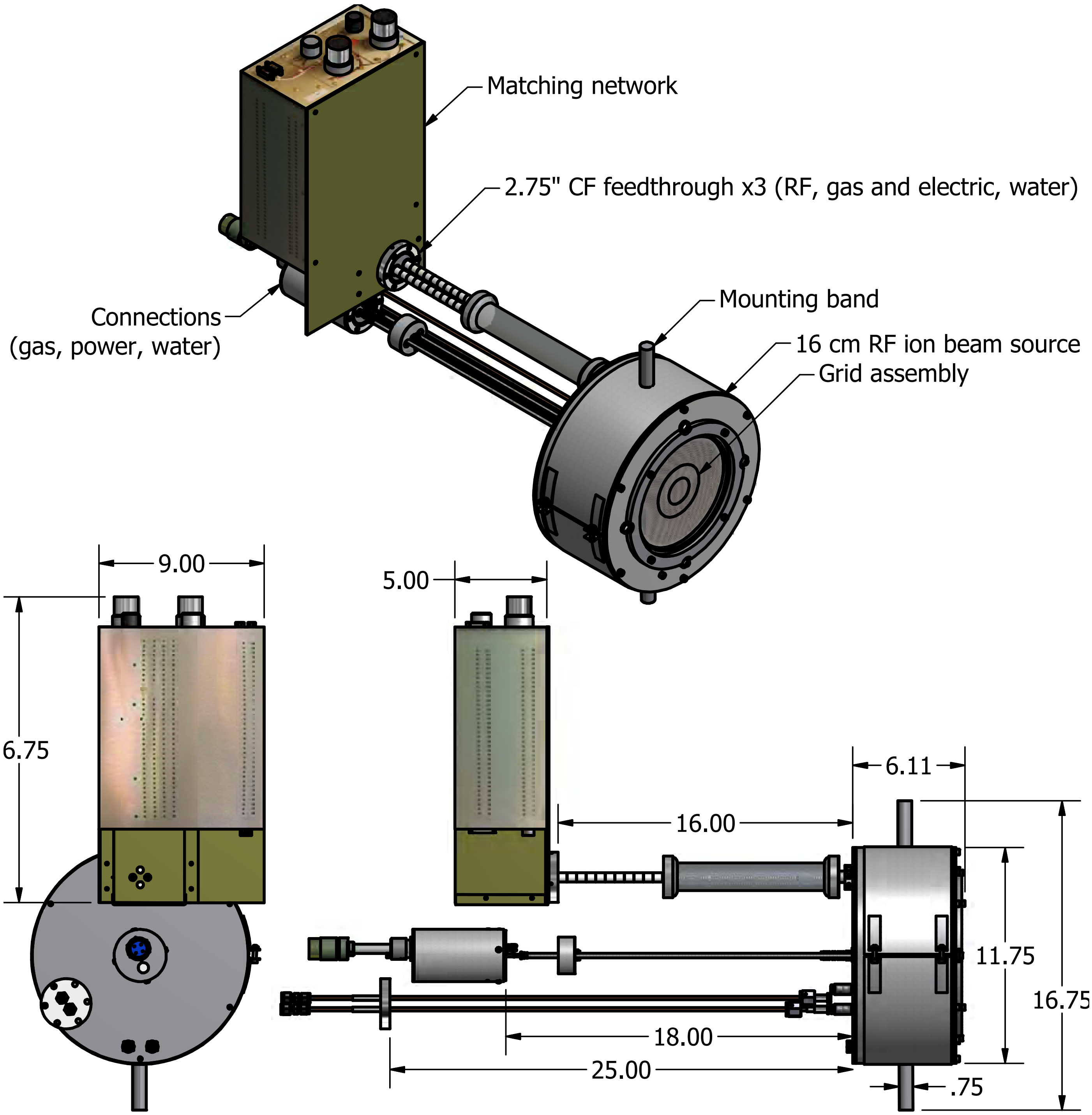
504901A - 16.5 conflat flange mount (with source, grids and matching network).

Extension flange mount interface kit part number 504902A.



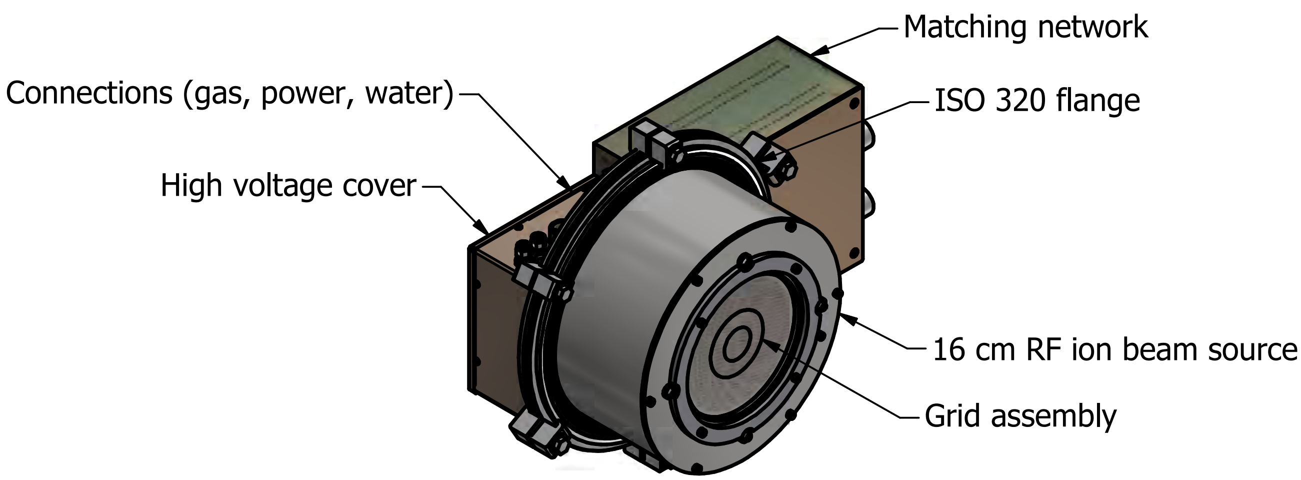
504902A - 16.5 conflat flange extension mount (with source, grids and matching network).

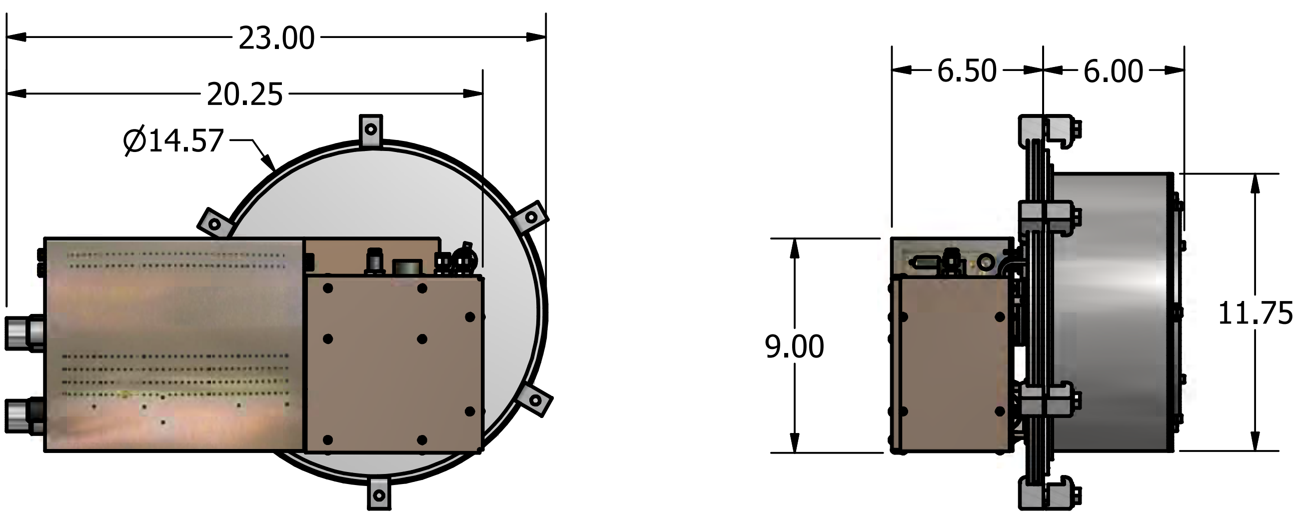
Internal mount interface kit part number 504903A.



504903A - internal mount 2.75" CF flanges x3 (with source, grids and matching network).

Flange mount interface kit part number 505037A.



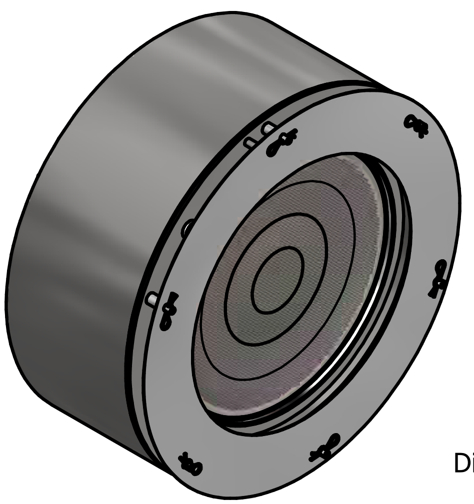


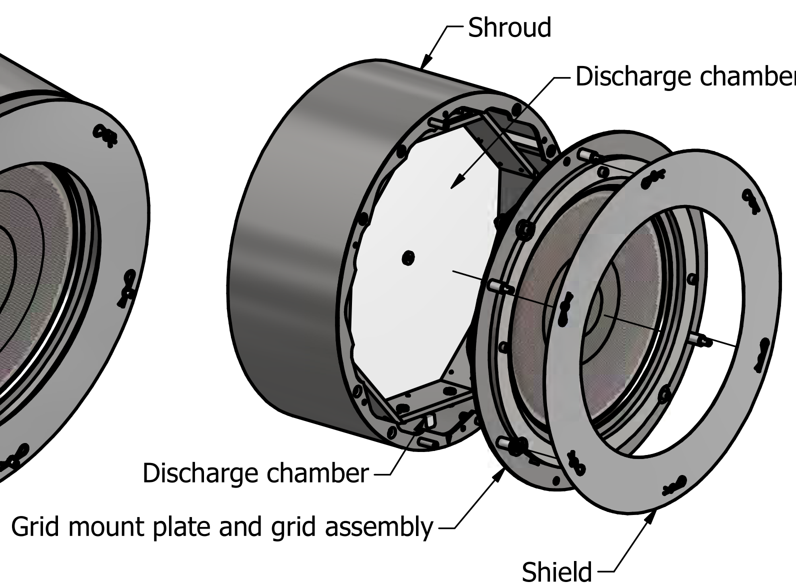
505037A - 320 ISO flange mount (with source, grids and matching network).

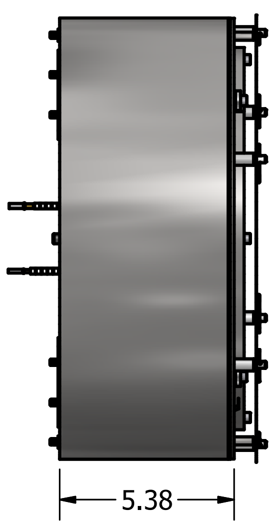
Section 8.6: Part Numbers for 23 cm RF Source

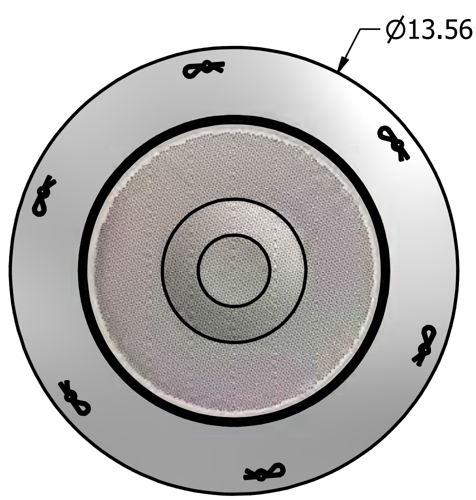
This section contains part numbers and drawings for the 23 cm RF source. Dimensions are in inches.

23 CM RF SOURCE PARTS	
PART NUMBER	**DESCRIPTION**
23RF	23 cm source. Includes shroud, antenna, grid mount plate and discharge chamber.
507281A	23 cm grid mount hardware kit (does not include discharge chamber)
507074	23 cm body backplate (discharge chamber ceramic)
504330	RF antenna insulator
507071A	23 cm RF antenna assembly
grid assemblies	please visit our website for a complete listing

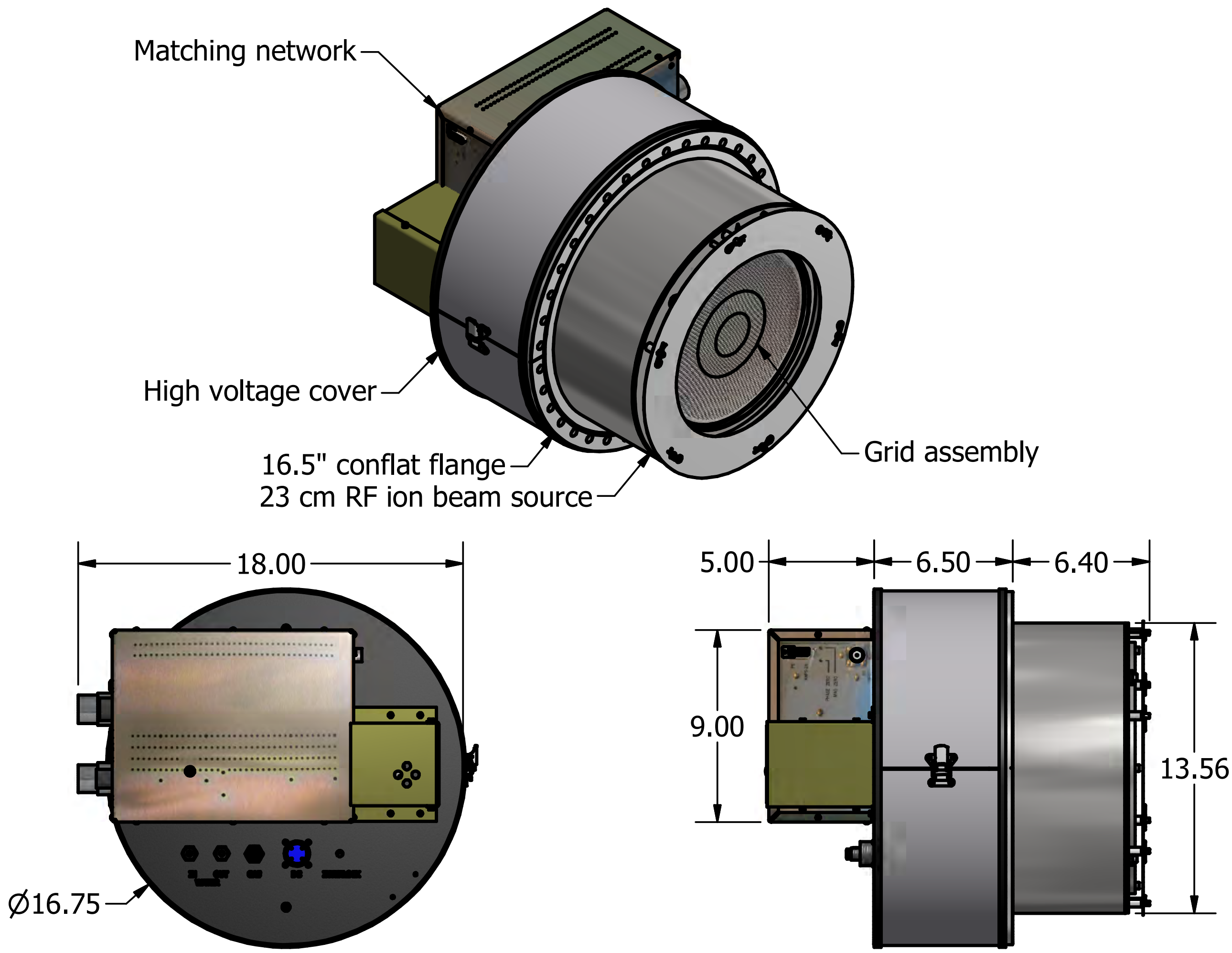






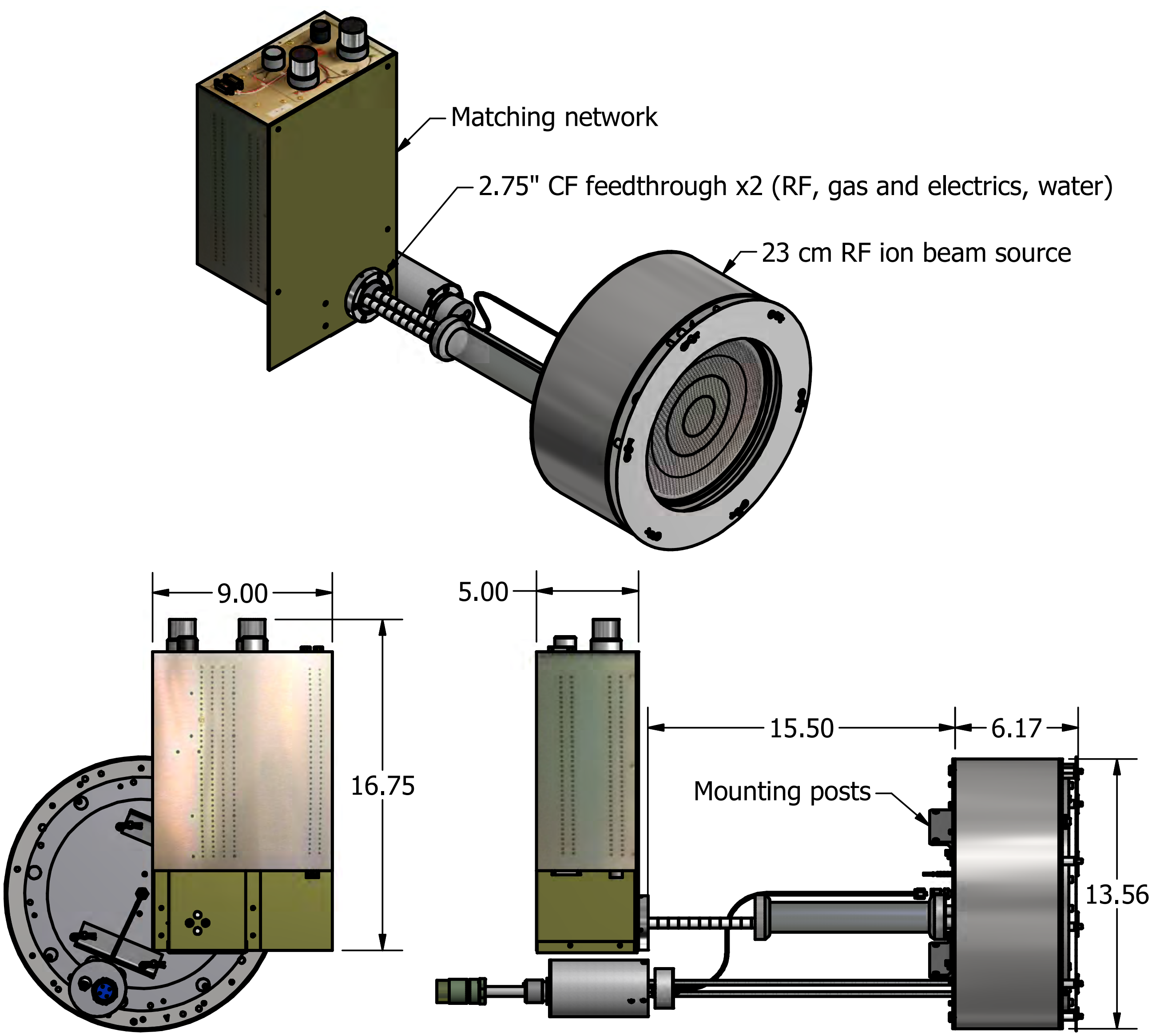


Flange mount interface kit part number 507226A.



<u>507226A - 16.5 conflat flange mount (with source, grids and matching network).</u>
Custom port may be required.

Internal mount interface kit part number 507178A.

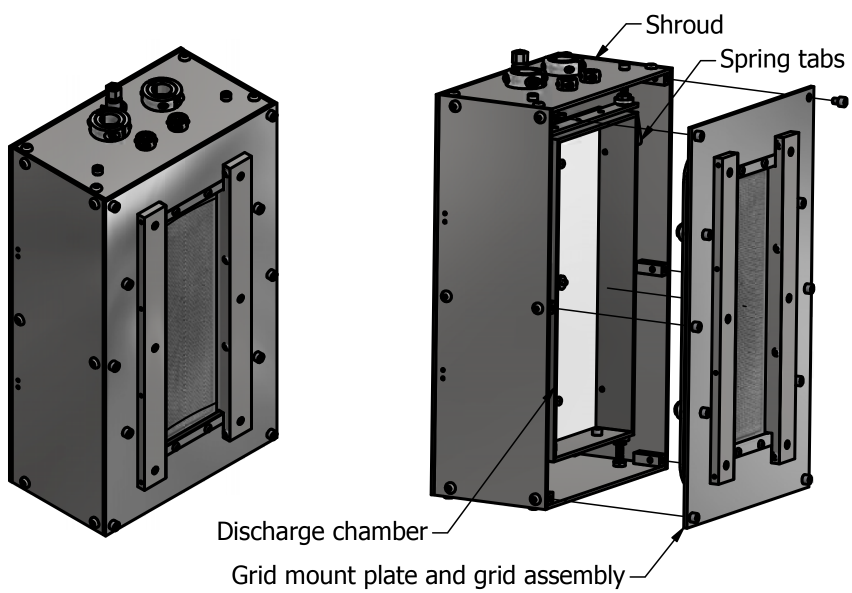


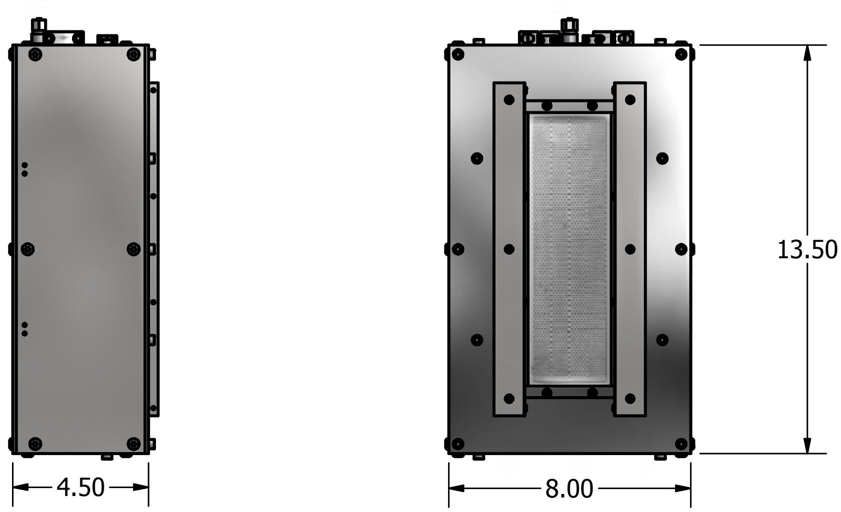
507178A - 23 cm interface kit, internal mount 2.75"CF flanges x2

Section 8.7: Part Numbers for 6x22 cm RF Source

This section contains part numbers and drawings for the 6x22 cm RF source. Dimensions are in inches.

6X22 CM RF SOURCE PARTS	
PART NUMBER	**DESCRIPTION**
06x22RF	6 x 22 cm source. Includes shroud, antenna, grid mount hardware, and discharge chamber.
505883	6 x 22 cm body backplate (discharge chamber ceramic)
504330	RF antenna insulator
grid assemblies	This source uses 6x22 grids only. Please visit our website for a complete listing

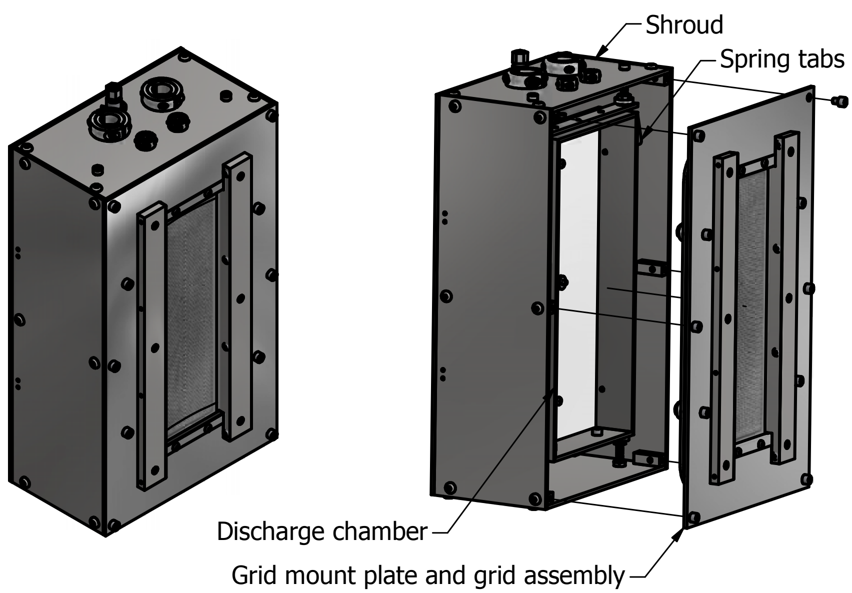


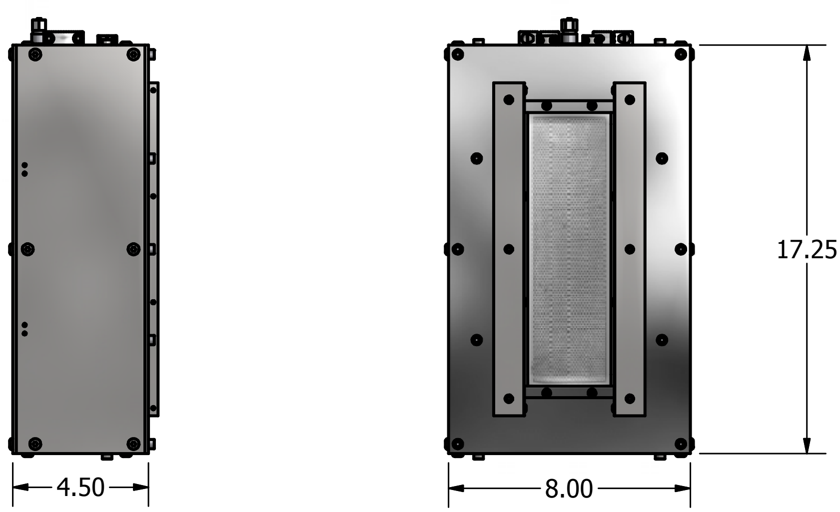


Section 8.8: Part Numbers for 6x30 cm RF Source

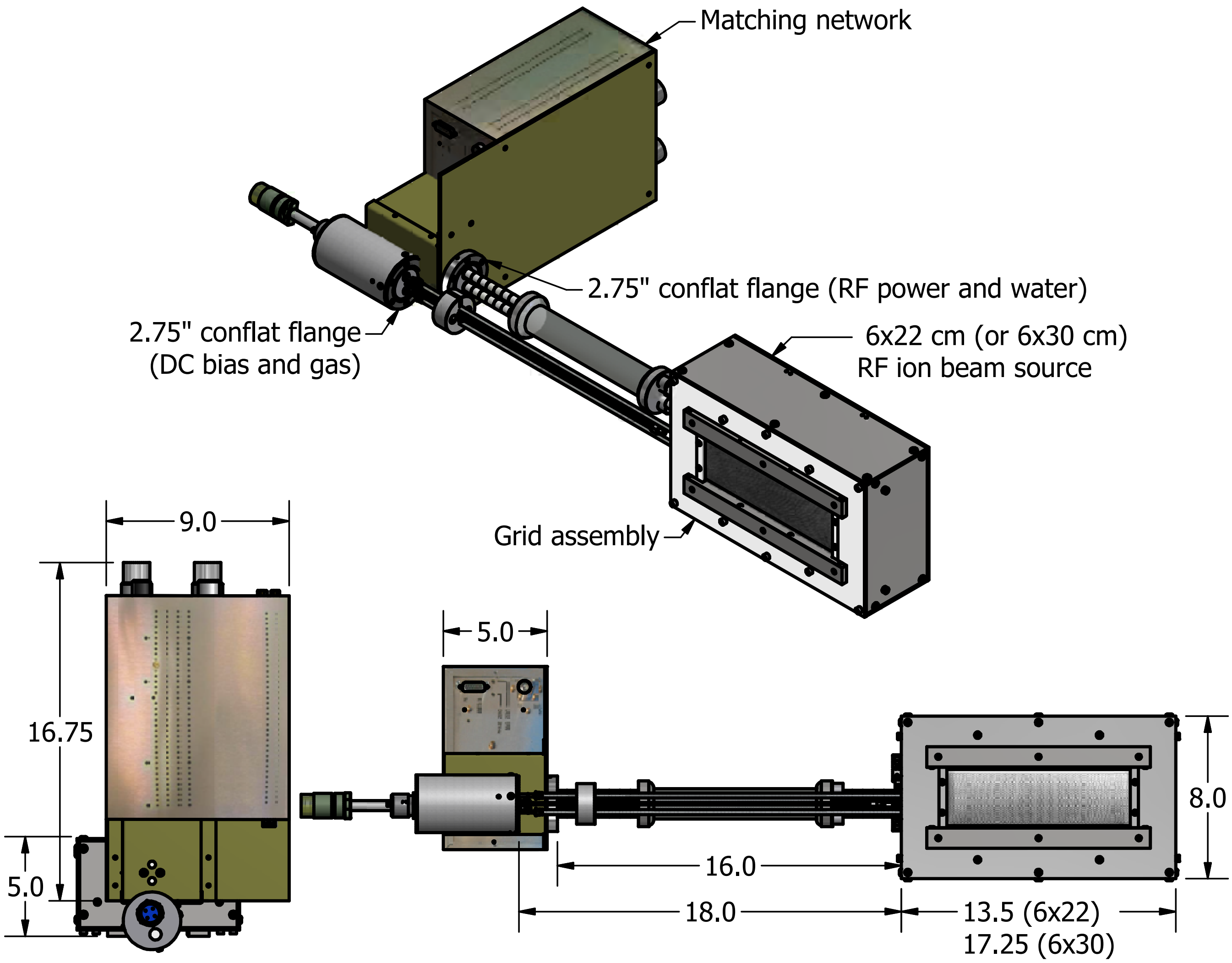
This section contains part numbers and drawings for the 6x30 cm RF sources. Dimensions are in inches.

6X30 CM RF SOURCE PARTS	
PART NUMBER	**DESCRIPTION**
06x30RF	6 x 22/30 cm source. Includes shroud, antenna, grid mount hardware and discharge chamber.
505799	6 x 30 cm body backplate (discharge chamber ceramic)
504330	RF antenna insulator
grid assemblies	This source can use 6x22 or 6x30 grid assemblies. Please visit our website for a complete listing.





Internal mount interface kit part number 505890A. The same interface kit works for the 6x22 cm and the 6x30 cm sources.



505890A - internal mount with 2.75" CF flanges RF, DC bias, and gas

Appendix A: Cleaning Guide

The item on the source that requires the most maintenance is the grid assembly as it quickly becomes coated with process material. Occasionally, source insulators and the source discharge chamber will require cleaning. In other rare cases, the RF antenna may require cleaning. This chapter provides tips for grid cleaning and reassembly. Other source hardware, such as discharge chambers and insulators can be cleaned using this procedure. Please consult our website for additional drawings and videos for assistance.

Section A.1: Molybdenum Grid Cleaning Procedure

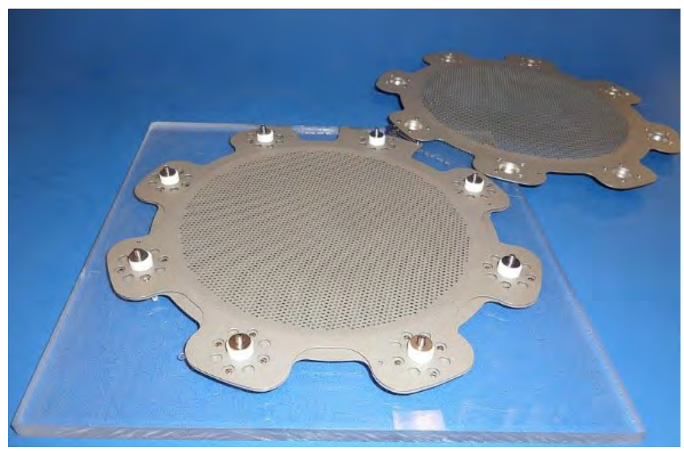
A work center should be setup as described in *Chapter 6 - Maintenance* to perform the work described in this section. Many grids are assembled in a similar fashion. It is best practice to obtain a grid assembly drawing from our website for proper reassembly. The example below will show a typical 16 cm grid assembly, but the process would be identical for other grid assemblies. *Graphite grids are not typically cleaned due to their fragile nature*, but they can be lightly sanded in some cases.

A. Disassembly:

Insert grid assembly into acrylic jig with the decelerator grid face down and remove the 6-32 nuts around the grid set. Lift each grid from the assembly and place on a clean surface.

Measure all spacing washers during removal to confirm they match the specified thickness and location in the stack per the part number drawing. Keep track of their order and note any differences with the drawing.

Remove remaining hats and strap connections from each grid.

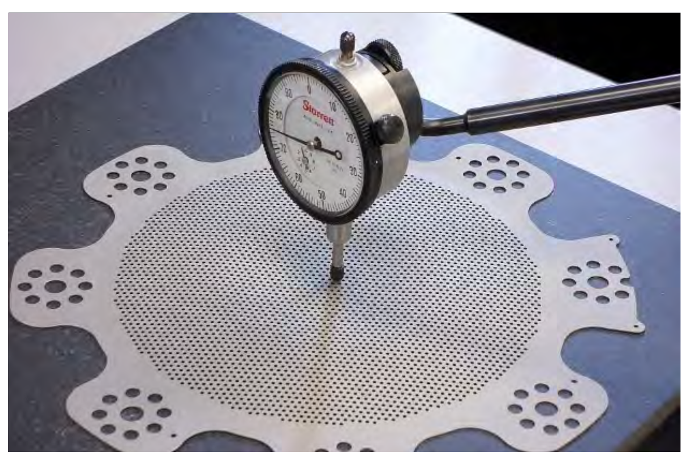


Disassemble the grids using the alignment jig. Remove all hardware from each grid.

B. Pre-clean Measurement:

Check the dome height on a granite block. Best practice is to capture the center of the grid. Other locations on multi-focal point grids can be useful. Document each measurement as a "before" for the screen, accel and decel grids.

These measurements are useful to track how much the grids have distorted from the original shape - prior to operation.



Measuring the dome heights on a flat surface using a dial indicator.

C. Grid Cleaning:

Media blast the grids using Aluminum Oxide 150 grit media and a pressure no greater than 40 PSI. Also, observe the following:

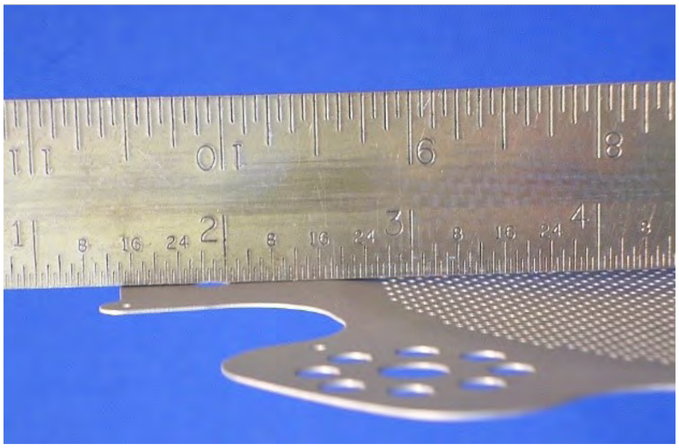
- Inspect the condition of the hoses and nozzle before use.
- Media blast with equal duration on each side of each grid to prevent deformation.
- Hold the nozzle at least 6 inches away from grid.
- Move nozzle in small circles while blasting.
- **Do not concentrate on one spot for too long!**
- **The hat hardware should be removed or they will warp.**

Media blast each side of the grid with consistent motion.

Wash grids in hot water filtered to 3 microns and dish soap and rinse thoroughly. Dry with clean room cloth and blow off with lab quality nitrogen.

D. Post Measurement:

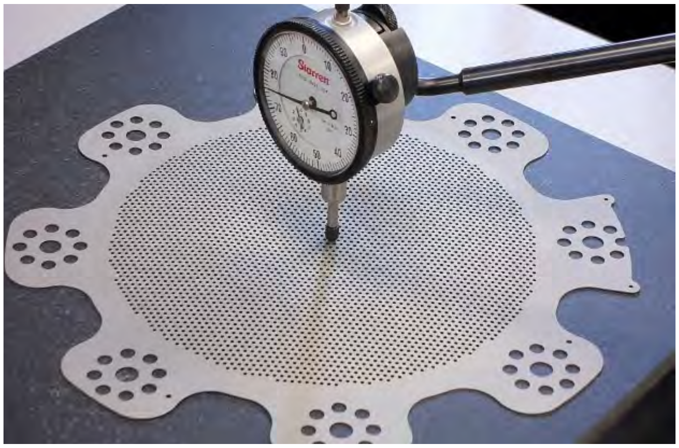
Using a straight edge, verify and adjust “ears” of each grid to confirm ears are flat.



Confirm the grid ears are flat and even after the blast cleaning.

Measure dome heights again on a granite block. Capture the same locations as the "before" measurements. Document each measurement as the "after" for the screen, accel and decel grids.

The dome heights should match at the same location for each grid. There will be some variation to within ± .003" at identical locations. The variation usually is between grids with larger holes compared to grids with smaller holes. If the variation exceeds this range, there might be some performance issues when the grids are reassembled.



Checking the dome heights again after media blast.

After final measurements are documented, inspect and media blast any imperfections in each of the grids, and repeat cleaning if necessary.

Wash grids in hot water filtered to 3 microns and dish soap and rinse thoroughly.

E. Final Clean:

Fill a 5-gallon ultrasonic tank with hot water and add 75 mL of Micro90 brand detergent cleaner as recommended by the manufacturer. Place grids into ultrasonic bath for 20 minutes.

Remove grids and rinse thoroughly in hot water filtered to 3 microns.

Fill a smaller container with fresh distilled water and suspend it in the ultrasonic. Make sure that no soapy water contaminates the distilled water of the smaller container. Add a grid and run the ultrasonic tank for 20 minutes. Change the distilled water and repeat for the other grids.

Remove grids and dry with lint free cloth. Blow off with lab quality nitrogen.

Rinse grids heavily with isopropyl alcohol and blow dry with lab quality nitrogen. Place on under a heat lamp for 15 minutes.

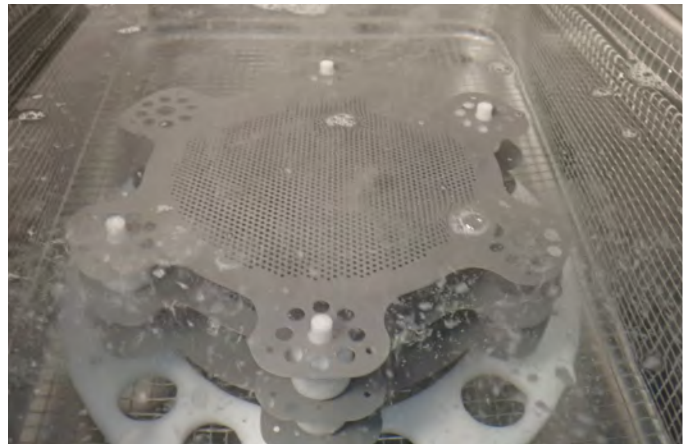
F. Hardware cleaning:

For grid mount assembly hardware cleaning follow procedures “C” and “E” described previously.

Media blast all ceramic insulators. Place in micro90 and ultrasonic bath for 20 minutes. Remove and rinse in hot water thoroughly. Rinse with isopropyl alcohol and place on a clean room wipe. Place under a heat lamp for 15 minutes.

Replace coated metal fasteners or media blast only the stainless-steel parts that are flaking material, for example the screw heads. **NOTE: Buff the threads of all bead-blasted screws to prevent thread seizing.**

Place stainless steel parts in a beaker of isopropyl alcohol and then suspend in the ultrasonic. Run for 20 minutes. Remove stainless steel hardware and insulators from containers and place on a clean room cloth under heat lamp for 15 minutes.



Use an ultrasonic tank to agitate and remove fine debris.

Bake the parts under a heat lamp to remove water vapor.

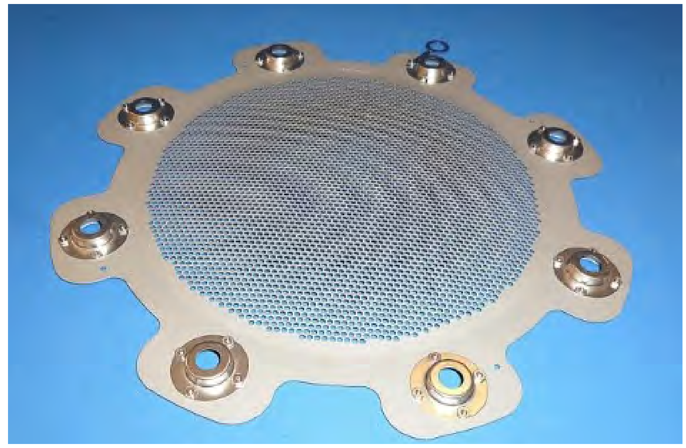
Clean smaller parts in a beaker within the ultrasonic tank.

Section A.2: Reassemble

Confirm all hardware with drawing

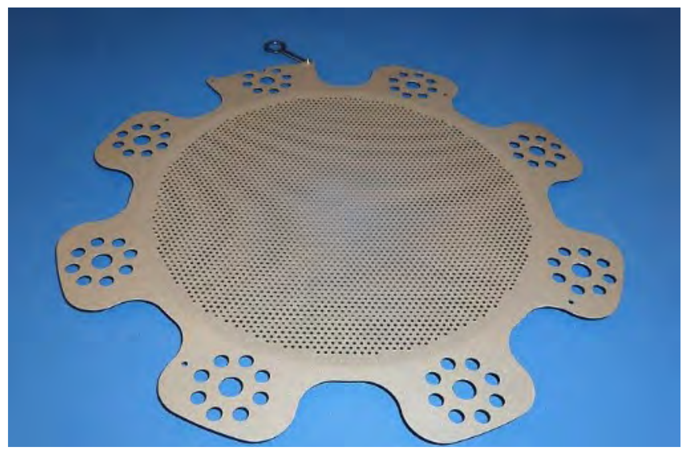
On a clean assembly surface, begin reassembly of the grids, spacers, insulators, and hardware following the assembly drawing for the appropriate part number. Confirm all spacing washers are accurate thicknesses by using a micrometer to measure each one before installation.

Start with the decel grid. Install the hats and ground strap. Note that there are two different styles of hats. Use the set with the larger holes (5/16” ID) in the center and mount them to the DOWNSTREAM side.



First mount all of the hats to the decel grid. Make sure they are on the correct side.

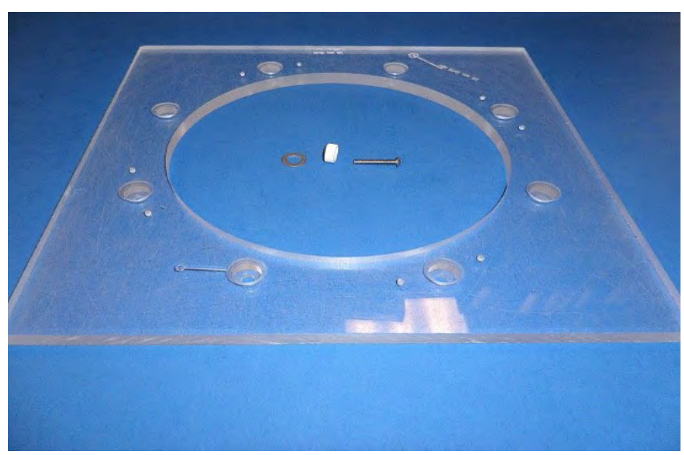
Attach the accel strap to the accel grid on the downstream side.



Attach the accelerator strap to the accel grid.

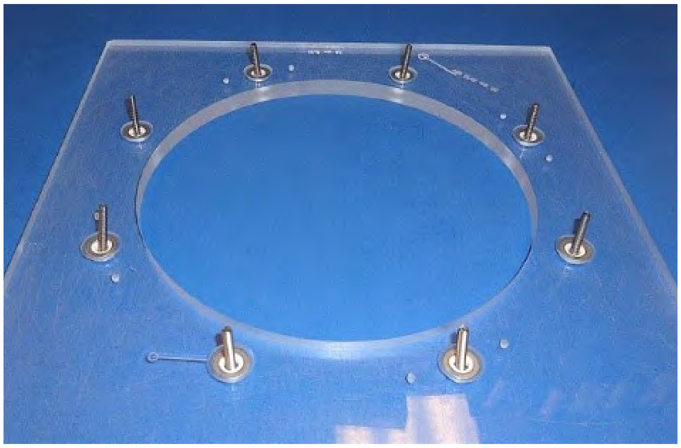
Clean the polycarbonate grid assembly jig and place on the work surface.

Line up the #6-32 x 7/8” screw, female ceramic insulator, and metal .500x.313x0.030 washer.



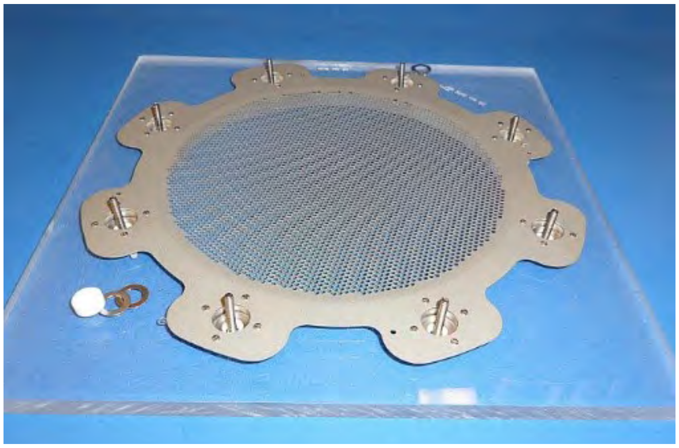
Each hardware stack will have similar construction.

Center the insulator and washer on the screw and place in the assembly jig as shown.



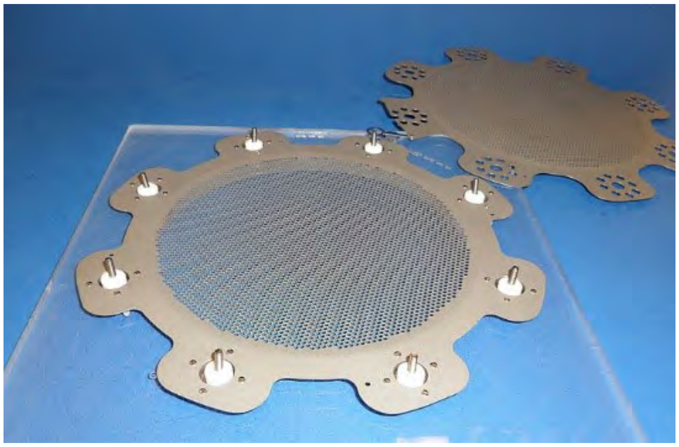
Face each screw upwards.

Place the decel grid over the screws (hat side down), and line up the serial number and strap with the markings on the fixture.



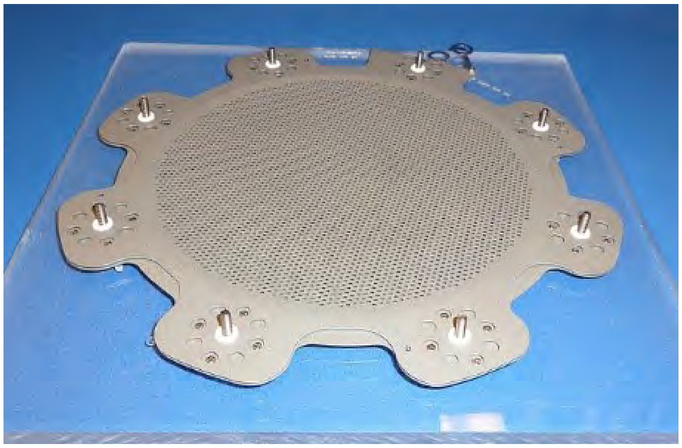
Add the decel grid with hats downward. They should catch into the jig.

As per the drawing, place flat washers and a male insulator over the screws with the male side up. Refer to drawing.



Add the washers and insulators which then form the decel to accel spacing.

Align the accel grid serial number with the decel grid and align the accel strap with the markings on the template. Place onto the insulators.



Add the accel grid to the stack.

Place the ceramic insulator and metal washers over the screws. Again, check the drawing for proper washer sequence. Center the insulator and washers on the screw and place in the assembly jig.

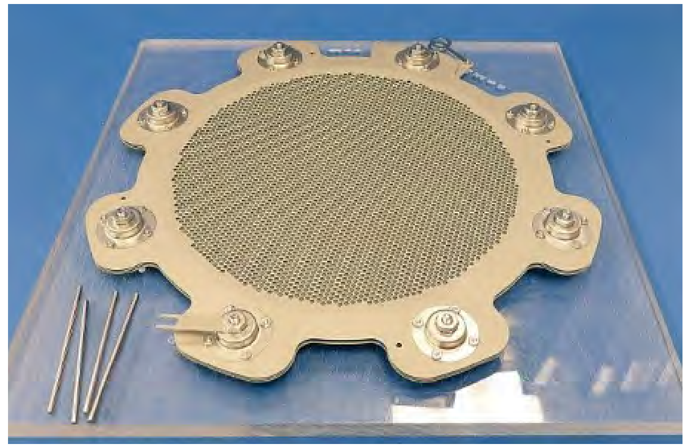
Install the hats on the screen grid. These are the hats with the smaller holes (#6) and mount them to the UPSTREAM side.

Add the next insulator and washers which then form the screen to accel spacing.

Place the screen grid over the screws (hat side up), and line up the serial number with the accel grid and markings on the fixture.

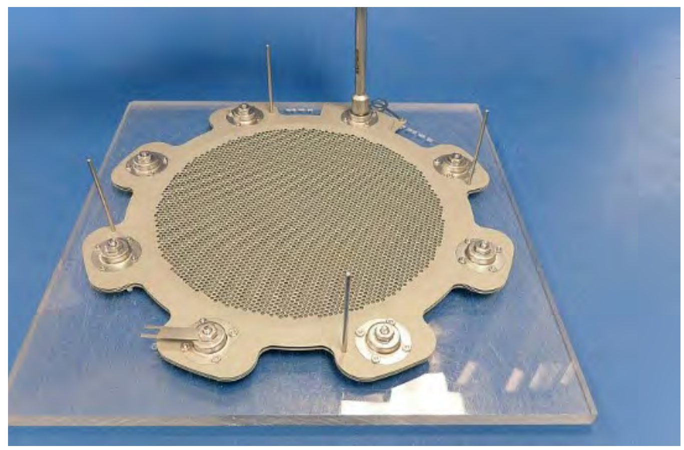
Place the screen grid on top.

Install the screen grid strap. Clean 4 alignment pins with isopropyl alcohol.   Add final washer and hex nuts to the posts, but do not tighten them yet.



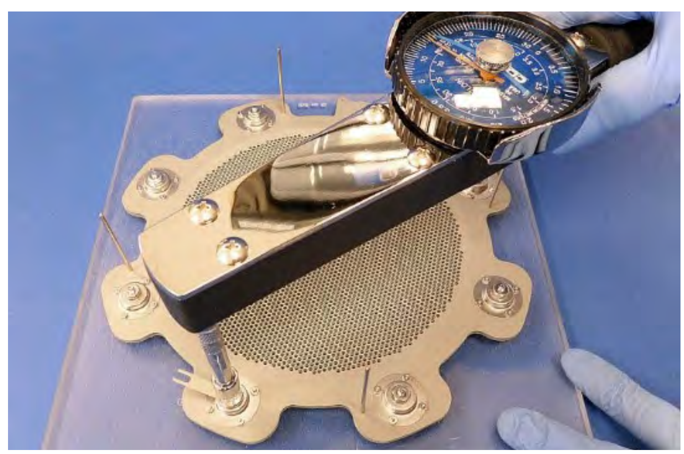
Add the final hardware.

Place the alignment pins into the alignment holes, all the way down into the jig, rotating while inserting. Do not force them. Adjust the positions of the grids as needed. When aligned, tighten the nuts to a snug condition.



With alignment pins inserted, finger tighten the nut.

Use a torque wrench to tighten the nuts to at between 12 and 15 inch-pounds. Over tightening will damage the ceramic insulators.

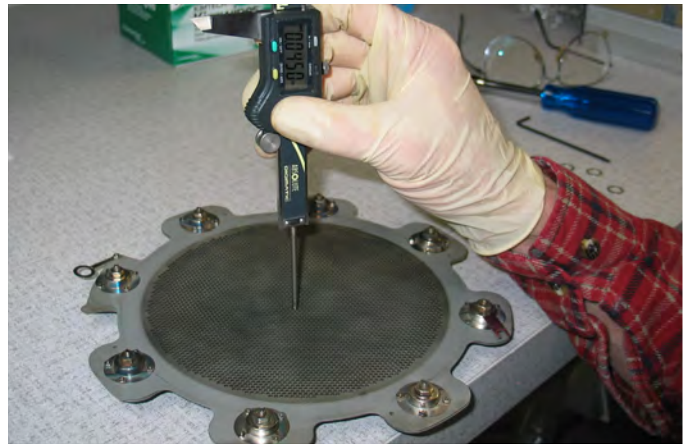


Finish tightening using a torque wrench.

Before installing into the mounting plates, use the pin-end of a micrometer to measure grid spacing between the screen and accel grid.

Install the mounting plates and tighten. Check the grid spacing again. If it has changed, then remove the mounting plates and add a washer of appropriate thickness to each mounting plate stack to eliminate the spacing change.

Document the final spacing at the bottom of the grid report sheet.



Check the gap between the grids.

Section A.3: Electrical Testing

Using an insulation tester, connect to opposing grids and test to 1000V. Resistance should stay in the GΩ range. Confirm the grids are not shorting, arcing or leaking current. Check for any conductive particles between the grids. Conduct this test between the screen and accelerator grids and between the decelerator and accelerator grid. Also check screen to ground; it should read as an open. If it fails, locate issue and repair as needed.

Before installing, blow through the grid assembly with lab quality nitrogen from all angles to remove any particulates gathered during the assembly process.

Check isolation on the grid assembly.

Check isolation on the completed assembly.

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