Nonsequitur Technologies Model 1402 Ion Gun
Users Manual 8/10/07

Nonsequitur Technologies
20664 Carmen Loop #3
Bend, OR 97702
Phone: 541-312-2410
FAX: 541-312-2412
Web: www.nonsequitur-tech.com

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Safety and Precautions

The model 1402 ion gun and controller incorporate a number of safety features to minimize the possibility of electrical hazard to the operator and equipment. This protection is required as the ion gun and controller are both designed to routinely operate with voltages up to 3 kilovolts.

In view of the high voltage hazards to personnel the grounded covers of the Model 1402A controller or the ion gun assembly should only be removed by qualified service personnel.

WARNING: OPERATION OF THE MODEL 1402A ION GUN WITH ANY OF THE SYSTEM GROUNDED SAFETY COVERS REMOVED MAY EXPOSE THE OPERATOR TO POTENTIALLY LETHAL HIGH VOLTAGE.

The model 1402A ion gun is equipped with various high voltage safety interlocks:

A cable interlock to prevent turn-on of the high voltage supplies in the event of the principal (13 pin) high voltage cable being disconnected from either the ion gun or controller.

A pressure sensitive interlock to prevent activation of supply voltages when the ion source pressure is excessively high.

System and auxiliary interlocks which shutdown the ion gun in the event of a system or auxiliary equipment detected failure.

CAUTION: OPERATION OF THE ION GUN WITHOUT INTERLOCKS MAY RESULT IN DAMAGE TO THE UNIT.

II. Specifications and Performance

The ion gun and controller undergo a full system test to verify all performance specifications are met prior to shipment. The gun assembly is hi-pot tested under vacuum to a 20% over-voltage condition in order to verify high voltage standoff and the absence of electrical leakage.

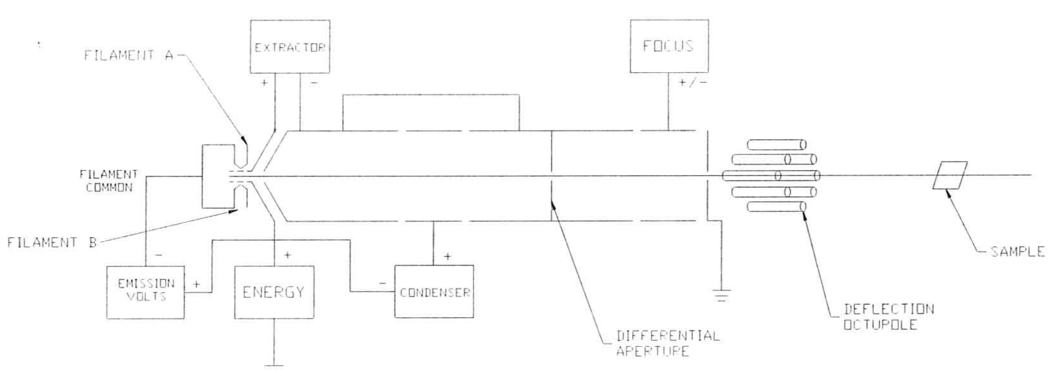
Intensity profiles are obtained by scanning the beam over the small pinhole in a Faraday cup arrangement. Spot size is measured at a primary energy of 500eV, 1keV, and 3keV with 6uA beam current with a working distance of 20mm. Spot size is also measured at 100eV, and 2uA of beam current. Additional operating conditions can be characterized by customer request. The operating specifications for the model 1402 ion gun and controller are:

Beam Energy	5V to 3000V Continuously Variable
Beam Current (Argon gas)	6uA maximum 1nA minimum
Spot Size(20mm W.D.)	0.4mm FWHM @ 6uA, 3keV 0.75mm FWHM @ 6uA, 1keV 1.0mm FWHM @ 6uA, 500eV 1.0mm FWHM @ 2uA, 100eV
Working distance	5mm to 25cm
Raster Area	5mm square @ 20mm W.D.
Electrical Power	115/220V 50/60Hz Auto select
Vacuum Mounting Flange	2-3/4 (70mm) Conflat
Supply Gas Inlet	1-1/3 (34mm) Conflat
Differential Pump Port	2-3/4 (70mm) Conflat

III. Principle of Operation

The Model 1402 Ion Gun is an electron impact ionization source capable very high beam currents at low beam energies. The Model 1402 is also capable of small spot size and high beam current performance for high sputter rate applications.

Dual filaments are standard to provide backup capability in the event of failure of the first filament. Inert gas, typically Argon, is fed through a leak valve, mounted on the gas inlet flange (1-1/3 CFF), to the ion source region. Electrons are emitted from the energized filament and are accelerated through an electrode screen surrounding the source region making ionizing collisions with atoms of the source gas. A potential of approximately 100 volts is applied between the filament and the screen electrode to produce the necessary energy for efficient ionization. An ion extraction electrode arranged in close proximity to the source axial exit opening is biased approximately 500-1000 volts negative with respect to the source. This serves to draw ions from the source region into the optics column. After extraction, the ions are then focused onto a beam shaping/differential focus aperture by the condenser lens. For smaller spots at lower currents the condenser lens may turned off to allow the beam to be trimmed by the aperture. In either mode the objective lens serves to focus the beam onto the sample. The objective focus lens is operated in one of two mode depending upon the application. For higher beam energies (>500eV) the objective focus is operated in a decelerating mode (positive voltage). For lower beam energies the objective focus is operated in an accelerating mode (negative voltage) to maintain a higher ion velocity until near the end of the column. This serves to minimize the effect of space charge repulsion in the beam.



NONSEQUITUR TECHNOLOGIES MODEL 1402 ION GUN

IV. Unpacking Instructions

The 1402 ion gun is shipped in two packages:

	Dim. (inches)	Gross Wt. (lbs)
Package 1	36x18x12	18 (8.2 Kg)
Package 2	24x24x12	32 (15.5 Kg)

Carefully unpack and remove the ion gun and 1402A controller from their shipping boxes. The ion gun is shipped with a fitted metal shipping cover to protect the electron optical elements. The shipping cover should not be removed until the system is ready to be installed. In the event of shipping damage please contact Nonsequitur Technologies at (541) 312 2410.

Each of the packages contains the following items:

Package 1:

- Ion Gun
- Maintenance Tool Kit
- Installation Gaskets
- Filament Assembly Fixture
- Aperture Installation Tool (optional accessory)
- Test Sample (optional accessory)

Package 2:

- Ion Gun Power Supply (Controller)
- 120 VAC Power Cable (220V cable optional).
- High Voltage Cable
- Vacuum Interlock and pressure monitor Cable (terminated with 9 pin D Connectors)
- System and Auxiliary Interlock Jumpers.

V. Pre-installation

Several requirements should be reviewed with the objective of purchasing, or fabricating, accessories which may be required for ion gun installation:

Working distance

In some case a custom made 2-3/4" CFF spacer nipple may be necessary in order to obtain the desired working distance from the gun final lens to the sample. Figure 3 and section II provide the relevant details to assist in the design of this nipple.

Differential pumping

To obtain optimum system vacuum during operation of the ion gun, careful consideration should be given to the location and pump speed of the differential vacuum pump used to evacuate the ion source region. Best results will be obtained with the maximum possible pumping speed at the differential pumping port. If it is not possible to directly mount the pump to the pumping flange then, the minimum length of stainless steel vacuum line should be used. A turbo pump with minimum pump speed 70 liter/second is recommended for pumping noble gases.

Ion Gun Alignment

Alignment of the gun axis to the sample mean position (center of the raster) should be made to better than 0.5mm pointing error if full use of the available raster area is necessary.

Errors larger than 5 mm will require the purchase of a port alignment device. Smaller pointing errors (approximately 1mm or less depending on working distance) can normally be corrected by careful selective tightening of the flange mounting bolts on the ion gun (see section IX).

For assistance with pre-installation issues contact Nonsequitur Technologies.

VI) Installation

1) Remove the shipping cover and install the ion gun onto the vacuum chamber using the copper gasket and fastening hardware provided. Tighten the gun mounting flange bolts with minimum but uniform torque to obtain necessary vacuum integrity.

NOTE: BOLTS SHOULD BE TIGHTENED WITH MINIMUM TORQUE TO ALLOW FINAL ALIGNMENT ADJUSTMENT TO BE CARRIED OUT (SECTION IX)

2) Install the differential pumping and Argon gas supply lines.

3) Insert the test sample into the chamber.

4) Install all electrical cables to the 1402A controller and to the rear bulkhead of the ion gun. Ensure that the high voltage 13 pin cable is firmly connected at both ends. Failure to properly tighten these connectors may lead to pin to pin arcing within the connector junction.

5) The two 4 pin (Amp) plastic connectors included are interlock jumpers which may be used as an alternative to hooking-up the controller to a parent system or other auxiliary equipment. These may be connected to the controller rear panel at socket locations J1 and J2. For the case where the ion gun is to be interlocked from external equipment the required interlock logic is detailed on the rear panel of the controller. This supports most interlock protocols with the options of 12-24VAC/DC or an external switch closure to signify interlock OK.

VII. 1402A Controller

The 1402A Ion Gun Controller provides and monitors all of the voltages and currents used to operate the ion gun. The X and Y raster can alternatively be controlled from an external source in order to scan the beam (to do this first switch the front panel raster to the Off position). The front and rear panels are shown in figures 1 and 2 respectively.

From left to right, the front and rear panel indicators, manual controls, inputs and outputs are described in table 1 and 2 respectively, with a brief description of the purpose of each.

Control / Indicator	Purpose
Source Pressure Panel Meter	Monitors ion source pressure
Interlock Status LED's	Monitors interlock status (green = OK, red = disabled)
Source Panel Meter	Monitors source parameters depending on setting of rotary function select / emission switches
Function Select Switch	Selects function to be displayed
Fil A / Fil B Toggle Switch	Selects filament to be energized
Standby Trim Potentiometer	Adjusts value of standby current in the filament. Used to ramp the filament current in degas procedure
Beam On / Off Toggle Switch	Switches the ion beam on and off
Beam On LED	Shows activity state of the ion beam (green – beam on, red – beam off)
Lens Voltage Panel Meter	Displays value of various lens voltages depending upon rotary function selection or condenser switch settings
Lens Rotary Selection Switch	Selects Lens voltage to be displayed
Condenser Potentiometer	Adjusts the condenser lens voltage.
Extractor Potentiometer	Adjusts the ion extractor electrode voltage
Energy Potentiometer	Adjusts the beam final energy (range 0 – 3 kV)
Focus Potentiometer	Adjusts the objective lens focus voltage
Raster Size Potentiometers (X and Y)	Adjusts the raster scan extremes in X and Y directions
X and Y Centering Potentiometers	Allows Mean position of the raster or spot location to be moved in the X and / or Y directions
Remote / Local Toggle Switch	Switches beam on / off control to external (rear panel, J1 input), or internal (front panel beam on / off) source
Raster On / Off Toggle switch	Switches the internal raster scan supply on and off
Power Switch	Mains power

Table 1 Front Panel Controls and Indicators

System and Auxiliary Interlocks	Provides the capability to activate and deactivate the ion gun from external equipment (e.g. a parent system)

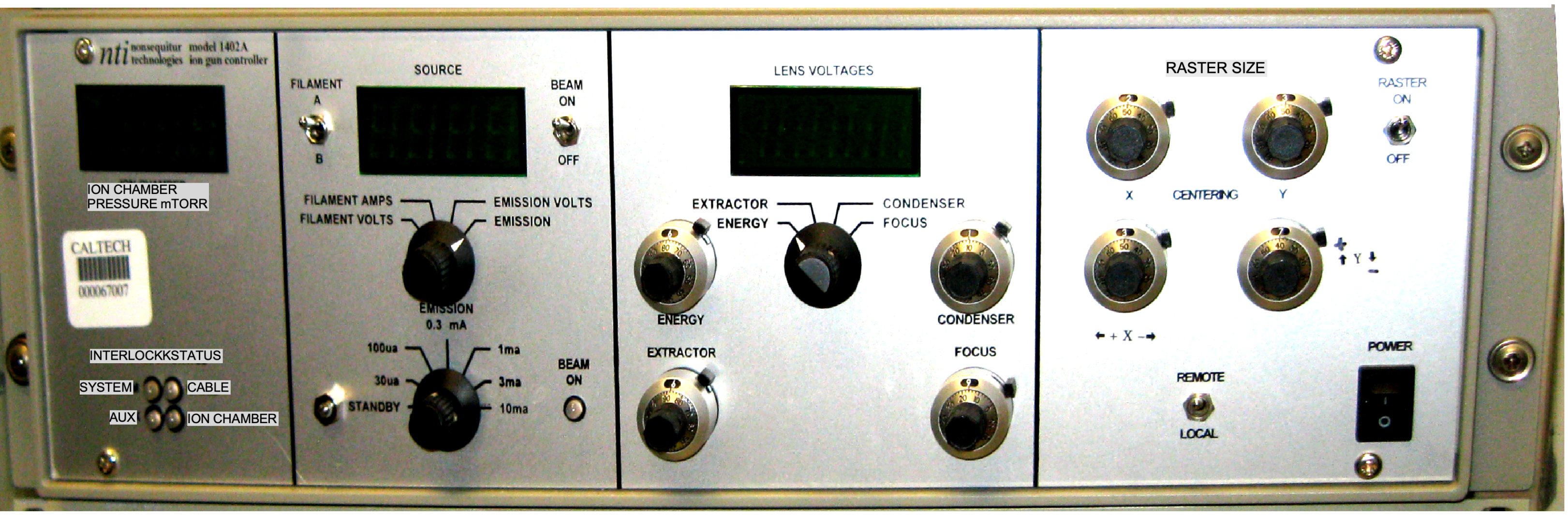
Mains power module	Mains power input
Working Distance Correction Potentiometer (see section IX)	Adjusts the symmetry of the beam rastered area to compensate for changes in working distance (section IX)
Y- Incidence Angle Correction Potentiometer	Adjusts range of Y scan to compensate for scan elongation resulting from changing incidence angle (Y direction only). See section IX
Trapezoid Correction Potentiometer	Compensates for changes in X scan range at the sample for Y glancing incidence geometry (see section IX)
Beam Current Input	Input from the ion gun faraday electrode
Beam Current Control	Voltage applied to steer the beam into the faraday electrode
Pressure Input	Vacuum pressure input signal from piranni gauge
Remote On / Off	External beam on / off signal.
X Raster In	External X raster input signal
Y Raster In	External Y raster input signal
X Raster Out	Internally generated X raster output signal
Y Raster Out	Internally generated Y raster output signal
Ion Chamber Pressure	Piranni gauge vacuum pressure signal output
User Interface (25 pin D connector)	Not Used
Ion Gun Output	Principal 13 pin high voltage connection to the ion gun

Table 2 Rear Panel controls and connections

1402A Electronic Schematic Drawings

Electronic schematic drawings for all of the 1402A controller circuit boards are available, upon request, in electronic or hardcopy form. Should these be required please contact Nonsequitur Technologies.

Front


nti nonsequitur technologies model 1402A ion gun controller
ION CHAMBER PRESSURE mTORR
CALTECH
000067007
INTERLOCKKSTATUS
SYSTEM
CABLE
AUX
ION CHAMBER
SOURCE
FILAMENT
A
B
BEAM ON
OFF
FILAMENT AMPS
FILAMENT VOLTS
EMISSION VOLTS
EMISSION
EMISSION 0.3 mA
100ua
30ua
STANDBY
1ma
3ma
10ma
BEAM ON
LENS VOLTAGES
EXTRACTOR
ENERGY
CONDENSER
FOCUS
ENERGY
CONDENSER
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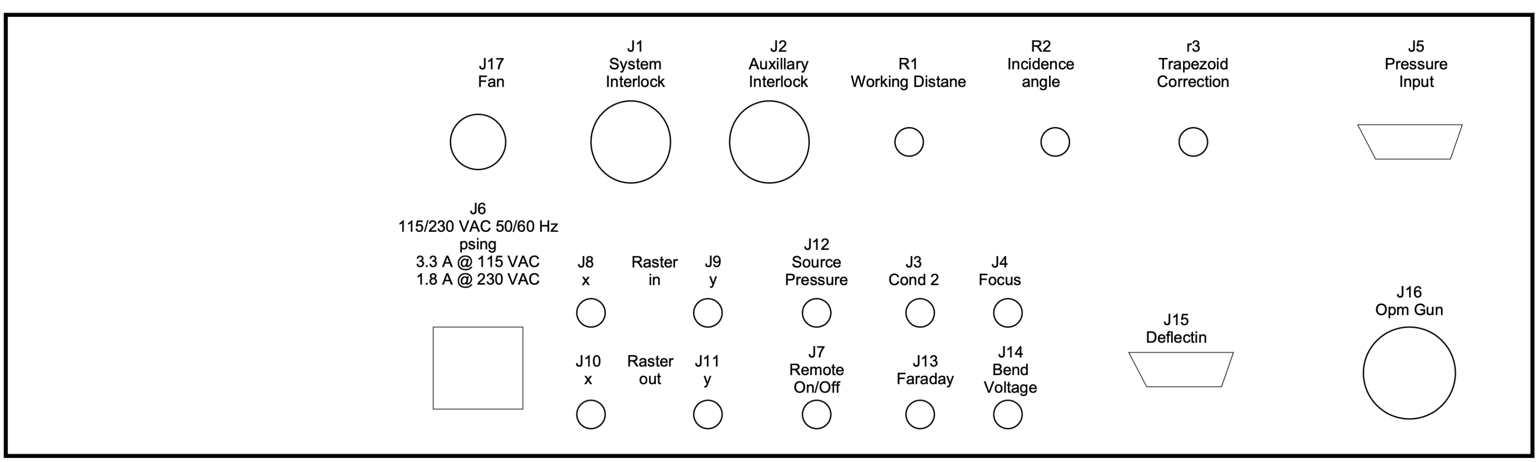
RASTER ON
OFF
X
CENTERING
Y
+ X −
+ Y −
POWER
REMOTE
LOCAL

Back


J17 Fan
J1 System Interlock
J2 Auxillary Interlock
R1 Working Distane
R2 Incidence angle
r3 Trapezoid Correction
J5 Pressure Input
J6 115/230 VAC 50/60 Hz psing 3.3 A @ 115 VAC 1.8 A @ 230 VAC
J8 x
Raster in
J9 y
J12 Source Pressure
J3 Cond 2
J4 Focus
J16 Opm Gun
J15 Deflectin
J10 x
Raster out
J11 y
J7 Remote On/Off
J13 Faraday
J14 Bend Voltage

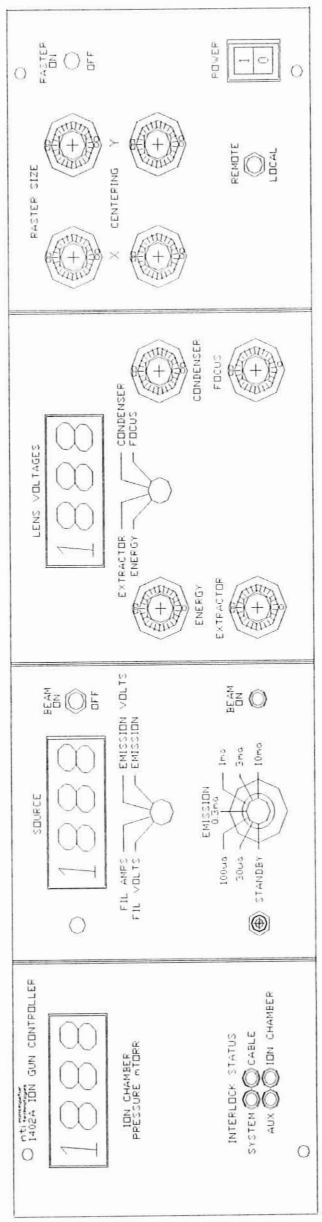


Figure 1. Front Panel Schematic 1402A

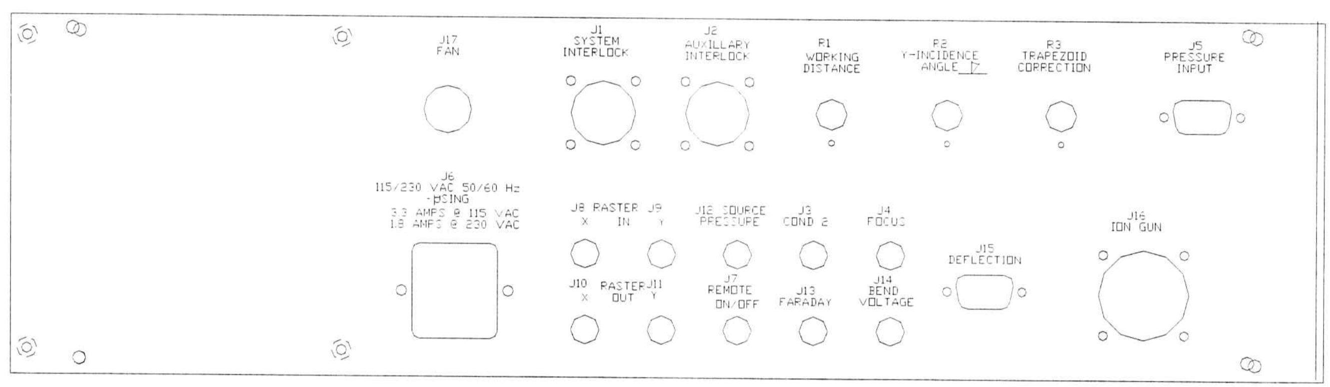


Figure 2. Rear Panel Schematic 1402A

VIII. Bake out and Conditioning

1. Pump the chamber to a pressure of 1 x 10^{-7} Torr or better. Wrap the cross hatched region shown in figure 3 and the differential pumping lines with a heater tape or blanket.

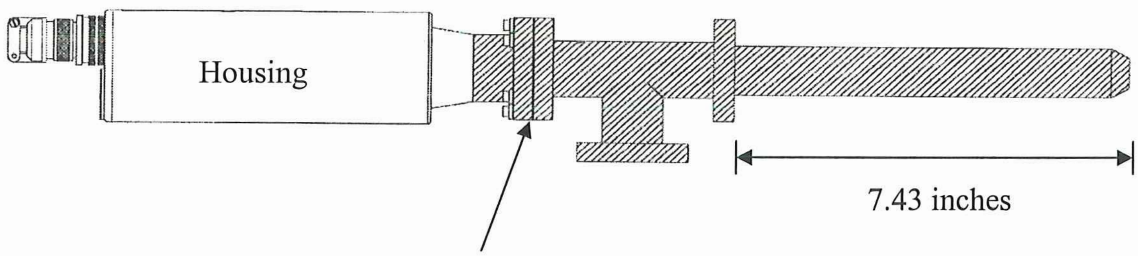


Figure 3. Ion Gun Schematic.

2. Using a Variac or temperature controller initiate ion gun bake out to a temperature of 150°C +/-25 °C for a period of at least 8 hours.

CAUTION: THE TEMPERATURE OF THE ANODIZED HOUSING SHOULD NOT EXCEED 50°C. FAILURE TO RESTRICT THE HOUSING TEMPERATURE TO THIS LIMIT COULD DAMAGE THE SYSTEM OR CREATE A FIRE HAZARD

3. Ensure that the emission select switch is set in the filament standby mode, the filament standby trim potentiometer and energy potentiometer are turned fully counter clockwise (CCW). Switch on the controller and allow it to stabilize for a several minutes.

4. Progressively rotate the filament standby potentiometer clockwise (CW) to increase the filament voltage and current while limiting the chamber pressure to < 5 x 10^{-7} Tor.

   NOTE: THIS PROCESS MAY TAKE SEVERAL HOURS TO COMPLETE

   When the potentiometer is finally adjusted to the fully CW position, the filament is degassed and the potentiometer can be returned to the fully CCW setting.

5. Repeat the procedure for the backup filament.

6) When the bake out and degas process is complete turn off the heater tape/blanket and

allow the ion gun to cool to < 50°C.

7) Rotate the emission switch to the 30 μA setting and allow the chamber pressure to recover to 5×10^{-7} Tor. Progressively increment the emission current setting to its maximum value (10 mA) ensuring the chamber vacuum pressure does not exceed 5×10^{-7} Tor at each step.

8) Gradually increase the beam energy to 3 kV using the ten turn energy potentiometer on the controller front panel. If arcing is observed temporarily reduce the beam energy until arcing disappears. Allow the system to stabilize for approximately 15 minutes and continue the procedure.

9) Repeat the two previous steps for the backup filament.

10) Reduce the energy to 2kV and set the emission current to 1mA. Open the leak valve SLOWLY and adjust the ion source pressure to 15 m.Tor, indicated on the left hand front panel meter of the 1402A controller.

11) Gradually increase the beam energy to 3kV; again pausing to allow the system to stabilize should arcing occur.

12) Progressively increment the emission setting to 10mA. At this time the ion gun should be ready for use.

NOTE: WHERE DIFFICULTY IS EXPERIENCED IN HIGH VOLTAGE CONDITIONING OF THE ION GUN IT IS OFTEN ADVANTAGEOUS TO RUN THE SYSTEM IN STANDBY MODE FOR SEVERAL HOURS WITH THE GAS FEED TURNED ON.

IX. BEAM SETUP

Firstly, align the beam spot or raster scan centroid with the desired analysis area on the sample. To do this turn on the ion gun and first position the sample as required. Assuming the ion gun pointing error is small (see section V) this alignment can be achieved by selectively tightening the bolts on the 2-3/4" CFF mounting flange so as to unevenly compress the copper sealing gasket to tilt the ion gun axis in the required direction.

CAUTION: THIS BOLT TIGHTENING PROCEDURE IS IRREVERSIBLE. DO NOT ATTEMPT TO UN-TORQUE BOLTS IN AN ATTEMPT TO COMPENSATE FOR OVERTIGHTNING.

For optimum ion gun performance the setup of several controls is required. These include: beam fine focus settings, the incidence angle, working distance and raster trapezoid corrections.

More precise setup of the beam focus can be made by etching samples which produce visible contrast after sputtering. Examples include: oxidized copper and a thin layer of gold deposited onto silicon or stainless steel. For fine spot size adjustment the raster is turned off and a systematic series of etched spots with focus intervals of 25 volts is then made. The voltage setting which provides the minimum etch crater size is then selected..

NOTE: FASTER ETCH RATES AND IMPROVED CRATER CROSSECTIONAL PROFILES ARE USUALLY OBTAINED WITH A FOCUS SETTING OF 50-100 VOLTS LOWER THAN RESULTS OBTAINED VISUALLY. IN GENERAL, LOWER FOCUS VOLTAGE RESULTS IN A SQUARER BEAM PROFILE COMPARED TO THE GAUSSIAN SHAPE OBTAINED AT BEST VISUAL FOCUS.

Assuming the approximate values of working distance and incidence angle are known, the required potentiometer corrections may be deduced from figures 5 and 6. More accurate setup of incidence angle and working distance correction is normally required only for applications with short working distance combined with an oblique incidence angle and large scan area.

For oblique incidence (Y direction only) the trapezoid correction is best setup iteratively. This can be carried out by etching a sample with raster scan turned on, observing the shape of the crater produced, adjusting the trapezoid correction potentiometer and then re-etching another crater. The process is complete when an etch crater having a square symmetry is obtained.

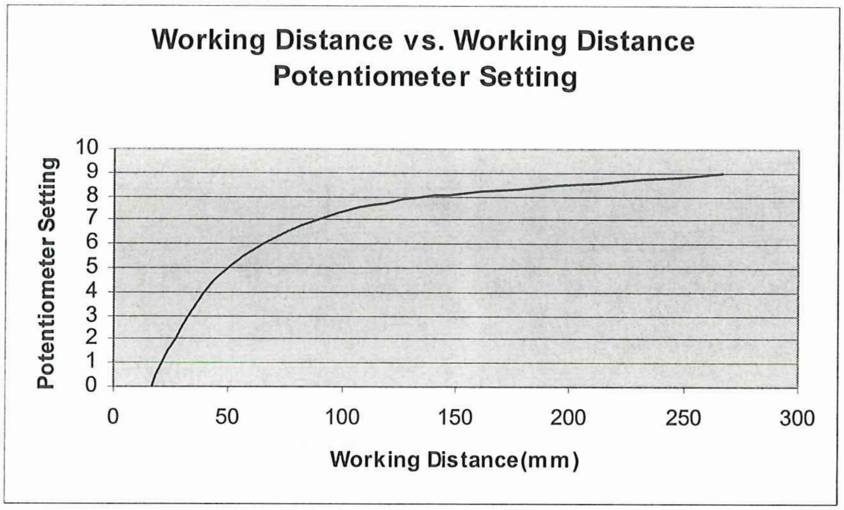


Figure 5. Showing the required setting for rear panel working distance correction potentiometer to compensate for changes in the raster size with working distance.

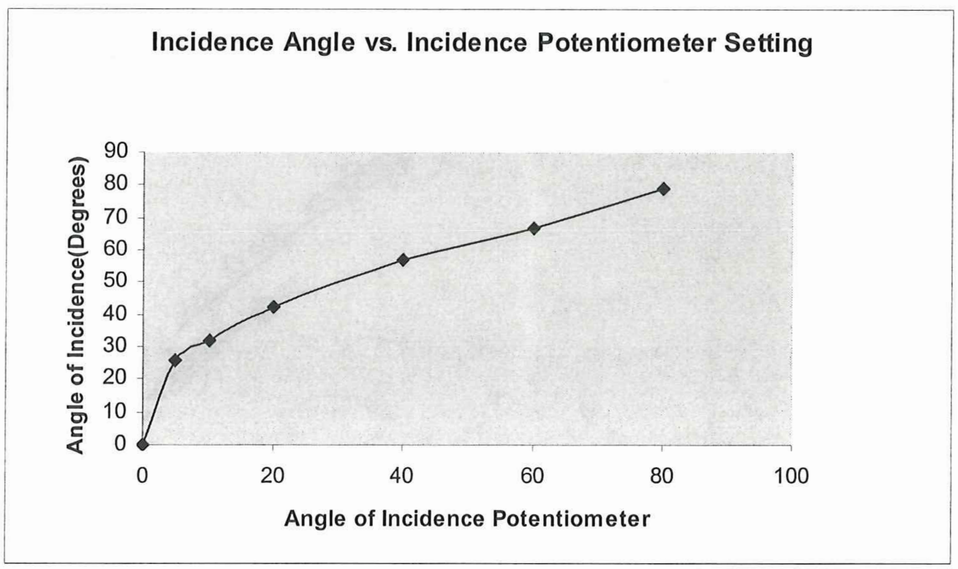


Figure 6. Showing the required setting for the rear panel Y- Incidence Angle Correction potentiometer in order to compensate for an oblique geometry.

Ion Gun Settings - with Working Distance of 20mm and Source Pressure of 34mTorr

Energy	Extractor	Condenser	Focus	I sample
3000	1205	149	2615	
1000	1205	158	915	
500	1205	150	451	
200	1204	160	-750	5.7 μA
100	1204	161	-540	
50	1204	154	-500	2 μA

working conditions:

3001 1204 0244 2617

raster: 2.5 x
3.5 y

Center: 4.75 x
5.5 y

Ion chamber pressure: 6.7

working distance: 1.5
Incidence Angle: 4.0
Trapezoid: 0.0

~~Spot:~~
~~x: 0.76~~
~~y: 0.[illegible]~~
~~x 0.19~~
~~y [illegible]~~

Ion Gun Settings – with Working Distance of 20mm and Source Pressure of 34 mTorr

Energy	Extractor	Condenser	Focus	I_{sample}
3000	1205	149	2615	
1000	1205	158	915	
500	1205	150	451	
200	1204	160	-750	5.7 μA
100	1204	161	-540	
50	1204	154	-500	2 μA

working conditions:

3001	1204	0244	2617

raster: 2.5 x
3.5 y

Center: 4.75 x
5.5 y

Ion chamber pressure: 6.7

working distance: 1.5
Incidence Angle: 4.0
Trapezoid: 0.0

~~x-0.76~~

X. Ion Gun Operation

If the ion gun is to be used for depth profiling, or it is desired to acquire survey spectral information prior to sample cleaning, then it is recommended that the following steps be performed before sample introduction. This procedure is suggested because the Model 1401 Ion Gun is capable of very high etch rates and exposure to the beam for a few seconds may result in a substantial change to the native sample surface.

Before turning on the system power set the following parameters on the 1401A Controller:

Emission	Standby
Energy	80% of full scale potentiometer
Beam On/Off	OFF
Condenser	Setting A, B or C as required
Raster	On/Off and X & Y Raster Potentiometer as required.
Remote/Local	Local for sample cleaning Remote for depth profile.

Turn on the system power. For best etch rate repeatability allow the ion gun to operate in standby mode for 30 minutes to allow the ion source to reach thermal equilibrium prior to use. Where possible, for consistent beam current repeatability, set the ion source pressure to a previously determined value, if available - typically maximum ion beam current is obtained at approximately 6 to 7 m.Tor source pressure for Argon. Alternatively, or as a check on performance stability, the ion gun internal Faraday cup may be used to optimize the source pressure for maximum beam current with the condenser C switch position and 10mA emission current selected. At this time the sample to be analyzed should be well removed from the analysis position to avoid inadvertently altering the sample surface while adjusting the source pressure.

Sample Surface Cleaning

1. For manual cleaning of a sample set the ion beam energy, emission and raster size to the desired values (3kV and 10 mA provide maximum erosion rate).
2. Switch the Beam On/Off toggle switch to the On position. The typical time to clean adventitious carbon from a sample surface is approximately 10 seconds.
3. Set the Beam On/Off toggle switch to the Off position. The cleaning cycle is complete.

Depth Profiling

1. Set the remote/local switch to remote to allow computer controlled shut-down of the beam during analysis.

2. Set the raster toggle switch to On to initiate the analysis.

   NOTE: EXCESSIVELY LONG ETCH TIMES MAY RESULT IN UNDESIRABLE SURFACE ROUGHNESS OR CONE DEVELOPMENT WHICH MAY LIMIT PROFILE DEPTH RESOLUTION.

3. Before turning off the controller, make the following adjustments in preparation for subsequent etch operations:

Emission	Standby
Beam On/Off	Off
Remote/Local	Local
Energy	80% of full scale potentiometer
Power	Off

4. Turn off the 1401A controller and shut off the gas supply.

XI. Routine Maintenance

Normal routine maintenance of the 1401 ion gun typically involves:

1. Replacement of the filaments after approximately 500 hours of operation.

2. Replacement of the differential pumping aperture after approximately 500 hours of operation.

3. Cleaning, or replacement, of critical source ceramics after 2000 hours of operation. Should the user desire to carry out the 2000 maintenance at their own location, then replacement parts and instructions can be obtained from the factory.

NOTE: NONSEQUITUR TECHNOLOGIES RECOMMENDS RETURNING THE ION GUN TO THE FACTORY FOR THE 2000 HOUR MAINTENANCE.

Filament Change

Replacement filaments assemblies are available from the factory. To replace a filament assembly carry out the following:

1) Turn off the ion gun and allow the gun to cool for one hour minimum.

2) Vent the vacuum system to dry nitrogen.

3) Disconnect all electrical cables and the gas supply inlet from rear bulkhead of gun housing.

4) Remove the six ¼-28 bolts on the flange closest to the gun housing (see figure 3) and remove the optical column assembly. A slight back and forth rotation of the optical column may make it easier to withdraw the optical column from the column housing.

NOTE: THE OPTICAL COLUMN HOUSING IS NOT REMOVED FROM THE VACUUM CHAMBER FOR THIS PROCEDURE.

5) Carry the ion gun to a clean particle free location to change the filament assembly.

6) Remove the two gold plated 2-56 screws securing each filament assembly to ion source. Lift the filament assembly perpendicular to column axis until the filament is clear of the ion source. Slide the connector socket off the feedthrough pin.

NOTE 1. ONE OF THE TWO FILAMENT ASSEMBLIES ALSO HAS THE FILAMENT COMMON LEAD SECURED BY ONE OF TWO 2-56 SCREWS.

NOTE 2. THE SCREW WHICH SECURES THE FILAMENT COMMON LEAD IS 3/16 INCH IN LENGTH WHEREAS THE OTHER THREE 2-56 SCREWS SECURING THE TWO FILAMENT ASSEMBLIES TO THE SOURCE ARE 1/8 INCH IN LENGTH.

7) Install the filament assembly into ion source. This install is carried out in reverse order of removal i.e. slide the connector socket onto the respective feedthrough pin and then carefully place the filament into the source. Secure the filament assembly to the ion source using two new gold plated 2-56 socket cap screws provided with the filament replacement kit. Reserve the longer 2-56 socket cap screws to secure the filament common lead. Repeat the process for the second filament assembly.

NOTE: IF THE DIFFERENTIAL PUMPING APERTURE IS TO BE REPLACED GO TO APERURE REPLACEMENT. OTHERWISE CONTINUE.

8) Using a new 2-3/4 Conflat gasket, re-install the gun optical column into optical column housing.

9) Pump the chamber, bake out and condition the ion gun as described in section VIII.

Aperture Replacement.

The differential pumping aperture is threaded into a tapped hole between condenser and objective lenses and is accessed through the opening in the sample end of the column. Earlier apertures require a straight blade screwdriver for removal. Newer apertures are removed and installed using a 3/32" hex driver supplied with the gun.

1. Using a flashlight look through the opening in the sample end of the column to determine which of the two types of aperture is installed.

NOTE: THE APERTURE IS APPROXIMATELY 1.5 INCHES (40 MM) FROM THE END OF THE COLUMN.

2. Using an appropriately sized straight blade screwdriver or the 3/32" hex driver (whichever is applicable), remove the aperture (turn counterclockwise to remove).

3. Install the new aperture on the end of the 3/32" hex driver and insert it into the tapped mounting hole.

4. Screw the aperture into place and tighten lightly. Continue with the installation of the optical column into the column housing as described in item 8 of the filament change section.