SPECS®

Surface Analysis and Computer Technology

Ion Source IQE 12/38

User's Manual

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Chapter 1 Introduction

The ion source IQE 12/38 has been designed for general sample cleaning and depth profiling applications in XPS, UPS and AES and as an primary ion source for SIMS, SNMS and ISS. Extremely homogeneous current densities and crater shapes are achieved by scanning a focussed ion beam with small spot size over an adjustable sample area. The special ion optical design of the IQE 12/38 allows the operation with variable beam diameters (small focus and large focus mode). Positive ion species of all inert gases as He, Ar, Ne, Xe, Kr, N_2 can be generated as well as reactive ions by use of O_2 or H_2. For high stability beam currents the atoms or molecules of the operating gas are ionized by collision with electrons, which are generated by a hot filament. The beam energy can be varied from 200 eV up to 5 keV and typical beam currents are in the range of less 1 pA up to 10 µA. The IQE 12/38 can be baked up to 250°C.

Additionally to the ion source IQE 12/38 SPECS offer a Wien mass filter WF-IQE package (order no. 10 867 440). The package consist of the Wien mass filter WF-IQE (10 867 045) and the Mass Filter Voltage Supply (10 867 945).

The Wien (E x B) type mass filter is used to purify the beam of an electron impact or plasma ion source operating in an UHV surface or thin film analysis system. In combination with the integrated neutrals beam stop (bend in the optical axis) surface contaminations induced by the ion source are minimized and dynamic range as well as depth resolution in dynamic SIMS and SNMS analysis (i.e. sputter depth profiling) can be improved. The high dispersion at small length and overall dimensions and the additional differential pumping port are general features of the filter.

Safety Hints

Before any electric or electronic operations please consult „SPECS Safety Instructions“ and follow them strictly.

Special Hints:

The IQE - 12/38 needs high voltages dangerous to life! You have to respect the following safety hints:

- Check whether your main voltage is the same as adjusted at the mains in socket of the Power Unit (visible at the fuse box).
- Use only original cables and connectors from SPECS. Pay attention that all cables are without mechanical defects. In case of doubt the cable has to be replaced by an original SPECS cable.
- Before switching on the Power Unit all plugs have to be connected to the corresponding socket.
- After switching off the Power Unit you have to wait at least one minute before opening connections.
- Replace cable or ion source only with the Power Unit switched off.
- Never operate the Power Unit with opened cover.
- If you use cable, ion sources or further equipment other than delivered by SPECS no warranty about the function and safety can be given. In case of doubt please contact the SPECS service department.

Some tests which might have to be carried out according to this manual are hazardous. At each such a point is there a warning label:

!!Attention!!

The tests described in the following have to be performed at connectors of the electronics not plugged into the source. Hazardous voltages are present, therefore only persons with the appropriate training are allowed to do the job.

Make measurements only with special insulated tools released for voltages higher than 5 kV.

Chapter 2 Description

2.1 Hardware Description

The complete IQE 12/38 ion source package, model no. 10 867 040, consists of the ion source hardware and the power supply with control electronics, PU-IQE 12/38, model no. 10 995 100.

The mechanical parts of the IQE 12/38 model no. 10 867 035, are shown in figure 1:

- ion gun housing
- ionizer and extraction assembly
- focussing and deflection unit
- gas inlet system (optional) with leak valve (optional)
- differential pumping equipment (optional, see figure 5 page 12)

All voltages and currents, which are necessary to operate the ion source, are generated and controlled by the PU-IQE 12/38 supply, as:

- Filament current with emission control
- Anode voltage
- Reflector (Repeller) voltage
- Extractor voltage
- Lens voltages (1 and 2)
- Deflection voltages (x and y)

A general layout and the electrical wiring is shown in figure 2.

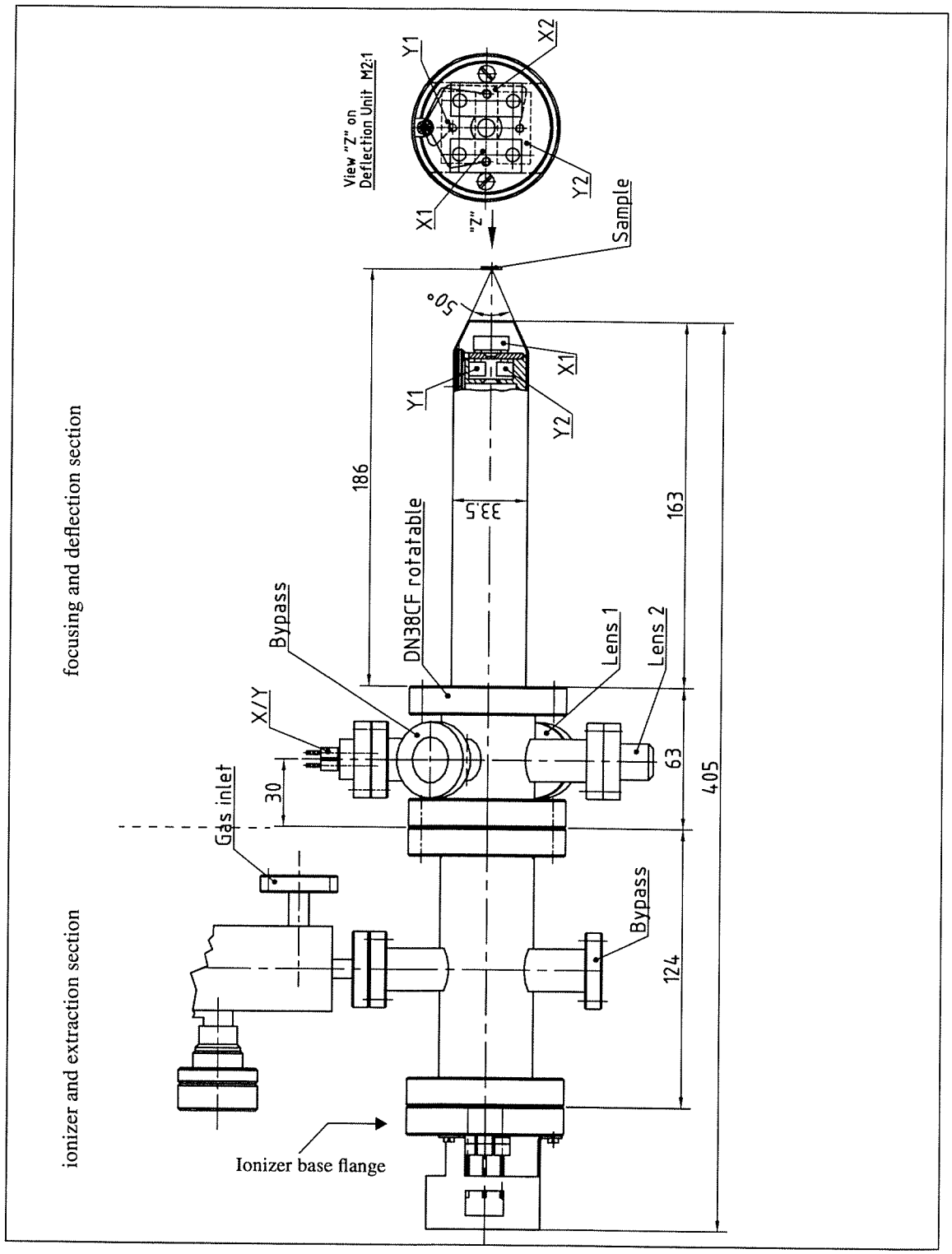

FIGURE 1 Schematic of Ion Source IQE 12/38

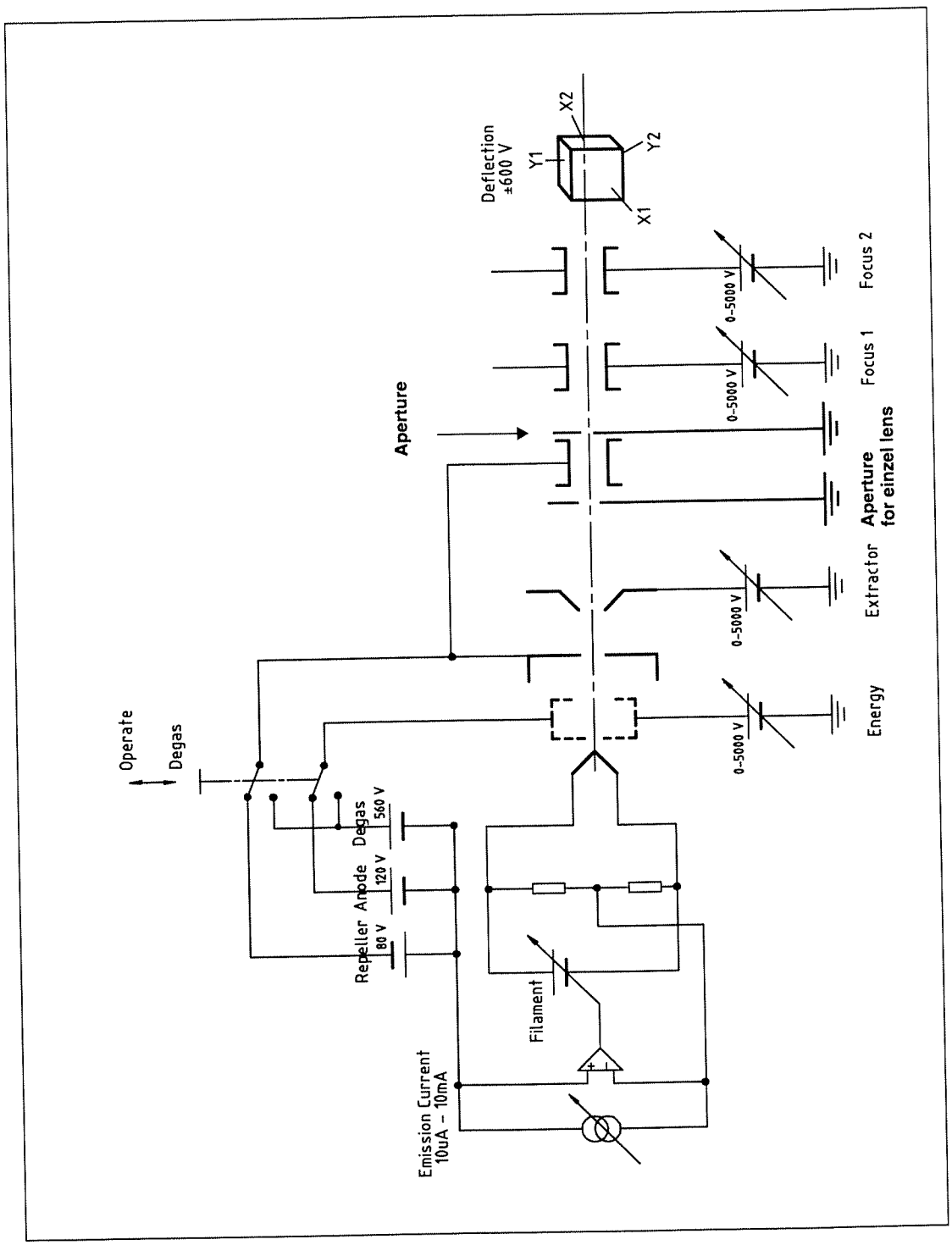

FIGURE 2 General Layout and Wiring

2.2 Basic Principles of Operation

2.2.1 Ion Formation

The neutral gas molecules and atoms are ionized by electron collision inside the ionization assembly (refer to figure 3 on page 10).

Inside a cylindrical housing ("repeller") a grid cylinder ("anode") is mounted. An Ω-shaped iridium ribbon filament is mounted around the anode in a constant distance. Electrons emitted from the filament are accelerated to the anode and enter the inner grid cylinder with an energy of about 100 eV. Here they may hit the gas particles, ionize them and form an electron-ion plasma. The conical extractor electrode accelerates the ions out of the plasma area and forms the ion beam.

An electron, which has been not effected by a collision, leaves the anode cage and is reflected by the potential on the reflector cylinder, to be accelerated again to the anode. The procedure is repeated until the electron is lost by an ionization process. This unique design allows an increase of the collision efficiency only by means of electrostatic forces, so that additional magnetic fields are not needed.

The total yield Y of the produced positive ions I_{tot} can be calculated by

$$Y = \frac{I_{tot}}{I_{em} \cdot p_s} \left[mbar^{-1} \right] \qquad \text{(EQ 1)}$$

with the emission current I_{em} and the pressure in the discharge area of the ion source p_S. For typical operating values of the IQE 12/38 as

I_{em} =	10 mA,
I_{tot} =	10 µA, and
p_S =	2×10^{-4} mbar Argon

the calculated yield of the ionization efficiency is 5 $mbar^{-1}$.

Please note, that the source pressure is the pressure in the discharge area of the ionizer assembly, not the main chamber pressure (see section 2.2.2)!

2.2.2 Ion Extraction

The ions in the discharge plasma are effected by the potential difference between the formation section and the conical extractor electrode. At 5 keV beam energy this voltage is about 150 V lower. Because the ratio of beam energy and extractor voltage is nearly constant over a wide energy range of the gun, the extractor voltage ratio can be adjusted at the front panel of the power supply, displayed in % of the beam energy, which can be varied and displayed from 0 to 5000 eV.

A single lens electrode, which is internally connected to the reflector cylinder, works as an extraction optics and focuses the ions into a spot of less than 0.1 mm. In the image plane of this lens a replaceable aperture of 1 mm diameter is positioned. It effects the ion beam in two ways. First, as a defining aperture it allows only particles to pass (about 85% of the originated ions), which move closed enough

to the system axis and can hence be focussed properly in the following lenses. Secondly, as a differential pumping aperture it separates the discharge area from the UHV system.

The conductivity of a thin aperture can be calculated by the following formula:

$$C_0 = \frac{\bar{c}}{4} \cdot \frac{d^2\pi}{4} = \frac{d^2\pi}{4}\sqrt{\frac{RT}{2\pi M_{mol}}} \qquad \text{(EQ 2)}$$

with:

C_0:	Conductivity under molecular gas flow conditions,
$\bar{c}$:	Average velocity of the molecules at temperature T,
d:	Diameter of the aperture,
R:	Gas constant,
M_{mol}:	Molecular mass of the molecules.
T:	Temperature

The vacuum pressure in the discharge section has a strong influence on the total ion current (see equation 1). Therefore, the measurement and the control of the gas pressure in the ion source is strongly recommended for accurate reproducibility. The pressure p_s in the source can be estimated, if the pumping speed of the pumping system S_{eff} and the pressure in the analysis chamber p_a is known.

$$p_s \cdot C_0 = p_a \cdot S_{eff} \qquad \text{(EQ 3)}$$

For Argon and air this conductivity is slightly less than 0.1 l/s, resulting in a pressure drop between the ionization volume and the front optics of 3 - 4 orders of magnitude for an assumed pumping speed of 100 l/s. For more informations please refer to "Vacuum Technology, its Foundations, Formulae and Tables", Leybold AG (1987).

Normally the main chamber pressure in a standard SPECS system is about 5 x 10^{-7} mbar, if the source pressure[1] is 2x10^{-4} mbar (Argon), not using the second pumping line for the focus housing. In the user system the vacuum meters will indicated different values (depending on the position of the meters and on the set up of the vacuum system) when the source is operated under optimal conditions.

2.2.3 Ion Beam Focussing

A double lens system transfers and focuses the ion beam, which has passed the aperture, onto the sample over a distance of 200 mm. Each lens is of the tubular type. It has an inner section, which is "long" relatively to its diameter.

A detailed analysis of the movement of electrically charged particles in electrostatic field with circular symmetry comes up with two important conclusions.

1. Please note, that the source pressure is the pressure in the discharge area of the ionizer assembly, not the main chamber pressure (see section 2.2.2)!

- The focussing property of a static electrostatic field is independent from the mass of the ions. Just energy defines the trajectories.
- The extraction and the lens potentials can be changed with a constant voltage ratio relatively to the ion energy without changing the electro-optical properties of the system.

The second conclusion has the consequence that the power supply needs only to control the voltage ratios to the energy, so that uncomfortable adjustments of the focussing conditions are avoided, if for experimental reasons the beam energy has to be changed. Only space charge effects due to changes of the discharge plasma and the ion current density of the beam need a new fine adjustment. For most of the standard applications the focus settings can be used without recalibration.

2.2.4 Ion Beam Deflection

Two pairs of deflection plates are mounted in front of the last lens element with an internal shielding. They are orientated that they form two electrostatic fields, which deflects the ions orthogonal to the ion source axis.

The deflection distance $D_{x,y}$ of a charged particle, which moves across the electrical field of a plate capacitor can be calculated with

$$D_{x,y} = \frac{eUls}{mdv^2} = \frac{eUls}{2dE_{kin}} \qquad \text{(EQ 4)}$$

$D_{x,y}$:	Deflection distance from the gun axis in x and y direction,
e:	Elemental charge,
U:	Voltage between opposite deflection plates,
l:	Length of the deflection plates,
s:	Capacitor-to-sample distance,
d:	Distance between the capacitor plates,
v:	Velocity of the particle before entering the capacitor field,
E_{kin}:	Energy of the particle.
m:	mass of the particle

The so called „Busch Equation" as the result for the movement of a charged particle in an electrostatic field shows, that the deflection distance is independent of the mass of ions.

If the data for the deflection geometry of the IQE 12/38 are used (d, l: 10 mm and s: 50 mm) a displacement of 5 mm can be calculated for 5 keV beam energy and deflection voltages of 500 V on the x- or y- plates. It can be verified, that this is in an excellent agreement with the experimental data.

Chapter 3 Mechanical Assembly

3.1 General

At the back of the IQE 12/38 ion source a 6-pin DN38CF feedthrough flange is mounted on an UHV cross DN38CF to DN16CF. The multiple feedthrough flange is the base of the complete ionization assembly (figure 4 page 10). The two DN16CF ports are used for the gas inlet leak valve and the tubulation for the first differential pumping section (figure 5 page 12).

Opposite to the 6-pin feedthrough flange a short DN38CF tube is fitted on the cross piece with four radial ports. They are used for feedthroughs (2 DN16 single pin for the focussing lens, one 4-pin DN16CF for the deflection unit, see figure 1 page 4) and the connecting port to the second differential pumping section (figure 5 page 12). Inside this short tubulation the lens and deflection unit is fixed.

To adapt a Wien mass filter WF-IQE to the IQE 12/38 the ionizer section and focus housing has to be separated as described in section 5.4 .

3.2 Ionizer and Extraction Assembly

The complete unit is mounted on the DN 38 CF feedthrough flange at the back end of the gun (see figure 3). It consists of

- the repeller housing with the internal anode cage and the filament ring (cathode),
- the extractor nose cone aperture,
- the repeller aperture and
- the repeller lens.

An isolating distance rod with spring suspension holds the ionization assembly in place and adjusts it properly in front of the defining aperture (1st differential pumping aperture) by pressing the repeller aperture against an internal mechanical stop, which is fixed inside the ion source housing. This also makes sure, that the repeller aperture makes contact to ground potential.

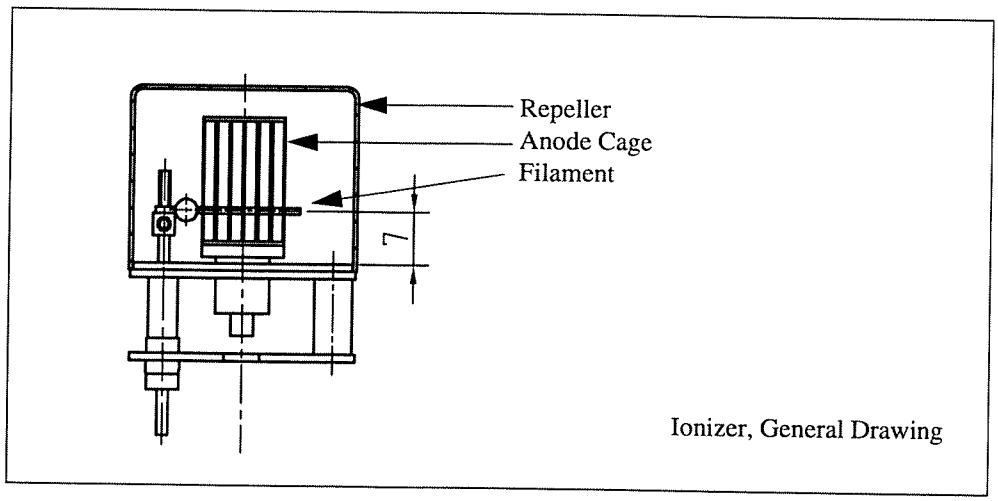

FIGURE 3 Ionization Assembly

The voltages and currents for operation of the ion source pass the base flange by the ceramic isolated feedthroughs, which are specified to hold 7 kV against ground potential. The respective pin diagram is sketched in figure 4. It should be mentioned, that pin 2 is not used.

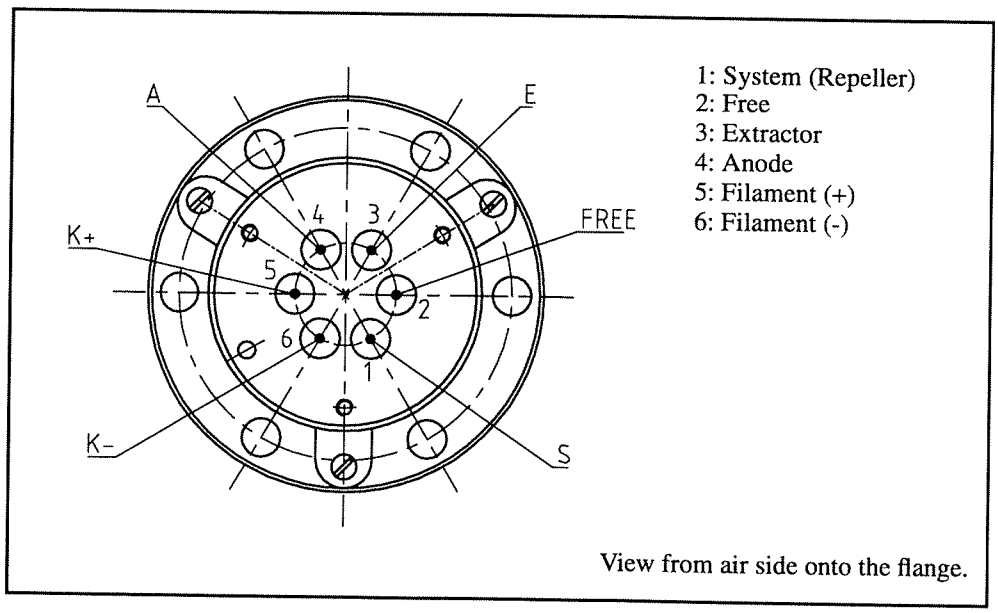

FIGURE 4 Pin Arrangement on Source Base Flange

3.3 Apertures and Ion Transfer

Two defining or differential pumping apertures are mounted along the ion source axis. The first, aperture, between ionization assembly and lens system, consists of a tantalum disc with an 1 mm opening as standard. For special experimental applications it can be replaced by a 0.5 mm or 0.2 mm

aperture, which are available as special spares at SPECS. For a Wien mass filter application the aperture should be 1.8 mm (see section 5.3). The second aperture, with an inner diameter of 3 mm is placed between lens and deflection system.

Due to internal sputtering effects the apertures have to be checked from time to time and, if necessary, replaced. Service on the lens and deflection system is very unlikely, because all insulating ceramics are shielded properly against deposition of sputtered materials.

The IQE 12/38 ion source can be dismounted in sections. This user friendly design makes necessary service work easy (see figure 1). The gun has not to be disconnected from the vacuum chamber in every case.

For replacement of aperture the flange connection between the source housing and the lens support tube with the radial feedthrough flanges has to be opened. The support plate can be disconnected and the aperture disc replaced (see section 5.3).

For servicing (see section 5) the ion formation module the 6 -pin feedthrough base flange at the gun end can be opened and the complete section removed. This allows an easy replacement of the filament or easy cleaning, if the section is contaminated.

3.4 Mounting Instructions

For mounting of the IQE 12/38 ion source the rotatable DN 38 CF flange at the lens support tube has to be connected to a suitable port on the UHV system. Standard distance from the mounting flange to the sample is 186 mm. Because of the easy focussing of the source other distances are possible.

Useful Note: Because of the rotation capability of the mounting flange the ion source can be fixed in any orientation. For a mechanical pre-alignment, which may be needed for some experimental reasons, the orientation of the deflection feedthrough port axis indicates the x direction (see figure 1). Using the SPECS Power Unit with the so called "keystone correction" possibility (see manual „Power Unit PU - IQE12") the deflection feedthrough port should point in the source axis - sample normal - plane. This will make the angle handling for the correction procedure easier.

If a separate differential pumping system or a bypass configuration is used, connect the first and second differential pumping stages to the pumping stack using the recommended differential pumping set (SPECS Cat. No. 10 861 170) and mount the DN 16 CF throttle valve in the first stage pumping line (see figure 5).

The ion source is working without any pumping stage also. Problem is the strong degassing of the filament after every system venting and during the initial operation procedure (see section 4.2.2).
The missing of the first pumping stage (DN16CF port at the ionizer section) will decrease the filament lifetime and the isolation of the ceramics in the ionizer and extractor assembly.
The missing of the pumping line to the focus housing of the ion source will limit the main chamber pressure to about 5 x 10^{-7} mbar during the sputter process (dependent on chamber volume and pumping speed of your system), but will not influence the source function itself.

Connect the gas inlet system (SPECS Cat. No. 10 869 202 or 10 869 200) via a high precision DN 16 CF leak valve to the DN 16 CF gas inlet flange on the ionization section housing.

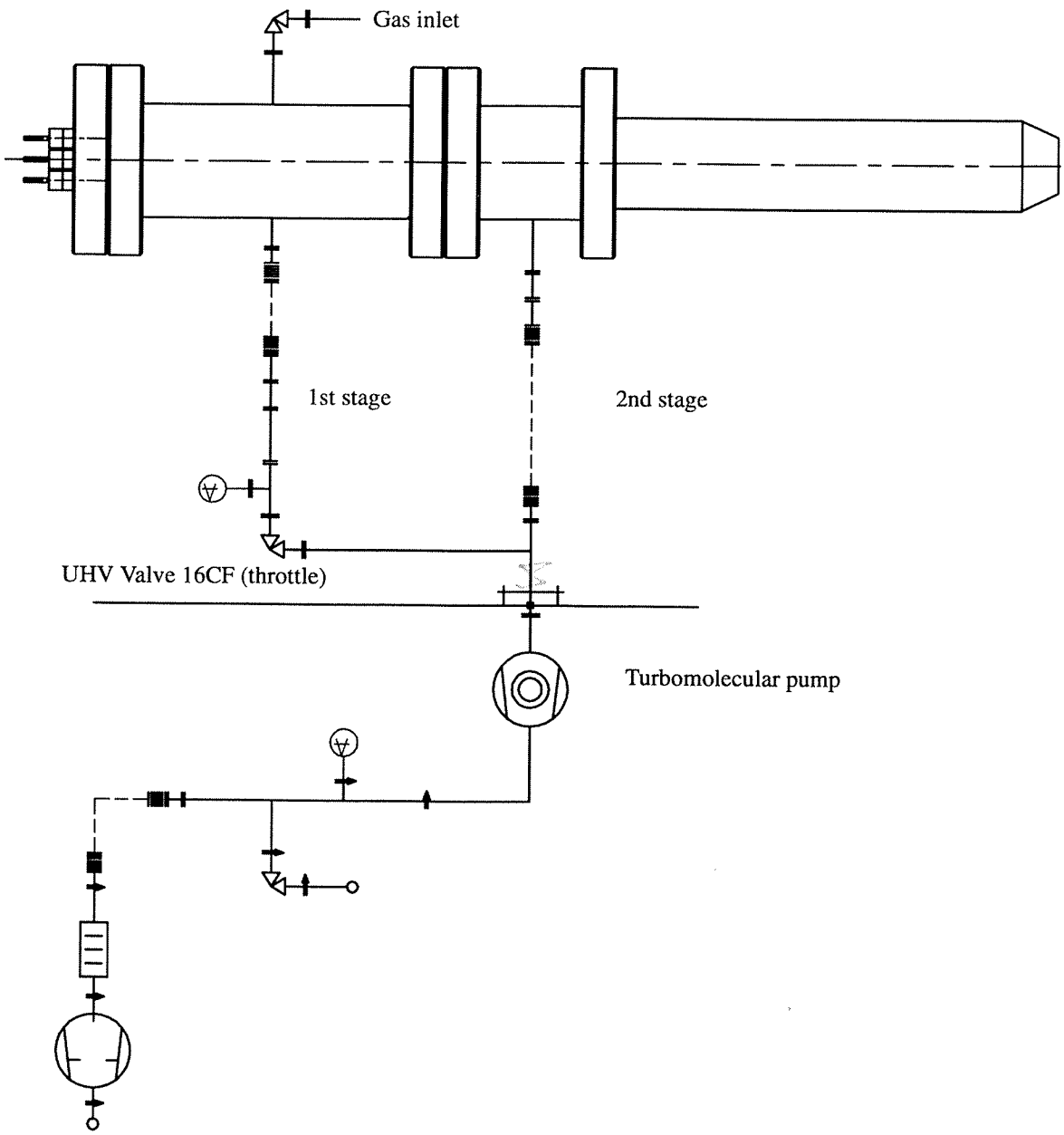

FIGURE 5 Differential Pumping System for the IQE - 12/38

Chapter 4 Operation

4.1 General

When mounting the IQE 12/38 ion source on a vacuum system without load lock, it should be checked first, if a suitable target is fitted on the manipulator (see 5.3.4).

After pump down a system bakeout is recommended for some hours at 200° C with all cables removed. The procedure should not be started before the pressure in the source[1] is less than 10^{-5} mbar.
A gauge at the gas inlet or bypass flange of the ionizer section is useful to monitor the source pressure[1] during bakeout and operation (see figure 5).
If no ion gauge is fitted for direct control of the internal vacuum conditions of the source, the pressure in the analysis chamber can be used as a rough indicator (using equation 3 from section 2.2.2). So, a total pressure of less than 10^{-8} mbar in the analysis chamber should be a good equivalent for the above mentioned limit.

The bakeout should clean the internal surfaces of the source as well as parts of the differential pumping and gas inlet system.

Please note: Open the valve in the first pumping stage (see figure 5 page 12) during bakeout!
The missing of the first pumping stage (DN16CF port at the ionizer section) during bakeout will decrease the filament lifetime and the isolation of the ceramics in the ionizer and extractor assembly!

If a gas bottle is already fitted to the inlet capillary, the bottle valve should be in closed position, while the precision leak valve should be open. This makes sure, that also contaminations from the gas inlet section are removed, which effects the lifetime of the ion source drastically during later operation.

After bakeout the system should be allowed to cool down. The gas inlet leak valve can be closed and the bottle valve opened. The connecting cables to the power supply can be plugged onto the respective feedthroughs. The IQE 12/38 ion source is ready for operation. In the next sections the steps are described for a first setup and optimization for routine work.

1. Please note, that the source pressure is the pressure in the discharge area of the ionizer assembly, not the main chamber pressure (see section 2.2.2)!

4.2 Setup for First Operation

Note: The ion source power supply is described in its manual separately, so that details of the electronics are mentioned only, if they are necessary for the operation of the ion source.

4.2.1 Initial Checks

To operate the ion source, some initial checks are recommended generally:

1. Make sure, that the pressure in the source is better 10^{-5} mbar (better 10^{-8} mbar in the analysis chamber).
2. Make sure, that, if an analog type power supply is in use, the settings of "EMISSION CURRENT" and "ENERGY" are zero, before starting the power supply.

Switch on the power supply.

4.2.2 Degassing Filament and Source

Please note: *During preparation of the filament, bakeout and using the "DEGAS" function from the power supply please open the valve in the first pumping stage (DN16CF port at the ionizer section, see figure 5 page 12). The missing of the first pumping stage will decrease the filament lifetime and the isolation of the ceramics in the ionizer and extractor assembly!*

Each source is tested and specified by SPECS. Nevertheless before the first operation (include "DEGAS" also) of a new cathode, the filament should be prepared as described in section 4.2.2.1 and after every system venting the ion source should be baked with your system and internally by using the "DEGAS" function from the power supply.

4.2.2.1 „New Filament" - Preparation

To prepare the filament for first operation and to stabilize the coating for a long lifetime wait in "STANDBY" mode (is set after turn on of the supply) until the pressure will be stable. Set "ENERGY" to 500 eV press "OPERATE" and increase the "EMISSION CURRENT" slowly until an increase of the pressure in the source is indicated.
Note:

- This is only possible with the PU-IQE 12 power supply (for detailed instructions please read the power supply manual).
  Using the model PS-IQE 12 choose less than 1 keV for energy and switch to "OPERATE".
- That this procedure will sputter with ions from residual gas and gas from the thermal wall desorption. The pressure in the source respectively chamber will increase.

Allow a pressure[1] of 10^{-3} mbar in the source. Stop at a setting of 0.1 mA. Wait until the pressure has dropped down below 10^{-4} mbar. By monitoring the pressure increase the "ENERGY" to a value up to 2 keV and increase the "EMISSION CURRENT" slowly up to 10 mA. Stop (STAND BY) if the pressure will not longer increase.

4.2.2.2 Degas

Before the operation the ion source should be baked internally by using the "DEGAS" function from the power supply. It is recommended to wait until the source pressure is better 10^{-6} mbar. After activation of the "DEGAS" mode the emission is automatically controlled increased, which can be observed by the emission current and the ion gauge read out. The pressure in the source will raise up to the 10^{-3} mbar range and drop after some time. The "DEGAS" mode is switched off automatically after about 3 min and the controller changes to "STAND BY" mode. Depending on the pressure increase it may be useful to repeat the degas routine one or two times, in addition.

In the "STAND BY" mode the voltages for energy and lenses are set back to zero, while the filament remains under current to avoid recontamination.

4.3 Start of Operation

4.3.1 Setup the Source Pressure

After cleaning (bake out) the ion source under vacuum conditions, the operation can be started by opening the gas inlet leak valve.
If a separate pumping system (figure 5) is used the throttle valve in the first pumping stage should be nearly closed for normal operation. The pumping in the first stage during sputtering is for a better dynamic behavior of the gas inlet procedure, only.

Open the gas inlet valve slowly. Adjust a source pressure[1] in the range from 5×10^{-5} to 1.2×10^{-4} mbar, if an internal pressure measurement is available (see "Multiplication Factors (Table)" on page 23 and equation 3 in section 2.2.2).

Because the adjustment via the pressure of the analysis chamber is difficult (especially using the second pumping stage) and needs some experience, the following procedure, which has been proved to be very usefully for testing the ion source, is recommended:

By a simple mathematical operation it can be shown, that equation 1 changes to

$$p_s \sim I_{tot} \sim I_{energy}$$

if the emission current is constant. I_{tot} can not be measured directly. But, the leak current between the energy HV module and ground, "I_{energy} ", can be metered easily by the power supply and can be used as a signal, which is representative for the source pressure[1].

1. Please note, that the source pressure is the pressure in the discharge area of the ionizer assembly, not the main chamber pressure (see section 2.2.2)!

I_{energy} is a sum of leak currents, which are contributed by the leaks inside the electronics, by the insulating ceramics inside the source and by the losses due to the ion formation of the gas molecules. To select I_{energy}

- press the ENERGY button at the PU-IQE 12 power supply and read the current in the middle of the display
- on the analog power supply model PS-IQE12 model no. 10867918 turn the display switch to this position.

During the test in the factory the current I_{energy} is listed for various settings of the emission current for each individual ion source at the optimum pressure point. A standard factory setting is stored permanently in the power supply memory (press "RECALL 0" at PU-IQE12 power supply).

A typical value for I_{energy} is about 40 µA at a source pressure[1] of about 10^{-4} mbar
using the standard setting ("RECALL 0" at PU-IQE12)

Energy:	5 keV,
Extractor Voltage:	about 92% of the energy,
Emission Current:	10 mA.

Please note: In the test documents the "I_{energy} " meter readout is listed with the initial leak currents. Please take into account that the leak current will increase with operating time of the source due to ceramics will covered and getting conducting. Therefore the leak currents have to be checked from time to time and to be added to the stated "I_{energy} " for the optimal pressure.

4.3.2 Operation Mode

Select a setting for large or small spot operation from the factory presetting, or use own parameters.

All parameters are set to enable the first operation. If you want to check them press the parameter name parallel to the key 0 to 9. This only switches the displayed parameter without changing it.

To create own parameters, which may be needed, if the ion source - sample geometry (angle of incidence or working distance, etc.) is strongly different from the specified dimensions of the IQE 12/38, the following set is recommended for a successful start:

Ion Energy:	3000 eV
Emission Current:	1 mA
Source pressure[1]:	ca. 10^{-4} mbar
Extractor Voltage:	about 90% of the ion energy

Go to "OPERATION" mode; all parameters as emission current and the voltages for energy, extraction, lenses and deflection are active.

1. Please note, that the source pressure is the pressure in the discharge area of the ionizer assembly, not the main chamber pressure (see section 2.2.2)!

With this settings a sample current should be metered.

4.3.3 Focussing the Ion Beam

To focus the ion beam the two lens voltages for "FOCUS 1" and "FOCUS 2" need to be optimized. They can be displayed absolute in Volts or in "%" of the ion energy, which makes checks easier, if the energy has been changed.

For a quick start some settings are adjusted by the factory and stored in the power supply memory (see specification report). First approximation is "FOCUS 1" = "FOCUS 2" and about 75-80% of energy voltage for the fine beam mode and "FOCUS 2"= 0 for the high current mode of the source.

Readjustment and creation of customized settings can be done easily on site, if the following additional equipment is available

1. a suitable target, as
   i. metal foil covered with fluorescent material (ZnO or fluorescence dye),
   ii. oxidized metal foil from Mg or Ta.
   iii. metal foil plated with ca. 100 Å gold, or
2. a Faraday cup with aperture and an electrometer amplifier.

If the fluorescent material is used, ions with an energy higher than 2 keV generate a visible bright spot on the target surface, which can be observed through a suitable view port of the vacuum system.

Alternatively, the spot can be optimized by means of a faraday cup. An aperture is recommended with an opening smaller than the beam diameter. (For testing the ion source in the factory a 100 µm aperture is used and the measured profile corrected; see the test documentation.)

By variation of "FOCUS 1" and "FOCUS 2" the spot size can be adjusted in the range from about 100 µm up to 5 mm, if the target is positioned at a typical working distance of about 20 mm in front of the ion source.

To optimize the spot size follow steps 1 to 5:

1. Use your settings or following standard setting
   Ion Energy: 5000 eV
   Emission Current: 1 mA
   Source pressure[1]: ca. 10^{-4} mbar
   Extractor Voltage: >90% of the energy
2. Set "FOCUS 1" to about 77% of energy voltage.
3. Increase the voltage for "FOCUS 2" until the beam size is as small as possible. This is normally at the same voltage for as for "FOCUS 1" if standard geometry is used. (see test documentation also)
4. Position the spot by means of the deflection centering voltages "X-Position" and "Y-Position".

1. Please note, that the source pressure is the pressure in the discharge area of the ionizer assembly, not the main chamber pressure (see section 2.2.2)!

5. Readjust "EXTRACTOR", "FOCUS 1", "FOCUS 2" and "X/Y Position" for Faraday cup until the beam size is acceptable.

4.4 Ion Current Measurement

For ion current measurement and optimization the faraday cup or a sample can be used, which is electrically isolated from ground. To avoid wrong current readouts by the emission of secondary electrons the surface has to be put on a positive potential (see figure 6 and figure 7).

As described in section 2 the ion current on a sample depends on

- the emission current,
- the gas pressure in the source,
- the gas species, and
- the ion energy.

4.4.1 Total Beam Current / Beam Profile

During factory test the general circuit layout of figure 6 is used to optimize the total ion beam current and the test circuit of figure 7 for the beam profile. For suppression of the secondary electrons a potential between 9 V (at Inner Shield) and 90 V (at Outer Shield) is applied.

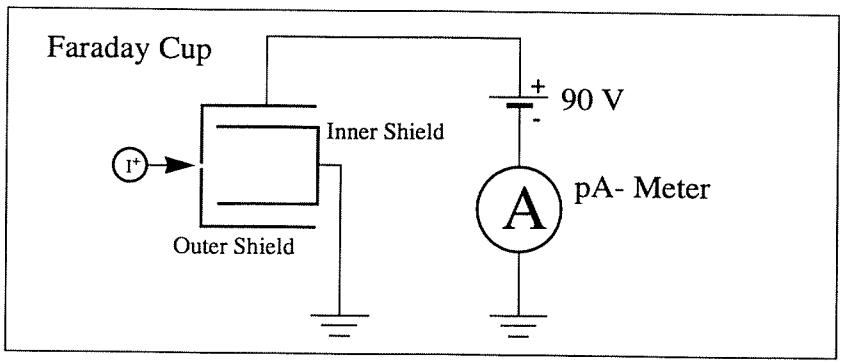

FIGURE 6 Test Circuit for Total Beam Current Measurement

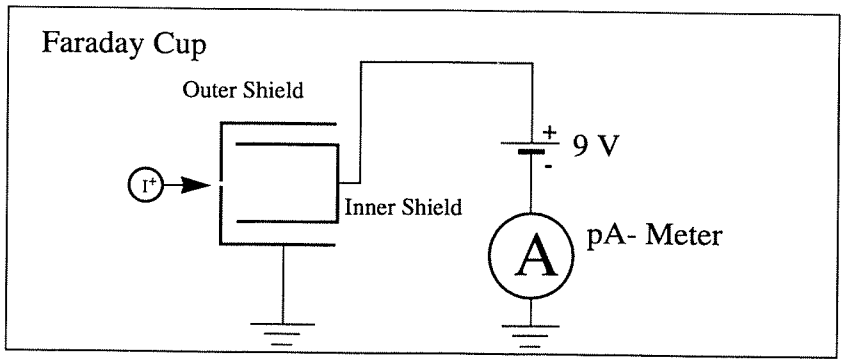

FIGURE 7 Test Circuit for Beam Profile Measurement

Chapter 5 Maintenance / Service

5.1 General

SPECS offers a complete cleaning and testing of your source (SPECS order no. 10867037 „Overhauling IQE 12/38"). This include filaments replacement, aperture replacement and ceramic replacement in the ionizer section and a complete specification report.

Safety Information:

- Note that products returned to SPECS for repair or maintainance must be free of harmful substances (e.g. radioactive, toxic, caustic or microbiological). Otherwise, the type of contamination has to be declared.
- Before starting any work on the ion source mechanics, strip down the respective wiring to the power supply and disconnect it from mains!

!!Mind the safety hints given on page 2!!

The IQE 12/38 ion source can be dismounted in sections. This user friendly design makes necessary service works easy (see figure 1). The gun has not to be disconnected from the vacuum chamber in every case.

Note the procedure for a New Filament-Preparation and the degas hints described in "Setup for First Operation" on page 14

5.2 Spare parts

Spare part	SPECS order no.
Filament	10867017
Anode (cage)	52470010
Ionizer Ceramics	20031951
Aperture 1.0 mm	20031537

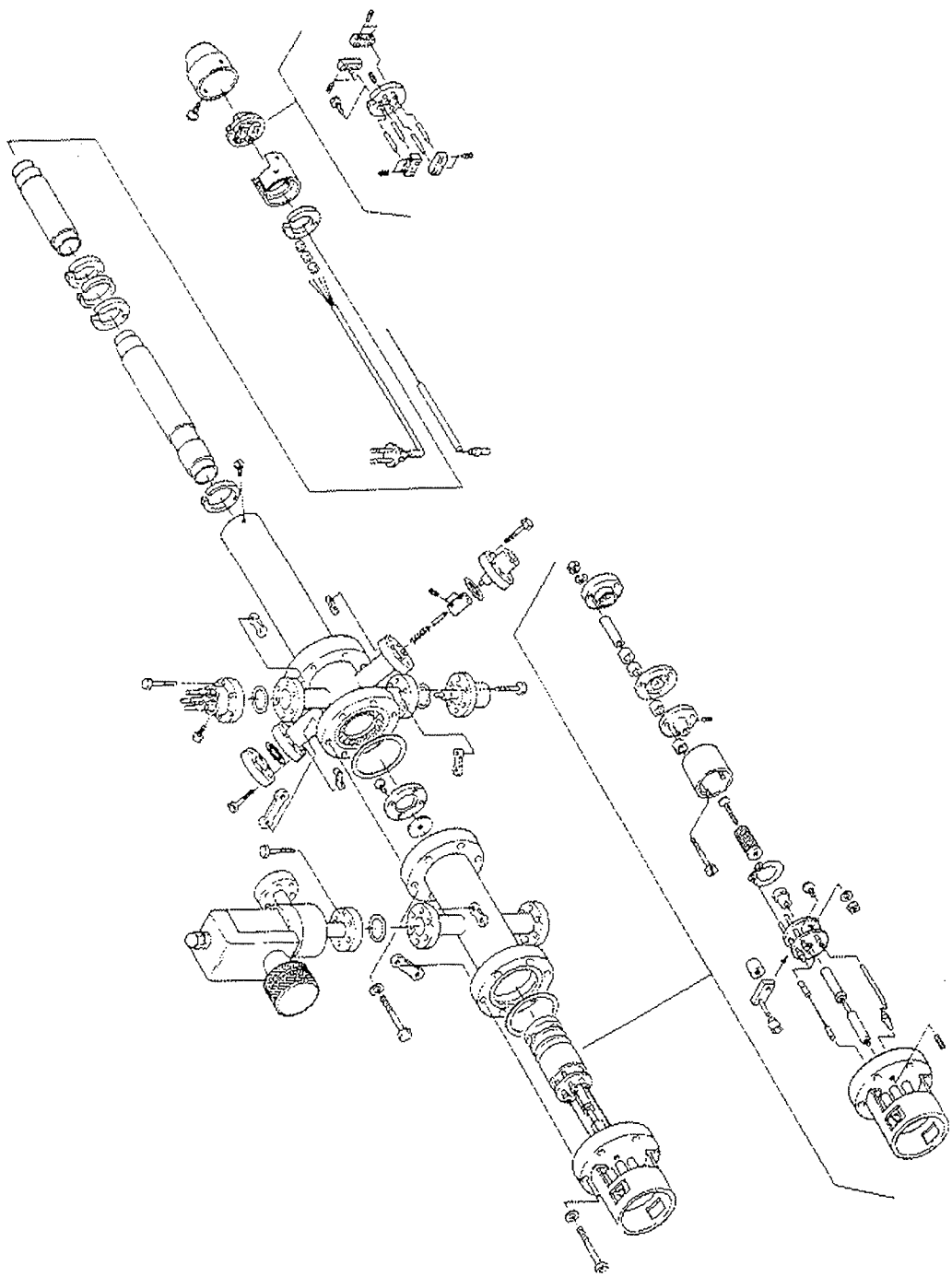

FIGURE 8 Expose IQE 12/38

Please use this expose for a special spare part request.

5.3 Filament/ Anode / Ceramic Replacement

To replace the ionization section the base flange (see figure 1) has to be removed. Take out the complete module on its base flange and put it at a clean place. Check the aperture (shape and diameter = 1.0 mm standard; 1.8 mm with Wienfilter) and replace it if necessary (see section 5.4)
For further dismounting follow the instruction steps:

1. Disconnect the cable from the extractor (Allen key 0.9 mm metric for Allen screw M2).
2. Open the two M2 nuts with 4 mm open-ended spanner and remove the top cap of the repeller with extractor, repeller lens and repeller aperture from the base plate.
3. Check the resistance between the reflector cap the einzellens and the extractor electrode. If one of the ceramic is contaminated please **replace all**. Sometimes not visible contaminations will increase the leak currents and limit the operation with your source in near future.
   The electrode package can be dismounted completely by loosing the three long screws at the front of the repeller lens.
4. If the filament is broken or if the yttrium oxide film is damaged, replace the cathode completely. Loosen the two Allen screws (Allen key 0.9 mm metric) on the cathode support pins and take the cathode assembly off. Mount the new filament 7 mm above the base plate (see figure 3 page 10)
5. Check the anode cage (shape) and replace if necessary.
6. To assemble the ionization module, follow above steps in reverse order.
7. Before mounting the module on the ionization section housing, check the resistance of all electrical connections by a multimeter. All electrodes and the filament should have no contact to ground or contact to each other, without the following exceptions:

Repeller Cap - Repeller Lens:	Contact
Filament 1 - Filament 2:	about 1 Ω

5.4 Changing the Aperture: 1st Pumping Stage

This tantalum aperture has a strong influence on the beam profile. Strong sputter effects at this aperture lead to an increase in beam diameter after a while. For Wien filter application this aperture should changed to 1.8 mm (order no. 79100066).

To change the aperture only the ionization section housing of the IQE 12/38 has to be separated from the lens support tube, i.e. the focus housing (see aperture placement at figure 8, page 20). Take off the complete module and put it at a clean place. For further dismounting follow the instruction steps 1 to 3:

1. Loosen the two screws of the aperture support ring and take the ring off.
2. Pick the Ta- aperture plate by a pincer and take it off.
3. Put a new aperture in same position, center it in the outer support and assemble in reverse order.

5.5 Hints for Operation

5.5.1 Life Time

The operating time of the source is limited by degrading of the cathode and the ceramic insulators inside the source. This degrading is very much influenced by the operating conditions of the source. Especially the gas pressure inside the source (source pressure[1]) must not exceed certain values.

The source pressure[1] is made up of the partial pressure of the residual gases and of the pressure of the operating gas. If the source pressure[1] is too high the cathode will be contaminated and the insulating ceramics will be coated with conducting layer. The coating is caused by the residual gas. For this the source has to be baked after system venting, be properly pumped during standstill, and degassed at starting for operation.

If the pressure of the operating gas is much too high a gas discharge will occur in the source contaminating the source within a short time.

The high voltage supply for the source is current limited to non-hazardous values (200 µA). If the degraded insulators will cause currents near the limit value the source has to be cleaned (see section 5.3).

5.5.2 Gas Pressure

The gas pressure determines the ion beam intensity and influences the shape of the ion beam. Also the heat transfer in the source (the gas cools the cathode especially if the first pumping line is used) and the obtainable minimum pressure inside the vacuum chamber depends on this source pressure.

Since the ion beam current is directly proportional to the product of emission current and pressure the source should be operated with high emission current and low pressure values. For the pressure value chosen the settings of the focussing parameters has then to be found by experiment.

5.5.2.1 Optimal Source Pressure

The optimal pressure for different operation modes can be determined by measuring the beam (sample) current or evaluation of the output signal of a SIMS- or ISS system.

This is done by determination of the sample-current-pressure-function $I_{Sample}=f(p_{source},U_{Extr.},U_{Foc1},U_{Foc2})$. This function shows a distinct current maximum at the optimal pressure setting.

Since the source pressure[1] itself can not be measured a pressure measured somewhere else in the system (bypass line, main chamber see also section 2.2.2), which is proportional to the source pressure[1], can be used to adjust the optimum.

1. Please note, that the source pressure is the pressure in the discharge area of the ionizer assembly, not the main chamber pressure (see section 2.2.2)!

Chapter 6 Appendix

6.1 Multiplication Factors (Table)

Ionized gas	Multiplication factor refering to Nitrogen	Air
He	6.9	6.0
Ne	4.35	3.7
Ar	0.83	0.71
Kr	0.59	0.5
Xe	0.33	0.33
H_2	2.4	1.8
CO	0.92	0.85
CO_2	0.69	0.59
CH_4	0.8	0.7
N_2O	0.7	0.6

Table 1: Factor of multiplication for pressure measurement with ionization gauges in extractor ion sources.

6.2 Ion Beam Current versus Ion Energy

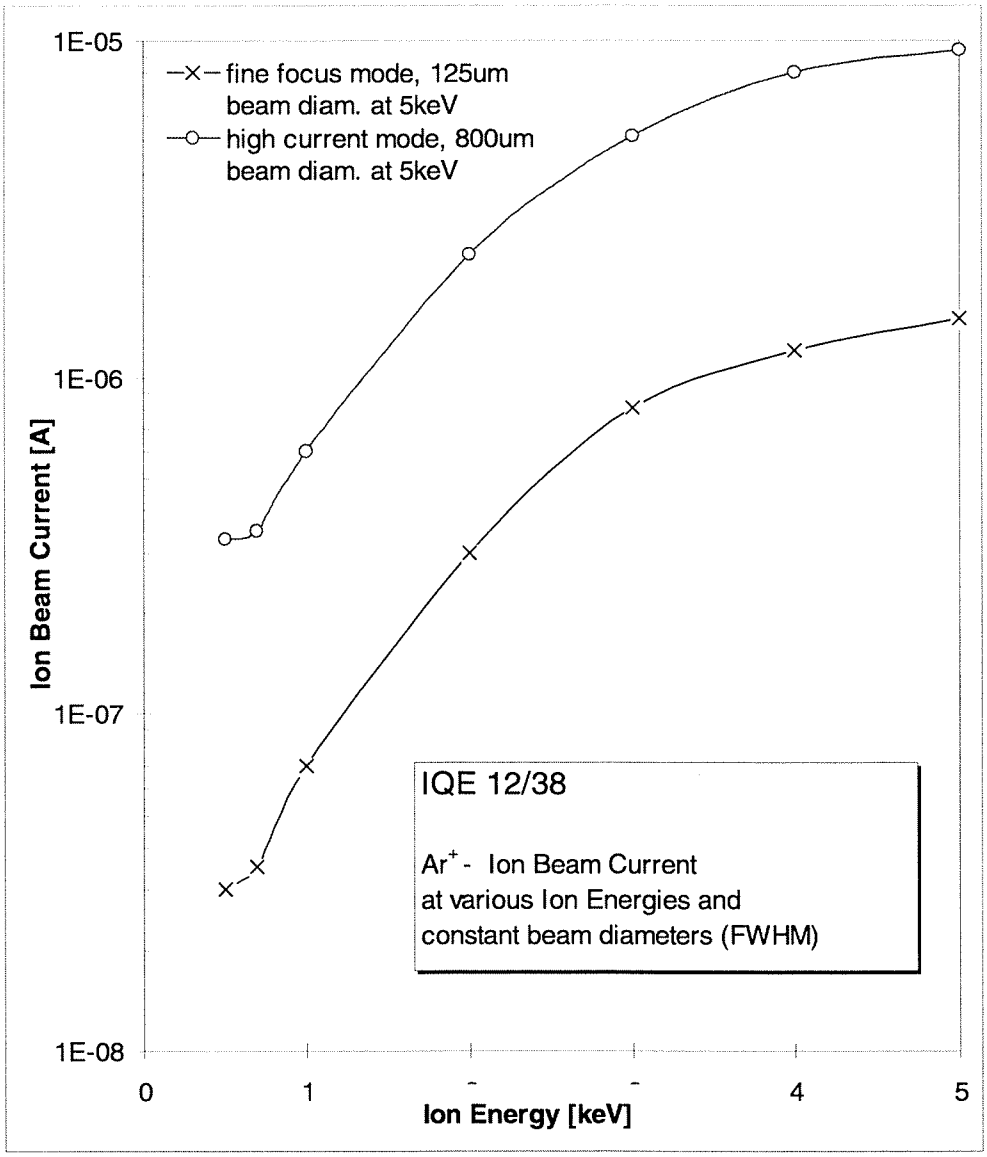

FIGURE 9 Ion Beam Current versus Ion Energy

6.3 Operating Characteristics as a Function of Energy

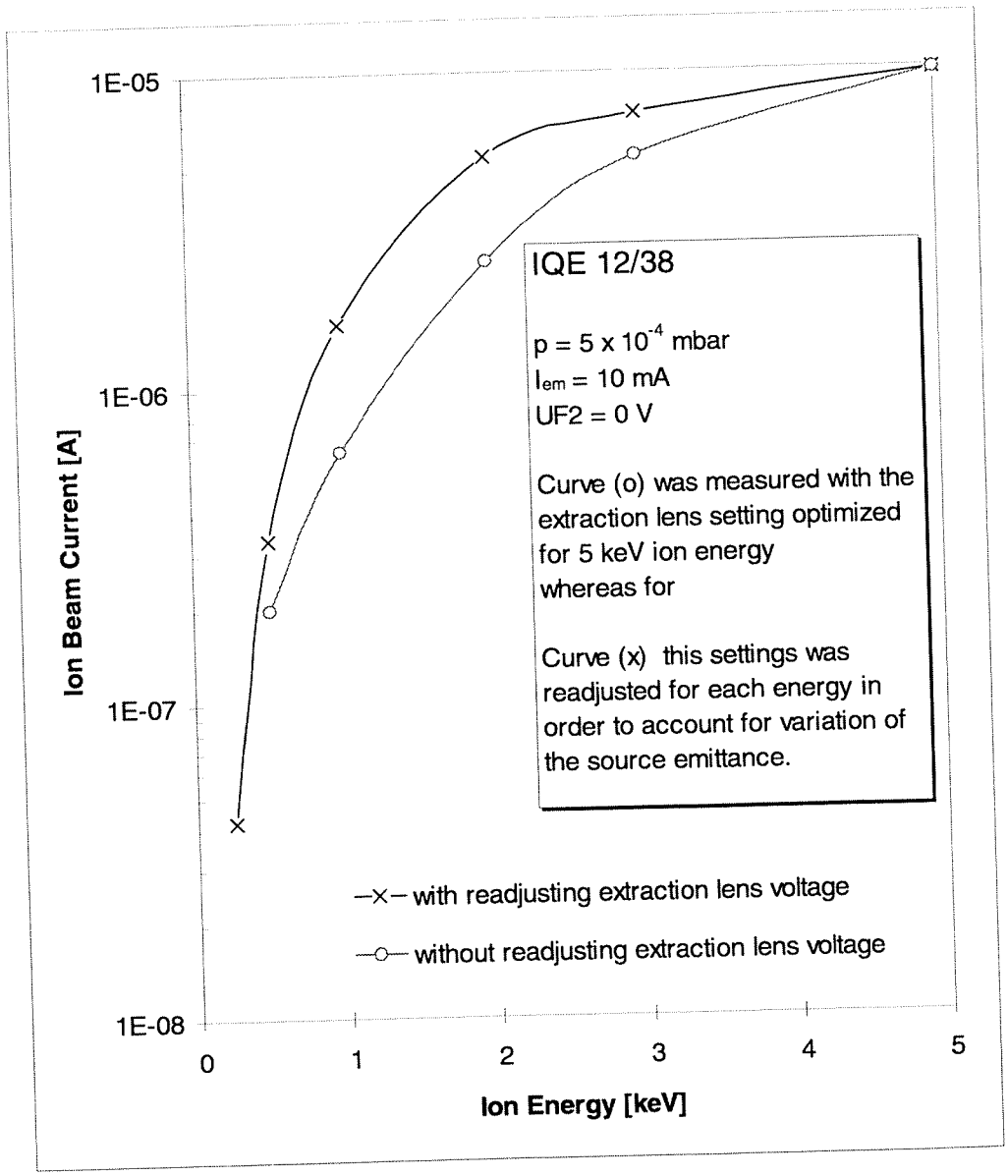

FIGURE 10 Operating Characteristics as a Function of Energy

6.4 Ion Beam Current versus Electron Emission Current

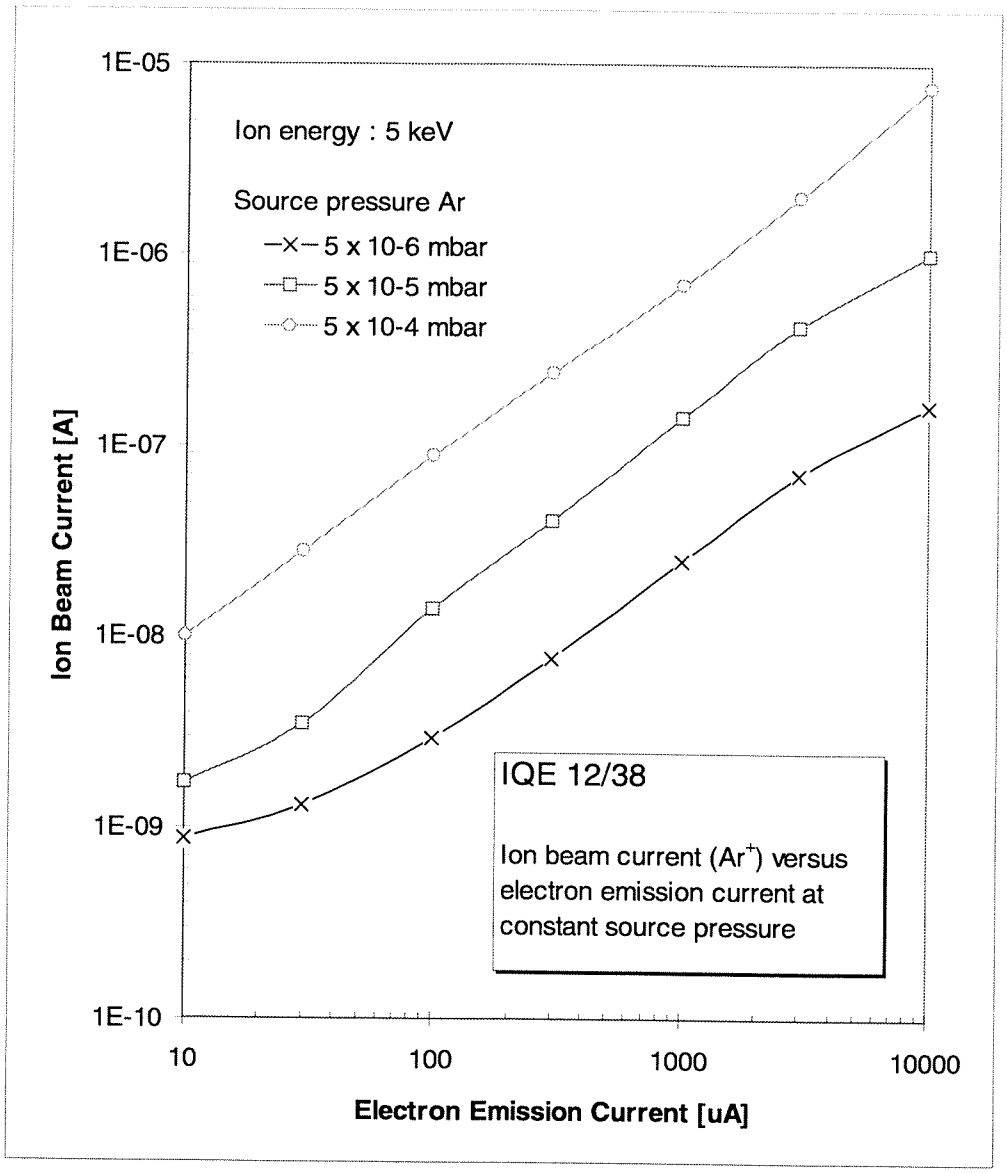

FIGURE 11 Ion Beam Current versus Electron Emission Current

6.5 Ion Beam Current / Beam Diameter vs. Working Distance

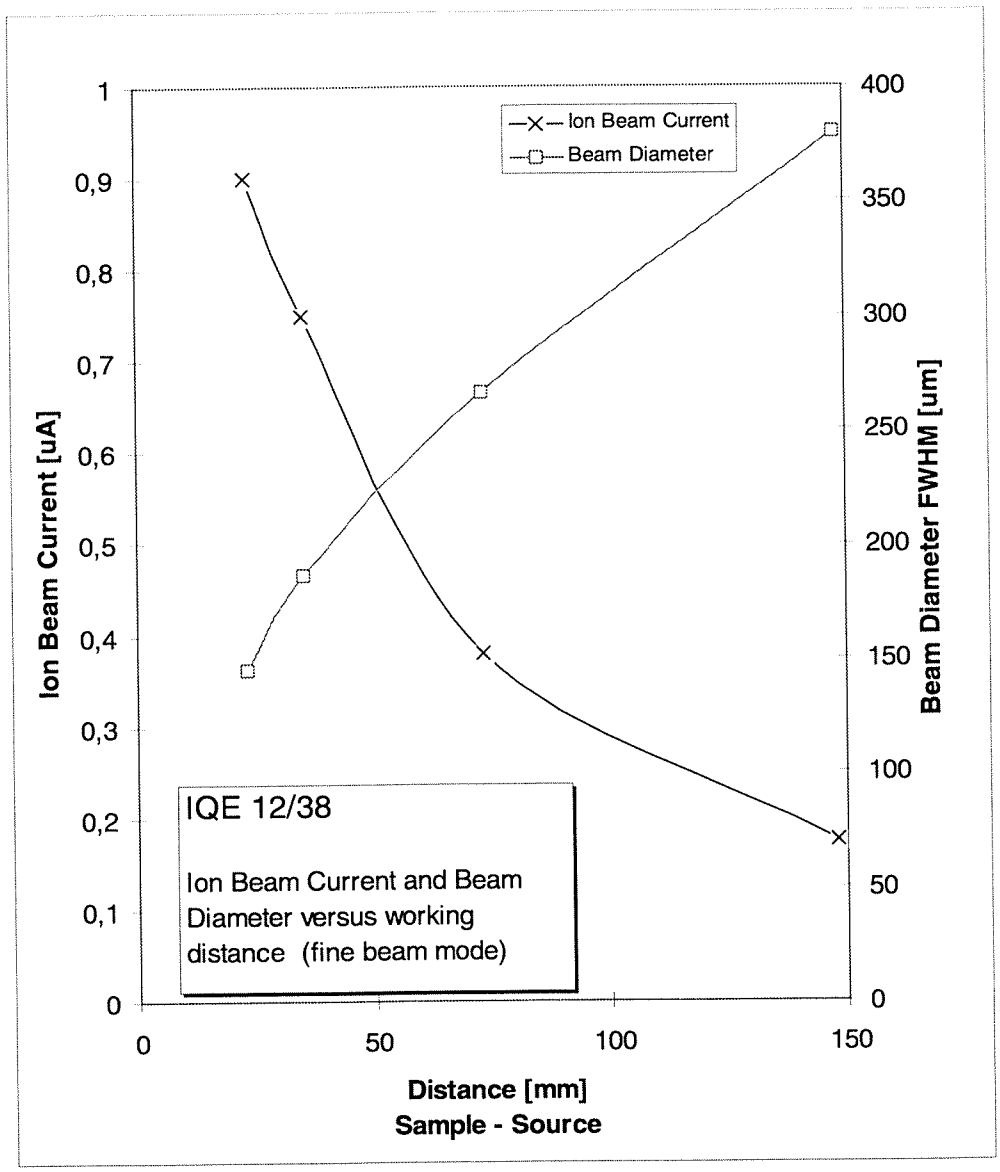

FIGURE 12 Ion Beam Current / Beam Diameter vs. Working Distance