ionLiNE

System Manual

Release 1.1

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Declaration

All information in this manual has been carefully prepared and is considered to be accurate and complete. If there is any doubt about any detail or if you require additional information, please contact Raith GmbH or one of its representatives.

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About this manual

This manual is part of the overall document of the ionLiNE. The complete documentation, in addition to this system manual, comprises:

- Software Operation Manual
- Software Reference Manual

This manual is intended as a guide for both users as well as for users with Administrator rights. It describes:

- The components, and the functioning principle of the ***ionLiNE***
- The basic operation and preparation methods for running the ***ionLiNE*** and its individual components
- The maintenance procedures which the user with Administrator rights must carry out

Always keep this manual within reach of the system.

Spelling conventions and symbols

The following spelling conventions and symbols will be used throughout this manual:

STEP 1: Initiates a sequence of action steps.

▶ Describes a single action step.

Keyword, which either indicates an operational element or a software command, which is related to the current description.

Sample Loading Italic font indicates the title of a paragraph, a table or a figure referred to from the current position in the manual.

DANGER

Such instructions warn of a possible burn injury to personnel. The instructions regarding avoidance of any danger must be followed.

NOTICE

Such instructions warn of possible damage to equipment or objects. Follow the instructions in detail to avoid errors in operation, which could lead to damage or destruction of system components.

Special notes and background information are marked by using the light bulb symbol, as shown in this paragraph.

Such references refer to information in the complete documentation, described in one of the following:
- Software Operation Manual,
- Software Reference Manual

Such references refer to actions that may only be carried out by one of the following:
- a user with Service user rights
- a local system specialist trained by Raith
- Raith service personnel

Chapter 1
System Description

1.1 System overview

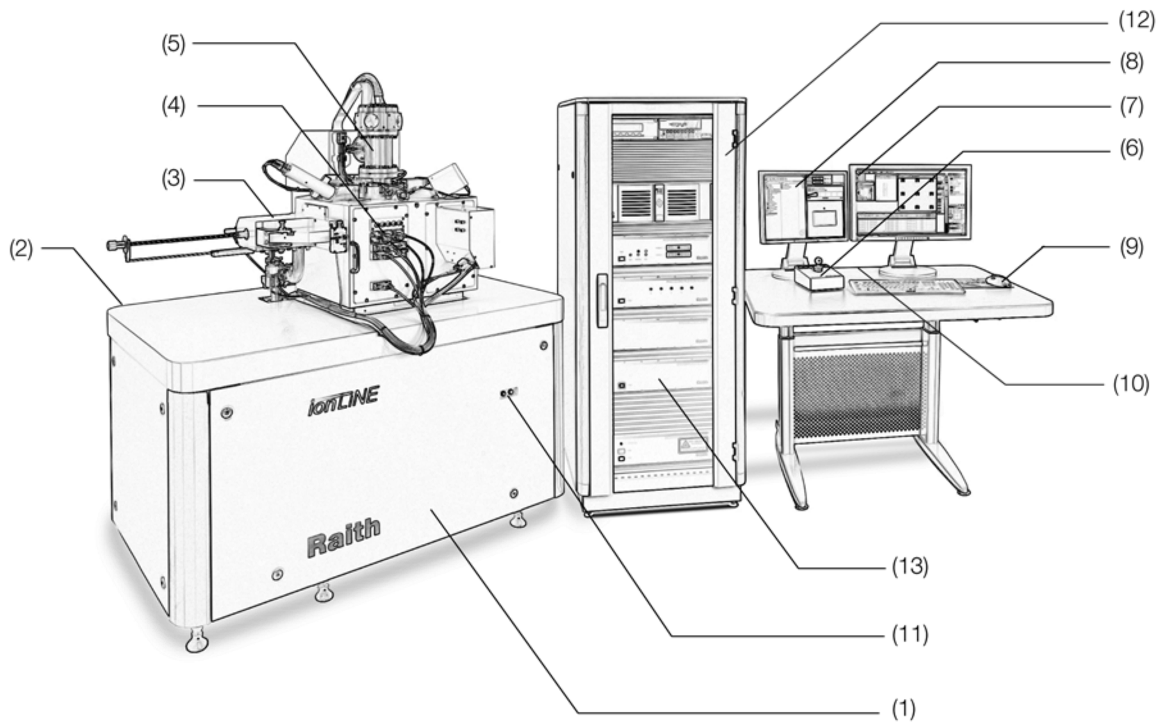


Figure 1-1: System overview *ionLiNE*

Legend

1	Plinth, containing the pumping system and high tension supplies	**8**	Monitor B as an additional monitor
2	Ports (hidden from view)	**9**	Keyboard and mouse to operate the software
3	Load lock	**10**	**Emergency Stop** button for immediate interrupt of the power supply
4	Chamber	**11**	Panel for **On** and **Standby** buttons with indicators
5	Column	**12**	Rack for control electronics supplies
6	Joystick for manual control of the sample stage	**13**	System Controller panel for **Off** button
7	Monitor A for the Raith *NanoSuite* software		

The rack houses the electronic controller. Some units are optional, whilst others are standard to all systems, such as the pattern generator, stage controller, system power supply, system controller containing the PCL, laser interferometer source, as well as the PC and the pico-ammeter.

The **system power supply** has only the power switch on the front panel. The red power switch is protected against accidental use by a plastic cover, which must be lifted before the power switch can be used. There are no LEDs used on the system power supply. The red power switch on the system power supply can be seen as an extension to the green **On** and yellow **Standby** switch on the front panel of the pump system.

A more detailed overview of the layout of the system is described below, from the viewpoint of the user, facing the instrument.

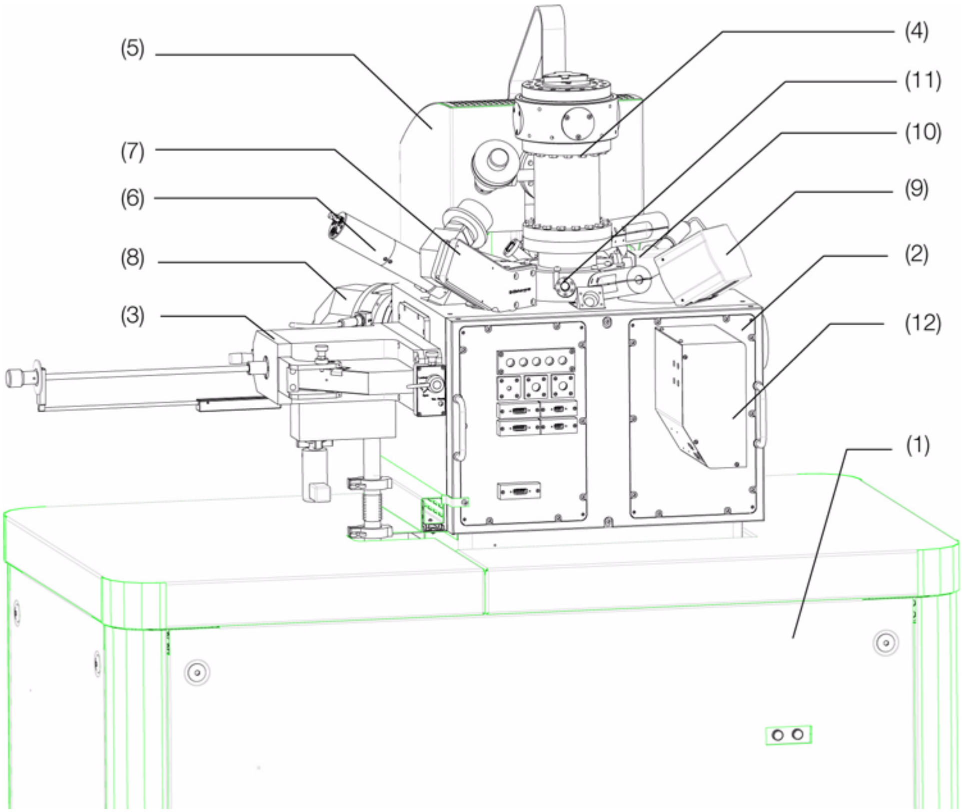


Figure 1-2: Instrument close-up front view

Legend

1	Plinth stand including **On** and **Standby** buttons	**7**	Height control
2	Chamber	**8**	GIS (gas injection system)
3	Load lock	**9**	Macroscope
4	Column	**10**	Aperture driver
5	Cover for ion pump and scan amplifier	**11**	Connection to Faraday cup
6	SE detector	**12**	Laser interferometer connection

1 - Plinth: The pump stand includes the vacuum system, the high voltage supplies and cabling. The front-mounted switches, with yellow and green indicators allow manual selection between the modes **Standby** and **On**.

2 - Chamber: The chamber is positioned directly beneath the column, with the load lock situated to the left of the chamber.

3 - Load lock: The load lock transfer rod enables the operator to transfer the sample holder between the chamber and the load lock, when the load lock door is closed and the load lock valve is open.

4- Column: The column contains the gun head and ion source at the top of the column and the main optics for focusing and scanning at the bottom of the column.

5 - Cover for ion pump and scan amplifier: Underneath the cover are the ion pump and the scan amplifier. The ion pump generates the vacuum for the ion source.

6 - SE detector: The outwardly visible portion of the SE detector is to the left of the column, above the load lock.

7 - Height control: Automated height control is an option to maintain optimum focus.

8 - GIS: The Gas injection system is an option. It is used for introducing vapor into the chamber for gas assisted etching and ion beam-induced deposition.

9 - Macroscope: The macroscope is used for optical top-down observation of the sample.

10 - Aperture driver: The aperture driver motor moves the apertures.

11 - Connection to Faraday cup: Below the column at the front of the instrument is a small feedthrough for the in-column Faraday cup, situated inside the ion optic. When the beam is blanked during operation, the beam current can be measured.

12 - Laser interferometer connection: The housing mounted to the front of the chamber incorporates the input for the laser interferometer, as well as plugs and feedthroughs for service checks.

1.2 Connections

Connections are situated at the front and rear of the system.

Connections which are not described here have no function in the standard version of the *ionLiNE*.

The following connections are accessed at the front of the system:

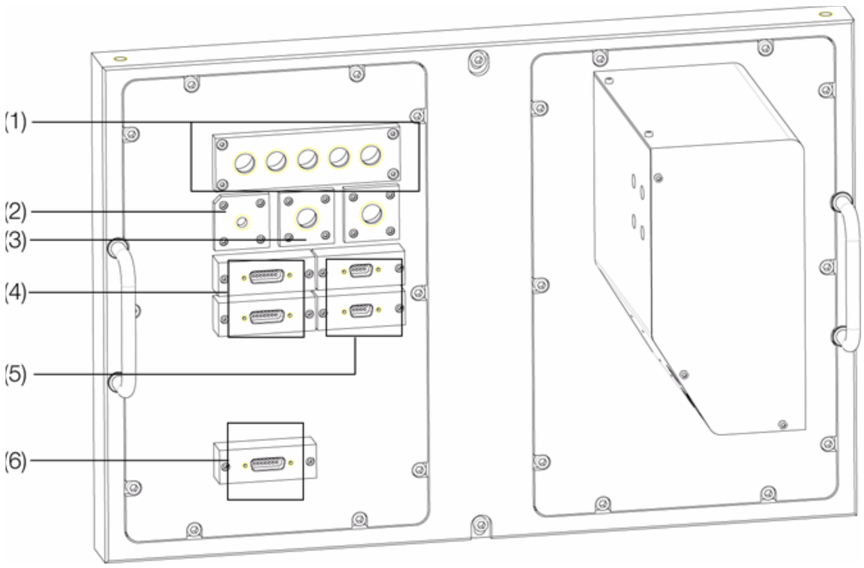


Figure 1-3: Front feedthroughs

Legend

1 An array of five triaxial feedthroughs, connected to five small coaxial connectors next to the sample holder, which can be used for in-situ measurements.

2 Faraday cup on holder

3 XY Piezo motor signal

4 Feedthrough for X and Y motor signals

5 Feedthrough for additional motors for the 3D module

6 Feedthrough for Z axis

The following connections are accessed at the rear of the system:

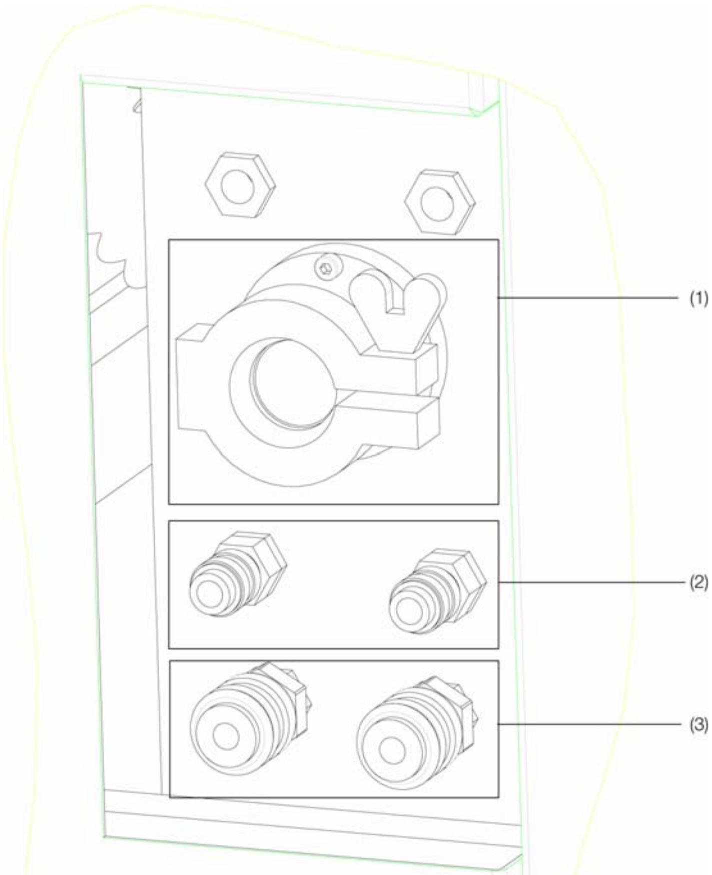


Figure 1-4: Rear view of plinth connections

Legend

1 Vacuum line connection

2 Gas connections

3 Water IN/OUT connections

1 - Vacuum line connection: Connection between the turbomolecular pump, situated inside the plinth, and the dry roughing pump, which is placed outside the plinth.

2 - Gas connections: There are two additional connections for gases. The black gas line is used for nitrogen, which is used to vent the chamber at a pressure of 0.3 bar. The blue line is used for compressed air, typically set at 6 bar, used for the vibration damping platform of the chamber, as well as to drive the valves and the GIS.

3 - Water IN/OUT connections: Below the gas lines, the connections for the two thicker tubes are **Water IN** and **Water OUT**. The cooling water is used for the turbomolecular pump and the GIS, if installed.

Chapter 2
Functional Principle

This chapter provides an overview of the functional principle of the *ionLiNE* and its individual components.

2.1 General functional description

The *ionLiNE* is a dedicated ion beam lithography, nanofabrication and engineering workstation for surface modifications, down to the sub-10 nm level. It has been designed as a versatile tool for advanced nanostructuring, applying direct patterning, resist-based lithography, gas-assisted etching and deposition processes. A wide range of integrated in-situ nanoengineering tools, such as gas injectors, nanomanipulators, sample holders, etc. are available. The dedicated nanolithography and nanofabrication architecture provides;

- large area direct pattering with field stitching and multi-layer alignment techniques
- full 16-bit nanopatterning capabilities directly from standard GDSII files
- seamless fabrication of extended features in unique Fixed-Beam-Moving-Stage^{TM} (FBMS^{TM}) mode
- superior beam stability, higher beam energies and excellent lateral beam selectivity
- dedicated nanowriter functionalities such as automated focus control by height sensing

The main target applications for this tool are focused on but not limited to:

- Micro- and nanomachining: Direct patterning of arbitrarily shaped and highly topographic samples, i.e. milling, drilling, cutting, prototyping and fabrication of 2- and 3-dimensional structures, membrane and nanopore engineering.
- Resist patterning: Exposure of thin photo resists and trimming of various resist masks.
- Nanoengineering: Ion beam-induced deposition and gas-assisted etching; in-situ sample manipulation and electrical measurements.
- Thin film engineering: Direct thin film patterning by milling of functional layers, milling of hard masks or intermixing of multi-layers.
- Surface functionalization for controlled self organization and self assembly processes i.e. by creation of well ordered artificial defects or pinning centers.

- Process control: In-situ process control and quality assurance by ion beam cross-sectioning and high resolution ion beam imaging.

2.2 Subsystems and individual components

The *ionLiNE* consists of the following subsystems:

- The patented NanoFIB ion beam column with;
  - stable gallium liquid metal ion source with patented ion extraction geometry
  - electrostatic lens system and fast electrostatic beam blanking
  - double stage octopole deflection system
  - scan generators for nanopatterning, ion beam imaging and mark registration.
- Free-standing plinth supporting the chamber (via integrated vibration isolation system), stage, ion optic system along with the high vacuum system, and high voltage units.
- Clean, dry high vacuum system with;
  - main chamber with feedthroughs and service ports
  - load lock for quick sample exchange
  - dry roughing pump and turbo molecular pump
  - ion pump for the source region
- High precision XYZ stage with laser interferometer for XY positioning.
- 20 MHz high speed pattern generator with digital signal processor technology.
- Sample holder for small samples up to 2”
- 3D module for tilt (-2° to +92°) and continuous rotation of small samples.
- Off-axis Everhardt-Thornley detector
- Infrared CCD-camera
- Top-view optical macroscope for navigation on and adjustment of samples.
- Graphical user interface software with process control of nanopatterning applications, ion beam imaging and alignment and metrology functions.
- Additional rack with system control electronics, computer and pattern generator.
- Table with flat panel displays, keyboard, mouse.
- Optional automated height sensing for automated focus setting.
- Optional gas injection system (GIS) and nanomanipulators.

In addition, the *ionLiNE* is delivered with a dry roughing pump, two water chillers and an emergency cut-off box, which will be positioned individually in specific spatial locations (⇒ *Spatial requirements and supplies* on page 4-1).

2.3 Button panel

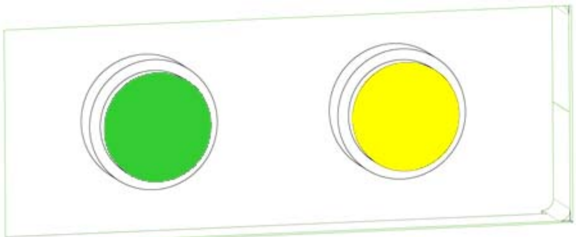


Figure 2-1: Buttons in the button panel

Legend

1 Green **ON** button

2 Yellow **Standby** button

Using the buttons in the button panel, the *ionLiNE* can be either switched **ON** or put into **Standby** status. The buttons are illuminated and indicate the current status of the system.

2.4 Load lock

The *ionLiNE* is equipped with a manual load lock. The load lock is used to load and unload samples precisely onto the sample stage within the evacuated sample chamber, with the aid of a sample holder. The sample holders are specifically designed by Raith for use in this load lock (⇒ *Raith sample holder* on page 2-9).

For a detailed description of how to operate the load lock, please refer to (⇒ *Exchanging samples* on page 5-8).

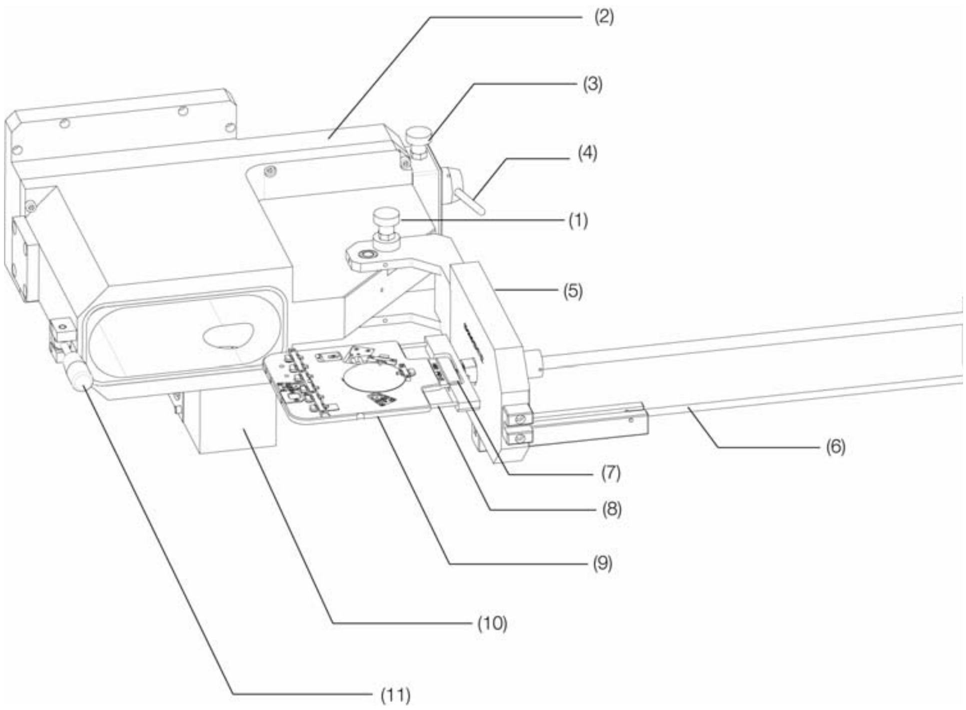


Figure 2-2: Load lock with sample holder

Legend

1	Lift knob for closing, only applicable when door has been opened fully	**7**	Guide groove on sample holder (corresponding to pillar on load lock)
2	Load lock valve	**8**	Transfer guide
3	Load lock knob	**9**	Sample holder
4	Load lock lever	**10**	Connection to pumping system
5	Load lock door	**11**	Locking mechanism to secure the load lock door when closing via screw knob
6	Transfer rod		

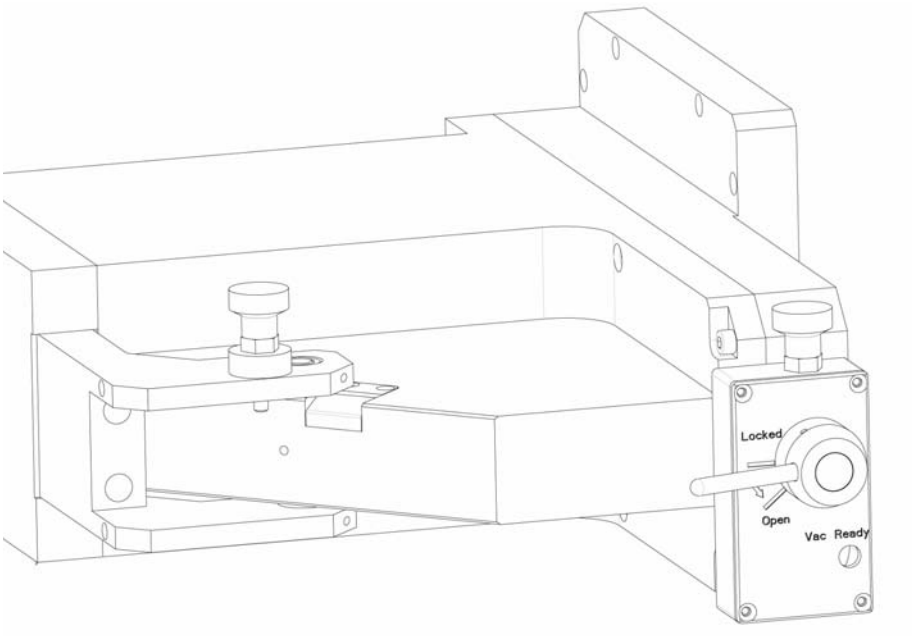


Figure 2-3: Vacuum LED on load lock

The **Vacuum ready** LED will be green when the vacuum is ready. This is not simply a static LED indicator, it is driven by the system controller, along with an electro-mechanical lock, which disables the load lock while the vacuum is not ready.

2.5 Emergency stop button

The *ionLiNE* is equipped with one emergency stop button, which will switch off the system immediately, interrupting the power supply to the system. The emergency stop button is situated on the operator desk. Only initiate the emergency stop button when either there is a immediate potential hazard for personnel or when considerable system damage is imminent. For example, initiate the emergency button, when there is imminent danger that the system housing may be surrounded by water (for example, if there is a water leak or if a water bucket is tipped over).

If you have turned off the power to the *ionLiNE* via the **Emergency Stop**, it will not be possible for the user to turn the system back on. Please notify either your house electrician or Raith Service personnel.

2.6 Joystick

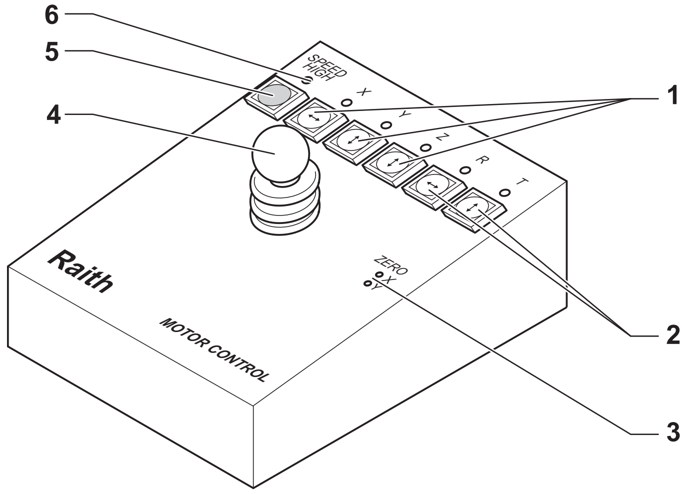


Figure 2-4: Joystick device overview

Legend

1	X, Y, Z- buttons to select the axis for stage movement	**4**	Control lever for moving the sample stage
2	No function assigned	**5**	**SPEED HIGH** button to toggle between normal and high speed modes
3	Potentiometer for fine adjustment of the joystick by Raith service personnel	**6**	Green LEDs to indicate the currently selected mode

Using the analog joystick, the sample stage can be moved in the X, Y and Z-directions. This is an alternative method to using the software commands. It is recommended to use the joystick when the sample stage needs to be moved over large distances - e.g. to move a small sample on the sample holder into the area of view.

The control lever (**4**) of the joystick has four movement directions with a stepless, continuous acceleration function in each direction:

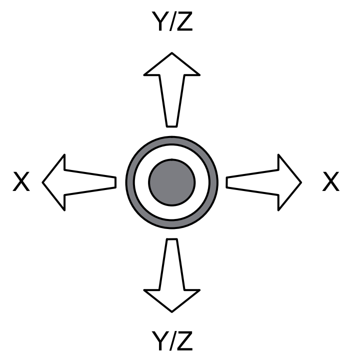


Figure 2-5: Movement directions and acceleration of the joystick

By pressing the X, Y or Z-button (1) you can toggle between activation/deactivation of any axis, when you move the sample stage. LED (6) indicates which axis or axes are currently active.

The X and Y axes can both be selected at the same time and the sample stage will move simultaneously in both axes. As soon as the Z-axis is activated, the X and Y axes are automatically disabled.

The joystick has two speed modes. The user can toggle between them via the **SPEED HIGH** button (5). When the high speed mode is activated, the green LED above the **SPEED HIGH** button will be lit.

2.7 PC and software

2.7.1 General

The *ionLiNE* is equipped with a PC running with the Microsoft Windows XP Professional operating system and two flat panel monitors.

Control of the system is performed via the Raith *NanoSuite* software for *ionLiNE*. Via the software, the following activities are carried out:

- Adjustment of the sample coordinate system
- Design and composition of the structure layout
- Optimization of the ion beam
- Ion column control
- Imaging
- Execution of patterning

The user interface for the software will be displayed on the right hand monitor.

For further information about how to operate the software, please refer to the **Software Operation** manual of the complete documentation package.

2.7.2 User levels

The *ionLiNE* suite is a multi-user platform, which is divided into two user levels, with different access rights, as well as displaying different dialogs.

- USER-level:

  With USER-level permission, you can perform all standard operations of the *ionLiNE*.

- EXPERT-level:

  With EXPERT-level, you can perform all standard operations and access some more advanced procedures.

- SYS-level:

  Within the SYS-level, it is permitted to edit the values and configurations of specific parameters and procedures. In addition, maintenance procedures can be carried out (⇒ *Maintenance* on page 8-1).

- SERVICE-level (SYS-level with special rights):

  An additional level has been created, since for some service tools, the SYS-level is not sufficient to be permitted certain aspects of software access. Therefore a SERVICE level has been created to permit this access.

2.7.3 Basic principles of PC operation

Take particular note of the following basic principles when working and dealing with the system PC, in order to ensure reliable functioning of the system and the display:

Operating system

- Do not install automatic Windows updates. In order to update your software, the latest Service version can be downloaded from the Raith home page, this update can be installed by the user. Alternatively, you can request a data CD from Raith.
- Do not modify the following monitor parameters:
  - monitor resolution and refresh frequency for the images
  - the number of colors and the type of color palette
  - font type and size
- Do not activate a screen saver.

Hardware

- Do not install any additional hardware components.

- Do not connect any external hardware components that may interfere with the system. It is permitted to use external data storage devices such as a USB memory stick or CD-drive.
- Do not connect any hardware components to connections which are used for the operation of the system.
- Do not adjust hardware components or the parameters for the corresponding driver.

If you are unsure about the use of specific hardware components, please ask Raith Support for advice.

Software

- Do not install any additional software.
- Do not un-install any software.
- Do not adjust any driver settings.

2.8 Raith sample holder

2.8.1 General

For various samples, masks and wafers, which can be used for the *ionLiNE*, Raith offers specific sample holders. The sample holders are designed for the high precision of the load lock and sample stage and to perform the required application functions.

The Raith sample holder is equipped with

- kinematic mounts made of sapphire (⇒ *Universal sample holder with tools for fixing the samples* on page 2-11), with which the sample holder is located on the stage. The user can perform a pre-leveling procedure (⇒ *Pre-leveling the sample holder* on page 5-23).
- a Faraday cup to measure the ion beam current.

It is recommended to use the Faraday cup in the ion column, as this is already installed and connected.

- For the standard system, the universal sample holder will be delivered.
- When one or both of the GIS and Nanomanipulator options are installed, the ultra-flat sample holder will be delivered instead.
- The 3D module is delivered as standard.

In addition, you can order the following sample holders from Raith as accessories:.

- Raith mask holder, (⇒ *Raith mask holder* on page 7-2)
- Raith wafer holder, (⇒ *Raith wafer holder* on page 7-2)
- Customized sample holders on request.

2.8.2 Raith universal sample holder (4 inch stage)

The Raith universal sample holder can be used for all samples that can be fixed using the mounting tools.

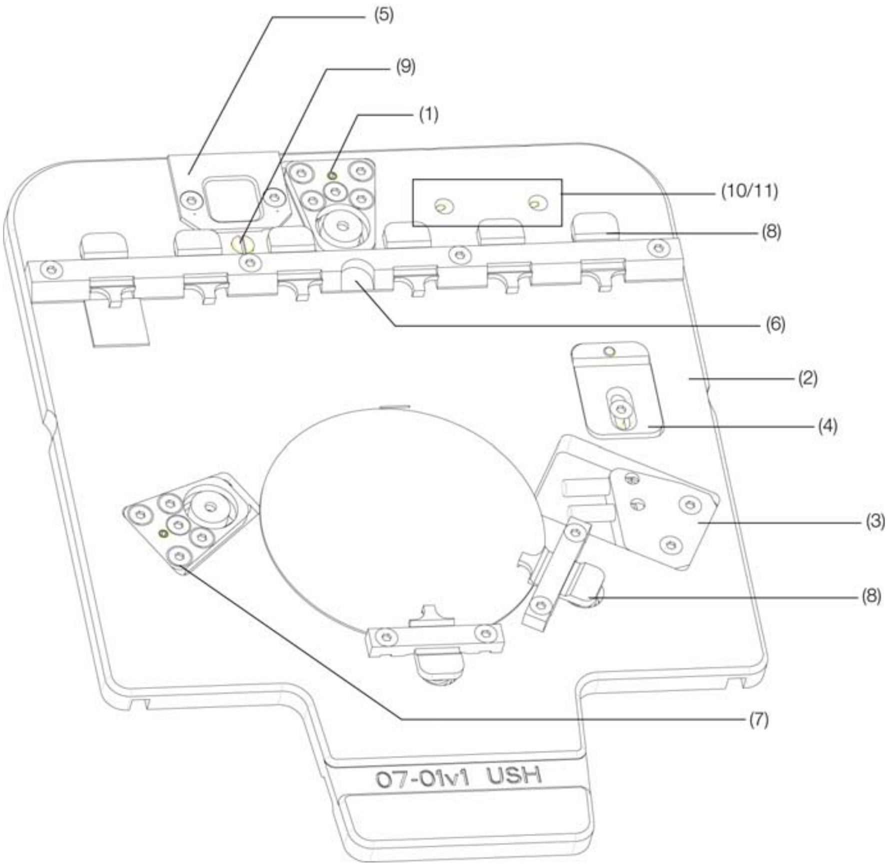


Figure 2-6: Universal sample holder with tools for fixing the samples

Legend

1	Adjustable kinematic holder	**7**	Adjustable kinematic holder
2	Mounting surface	**8**	Clamps for wafer and wafer fragments up to 2 inch or 50 mm edge length.
3	Fixed kinematic holder	**9**	Contact pin for the measurement of sample current
4	Slide clamp to fix inclined samples at an angle of 45° or 90°.	**10**	Holding device for stubs
5	Frame for permanently mounted reference samples	**11**	Setscrews for fixing the stubs
6	Faraday cup for measuring the ion current		

The universal sample holder offers the following tools to fix a variety of samples:

- Full wafers or wafer fragments of up to 2-inch diameter or 50 mm edge length can be mounted with the aid of clamps (8) on the universal sample holder.
- Alternatively you can mount a wafer or wafer fragments with a conductive adhesive double sided tape or an adhesive double sided carbon pad on the mounting surface (2). When removing the sample, take great care not to leave any adhesive residue on the surface of the sample holder.
- The frame (5) can hold large wafer fragments up to 10 mm x 10mm. Also use this frame to fix reference samples which are permanently required - e.g. a calibration sample for automatic field calibration or position drift corrections. In order to exchange the reference sample, the frame must be unscrewed.
- The slide clamp (4) can hold small samples, which are inclined by either an angle of 45°or 90°. In order to move the slide clamp, loosen the screw. Put the sample into the required position and fix the slide clamp.

  When using the slide clamp, the following sample dimensions may not be exceeded:

Table 2-1: Permitted sample dimensions for inclined samples

Inclined angle [°]	**Max. sample dimensions [mm]**
45°	14 mm x 10 mm
90°	14 mm x 7 mm

2.8.3 Raith ultra flat sample holder

The ultra flat sample holder is used when the GIS or Nanomanipulator options are installed.

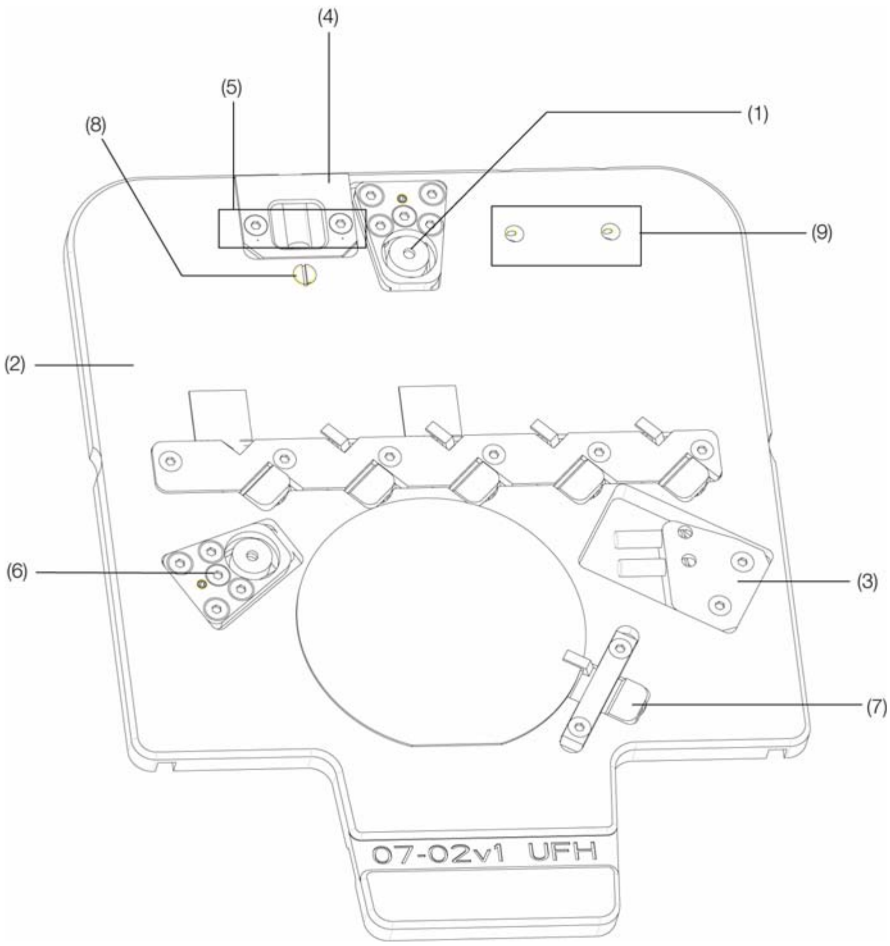


Figure 2-7: Ultra flat sample holder

Legend

1	Adjustable kinematic holder	**6**	Adjustable kinematic holder
2	Mounting surface	**7**	Clamps for wafer and wafer fragments up to 2 inch or 50 mm edge length.
3	Fixed kinematic holder	**8**	Contact pin for the measurement of sample current
4	Frame for permanently mounted reference samples	**9**	Holding device for stubs (hidden)
5	Faraday cup for measuring the ion current	**10**	Setscrews for fixing the stubs (hidden)

2.8.4 Raith 3D module

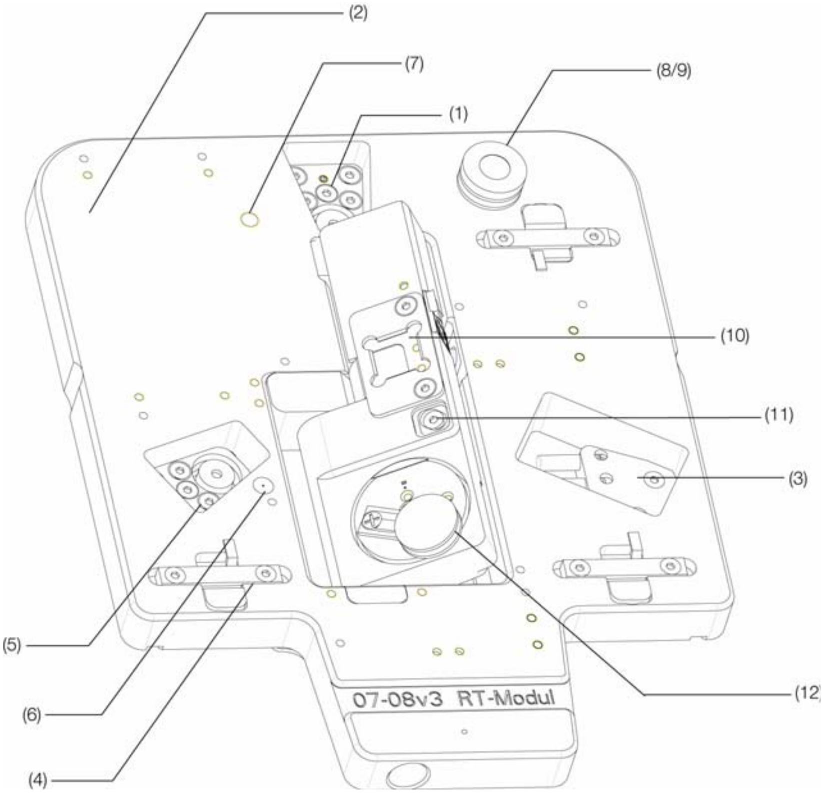


Figure 2-8: 3D module

Legend

1	Adjustable kinematic holder	**7**	Contact pin for the measurement of sample current
2	Mounting surface	**8**	Holding device for stubs (hidden)
3	Fixed kinematic holder	**9**	Setscrews for fixing the stubs (hidden)
4	Clamps for wafer and wafer fragments	**10**	Tilt position with sample mounting frame
5	Adjustable kinematic holder	**11**	Tilt position for mounting small samples, e.g. TEM grids.
6	Faraday cup for measuring the ion current	**12**	Tilt and rotation plate for mounting samples. Either an SEM stub can be mounted or various clamping devices and frames can be used to mount a wide range of samples.

In addition to the generic sample loading area, utilizing a clamp, a tilt area is available to mount the samples.

A tilt and rotation area is available, where the sample can be tilted from -2 to +92 degrees and rotated forwards and backwards or continuously in one direction from 0-360 degrees.

The required stage drive and controller are delivered with the 3D module.

In order to connect the module controller to the laser interferometer stage, there are four additional spring contacts mounted underneath the 3D module.

NOTICE

The spring contact and the tilt areas are very sensitive to damage. It is therefore important to use the transport box supplied, when the 3D module is not loaded in the load lock.

- Store the 3D module only in the transport box.
- Take great care with fragile protruding components when resting the 3D module on a surface.
- Attach specimens carefully, using minimum force.
- Attach specimens only when the 3D module is placed in the transport box.

Chapter 3
Safety and Transport

This chapter contains safety information, to which the user needs to pay particular attention when using the *ionLiNE*. Read this chapter in detail to avoid any injury to personnel and any instrument damage.

Note all of the special safety hints before carrying out any actions described in the relevant chapters of this manual.

3.1 Correct use

The *ionLiNE* is used for structuring, measuring and analyzing suitable samples, masks and wafers (all referred to as “samples” in the following), of dimensions up to:

For the USH and UFH module:

- 12 mm sample thickness
- 2x2 inch square
- 150 g weight

For the 3D module:

- 6 mm sample thickness
- 12x12 mm square
- 10 g weight

It is only permitted to use Raith sample holders for each sample. The instructions which describe the fixing of the samples onto the sample holders must be followed. If improper usage results in damage or injury, no liability will be accepted by Raith.

If you are unsure about suitable sample mounting, please consult Raith support.

3.2 Safety equipment

The *ionLiNE* is equipped with one emergency stop button. Press the emergency stop button in the event of any potential hazard to persons, or if serious damage to the system might occur.

Only press the emergency button in case of danger. To turn off the system normally, use the procedure described in chapter 5, Operation, (⇒ *Switching off the system* on page 5-29).

3.3 Additional hazards

The *ionLiNE* has been designed and built using the latest technology and accredited, accepted technical safety standards. Take note of the following additional potential hazards.

3.3.1 Operation

- Follow the instructions of the establishment within which the system is in operation, with regard to the wearing of protective clothing. Follow the working instructions related to the Class of cleanroom.
- During operation, avoid any collision of the sample or the sample holder with the gun. A collision can damage the gun, sample and sample holder.
- Only use materials which are suitable for operation in the ***ionLiNE***. Unsuitable materials can cause outgassing when they are used over longer periods, which might damage the ion column.
- Only use sample holders from Raith, as these have been specifically designed for use in the ***ionLiNE***, corresponding to the high precision of the load lock and sample stage and performing the required application functions.
- Always ensure that the sample and sample holder fit together correctly and fix the samples according to the instructions. Samples which do not fit onto the chosen sample holder, or are not fixed properly, might move in an uncontrolled way, may fall off the sample holder or might collide with other parts of the system. This may lead to damage of the sample, sample holder or system.
- Keep the samples and sample holder dust-free and away from any dirt. Dust and dirt might outgas under the ion beam and will lead to a degradation of the vacuum system, which might take a few days to return to normal:
  - Always use suitable rubber gloves when handling the sample and sample holder.
  - Clean any dirt off the sample and sample holder before inserting it into the load lock.
- Avoid contact of samples and sample holder with any metallic objects, as these might damage the surface. Only use plastic tweezers when handling small samples.
- Store the 3D module only in the transport box when it is not in the load lock or chamber. In particular, use the transport box when changing sample.

3.3.2 Transport and storage

- The transport of the ***ionLiNE*** and its individual components must be exclusively carried out by Raith and its authorized partners.
- Always transport the Raith sample holders in the transport boxes supplied, to protect them from jarring and from falling over.
- Store the sample holders only in the transport boxes or in the sample holder chamber of the ***ionLiNE***, to protect them from dust and dirt and to store them safely.
- Each of the Raith sample holders is delivered in a specific transport box, which has a transport lock. The user must deactivate the transport lock first, before taking the sample holder out of the transport box.
- Always transport the Raith sample holders inside their transport box with the transport lock activated. This will protect it from jarring and falling over. Always keep the sample holders in their transport box.
- Always transport the Raith 3D module inside the transport box. Always keep the 3D module in the transport box.

NOTICE

The spring contact and the tilt areas are very sensitive to damage. It is therefore important to use the transport box supplied, when the 3D module is not loaded in the load lock.

- Store the 3D module only in the transport box.
- Take great care with fragile protruding components.
- Attach specimens carefully, using minimum force.
- Attach specimens only when the 3D module is placed in the transport box.

NOTICE

Whenever you mount sample on the 3D module, ensure that the tilt axis has been returned to 0° degrees tilt by the software and put the 3D module into the specific transport box. Then use a suitable screw driver and carefully, with minimal (vertical) force, unscrew and change samples. Take particular care with samples on the tilting part of the 3D module, otherwise, system damage might occur. Never move the tilt manually.

3.3.3 Maintenance

All maintenance procedures may only be carried out by the following persons:

- Users who have at least Administrator rights and who have received dedicated administrator training by Raith.
- Local system specialists, trained by Raith
- Raith service technicians and engineers.

3.3.4 Decommissioning and disposal

The decommission and disposal of the *ionLiNE* and its individual components may only be carried out exclusively by Raith.

Chapter 4
Commissioning

This chapter will give the user information about installation of the *ionLiNE*, including the spatial requirements and the required technical supplies.

4.1 Installation and commissioning

The installation and commissioning of the *ionLiNE* is carried out exclusively by Raith or by one of their authorized partners.

4.2 Spatial requirements and supplies

4.2.1 Room layout

ionLiNE top view dimensions are in mm. This is a suggested layout. Other layouts are possible. Please inquire about your layout.

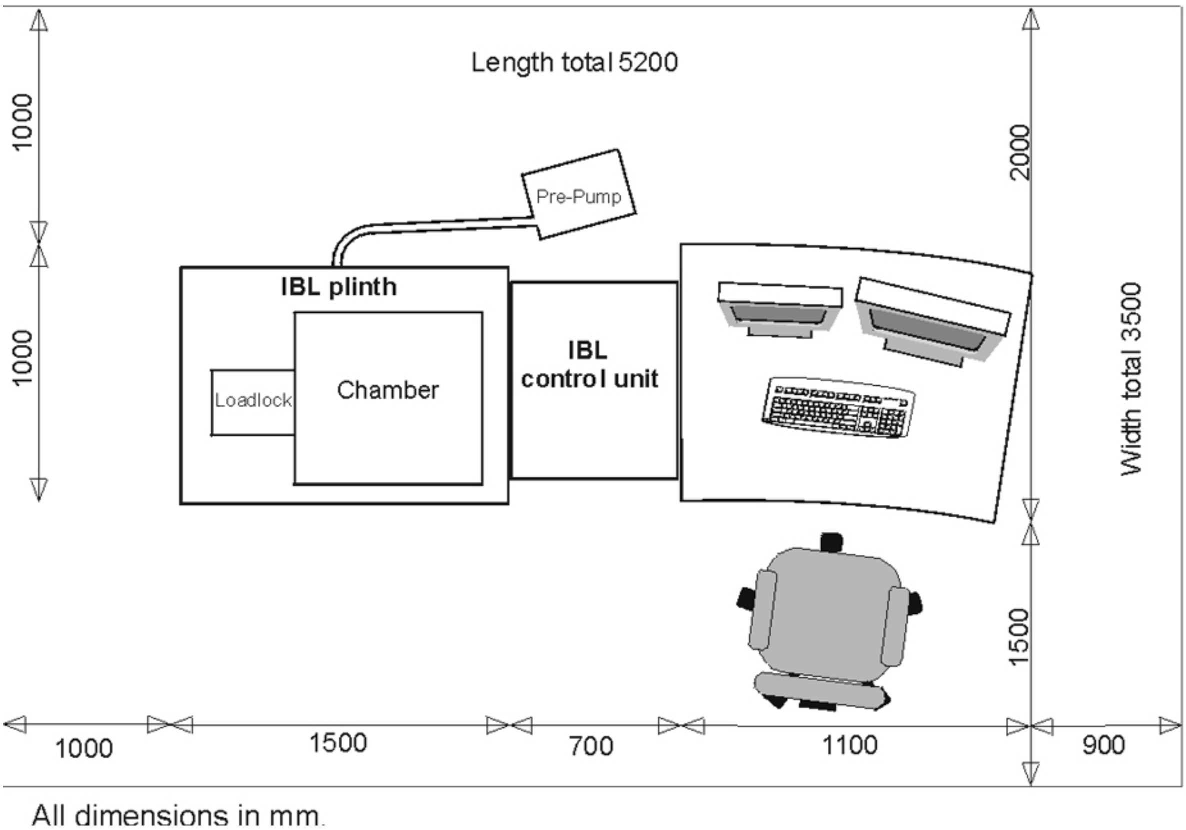


Figure 4-1: Spatial requirements for the *ionLiNE*

When ordering several optional components, such as the gas injection system and nanomanipulators, a second IBL control unit might be necessary.

4.3 Summary of utility and environmental requirements

Parameter	Value
Mains	230 V (U.S. option of 208 V with boost transformer); second protective ground with < 0.1 Ohm and >16 mm². 2.5 kVA consumption depends on accessories.
Nitrogen	2 liter/minute at 0.2 bar, 0.3 bar maximum, regulator required.
Compressed air	6 bar static, 7 bar maximum, clean, dry, oil-free, regulator required.
Water supply	Flow rate 2 liter/minute with 2 bar differential pressure, 3 bar maximum, temperature 18 °C to 22 °C.
Ambient temperature	20-25 °C.
Relative humidity	Between 30% and 65 %.
Floor vibration	In 1/3-octave bandwidth spectrum less than 0.8 µm/sec RMS at frequencies below and within the 16-Hz band, less than 1.0 µm/sec RMS at frequencies above the 16 Hz band.
Magnetic fields	Less than 10 mG (1 µT) RMS integral below 100 Hz.
Acoustic noise	In 1/3-octave bandwidth spectrum less than 70 dBc at frequencies below and within the 100-Hz band, less than 60 dBc at frequencies above the 100-Hz band.

4.3.1 Summary of essential specifications

Parameter	Value
Source	Ga LMIS emitter
Stage travel range	100 mm x 100 mm x 30 mm
Stage positioning resolution	1 nm
Minimum beam size	< 8 nm at 35 kV
Beam energy range	15 kV – 35 kV

Parameter	Value
Beam current range	1 pA - 1 nA
Beam current stability	< 1% / hour
Beam position stability	< 400 nm/hour
Minimum patterned feature size	< 10 nm
Minimum width of extended lines over 1 mm	< 20 nm
Field stitching accuracy	≤ 60 nm (|mean| + 2 · sigma)
Overlay accuracy	≤ 60 nm (|mean| + 2 · sigma)
Import data file formats	GDSII, DXF, CIF, ASCII, (grey level) BMP

4.3.2 Transport and packing

Overall system weight is approximately 1800 kg and will arrive on several shipping pallets. All components are packed into special transport boxes and are secured with plastic foil. Small components, wires, tools, etc., will be packed into paper boxes with foil and are likewise fixed on a pallet.

Critical crates are equipped with tilt/tip/shock indicators. Please make note of the condition of pallets and crates when shipment arrives.

Chapter 5
Operation

This chapter gives an overview of the basic operations required to carry out tasks on the *ionLiNE*.

5.1 Switching on the system

STEP 1: Switching on the hardware

Ensure that the electrical, gas and cooling water supplies are functioning before switching on the system.

- If the system is completely switched off, lift the protective cover over the red button on the system power supply inside the rack and press the button. The button will be illuminated in red. Wait for 10 seconds. This will transfer the system into **Standby** mode.
- The Standby button will now be illuminated in yellow, as the system transfers automatically into **Standby** mode. In Standby mode, the system controller is running, as are all pumps, to maintain the vacuum. All other components, such as the PC and particularly the high voltage supplies, are switched off
- Press the green **ON** button to switch on the *ionLiNE*. Only when the green switch on the front panel is switched on, to transfer the system into operational mode, will the high voltages, PC and all other components be switched on. The PC will boot up automatically and will then display the log-in screen for the user.
- The PC and the other controllers will now be switched on.

STEP 2: Starting the *ionLiNE* software

Double click on the *ionLiNE* icon on your desktop to start the Raith *Nano-Suite* software for *ionLiNE*.

The **Login** dialog will be opened:

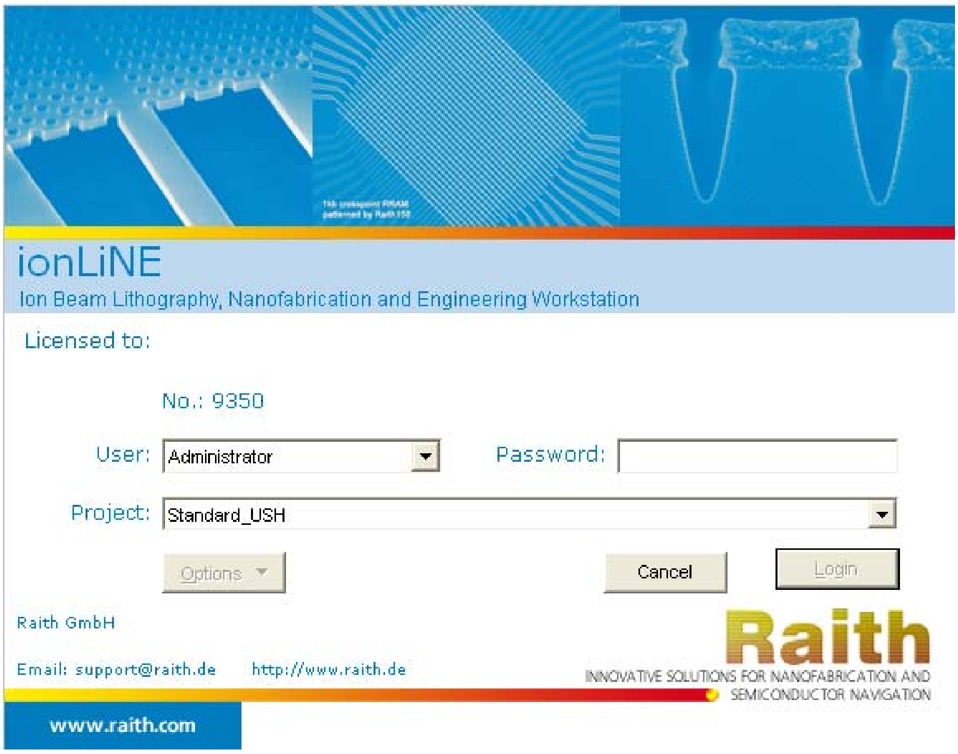


Figure 5-1: Login Screen of the Raith *NanoSuite* software program.

Enter your personal login data or the default login **User: training**, **Password: training**.

- Go to **Project** and select **New** from the dropdown list to start a new project. Alternatively you can open an existing pre-written project, such as **Standard_USH/_UFH/_3D**.
- Click on **Login**.

The software will be started, displaying the user interface on the large monitor.

STEP 3: Starting the Column

- Click on the **Column Control** icon in the control bar to open Column Control. Select a parameter set and click the **Play** button. This parameter set will now be initiated and the start-up will be performed automatically.

NOTICE

Start-up should only be performed using a predefined column parameter set. It is not permitted for the user to simply set the acceleration voltage to 20 kV or 30 kV. The reason for the controlled ramp up via a column parameter set is that the emitter source has to be slowly ramped up as well.

It is of vital importance that the emitter is ramped up under precise software control, while the acceleration voltage is ramped up to the defined voltage.

STEP 4: Automatic ramp up procedure to Standby mode

The procedure described is performed automatically, whenever **Column Standby** is selected in the software.

- In order to define the ion source current and acceleration voltages, two separate power supplies are required in the hardware setup, since the values must be set and controlled independently of each other.
- The required values are entered in the software. The associated hardware components are the **Gun source** and the **Gun extractor**, which can be observed in the **Power Supply Monitor**.
- One high voltage supply is connected to the very tip of the ion source, the other power supply is connected to the extractor electrode.

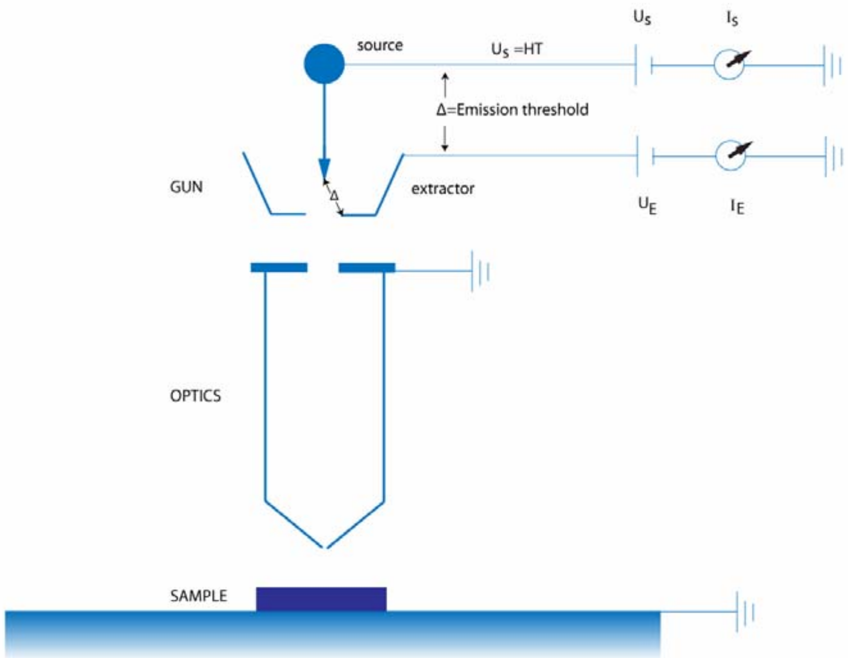


Figure 5-2: Schematic of the voltage supply

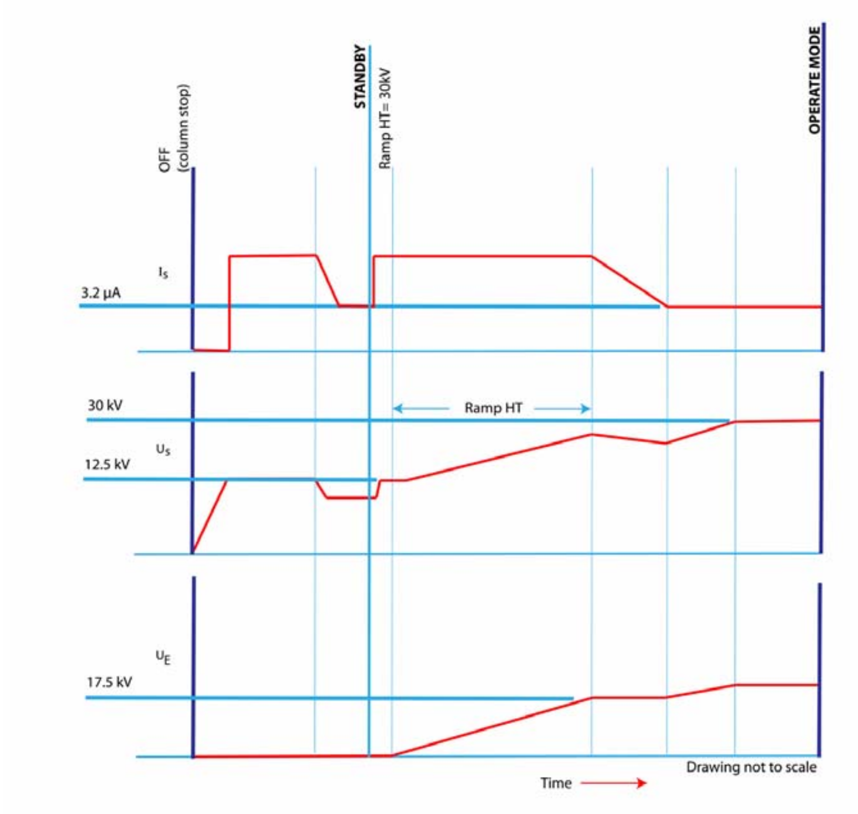


Figure 5-3: Ramp-up procedure for Standby and Operate modes: control of source current, source high tension and extractor high tension

- The high tension is the voltage between the tip of the source and the general earthing, between gun source and ground. The voltage difference is what defines the energy of the ions.

- The ion source always delivers the required current and is indirectly regulated by the extraction field, given by the difference between the high tension (gun source) and the extractor voltage (gun extractor). The ion source and the gun source power supply are controlled via the current.

It is not possible to drive a source, which has its own I/U characteristic with only one power supply. Therefore, only one parameter can be defined and the other will result from the set values. Therefore two separate power supplies are required, as one of the power supplies, the gun source power supply, supplies the current. The high tension voltage is indirectly defined via the extractor power supply.

- When the ion source is switched on via the **Column Standby** and the source starts to emit ions, the current is set to a defined value. The voltage is not defined and is more or less indefinite. The current is constrained to a defined value, but the voltage will have whatever value is required to deliver the defined current. The voltage will result from the I/U characteristic of the ion source.

- When the ion source is initiated, a higher current is set for the gun source. Depending on the I/U characteristic of each individual ion source, approximately 12.5 kV will result.
- After a short waiting time, to stabilize the ion source, the emission current for the gun source will be reduced step by step, to approximately 3.2 µA, which is the normal operating emission current.
- Up to this point in the procedure, the extractor is still set to 0 V.
- For now, only the emission threshold voltage is applied to the tip of the ion source, e.g. 12.5 V versus an extractor setting of 0 V.

This difference in voltage between the source and extractor is the field, which is required to sustain the emission current. This can be described as the field emission effect. The source is not heated. It consists of liquid gallium, which forms the tip of the source, from where the ions are emitted.

- When the system is in **Standby** mode, the emission current is reduced to 3.2 µA, which will result in a slightly lower voltage, depending on the I/U characteristic of the source.

STEP 5: Automatic ramp up procedure to Operate mode

- When a column parameter set is initiated, the instrument will be automatically transferred to operate mode and the defined voltage of the column parameter set, e.g. of 30 kV, will be set.
- For example, the tip of the ion source is already at 12.5 kV, only the remaining difference of 17.5 kV has to be applied to reach a total of 30 kV.

Even if the instrument is in **Column Stop** mode, when the column parameter set is activated, the automatic start-up procedure will include the **Column Standby** mode, as an in-between step during the start up.

If the column parameter set is initiated when the instrument is in **Column Stop** mode, **Column Standby** is activated first. A high emission current will be drawn from the gun by the applied emission threshold of approximately 12.5 kV.

Now the emission current will not be reduced to 3.2 µA, instead the high current is maintained and the voltage is ramped up to the set value, when finally, the current will be reduced to 3.2 µA.

- When the voltage is ramped up, the emission current must be set to a higher value, as the emitter has to follow the voltage ramp up. The emitter will remain more stable during the voltage ramp up when it is set to the higher emission current.
- Now the higher current is drawn from the gun source and the required voltage is 12.5kV at the gun source, while the gun extractor is still set to zero.
- The gun extractor voltage will be increased by the power supply and there will also be an increase in source voltage, maintaining emission stability.
- As the gun source power supply is not limited with respect to the voltage, it can ramp up when the gun extractor voltage is ramped up.
- The software will monitor the actual emission threshold voltage during ramp up to 30 kV. Therefore, the extractor voltage will be ramped up by the difference of 17.5 kV. This will be done step by step.
- The extractor voltage will then be 17.5 kV. The source will therefore theoretically be at 30 kV. Due to certain other characteristics, this value might not be reached exactly.
- The emission current will be ramped down from the high current to 3.2 µA which is the normal operating condition. This will result in a small shift in the voltage due to the I/U characteristic of the ion source.

It is only possible to ramp up the voltage very slowly and over a small range, when the emission current is set at the operating current of 3.2 µA. When the voltage needs to be adjusted over a wider range, the emission current has to be set to a higher current to keep the source emission stable.

- Now the defined set value of 30 kV has been reached on the gun source. This procedure will take 1-2 min.

STEP 6: Correction mode - monitoring the voltage

- The gun source voltage should be as close as possible to the defined value, e.g. 30.000 kV, at the set current of 3.2 µA. As the ion source is emitting and there is interaction with the vacuum, the I/U characteristic of the source is in itself not 100% stable. Therefore, as the emission current is fixed, the resulting voltage of 30 kV might vary when the I/U characteristic is not stable.
- The software is therefore constantly performing a correction, following an automatic check, typically every ten seconds. When the voltage, for example, has changed to 30.001 kV instead of 30 kV, the software calculates that the voltage is too high and the software subtracts 1 V to the extractor voltage. The correction mode is automatically switched on when a column parameter set is activated.

STEP 7: Protection mode for voltage changes

- Protection mode is based on the same measurements as the correction mode. The voltage is checked every ten seconds.
- When the voltage changes slightly, the correction mode will correct the voltage every ten seconds. If the voltage change is significantly higher within the measurement interval of ten seconds, e.g. by several hundreds of volts, **Protection** mode will be activated, since with such a large, sudden voltage change it must be assumed that the ion source will no longer be stable.
- Protection mode is only initiated when the voltage is outside the normal drift range. If this occurs, a new window opens, displaying a warning message.

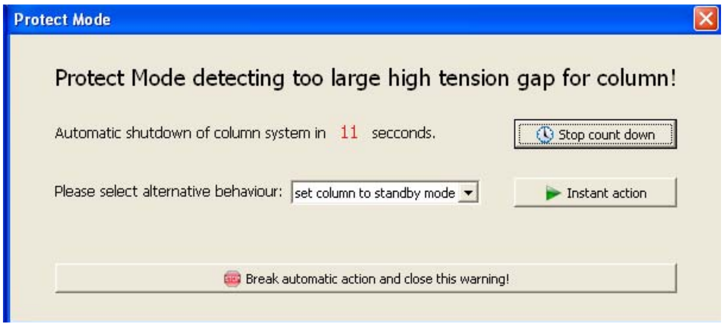


Figure 5-4: Protection mode

- A timer of 20 seconds is displayed, through which the user can interact with the software concerning the action that should be taken. Generally, the column will be transferred to **Column Standby**. If the instrument is unattended or if the user does not interact during the timed countdown of 20 seconds, **Column Standby** will be automatically activated.
- If the user interacts during the countdown, any actions can either be ignored, or transfer to **Column Standby** can be initiated immediately. The user can also initiate **Column Stop**.

5.2 Switching the system off

- To switch off the system, press the yellow **Standby** button. This will transfer the system to Standby mode.

This system **Standby** is not to be confused with the software Column Standby. The **Column Standby** is defined in the software in the **Column Control** section and its purpose is to transfer the column into Standby. The hardware button is a system Standby.

- Before the system can be transferred to Standby, the following software procedures must be carried out:
- Perform the **Column Stop** via the software
- Close all software windows
- Turn off the PC.
- Press the **Standby** button on the front panel of the pump housing.

Once the system is in **Standby** mode, you may switch off, using the red power button on the system power supply.

5.3 Exchanging samples

The **Unload** and **Load** procedures will be explained in detailed steps.

NOTICE

As it is a manual procedure, please follow the steps outlined very carefully, otherwise system damage may occur.

5.3.1 Unload procedure

(⇒ *Load lock* on page 2-3) please refer to Chapter 2, **Functional Principle**, for the load lock drawing and identification of all parts of the load lock.

STEP 1: Initiating Unload procedure and Column Stop

As soon as the Column Stop is initiated, the CCV valve in the upper part of the column will be closed, in order to maintain the high vacuum for the ion emitter source, while the sample unload procedure via the load lock is taking place.

- Open the Navigator, the *ionLiNE* load lock, in the main Tool bar, a new dialog will be displayed. Select the **Unload sample** procedure via load lock.

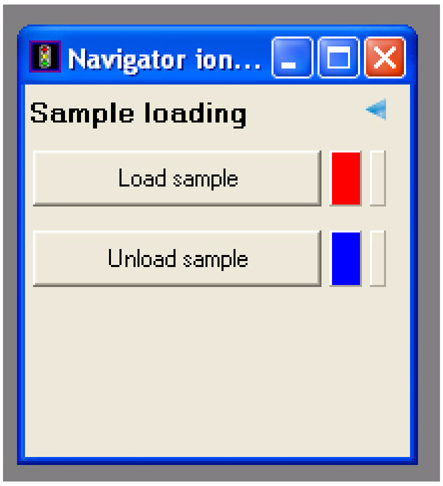


Figure 5-5: Select Unload sample in the Navigator

As a sample holder is currently loaded, the **Load sample** button will be marked red and will be disabled. The **Unload sample** button will be marked blue and is enabled.

▶ Click on **Unload sample**, which will initiate the unload procedure. The Unload button will become green/yellow.

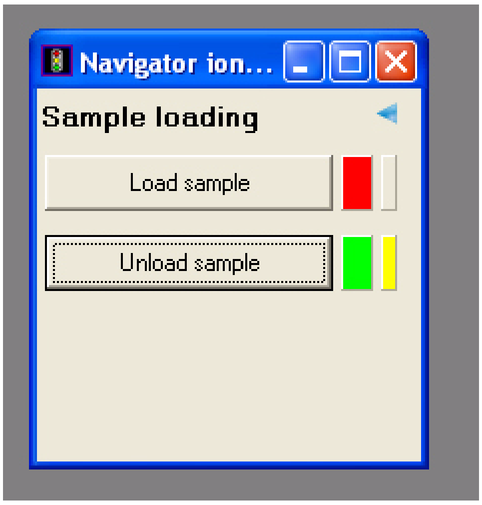


Figure 5-6: Unload sample procedure initiated

NOTICE

Some parts of the procedure have to be carried out manually by the user and some are carried out by the software. Throughout the full procedure the software will display prompt messages, which will have to be confirmed, to guide the user through the process.

- A prompt message to confirm the initialization of the Unload procedure will be displayed. Confirm with **OK**. The overall duration will be approximately 8 min.
- The TV camera will now be automatically switched on, showing the sample holder situated on the kinematic mounts on the sample stage.
- A message prompt will be shown to check that the load lock door is closed. It should normally be still closed from the last loading procedure, but it is safer to double check it. Once checked, confirm with **OK**.

NOTICE

Ensure that the screw-knob, situated at the load lock, is turned hand tight all the way in to lock the load lock door firmly. This will ensure that the O-ring of the door is firmly in place.

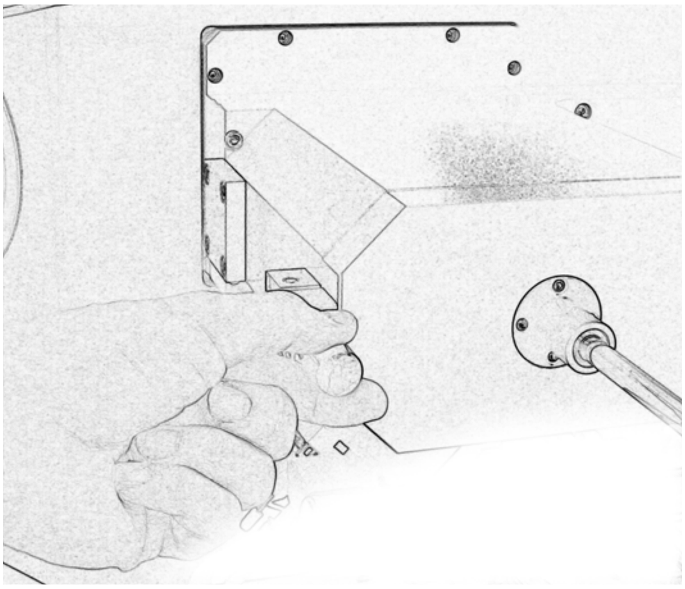


Figure 5-7: Checking that load lock door is closed

- The Column Stop will now be initiated by the Unload procedure.

The Unload procedure in the software will also initiate a **Column Stop**, if the user has not manually selected a Column Stop.

STEP 2: Moving sample holder into transfer position

- The Z stage is now moved to the transfer position. At the same time, the load lock is pumped to obtain a vacuum sufficient to open the load lock valve.

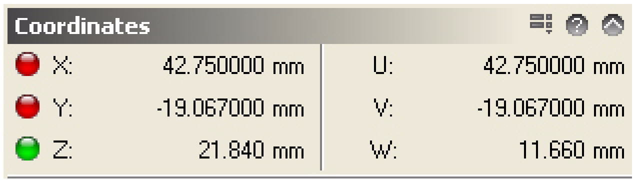


Figure 5-8: Moving down Z axis to transfer position

- The LED light for the Z axis is green, as it is currently moving downwards. The X and Y axis LED lights are red, as they are locked during this procedure in order to avoid any accidental movement via the joystick. It is important that the load lock transfer position is reached for the unload procedure via the transfer guide.
- As soon as the load lock transfer position is reached, all axes will be disabled and displayed with red LED lights.

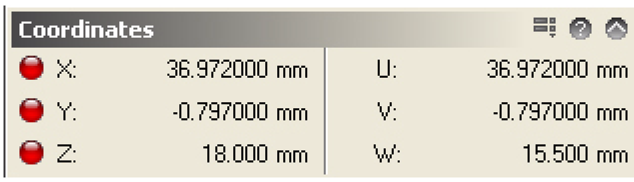


Figure 5-9: Transfer position is reached and all axes are disabled

STEP 3: Opening the load lock valve

- A software prompt will be displayed, that the load lock is ready and the load lock valve can be opened manually.
- You can now open the load lock valve. First, pull the knob upwards to allow the lever to be moved. Move the lever from **LOCKED** to **OPEN**. Once the lever is in the OPEN position, you can release the knob, and pull the lever forward.

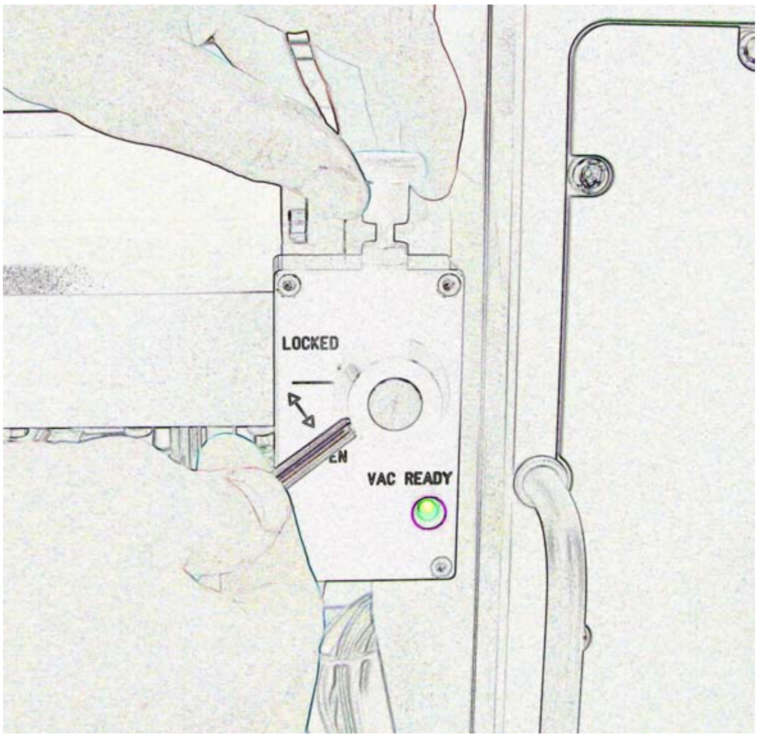


Figure 5-10: Moving the lever from LOCKED to OPEN position while pulling the knob upwards

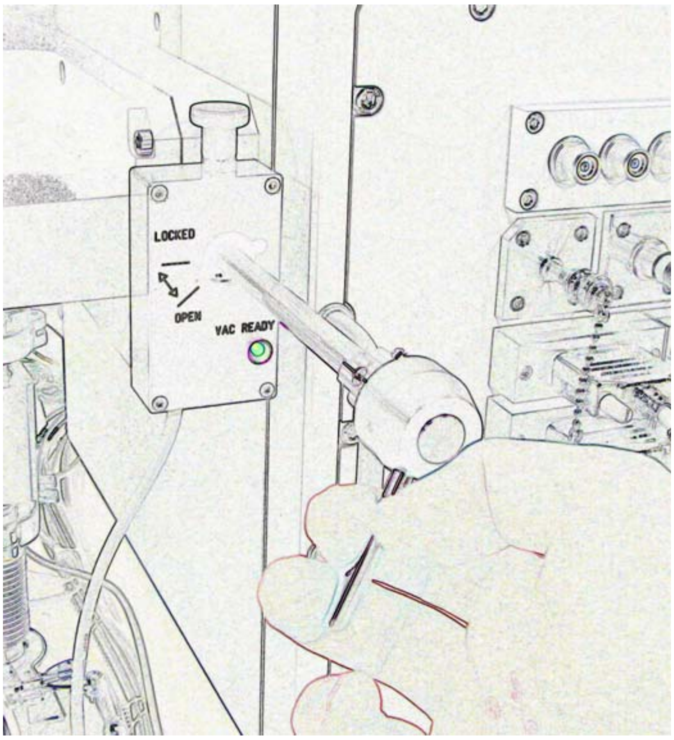


Figure 5-11: Opening the load lock valve

▶ Pull the lever all the way out to the mechanical end stop.

- Confirm the software prompt with **OK**, that the load lock valve has been opened.

STEP 4: Pushing in the transfer rod

- The software will now prompt the user to the next step of the procedure, to push in the transfer rod so that its transfer guide will be situated underneath the sample holder. Push the transfer rod gently to the mechanical end stop.
- Confirm the software prompt with **OK** when the transfer rod has been pushed in.

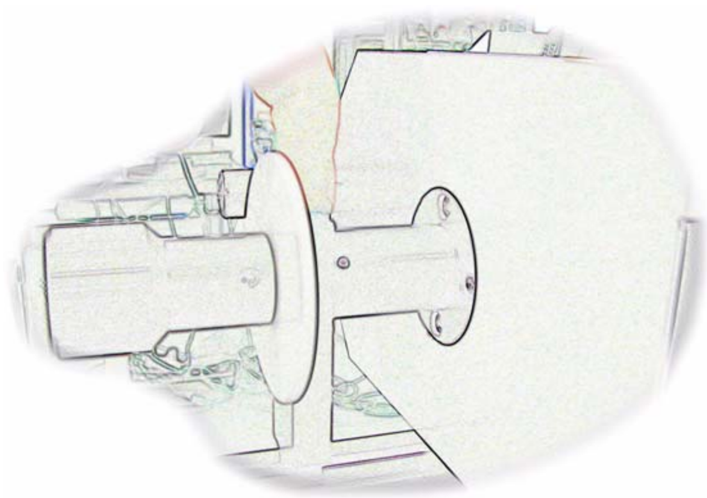


Figure 5-12: Transfer rod fully inserted

STEP 5: Sample holder transferred to transfer rod

- Now the stage will be automatically moved downwards. In the load lock transfer position, there is a gap of a few mm between the stage and the sample holder. The sample holder is situated on the kinematic mount during this procedure step.
- Within this gap is the transport guide of the sample rod. The stage is moved downwards until the minimum Z stage position has been reached. This will now allow the sample holder to be positioned on the transport guide of the transfer rod. This process can be monitored via the TV camera.

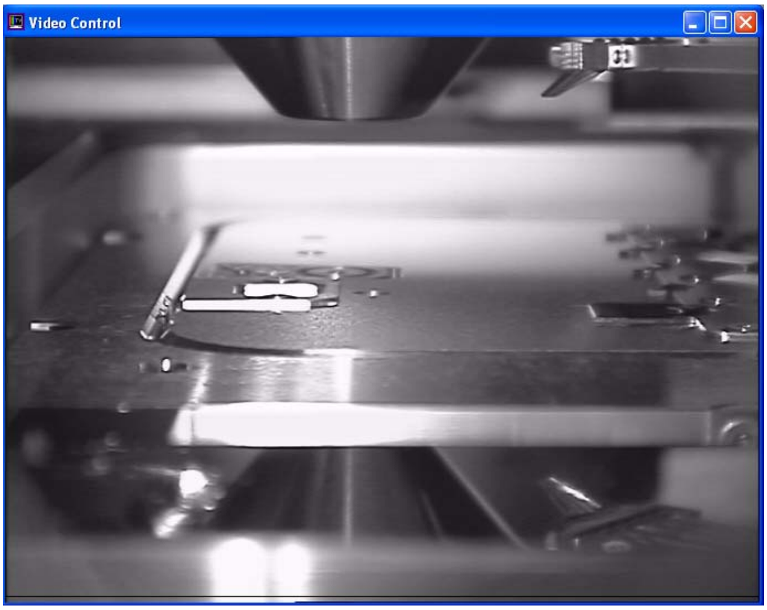


Figure 5-13: TV image showing sample holder in load lock transfer position

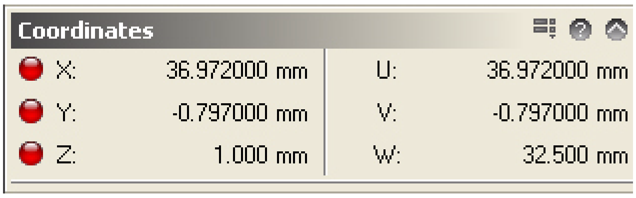


Figure 5-14: Z axis at minimum position of 1 mm

- It can now be observed that the sample holder is situated on the transfer guide of the transfer rod, and no longer on top of the stage. The transfer guide can not be seen with the TV camera, but the gap between the sample holder and the stage is clearly visible with the TV camera. The coordinates window shows that the Z stage is at its minimum position at 1 mm and all LEDs are red, since all axes are currently disabled.

STEP 6: Pulling out the transfer rod

- The next step is to pull out the transfer rod, this time with the sample holder. A software prompt will instruct the user to pull out the transfer rod.

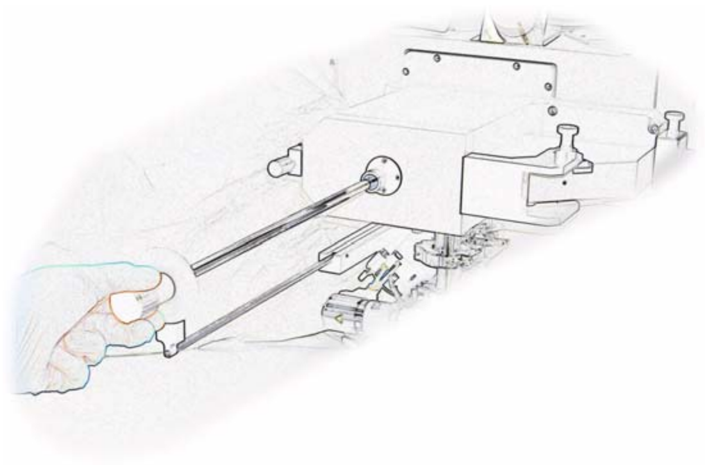


Figure 5-15: Transfer rod fully pulled out

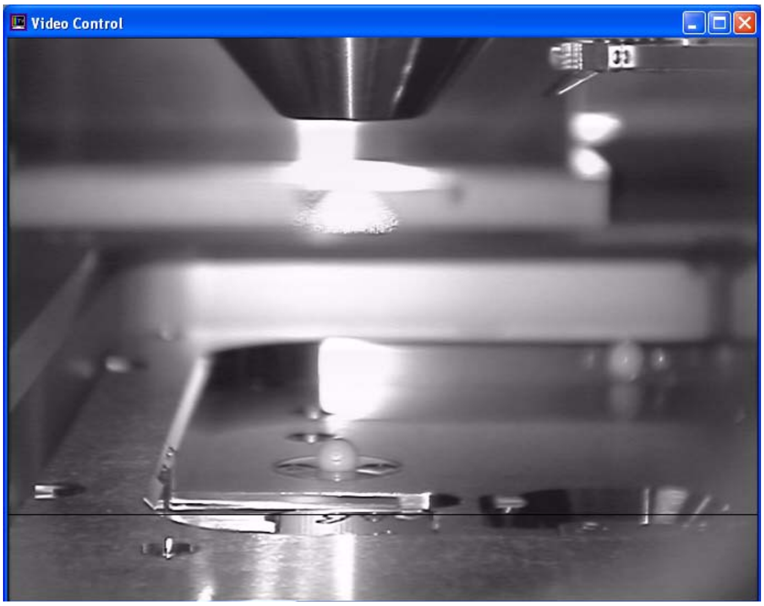


Figure 5-16: TV image showing the empty chamber

▶ Using the TV camera image to monitor the sample holder, slowly pull back the transfer rod to its mechanical end stop.The sample chamber is shown without the sample holder and the sample.

STEP 7: Closing the load lock valve

▶ The software will now prompt the user to close the load lock valve. Push in and turn the lever back to the **LOCKED** position.

NOTICE

It is important to move the lever a little way back and forth around the **LOCKED** position, until you feel that the knob clicks into its locking position.

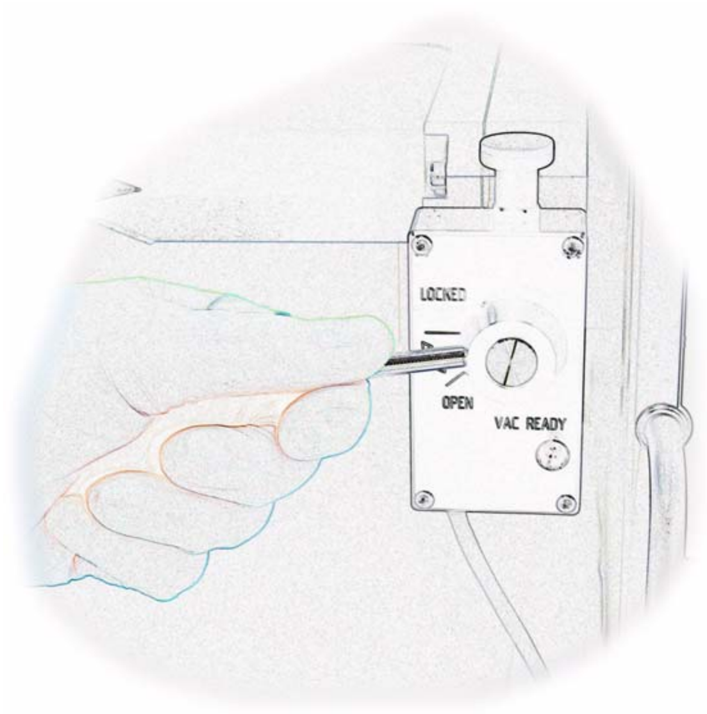


Figure 5-17: Load lock valve in LOCKED position

- ▶ Confirm in the software that the load lock valve is closed. The unloading procedure within the software is now complete. All axes are enabled, all stage axis LEDs are green. The load lock is vented. The **Load sample** button has become blue and is enabled. The Vacuum LED within the **Column Control** is green again as the system vacuum is within specifications with the load lock valve closed. Only the load lock is vented.

Coordinates			
X:	36.972000 mm	U:	36.972000 mm
Y:	-0.797000 mm	V:	-0.797000 mm
Z:	1.000 mm	W:	32.500 mm

Figure 5-18: All axes enabled again

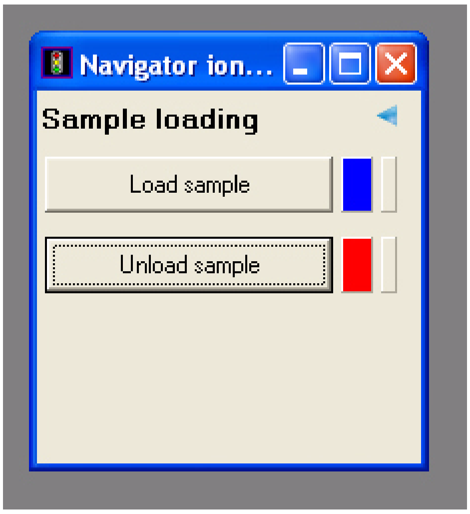


Figure 5-19: **Load sample** button enabled

STEP 8: Opening the load lock door to exchange samples

▶ The next step is to open the load lock door to take out the sample with the sample holder. Loosen the knob and turn the lever next to the load lock door outwards to open the door.

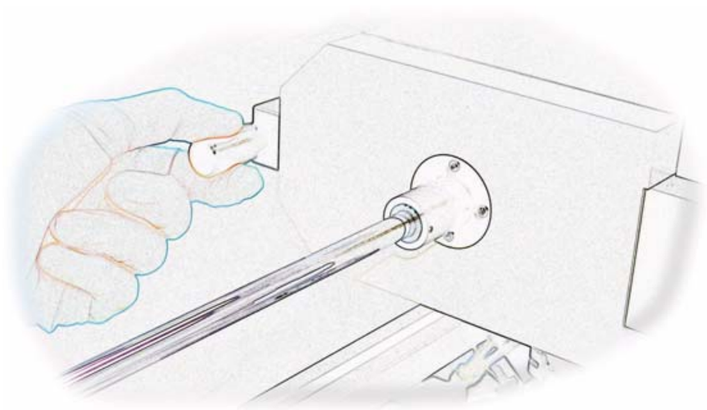


Figure 5-20: Loosen the knob on the load lock door to open it

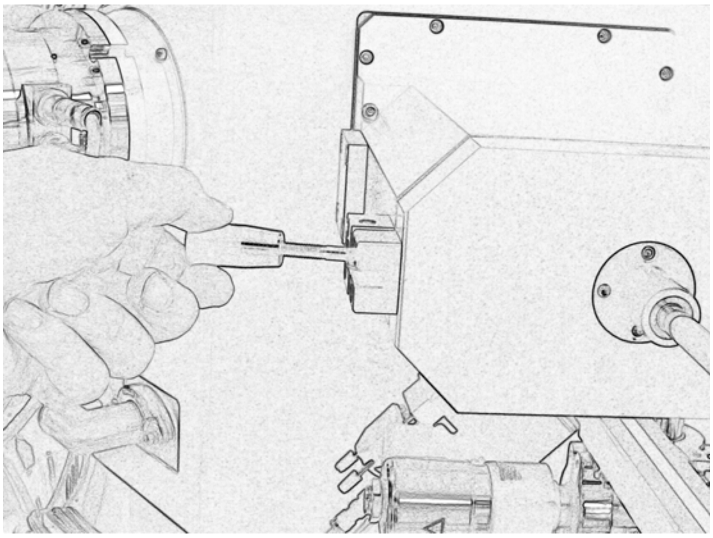


Figure 5-21: Opening the load lock door

- If you swing the load lock door fully open, a safety knob will engage, with an audible click, ensuring that the door stays open. This prevents accidental closing or swinging of the door while the user is working on the sample holder. The device will not operate when the door is only opened part way.
- Before touching the sample holder, ensure that you are wearing gloves. You can now remove your sample and the sample holder.

NOTICE

It is of vital importance that you always store the sample holder in the transport box supplied when it is not mounted on the stage. Only ever change the samples with the sample holder in the transport box. Never attempt to change a sample while the sample holder is still on the stage. Due to the fine mechanism, you may cause damage if you do not follow this procedure.

5.3.2 Load procedure

STEP 1: Placing sample holder into load lock

- Always load the sample onto the sample holder whilst it is placed in the dedicated transport box.

NOTICE

Only change the samples while the sample holder is in the transport box. Never attempt to change samples while the sample holder is mounted on the instrument. Due to the fine mechanism, you may damage the system if you do not follow this procedure.

- To load the sample, the sample holder has to be placed onto the load lock transfer guide of the transfer rod. One of the transfer guides is shorter than the other and a groove is situated between the two transfer guides, to ensure that the sample holder fits in snugly into its position. Place the sample holder onto the transfer guide and take care that the sample holder fits into the groove.

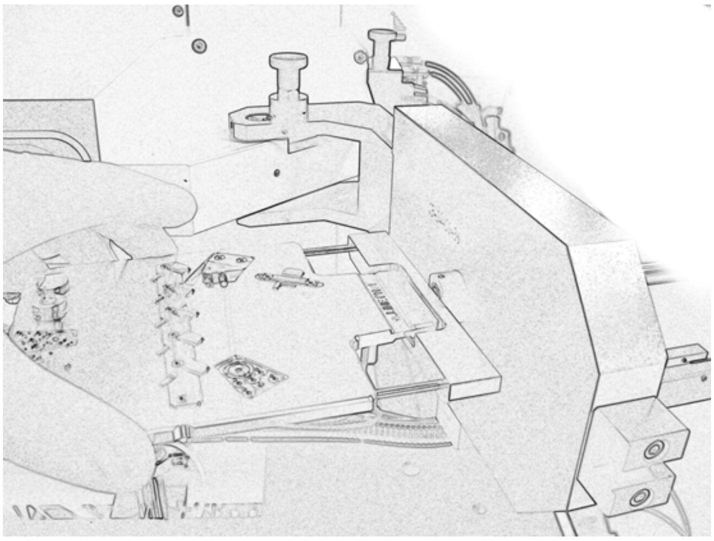


Figure 5-22: Placing the sample holder onto the transfer guide

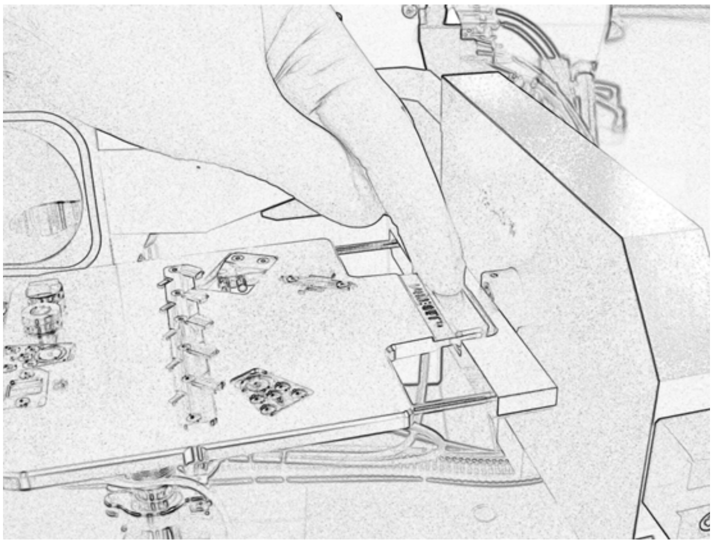


Figure 5-23: Ensuring that the sample holder fits into the groove of the transfer guide as indicated

- To close the load lock door, first release the locking device and then close the door, placing your hand on the door, not on the transfer rod. The transfer rod is a precise component and it moves freely. There is a risk that the rod may be slightly bent by putting sideways pressure on it.

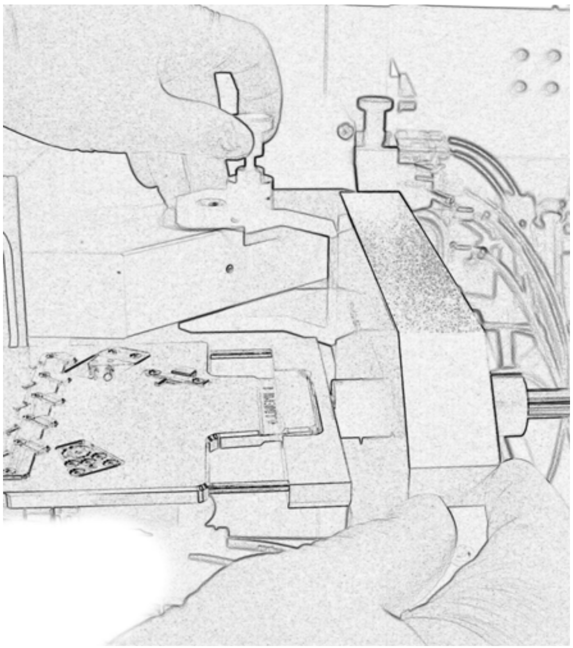


Figure 5-24: Closing the load lock door

- Close the load lock door and lever.

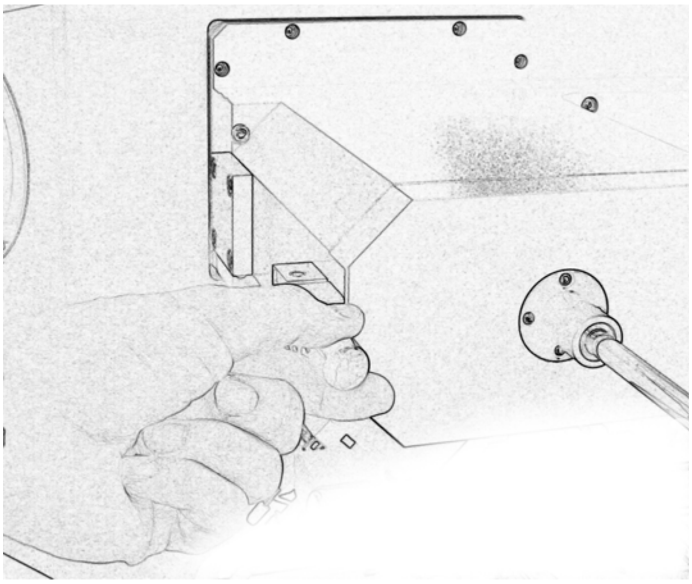


Figure 5-25: Tightening the knob on the load lock door to ensure a good seal

STEP 2: Pumping down the load lock

- Click on **Load Sample** in the software navigator. The loading procedure will take approximately eight minutes.
- The software will now prompt the user for confirmation that there is no sample holder in the chamber. This is an important question, as several sample holders may be in use. Check on the TV image that the sample chamber is empty. If it is empty, confirm with **Yes**.

- The software will prompt the user to close the load lock door. Ensure that you turn the knob next to the load lock door to ensure a tight seal. Confirm with **OK**.
- The software will now perform a **Column Stop**. All axes are disabled and the LEDs for X, Y and Z are shown in red. The load lock will be pumped.

STEP 3: Opening the load lock valve

- Once the vacuum in the load lock has been reached, the load lock valve can be opened. The software will now prompt the user to open the load lock valve, the Vac ready LED will be illuminated in green. First, pull the knob upwards to allow the lever to be moved. Move the lever from **LOCKED** to **OPEN**. Once the lever is in the OPEN position, you can release the knob, and pull the lever forward
- Confirm to the software that the load lock valve is open.
- The software now prompts the user to insert the transfer rod with the sample holder into the chamber.

STEP 4: Transferring the sample holder into the chamber

- Watch the TV image to view the sample holder slowly being inserted, while you are pushing the transfer rod into the chamber.

NOTICE

It is important to push the transfer rod all the way to its mechanical end stop to ensure that the dedicated transfer position for the sample holder has been reached. When in the transfer position, the sample holder will be transferred from the transfer rod to the sample stage. Damage to the system might occur if this procedure is not followed.

- Once the transfer position is reached, confirm with **OK** in the software. The Z axis of the stage will now be driven upwards to make contact with the sample holder and to lift it off the transfer guide.

STEP 5: Pulling the transfer rod back

- Once the sample holder is placed on the stage, the transfer rod can be pulled back from the sample chamber. Ensure that you pull it back to its mechanical end stop.

STEP 6: Closing the load lock valve

- Close the valve by pushing in the lever and turning it from **Open** to **Locked**. Ensure that the lever clicks into its position.

STEP 7: Initiating Operating mode

- The vacuum LED in **Column Control** will become green again, soon after the load lock valve is closed, since the chamber vacuum will be reached again. The CCV valve will open, once the chamber vacuum has been reached.
- The load lock will be vented under normal operating conditions.

If the software now displays an error message, indicating that it was not possible to open the valve, click on either **Retry** or **Cancel**. Normally, click on **Retry**, since this error message can be caused by a timing error. The chamber vacuum may not have not been reached as quickly as the timer setting.

- Once the CCV valve has been opened, the software will now ask if the UV adjustment should be reset.

In most cases, it is recommended to click the **Reset** button.

It will not have to be reset, for example, if a sample has been unloaded and then reloaded to continue work at the same position, if the position of the sample on the sample holder has remained unchanged. In this case, the UV adjustment does not have to be reset, as the correct coordinates will be reached.

In all other circumstances it is recommended to reset the UV adjustment.

- Now the software will display a prompt to use the most recently used column parameter set. The name of the parameter set is displayed. Confirm with **Yes**, if you would like to use it. Select **No**, if you wish to choose a different parameter set.
- A prompt message will now be displayed that the **Load** procedure has been completed successfully.
- You can now enter a sample name, which will be listed in the Protocol tool, if you wish.
- All the stage axes are now green and enabled.
- In the **Navigator** window, the **Load** button is displayed in red and the **Unload** button in blue. Only the Unload button is enabled.
- The system is now in **Operating** mode.

5.3.3 Load procedure via the front

The load procedure via the front door should only be carried out in special circumstances, e.g. for service work, or when large samples or measurements are to be carried out on special assemblies. In-situ measurements can be done via the five BNC connectors between the sample holder and the stage.

- In order to load via the front door, the complete chamber must be vented. Go to the **Status bar** in the **Column Control**. Click with the right mouse button on **Vacuum** and select **Vent**.
- The **CCV** valve will now close automatically and the chamber will be vented.
- The Z axis will move downwards to the minimum position.
- Once the sample is loaded via the front door, select **Pump** via the right mouse button to initiate the pumping of the chamber.
- When the chamber vacuum has been reached, the CCV valve will open.
- The system will now be in **Operate** mode.

5.4 Pre-leveling the sample holder

The following steps explain the pre-level procedure for the sample holder.

5.4.1 Tools required

The following hexagon keys are needed to carry out the sample loading procedure.

Allen key size	usage
0.9 mm	grub screw of kinematic mount
1.5 mm	kinematic mount countersunk screw
2.0 mm	sample holder transport lock
3.0 mm	wafer holder case
5.0 mm	case for electrostatic chuck and mask holder case

Deactivate the transport lock before opening the sample holder case.
Activate the transport lock again prior to any transport of the sample holder.

The Raith sample holder provides the ability to pre-adjust the holder with respect to the stage. The described course of action only needs to be done once after beginning to use a new sample holder or in case of misalignment.

The working distance of the sample holder above the three mounts must be measured by focusing on these positions. If the working distances are equal or within 50 µm, the pre-leveling is perfect. Using the measured working distances, the required adjustment of the two adjustable mounts can be calculated. Adjustment is done by turning the setscrew by a number of rotations R_{px}, followed by locking the setscrew, using the grub screw.

- Load the sample holder with no sample.
- Switch on the beam using approximately 50 pA and 30 kV high tension. Select a working distance of approximately 10 mm.
- Measure the working distance WD_{PX} at the following positions:

WDP_1: X = 39 mm Y = -6 mm

WDP_2: X = -13 mm Y = 41 mm

WDP_3: X = -33 mm Y = -30 mm

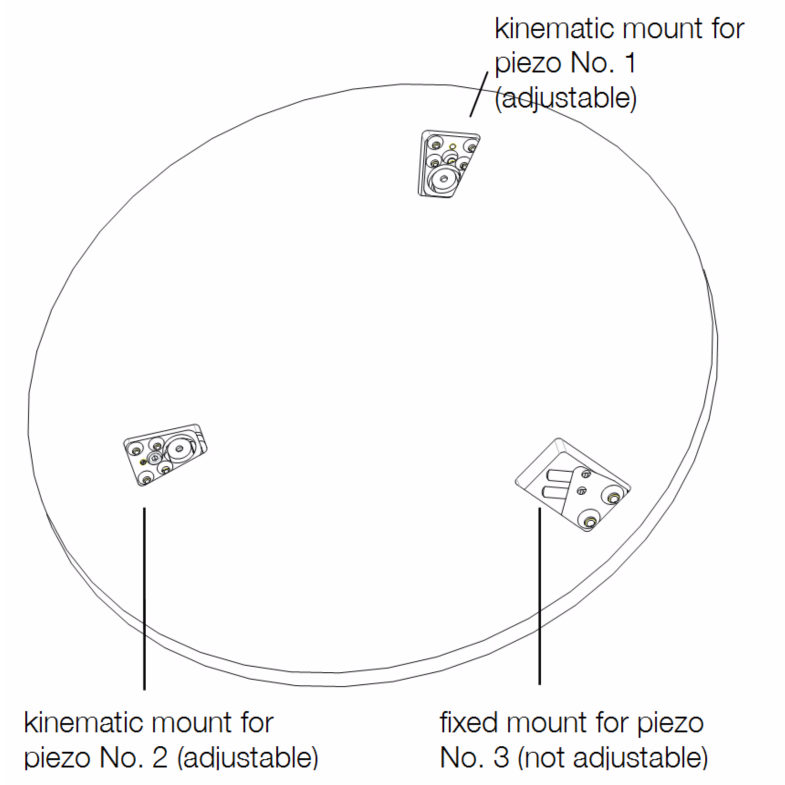


Figure 5-26: General overview and description of kinematic support points

- Unload the sample holder.

▶ Calculate the necessary height modification ΔWD_{Px} by using the following formulae:

$\Delta WD_{P1} = WD_{P3} - WD_{P1}$
$\Delta WD_{P2} = WD_{P3} - WD_{P2}$

If the absolute values of ΔWD_{P1} and ΔWD_{P2} are lower than 50 µm, no further leveling procedure is necessary. The following steps can be skipped.

▶ Calculate the necessary screw rotation R_{Px} by using the following formula:

The values 0.169 and 0.133 are the height changes for one rotation.

$\Delta WD_{Px} > 0$	$R_{PX} = \Delta WD_{Px} \,/\, 0.169$ mm
$\Delta WD_{Px} < 0$	$R_{PX} = -\Delta WD_{Px} \,/\, 0.133$ mm

▶ Modify the heights of the kinematic mounts:

$\Delta WD_{Px} > 0$ Loosen the grub screw.

Rotate the countersunk setscrew clockwise by R_{Px} revolutions. Fix the grub screw again.

$\Delta WD_{Px} < 0$ Loosen the countersunk screw.

Rotate the setscrew clockwise by R_{Px} revolutions. Fix the grub screw again.

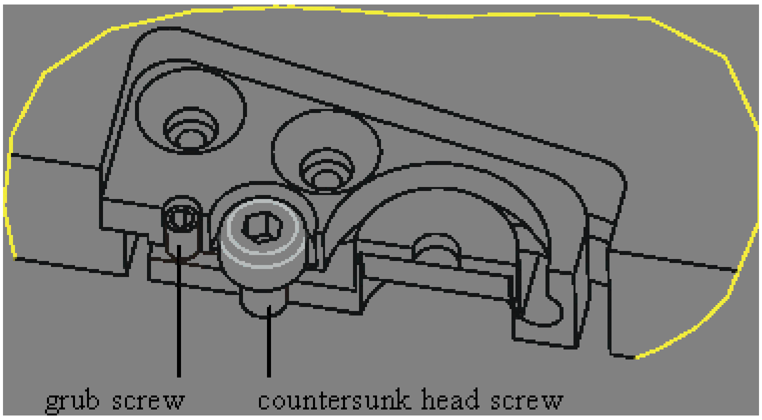


Figure 5-27: Cross section view of kinematic support point

Load the sample holder once again to check the result. Measure the working distance at the positions mentioned above. If either of the absolute values of ΔWD_{P1} or ΔWD_{P2} is still higher than 50 µm, repeat the pre-leveling procedure.

5.5 Sample insertion

NOTICE

The following chapter gives instructions for placement of a sample on the sample holders. Read the instructions carefully before any operation.

Never load a sample for which the sample holder is not explicitly designed. Improper handling may result in damage of the sample or the sample holder itself. More seriously, the system may be damaged during the load procedure.Always use gloves when handling the sample holder to avoid contamination.

5.5.1 Loading the universal sample holder

NOTICE

The maximum permitted sample height is 12 mm. Never load in a taller sample, otherwise the sample, the sample holder, the stage or the gun may be damaged during the load procedure.

The universal sample holder offers various ways to fix different sample sizes on the holder.

- To fix wafer pieces or whole wafers up to 2 inches, use the clamps on the holder. Alternatively, the sample can also be fixed directly onto the sample holder surface by using conductive tape or a double-sided cleaving carbon pad. After removing the sample, make sure that remaining adhesive is completely removed from the sample holder.
- Stubs can be mounted on the universal sample holder as well. Use the specified pin hole and the corresponding edgewise grub screw to fix the stub holder.
- The additional frame on the holder can carry 10 mm x 10 mm square pieces of wafer. Use this frame to fix repeatedly-used samples such as calibration samples. The frame must to be unscrewed when exchanging the sample.
- A further mechanism can by used to mount a sample. Loosen the screw to move the slider. Fix the slider with the screw after sample arrangement.

maximum dimension	**tilt**
14 mm x 10 mm	45 degrees
14 mm x 7 mm	90 degrees

5.5.2 Loading the 3D module

NOTICE

The maximum permitted sample height is 6 mm. Never load a taller sample, otherwise the sample, the 3D module, the stage or the gun may be damaged during the load procedure.

- The frames can carry 10 mm x 10 mm square pieces of wafer. Use this frame to fix samples on the tilting part of the 3D module. The frame must be unscrewed very carefully when exchanging the sample.
- To fix wafer pieces onto the fixed mounting surface, use the clamps on the 3D module.
- Stubs can be mounted onto the 3D module as well. Use the specified pin hole and the corresponding edgewise grub screw to fix the stub holder. Check that the height does not exceed 6 mm above the mounting surface.

5.5.3 Loading the mask holder (option)

Make sure that the mask is within the range of the mask holder specification to avoid any damage of the mask or the mask holder.

Follow the instructions below when using the mask holder.

- Open the transport box.
- Move the lever underneath the mask holder to its vertical position. The inner part of the mask holder will move to its lower position.
- Make sure that the reverse side of the mask is free from particles or dust.
- Place the mask on the mask holder.
- Push the mask carefully against the three metal cylinders to achieve the correct position.
- Hold the mask holder horizontally and move the lever underneath the mask back to its flat position.
- Make sure that the mask does not fall from or move on the mask holder. The inner part of the mask holder will move upwards and push the mask against the four clamps.
- Place the mask holder into the stage or the transfer guide of the load lock

Now the mask holder can be loaded.

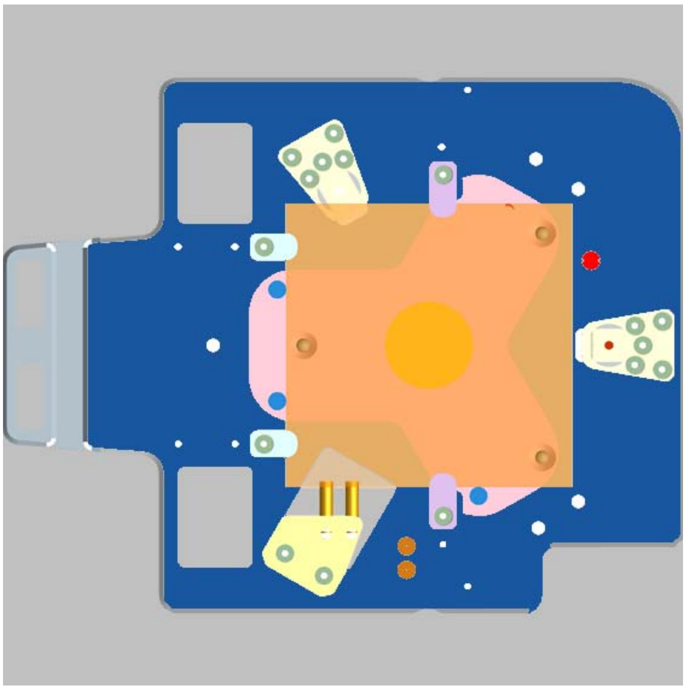


Figure 5-28: Schematic of mask holder

5.5.4 Loading the wafer holder (option)

Make sure that the wafer is within the range of the wafer holder specification to avoid any damage to the wafer or the wafer holder.

Follow the instructions below when using the wafer holder.

- Open the transport box.
- Rotate the knob at the lower right corner through 90 degrees. The lower right socket will move to an outer position.
- Place the wafer on the holder, touching the sockets. The flat should be placed at the corresponding left sockets.
- Rotate the knob through 90 degrees in the opposite direction, so that the socket moves in again to touch and clamp the wafer.
- Place the wafer holder into the stage or the transfer guide of the load lock

Now the wafer holder can be loaded.

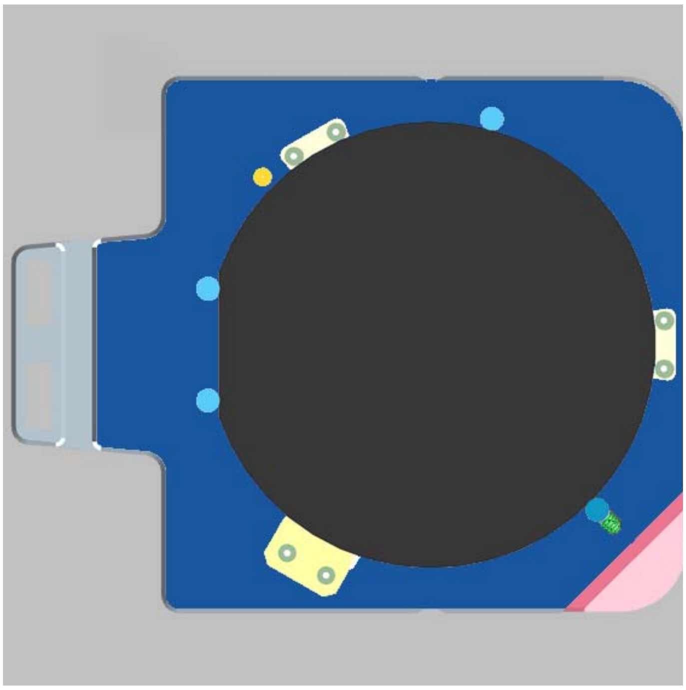


Figure 5-29: Schematic of wafer holder

5.5.5 Switching off the system

The *ionLiNE* can be permanently switched on. Only switch the system off either for significant technical reasons or if you do not need to use it for longer periods of time.

Whenever you switch off the system, the high tension and ion source must be switched off too.

- To switch off the system, press the yellow **Standby** button. This will transfer the system to Standby mode.

This system **Standby** is not to be confused with the software Column Standby. The **Column Standby** is defined in the software in the **Column Control** section and its purpose is to transfer the column into Standby. The hardware button is a system Standby.

- Before the system can be transferred to **Standby**, the following software procedures must be carried out:
- Perform **Column Stop** via the software.
- Close all software windows and exit the software.
- Confirm with **OK**, if you wish to save any changes.

- Go to the Windows start menu and click on **Logoff**.
- Go back to the Windows start menu and click on **Turn off Computer**, to shut down Windows.
- Press the **Standby** button on the front panel of the pump housing to initiate the Standby mode for the *ionLiNE*.

  The PC and the other components will be switched off sequentially. When the system is in standby mode, the **Standby** button will be illuminated in yellow.
- Wait at least one minute, then press the **OFF** button to switch off the *ionLiNE*, using the red power button on the system power supply.

Raith

Chapter 6
Software Reference

This Chapter gives an overview of all functionalities of the dialogs and fields that you will need for the basic operation and preparation of the *ionLiNE* and its individual components. The Column Control in the Raith *NanoSuite* software has control over many functions and parameters.

Please refer to the Software Reference manual for a detailed description of the Raith *NanoSuite* software.

You may call up **Column Control** by clicking the (Column Control) symbol in the control bar.

Column Control consists of the following three dialogs:

- **Column Control** dialog for:
  - generating, saving, loading and adjusting column datasets
  - controlling the gun and the high tension (EHT). These are monitored via the **Status** LEDs.
  - pumping and ventilating the chamber
- **Fine Tune** dialog to adjust the current column parameters
- **Focus Wobbling** dialog to switch focus wobbling on and off with user-defined amplitude and period.

6.1 Column Control Standby and Column Stop

The **System ramp down modes** are located at the bottom of the **Column Control** window. They are also global settings which can not be edited. They consist only of **Column Standby** and **Column Stop** parameter sets.

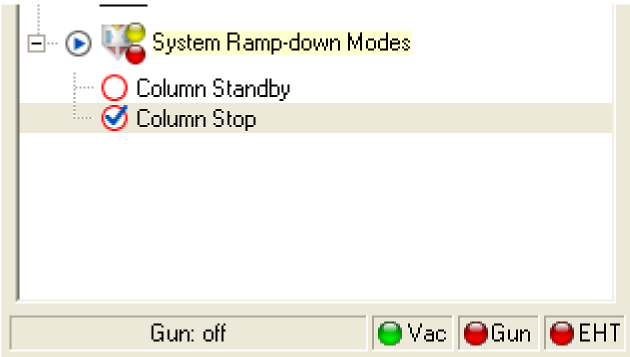


Figure 6-1: Column Stop and Standby

Column Stop: All high voltages are switched off, including the Ga emitter.

Use **Column Stop** if the instrument will be out of operation for several hours, as this will extend the life of the Ga source emitter.

Column Standby: All high voltages are switched off, except the voltage for the Ga source emission. The aperture driver is moved to a position at which there is no aperture, in between two apertures. This will extend the life of the apertures, as they are not exposed to any milling.

Use **Column Standby** when the instrument will not be in operation for a short period of time, of the order of an hour. Another reason for leaving the instrument in **Column Standby** instead of **Column Stop** would be if the application demands highest stability of the Ga emitter. The user may then choose to leave the Ga emitter switched on.

6.2 Vacuum Control via Status bar

The status bar is divided into two subsets:

- On the left-hand side, messages regarding current system processes of **Vac**, **Gun** and **EHT** are displayed (**System pumping** and **gun busy**, for example). These message display changes in hardware settings.
- The right-hand side is used to indicate the status of the following;

Control element	Function
Vac	vacuum status
Gun	represents the status of the gun source.
EHT	Electrical High Tension. The EHT includes all high voltage settings for the electrostatic column, including the high voltages supplied to the condensor lens and objective lens.

The displays resembling LEDs can have the status green, yellow or red to indicate operating mode.

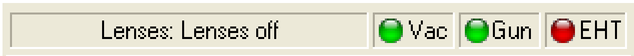


Figure 6-2: **Column Control** status bar

To switch **Gun** or **EHT** on or off manually, or to pump or ventilate the chamber, click on the corresponding command in the context menu.

Table 6-1: Colors of the Vac, Gun and EHT LEDs

	Vac	**Gun**	**EHT**
Red	No vacuum	Gun switched off	EHT switched off
Yellow	Pump running	Gun being switched on/off	EHT being switched on/off
Green	Vacuum OK	Gun on	EHT on

The green light for **Vacuum** indicates that the vacuum is sufficient to ramp up the column.The green light for **Gun** indicates that the gun settings have been reached.

The red light for **EHT** indicates that all high voltages are switched off, except for the voltage supplied to the gun, which is indicated in the **Gun** LED.

The gun can be switched off if the instrument is not being used for several hours, as this will extend the lifetime of the Ga emitter.

6.3 Fine Tune window

You can use the **Fine Tune** dialog to set the column parameters during operation.

There are two ways of entering values in this dialog:

- Using text fields: The values are only adopted when you click on the **Send** button.
- The slider bars or the control marker can be adjusted by dragging the mouse to the new position. The further the mouse is moved, the more the value will be changed.

- By scrolling with the mouse wheel, the sensitivity range of the slider bar is changed, from coarse to medium to fine. These changes are adopted immediately.

Software tools within the **Fine Tune** dialog enable the fine adjustment of the parameters, **Magnification**, **Focus**, **Detector**, **Aperture** and **Stigmator**.

The software tools consist of one-dimensional slider bars, e.g. for **Contrast** and **Brightness** or **Focus** setting, as well as a two-dimensional field, used for the **Aperture** and **Stigmator**.

Select the aperture diameter in the **Aperture** tab and set the correction values for the penetration point of the beam.

It is recommended to change the aperture only via a column control parameter set, since a change of aperture also requires a change of lens settings.

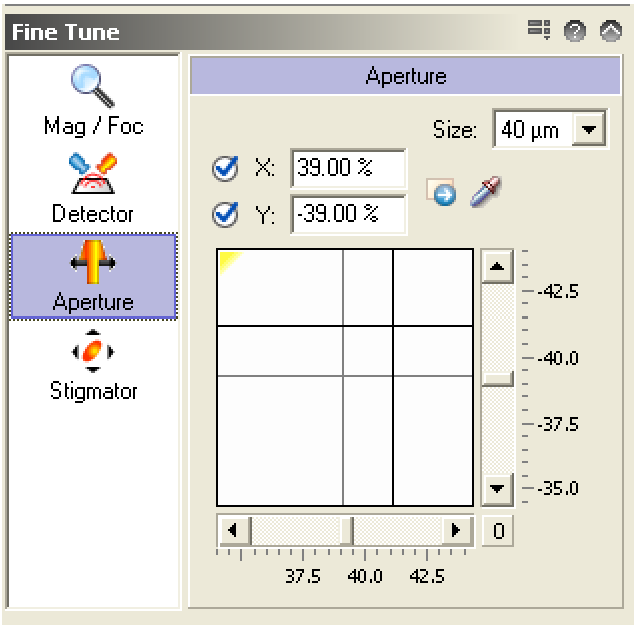


Figure 6-3: **Fine Tune** dialog – **Aperture** tab

The **Aperture** is tuned on a real image, using the wobbling. The aim is to fine tune the aperture so that it is situated in the center of the beam. The aperture is moved in X and Y directions to place it into the center of the beam. When optimized, the image should not shift during wobbling. The image will become sharp and less sharp during the wobbling, but should not shift in X or Y direction.

The aperture driver used is a piezo driven device to move between the different apertures. In the *ionLiNE* system the aperture is physically driven to a position under the beam. Typically, 12 apertures are used in the system.

For each aperture, the size of the aperture is displayed, followed by a number in brackets, which corresponds to the position on the aperture driver.

After the user has selected the aperture, the software sends a positioning information signal to the motor. This is the default position of the aperture center. This default position can not be the optimum position for all acceleration voltages and lens setting, working distances etc.

Using the wobbling, the user can adjust for the optimum position of the aperture, depending on the current operating conditions.

6.4 Power Supply monitor

The **Fine Tune** menu will open the following menu options:

Clicking on the **menu** icon the **Fine Tune** menu is displayed.

Fine Tune menu item	**Function**
Power Supply Monitor	The **Power Supply Monitor** displays the status of the important power supplies for the column. This dialog is only available for Master level users.
System Status Report	This is an overview monitor window. A new dialog opens.
Safe Controller Sensitivity	The currently selected sensitivity ranges for all control elements will be saved as their new default values.

Selecting the **Power Supply Monitor** will open the following dialog

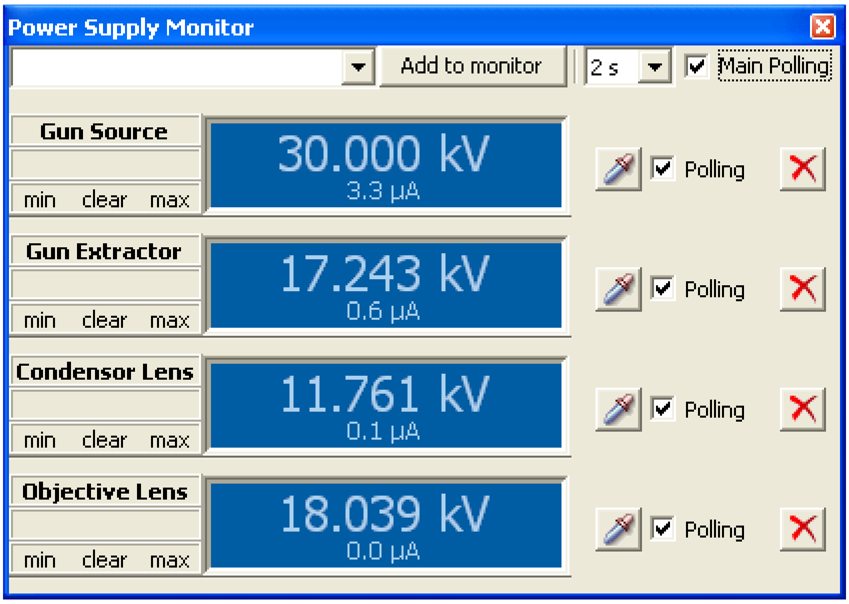


Figure 6-4: **Power Supply Monitor** dialog

Control element	Function
Power Supply Monitor drop-down list	A dropdown list will display a list of all available power supplies to be selected for monitoring. The **Condensor Lens**, **Objective Lens**, **Gun Source** and **Gun Extractor** are typically the principal ones to be monitored.
Add to monitor	Via the command **Add to monitor**, other supplies can be added, for example, the gun heater. Up to five supplies can be monitored at any one time. Once the **Add to monitor** is pressed, the selected supply will be displayed. The current value as well as the minimum/maximum values will be displayed.
Timescale	Alongside **Add to monitor** is a dropdown box, where the timescale for the measurement intervals can be selected within the given range of 1 -60 s.
Main polling	When **Main Polling** is checked, the supplies are now selectable for polling by individually placing a checkmark next to the supply. The supplies displayed in the monitor will be measured automatically at a set interval, e.g. every second.
	Clicking on the **Pipette** icon, a measurement will be taken directly.

Control element	Function
Display setting	The monitor display shows a blue field with a large number and a smaller number situated underneath. The more important value is the larger one, e.g. either the current or voltage setting for the display is chosen as the large letter. For each parameter, the default configuration is set. Placing the mouse cursor on the display field and clicking with the right mouse button enables the user to change the **Display Setting**. The priority between the large and the small display can be toggled via **Switch U/I** and the units for the display can be selected, the software will automatically calculate the value in the selected units. For example, the gun heater has a large **Ampere** displayed and a small **Voltage**.
	The red **Delete** button after each displayed parameter will delete this parameter from the monitoring list. Please note that it will be only deleted from the monitoring. This button is the opposite to **Add to monitor**, it simply means **Delete from monitor**.

6.5 Beam current measurement

The user may call up **Patterning** by clicking the  (Patterning) icon in the control bar.

The **Beam Current** measurement will be displayed.

Figure 6-5: Beam current measurement

Control element	Function
Display field	The larger value is the current value and the smaller value beneath is the last measured value.
Units	The user can change between units by selecting the unit from the dropdown list. The software will automatically recalculate the value in the new unit and display it.

Control element	Function
Measure	Clicking on the **Measure** button will initiate a new measurement of the beam current.
<current position> field	From the dropdown list, the user can choose where the beam current should be measured, most sample holders include a Faraday cup to measure the beam current. Stage will automatically drive to the specified position to measure the current and if the **Drive back** checkbox is checked, drive back to the previous stage position.

Whenever a beam current measurement is performed, the reading will be saved in the patterning parameters, so that the dwell times for Areas, Lines, Dots etc. have to be recalculated via the **Patterning Parameter Calculation** dialog.

Chapter 7
Accessories

This Chapter gives an overview of the available accessories and their components, with which you can extend the functionality of the *ionLiNE*.

7.1 Starter kit

Upon delivery of the *ionLiNE* you will receive a Starter Kit, with which you can perform the first few steps with the system. If required, you can request further kits from Raith.

7.2 Offline licenses

As standard, the Raith *NanoSuite* is installed with the *ionLiNE*, which the user can only use during the operation of the system. In addition, one offline licence for the preparation of designs or post-processing of the data is supplied.

7.3 Raith sample holder

There is a selection of specially designed sample holders available from Raith for a variety of samples, masks and wafers.

In the following paragraphs, the application, functionality and the operation of the optional Raith sample holders are described:

- Raith mask holder (⇒ *Raith mask holder* on page 7-2),
- Raith wafer holder (⇒ *Raith wafer holder* on page 7-2)

If you have requirements for a sample holder, adapted to your individual applications, please consult Raith support.

7.3.1 Raith mask holder

The Raith mask holder is suitable for the processing of standard masks up to 5 inches. There are three different Raith mask holders available, which can hold masks of different thickness.

The Raith mask holder is suitable for masks with the following dimensions:

- 2.5 inch mask holder (1-OR100-M2.5)
- 4 inch mask holder (1-OR100-M4)
- 5 inch mask holder (1-OR100-M5)

7.3.2 Raith wafer holder

The Raith wafer holders are suitable for wafers with little curvature and little surface non-flatness. There are two different types of Raith wafer holders available for wafers up to a diameter of 4 inches:

- 3 inch wafer holder (1-OR100-W3)
- 4 inch wafer holder (1-OR100-W4)

7.4 System additions

The *ionLiNE* can be extended with the following components:

- Gas Injection System (GIS) for performing ion beam induced deposition (IBID) and gas assisted etching (GAE).
- Nanomanipulators
- Residual gas analyzer
- Automatic height sensing.

Chapter 8
Maintenance and Troubleshooting

This chapter gives an overview of the maintenance procedures, which need to be carried out at regular intervals to ensure the optimum performance of your *ionLiNE*.

NOTICE

Only Service users with special training are permitted to carry out maintenance procedures.

If you have any questions or comments regarding the maintenance procedures, please contact Raith support.

8.1 Maintenance

8.1.1 Aperture exchange

The aperture driver is an assembly, consisting of a long rod, the aperture rod, which holds aperture orifices at the front of the rod, as well as a unit holding the piezo motors for driving the aperture holder. The unit with piezo motors can be dismantled from the assembly flange.

The aperture rod needs to be exchanged when the aperture opening is becoming too wide or is no longer circular.

NOTICE

During this maintenance procedure, the complete aperture rod will be exchanged. The apertures are positioned at the end of the open driver, consisting of several apertures of various sizes. The apertures themselves are the most delicate part of the assembly and can easily be damaged, particularly when removing or installing the assembly from and to the instrument

STEP 1: Venting the chamber

▶ Go to **Vacuum** in **Column Control** and click with the right mouse button. Select **Vent**. This will vent the chamber.

The motor for the aperture driver and the driver itself are situated underneath the column chamber valve within the chamber vacuum region. This has the advantage that the user only needs to vent the chamber for any maintenance work on the aperture rod.

STEP 2: Opening the Aperture Service window

In order to perform the aperture exchange, the user needs access the service window of the aperture driver.

- Go to **Column Control\Fine Tune\Context** menu and select the **Aperture Service** window.
- The **Aperture Service** window appears to be quite complex, but only specific parts of it need to be used for exchanging the apertures. Ensure that the X and Y motor values, displayed in the upper left corner of the window, are set close to 0 µm. If a larger value is displayed, drive the aperture motor until near-zero hardware values for the X and Y motor are reached. This will ensure that the XY driver motors are in the center of their movement range, the 0,0 position.This will simplify the overall procedure. The aperture window will be explained in detail in Step 7: (⇒ *Initializing the Aperture Service window* on page 8-6).
- Close the **Aperture Service** window and log out of the Raith ***NanoSuite*** software to exit it.

STEP 3: Switching off the power to the aperture driver controller

- Prior to dismantling the driver motor and pulling it out, together with the aperture rod, the power must be switched off. Go to the right hand side of the plinth and open the cover. The third controller counting from the bottom of the rack is the controller, which contains the aperture driver controller, macroscope controller etc. Switch off the unit labelled **Aperture driver**.

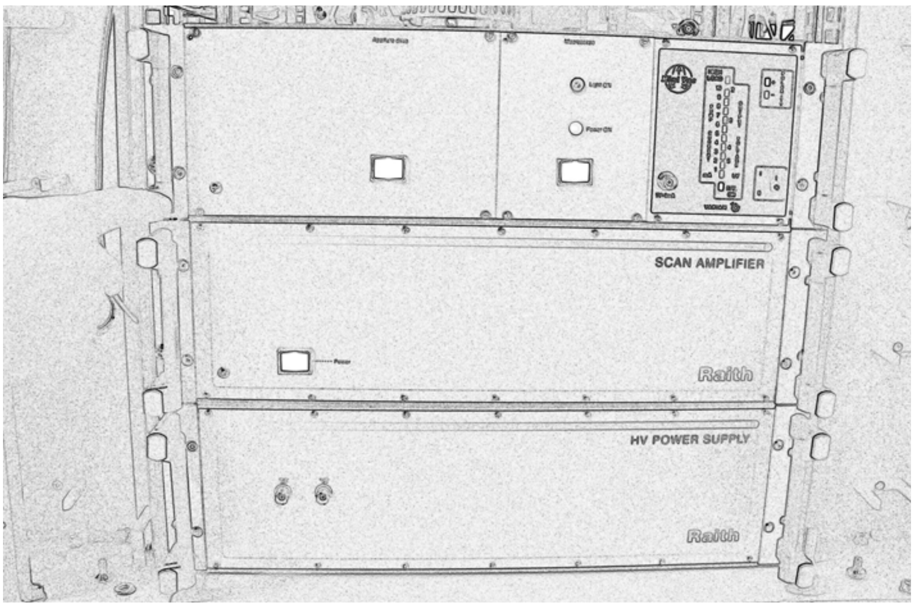


Figure 8-1: Switching off the power to the aperture driver controller

STEP 4: Dismantling the aperture driver

- Unscrew the screws of the D-sub plug of the aperture driver and pull out the complete plug assembly very carefully.

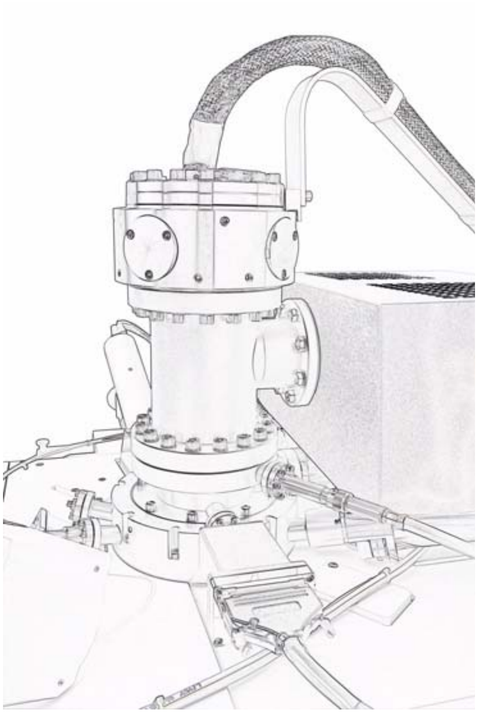


Figure 8-2: Column with aperture driver

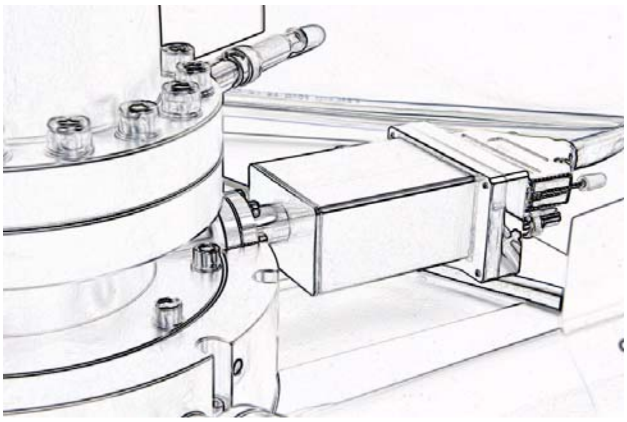


Figure 8-3: Take off the D sub-plug

- Unscrew the screws in the flange and take out the aperture rod and piezo motor assembly.
- Take out the complete aperture driver, very carefully. The space is tight and the aperture driver consists of a long rod, the aperture rod. Withdraw the aperture driver, in a straight movement, until it is completely clear of the instrument.

▶ Place the aperture driver on a table and support the base plate flange, so that there is no strain on the aperture rod.

NOTICE

Ensure that the long rod is in balance, by supporting the base plate flange. Avoid that the rod is in contact with a surface, e.g. the table surface. That would put too much strain on the motor assembly and might lead to damage.

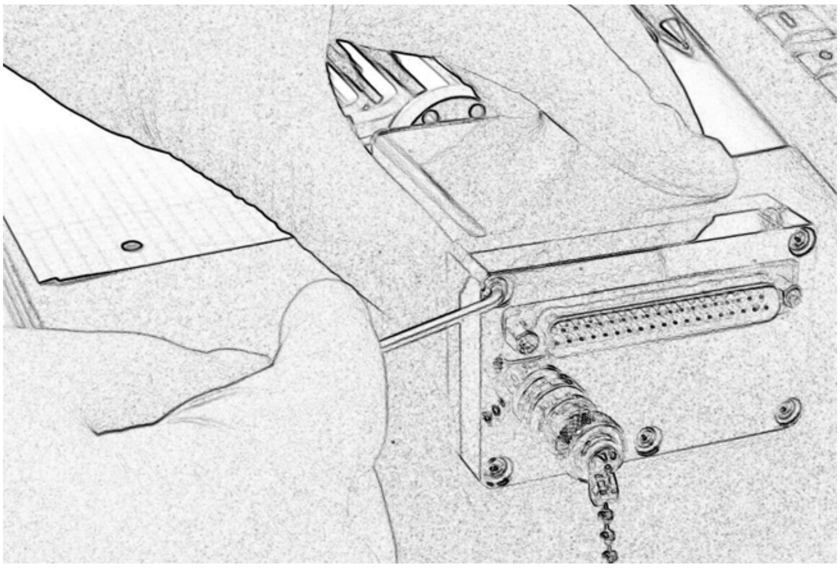


Figure 8-4: Loosen the screws in the flange

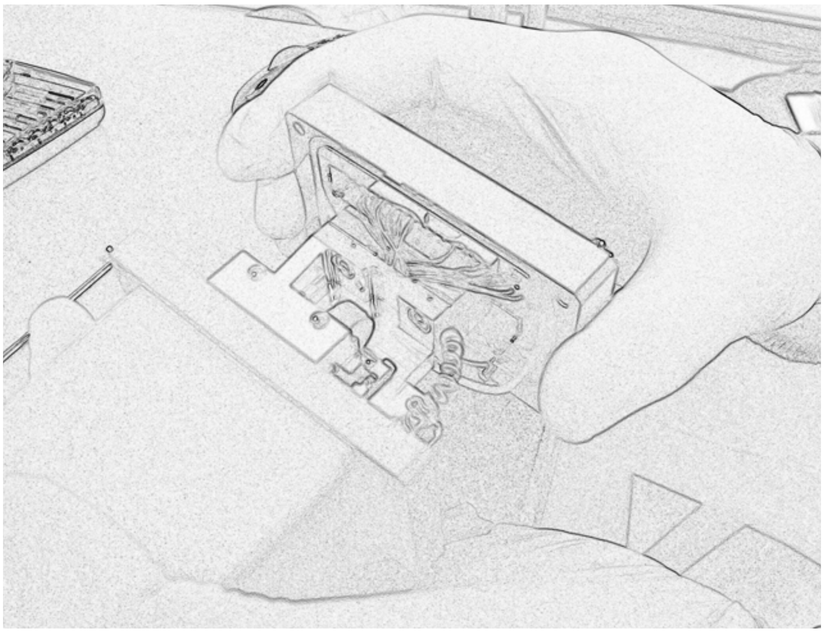


Figure 8-5: Dismantle the flange to gain access to the piezo motors

- Now unscrew the set screw of the aperture rod. Take out the old aperture rod.
- The apertures are the most delicate part of the assembly and can easily be damaged. Pay particular attention to the apertures when installing the assembly to the instrument.
- Insert the new aperture rod. The smaller screws will fix the assembly into place. There is a bigger screw at the lower left corner, which will make the slit smaller and will therefore hold the rod in place. Ensure that the new rod is horizontally aligned by referencing it visually to the piezo motor base plate or to the aperture driver flange.

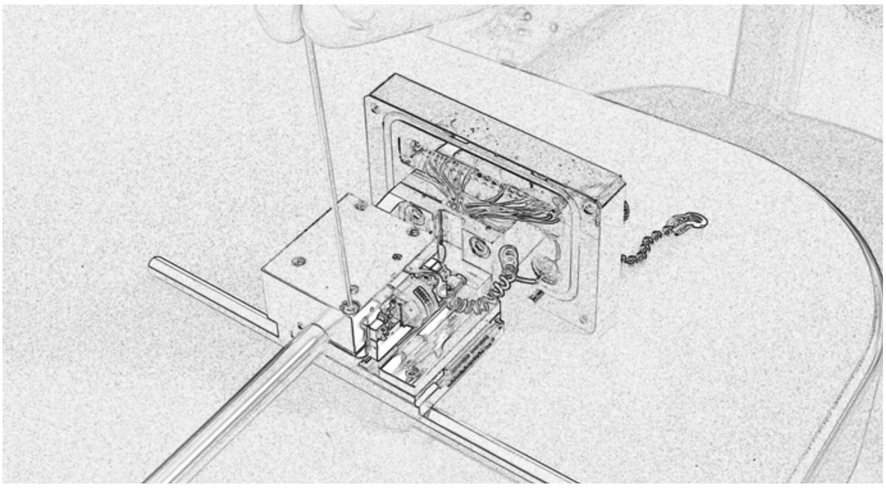


Figure 8-6: Insert the new aperture rod and fix the rod using the screw

- It is recommended that you ensure the piezo driver motors are in alignment, so that no offset is visible, prior to inserting the aperture rod into the system. Both piezo motors are stacked one on top of the other and when at (0, 0), they should be perfectly aligned, so that they do not protrude either in the X or the Y direction.
- With the power off, the piezos may be moved manually, slowly and with great care, so that they are perfectly positioned with no visible offset. Doing so will be a significant aid to the procedure when the aperture rod has been inserted, as the piezo motors will already be at the 0, 0 position.

NOTICE

Take great care to move the piezo motors only very gently and with great care. This can only be performed when the power is disconnected. When aligned, the piezo drivers will be at the 0,0 position.

STEP 5: Inserting the new aperture driver into the system

- Carefully insert the aperture driver into the system. Take your time and push it very gently and slowly. Ensure that you are careful with the cables so that you do not pinch them upon insertion.
- Tighten the screws on the flange.
- Connect the plug and tighten the screws.

STEP 6: Switching the power on and restarting the software

- Switch the aperture driver controller back on.
- Start the software and log in.
- Go to **Column Control** and right mouse click on **Vacuum**, select **Pump** from the dropdown list. The chamber will now be pumped.

STEP 7: Initializing the Aperture Service window

Whenever the aperture driver controller has been switched off and on, the controller assumes that the position of the XY driver is set to the 0,0 position, which is in the center for the movement range. This should be close to the current position, as you should have manually moved the piezo motors to that position, prior to inserting the aperture driver into the system.

The aperture driver consists of a stack of two 20 mm piezo-based motor elements. The X motor has a movement of +/-10 mm, and the Y motor has a movement of +/-5 mm, whereby 0,0 is the center position.

- Open the **Aperture Service** window, which contains the following:

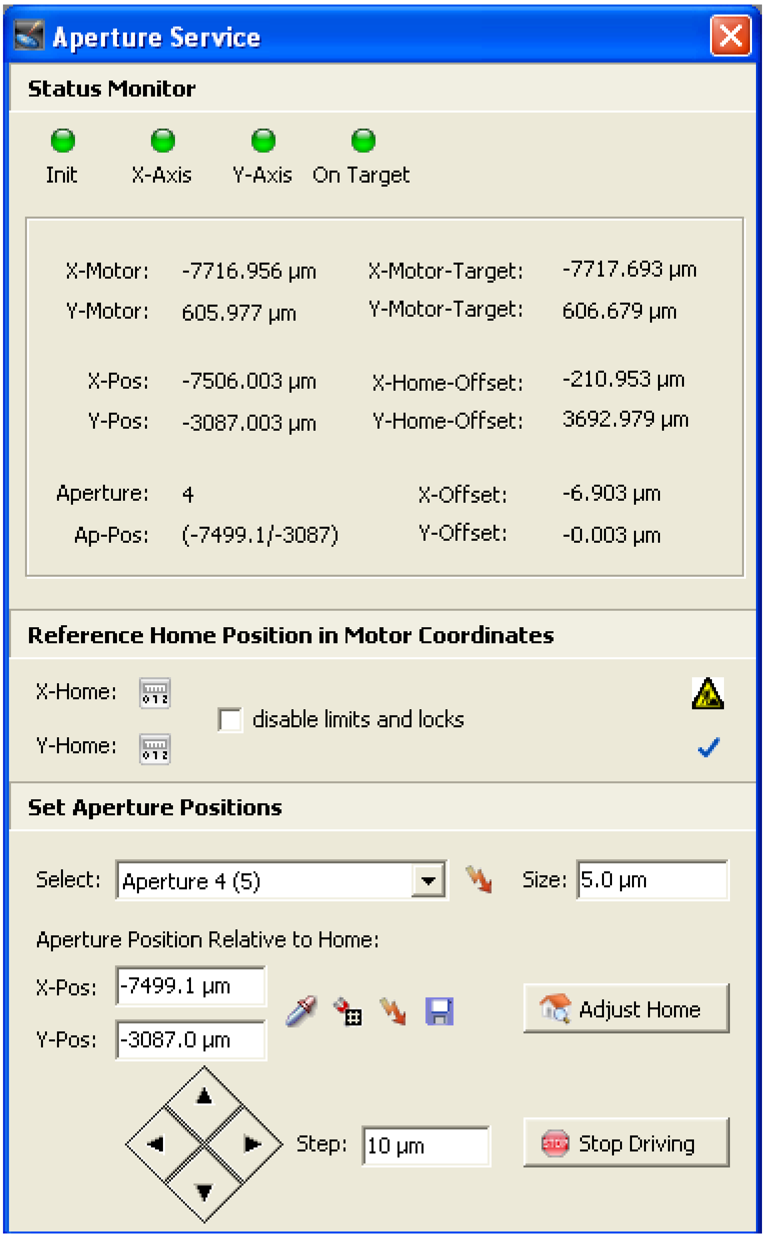
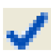


Figure 8-7: **Aperture Service** window

Control element	Function
Status Monitor subset:	
Init LED	The LED is typically green, indicating that the connection to the driver motor is working.
X, Y-Axis LED	The LED gives the status of the XY axis. Blue: axis is stationary, but connection is ok. Green: axis is moving.

Control element	Function
On Target LED	The LED is green when the Target position is close to the current position. The accepted tolerance is typically set to 1-2 µm. When the target value has been reached, the LED will be green.
X, Y Motor	The current coordinates are displayed.
X, Y Motor Target	The Target coordinates are displayed.
X, Y Pos	The X, Y positions are displayed.
X, Y Home-Offset	The **Home Offset** relative to the motor coordinate results in the X and Y Pos value. The coordinate system therefore has a shift, which is defined by the offset.
Aperture	The **Aperture number** is displayed, which shows the corresponding aperture position. The XY coordinates of the current aperture positions are displayed.
Ap- Pos	The Aperture position is displayed.
X, Y Relative	The distance from the default aperture position.
Reference Home Position in Motor Coordinates subset:	
X, Y Home	The X and Y Home positions are displayed.
disable limits and locks	The limits and locks can be disabled.
	Button to assign ‘work in progress’ symbol to all column datasets, after the apertures have been exchanged. Will be removed after checking and saving the individual dataset.
	Button to remove ‘work in progress’ symbol from all column datasets.

Control element	Function
Set Aperture Positions subset:	
Select	A dropdown list of all apertures available. The list of available apertures is defined in the configuration file.
	Click this button to drive to the selected aperture.
Size	The size of the aperture is displayed
Aperture Position Relative to Home	The aperture position relative to the Home position is shown.
X, Y Pos	The difference will be displayed.
	To read the current X, Y position
	To read in the theoretical design coordinates of the aperture
	To save the X, Y position
Adjust Home	Click this button to adjust the Home position.
	To move the aperture rod in defined steps using the up, down, left and right arrows
Step	The step size can be defined for the driver movement.
Stop Driving	Click this button to stop the motor drives.

Ensure that the current X, Y position has been read in via the **Pipette** icon before clicking the button **Save values**.

Typically, one aperture is defined as the origin aperture. All other positions on the aperture rod will be relative to the origin aperture.

- After the aperture rod has been exchanged during a maintenance procedure, the user must perform the following steps.
- First, click on the X and Y **Ref** button. The stage will now be driven in the negative direction on each axis until the 0,0 position has been found.

It is important to ensure that the stage is on the positive side of the 0,0 position, otherwise the 0,0 position cannot be found when the stage drives into the negative direction.

You can check the checkmark for **Auto Drive +**. When this is checked the stage will be driven stepwise into the positive direction when the **Ref** button is pressed, until the mechanical end stop has been reached. Then the stage will be driven in the negative direction to find the 0,0 position.

This option should only be used if you are unsure about the current position of the stage, as normally you should avoid driving the stage to its mechanical end stop.

When the piezo motors are aligned prior to insertion, it should be sufficient to drive a few mm in the positive direction after insertion and then to initiate the **Ref** button. This should ensure that the 0,0 position can be found.

- Carry out **Ref Y**, since the Y axis is the shorter axis, with +/- 5 mm movement. This will ensure that the Y axis is not too close to the flange and that the Y zero positions will be set before **Ref X** is initiated. Move the Y axis a few mm in the positive direction, with respect to the Y motor coordinate, then initiate **Ref Y** without checking the **Auto Drive +** option. Keep the mouse over the **Stop** button, to be ready to stop the procedure if the Y motor coordinates display - 2 or -3 mm. If this occurs, the stage is getting closer to the mechanical end stop. If this happens, move a few more mm in the positive direction before starting **Ref Y** again.
- Repeat the same for **Ref X.** Move 4 or 5 mm in the positive direction, with respect to the X motor coordinate, as the X axis has a movement of +\- 10 mm, then click **Ref X** without checking the **Auto Drive +** option. If the stage moves to -6 or -7 mm, press the **Stop** button and move a few mm further in the positive direction before initiating **Ref X** again.

STEP 8: Initiating Operate mode

- Go to **Column Control** and select a suitable parameter set, eg. 30 kV. This will transfer the column into **Operate** mode.

- Start with the origin aperture, which is typically labelled **Aperture 1** with a 30 µm orifice.

This will achieve a coarse alignment for all other apertures. It is recommended to optimize the alignment for each aperture. For each selected aperture, the position should be optimized, then read in by the **Pipette** button, followed by the **Save values** button.

The **Justify Home** button should only be used for the origin aperture to calculate the new **Home** position and the offset for the other apertures. The positions of the other apertures should be optimized and saved using the **Save values** button.

- Optimize the origin aperture alignment via the arrow buttons in the **Aperture Service** window using **Focus Wobbling** on an image.
- Once optimized, read in **X Diff** and **Y Diff**. Click on **Justify Home**. This will now take into account the offset between the old aperture rod and the new one.
- Check each aperture for alignment and save.

It is important to select each aperture via the suitable column parameter set, as each aperture size requires a different condenser lens setting.

You must, however, ensure that the same aperture is then selected in the dropdown list of the **Aperture Service** window, The **Pipette** (Read) button must then be clicked to read in the new coordinates and then the **Save value** button must be pressed for each aperture, to save the new setting in the **Aperture Service** window.

Always ensure that the same aperture is selected in the parameter set, as well as in the Aperture Service window, before saving the new coordinates.

8.1.2 Nitrogen and air

The *ionLiNE* uses:

- Nitrogen (N_2) for venting the sample chamber and load lock
- Compressed air to operate the pneumatic valves and the integrated damping platform

Check the pressure of nitrogen (N_2) and air regularly. Take note of the following target values and maintenance intervals:

Table 1: Target values and maintenance intervals for nitrogen and air

Gas	Target value	Maintenance interval
Nitrogen (N_2)	Maximum 0.3 bar	Control the pre-set pressure on a monthly basis.

Table 1: Target values and maintenance intervals for nitrogen and air

Gas	Target value	Maintenance interval
Air	Maximum 8 bar	Control the pre-set pressure on a monthly basis.

8.1.3 Care of the Raith sample holder

The sample holders for the *ionLiNE* must be free of dust and dirt when in use. Clean the Raith universal sample holders, masks, ultra-flat holder, wafer holder as follows:

- Clean the sample holder regularly in an ultrasonic bath.
- Check the sample holder and the sample, before use, for any dirt. Clean with isopropanol (propan-2-ol) or acetone (propanone), using a lint-free cloth.
- Always clean the underside of the sample holder, particularly the kinematic holders.

NOTICE

The 3D module is only to be cleaned with a dry clean cloth.

8.1.4 Operating system

Carry out the following tasks to maintain a stable operating system and to avoid any loss of data:

- defragmentation
- data backup

Backup your data at regular intervals onto an external data storage device, otherwise in the event of a hard drive crash, you might loose all customer-specific parameters and user data. Raith can, in such circumstances, only provide the standard parameters and standard system data.

- Install an up-to-date service pack.

You can download the current service packs from the Raith Home Page.

- Anti-virus protection:

Install an anti-virus protection software and a firewall on your PC, when you wish to either connect to the internet or need to exchange data between computers.

Raith does not give any recommendation regarding the choice of anti-virus protection and firewall software. The industry-standard software products have been proven to be reliable.

If you are unsure about the selection of suitable anti-virus and firewall software, please ask either your IT department or Raith support.

8.1.5 Laser interferometer stage

The Laser interferometer source and the motor controller are maintenance free.

Measuring the signal voltage, as well as cleaning the fiber should be performed once every month.

Measuring signal voltage

You will need a digital voltmeter (DVM), BNC adapter and BNC cables.

a) Measuring the signal voltage using a digital voltmeter

- Connect the DVM to BNC X1 (20 V DC range).

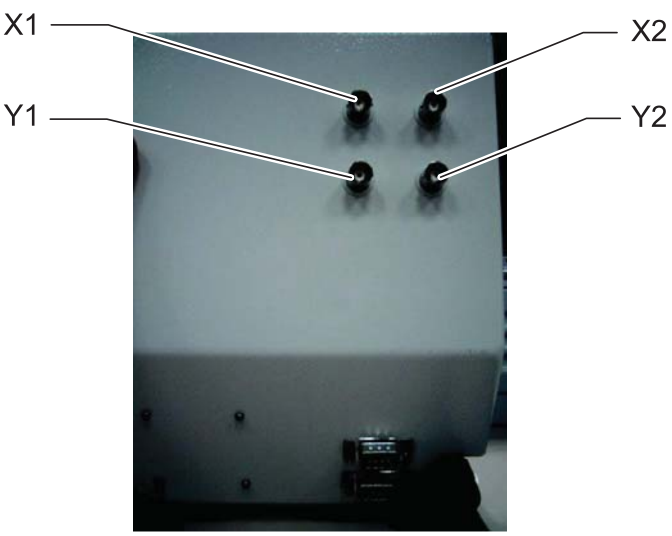


Figure 8-8: BNC connectors for measuring the laser signal voltage.

- Move the stage in 10 nm steps in the X-direction, using the software, until the reading on the DVM reaches a maximum.

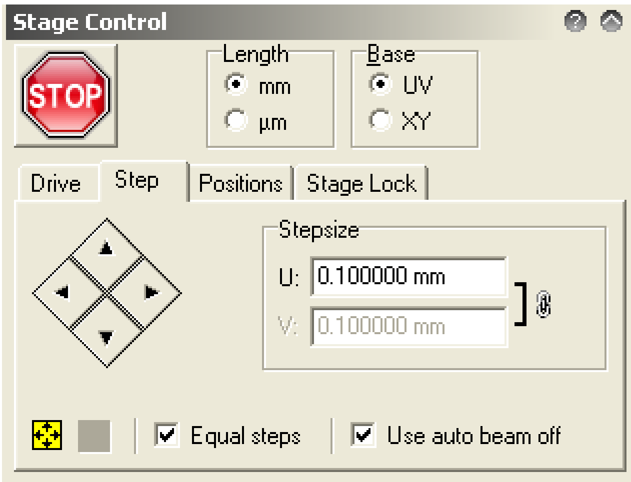


Figure 8-9: **Stage Control** window

- Note the measured value.
- Connect the DVM to BNC X2.
- Note the measured value.
- Connect the DVM to BNC Y1.
- Move the stage in 10 nm steps in the Y-direction, until the reading on the DVM reaches a maximum.
- Note the measured value.
- Connect the DVM to BNC Y2.
- Note the measured value.

If the measured voltage is below 5 V, the fiber should be cleaned.

b) Measuring the signal voltage using an oscilloscope

You will need an oscilloscope and a BNC cable

- Connect channel A of the oscilloscope to X1 and channel B to X2.
- Switch the oscilloscope to XY mode, 2 V per division.
- Move the stage over the whole travel range. The observed signal on the oscilloscope should form a circle.
- Note the maximum and minimum values for X1 and X2.
- Connect channel A to Y1 and channel B to Y2.
- Move the stage over the full travel range.

If the measured voltage is below 5 V, the fiber should be cleaned

8.1.6 Fiber cleaning

During operation, the end of the laser fiber can become contaminated, resulting in a gradual decrease of the laser signal.

This is a well known effect called "optical tweezers". Because of the strong electrical field of the laser signal at the end of the fiber, particles are accelerated towards and collect at the end of the fiber.

If the stage does not move or the software shows a hardware error, this indicates that the laser signal has fallen below a threshold value. If this happens, proceed as follows:

- Switch off the motor controller and the laser interferometer source.
- Vent the system.
- Pull out the stage.
- Locate the fiber mount and unscrew the head nut that keeps the fiber in place.

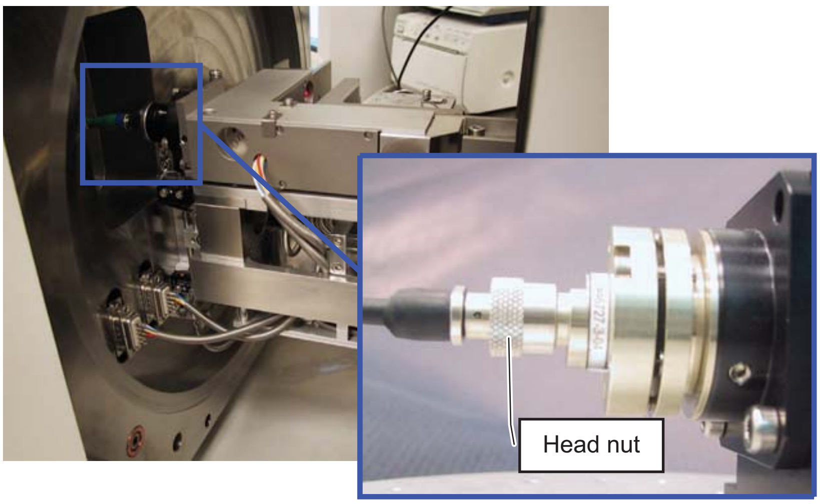


Figure 8-10: Fiber mount

- Pull out the fiber

NOTICE

Handle the fiber with great care.
Do not apply any force to the fiber.
Ensure that the fiber always has a bend radius of greater than 5 cm.

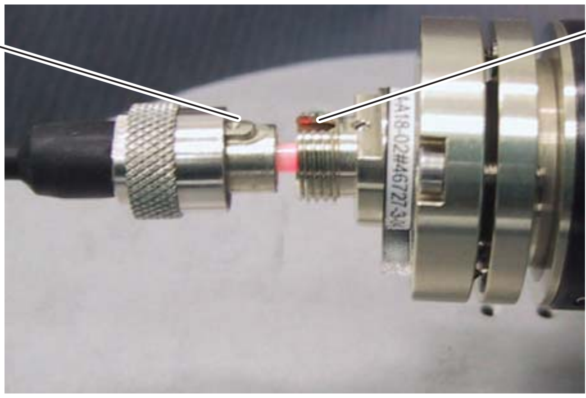


Figure 8-11: Open fiber mount

- Wipe the fiber end with a soft tissue moistened with propan-2-ol (IPA). After the fiber has dried, hold the end 5cm from a white surface and check that the visible spot has an apparent Gaussian distribution.

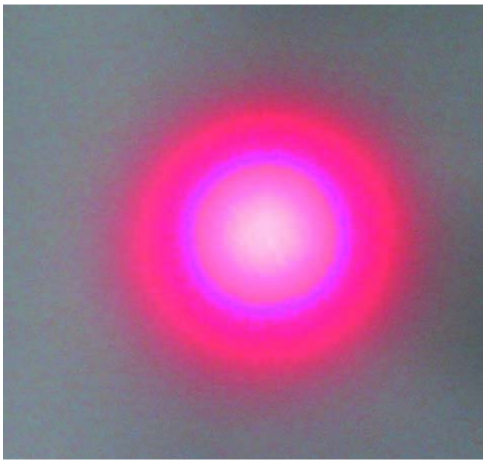


Figure 8-12: Spot directed on a surface with 5 cm distance. Diameter approx. 1-2 cm

- Insert the fiber into the mount. To ensure the correct orientation, the fiber has a latch that fits into a notch on the mount.
- Screw on the head nut, finger tight.
- Switch the laser interferometer source **ON** and wait until the green light indicates that the frequency is locked.
- Switch on the motor controller.
- Move the stage across the whole travel range using the joystick.
- Close the stage door and evacuate the chamber.

8.2 Troubleshooting

This chapter gives an overview of possible system errors and interruptions to the operation of the *ionLiNE*. Some solutions are also outlined.

8.2.1 Inaccurate stage movement

If the sample stage moves inaccurately at high magnification, it may be that the frequency of the laser interferometer is not stable or that the stage is running in **Encoder** mode. This can occur if the laser interferometer source has only recently been switched on. In such cases, wait for approximately 20 minutes. When the frequency has stabilized, you can change the sample stage to laser mode via the dialog **Laser Stage Control**. Click on the **Laser** icon:

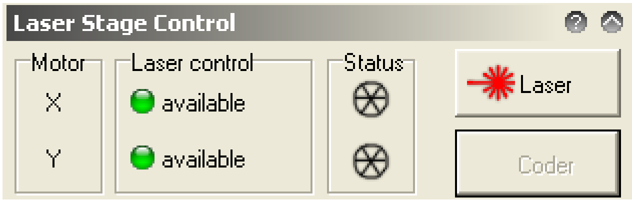


Figure 8-13: **Laser Stage Control** dialog – Encoder-Mode

Chapter 9
Technical Data

This chapter gives you an overview of the most important technical data, specifications and properties of the *ionLiNE* and its individual components.

9.1 Ion beam column and optics

Parameter	Value/description
Ion source	Ga liquid metal ion source.
Beam energy range	15 kV to 40 kV, continuously variable.
Gun control	– Automatically controlled emission ramp up to the preset gun conditions. – Mechanical gun alignment.
Vacuum at source region	< 6 x 10^{-8} mbar.
Filament life	>1500 hours typically.
Lenses	Electrostatic condenser and objective lenses.
Deflector	Double stage octopole pre-lens electrostatic deflection unit.
Stigmator-Aligner	Electrostatic octopole type for stigmation and beam position alignment.
Beam blanker	Electrostatic beam blanker with 50 ns rise time.
Beam size	Gaussian beam profile with <8 nm beam diameter (FWHM) at 35 kV and 10 mm working distance.
Beam current density	> 10 A/cm² at 8 nm beam diameter and 35 kV.
Beam current stability	< 1% / hour for room temperature variation < ± 0.5 °C.
Beam position stability	< 400 nm/hour for room temperature variation < ± 0.5 °C.
Apertures	– 12 apertures with motorized selection for precise alignment: diameters ranging from 5 µm to 200 µm. – Customized arrangement possible.

Parameter	Value/description
Beam current range	Selectable between approximately 1 pA – 1 nA.

9.2 Secondary electron detector

Parameter	Value/description
Detector	Chamber mounted Everhardt-Thornley electron detector.
Controls	Manually adjustable contrast/brightness.

9.3 Deflection system

Parameter	Value/description
Principle	High speed electrostatic pre-lens double stage octopole deflection.
Patterning field sizes	Selectable from 1 µm up to approx. 200 µm.
Magnification range in imaging mode	200 times to 200,000 times, depending on voltage and working distance.
Field size adjustment	– Corrections for rotation, orthogonality and two axes independent scalings. – Corrections can be entered manually or in an automated mode using metrology of laser interferometer stage.
Minimal addressable step size	Field Size / 65536 (16-bit).

9.4 Scan generation

ionLiNE scan generations are based on a digital pattern generator for nano patterning and for imaging with the following specifications:

9.4.1 Digital pattern generator

Parameter	Value/description
Principle	– Real time, high speed, and digital pattern generator with digital signal processor of 400 MHz and 1 Mbytes static cache memory. – Fast, SCSI-type data link with 5 MB/s data transfer rate. – Synchronized control of electrostatic beam blanker unit.
Operation	– Vector scan (direction) mode patterning polygons and circles line-by-line or by meander scan. – Concentric mode patterning polygons and circles concentric inwards or outwards, clockwise or counter-clockwise. – Ability to pattern arbitrarily shaped single pixel lines and dots. – Capable of bit-map/ raster scan.
Shapes of individual patterns.	– Rectangles, triangles, any polygons of any orientation and shape. – Dots, lines and single pixel wide curves at any orientation. – Alphanumerical text. – Shapes generated by mathematical functions.
Digital analog converter	– Resolution 16 bit in X and Y. – Bandwidth 25 MHz with additional deglitch circuits thermally controlled and shielded against high frequency noise.
Minimum step size	Field Size / 65536 (=16-bit) rounded up to the next smallest metric step size.
Step size increment	Minimum step size increment 0.1 nm.
Dwell time and resolution	– 50 ns minimum dwell time. – 8 s maximum dwell time. – 0.1 ns increment.

Parameter	Value/description
Writing speed	– 0.125 Hz to 20 MHz pixel frequency in area mode. – Maximum 10 MHz for random addressing of pixel, i.e. both DACs are addressed simultaneously.
Dose control	Dose for each individual element can be varied using a dwell time factor ranging from 0.001 up to 17797.500.
Beam blank control	Precisely synchronized to the patterning.
Field alignment	– Automated and integrated **writefield** corrections. – Writefield calibration and correction is performed by a matrix of six 16-bit D/A converters. Adjustments are accessible in both axes for offset, scale, and angular orientation. This method of field alignment does not affect either the accuracy or the speed of any patterning. – Thermally controlled and shielded against high frequency noise.
Data acquisition	– Based on SE image or line scan acquisition using the Everhardt-Thornley electron detector. – 14 bit A/D conversion with 360 ns sampling time for each pixel. – Freely selectable angle for intensity profiles along lines. – Up to 4 images/s with 512 x 512 pixels, no averaging.

9.4.2 Image generation and display functions

Parameter	Value/description
Imaging operation	– Raster scan with optional line-by-line or frame averaging, reduced raster, adjustable in size and position. – Line scan: Repetitive scan of line on sample. – Scan rotation: up to 360° scan rotation at all scan rates.
Image processor	– Pixel resolution of images continuously variable up to 4096 x 4096 and 14 bit gray scale resolution. – Selectable square or 4:3 rectangle image formats.

9.5 Laser interferometer stage

Parameter	Value/description
Type of stage	– 3-axis XYZ high vacuum stage. – Laser interferometer position sensing in X and Y with precision L-shaped reference mirror. – Interferometer measuring path completely inside the vacuum, hence no environmental compensation required. – Rotary encoder position sensing in Z.
Travel range	– 100 mm travel in X and Y. – 30 mm travel in Z at full laser interferometer control.
Motor drives	DC motors directly mounted on drive spindles for X-, Y-, and Z-axes. X- and Y- axes equipped with additional piezo drives.
Laser interferometer resolution	1 nm
Controller	DSP controlled motion control unit, which also incorporates manual joystick control.
Stage travel velocity	Up to 3 mm/s in X and Y.
Laser source	Frequency stabilized 632.8 nm HeNe laser.

9.6 Sample handling

Parameter	Value/description
Patterning area	100 mm by 100 mm symmetrical.
Load lock	Samples up to 100 mm x 100 mm in size are introduced to the stage via a fast entry load lock.
Sample mounting	Samples are placed directly onto a sample holder. The sample holders are equipped with sapphire inserts and are placed on a platform on top of the laser stage. The platform consists of three ceramic balls designed to match the positions of the sapphire inserts. This is designed for long-term stability and acts as a kinematic mount for the sample holder.

Parameter	Value/description
Current measurement	– Faraday cup built into ion optics is used for measurement. – Faraday cup built into top of sample holders (not in use). – High quality pico-ammeter with IEEE interface.

9.7 Chamber and vacuum system

Parameter	Value/description
Chamber dimension	Inside width by depth by height: 490 mm by 380 mm by 300 mm.
Vibration isolation system	– Self-centering air damping system, integrated in plinth. – High damping and isolation with low resonance frequencies: 1.5 Hz vertically, and 1.0 Hz horizontally
Vacuum control	Fully automatic high vacuum system controlled by programmable logic controller (PLC) unit.
Pumping scheme	– Main chamber: Dry vacuum forepump in combination with turbomolecular pump (240 l/s). – Ion gun: Ion getter pump (50 l/s) for continuous ultra-high vacuum in ion source region. – Load lock: Utilizing main chamber pumping scheme with automated valve control.
Vacuum	– The base pressure in the specimen chamber is better than 2×10^{-6} mbar. – The base pressure in the gun region is better than 6×10^{-8} mbar.
Observation	Built-in infrared camera system with optics for visual control and orientation purposes.
Optical macroscope	– Integrated optical macroscope for top-down observation of the sample surface at the beam position. – Projection corrected optical arrangement with approx. 5 x 4 mm^2 field of view captured with gray scale CCD camera. – Illumination by LED array, thermally decoupled by fiber and collimation optics. – Up to about 30X magnified display on control PC screen via frame grabber.

9.8 Control data system

The entire system control including pattern generation and imaging mode operation is based on a computer data system with the following minimum specifications:

Parameter	Value/description
Central processor	Intel CPU, latest technology with ≥ 2.4 GHz.
Memory	Minimum 2 GByte RAM.
Operating system	Microsoft Windows XP Professional.
Application software	Raith *NanoSuite* software suite for patterning and imaging.
Disk drives	300 GB hard disk, and CD-RW / DVD-RW drive.
Networking	RJ45 high speed network.
Display	Two flat panel displays.

9.9 User interface and system control software

Parameter	Value/description
Multi-user platform	– Settings, files, and tasks stored separately for each user. – Automatic restoration of settings after next log on.
Automation	Interface to Microsoft scripting capabilities for generation of powerful, unattended batch jobs.
Patterning functionalities	– GDSII based direct patterning with advanced attributes. – Patterning on Images. – Gray level bitmap patterning. – Fixed beam moving stage patterning for mm-long features.
General patterning control	– Automatic, real-time division of arbitrarily shaped patterns directly from GDSII format into lines and dots. – Patterning in fast vector (direction) scan mode with freely selectable scan direction and order. – Patterning of single pixel lines and dots. – Patterning of bitmaps in raster scan mode. – Patterning in concentric mode. – Selection between several patterning modes, e.g. meander scan, line scan, or scan orientation and direction.
Patterning on Images	– Rapid prototyping and process development. – Drag-and-drop and editing of GDSII designs on image scan.
Recipe Manager	– Convenient handling of advanced patterning attributes. – Read current parameter set or edit manually. – Save, manage and recall full patterning parameter sets.
Beam tracking	– Tracking of stage position by laser interferometer. – Continuous error tracking with up to 50 kHz. – Low frequency correction by stage piezo motors. – High frequency correction by beam deflection.

Parameter	Value/description
Writefield and overlay alignment	– Free selection, definition and scanning of mark fields with any pixel size. – Up to 8 marks in each writefield. – Automatic and semi-automatic mark detection. – Reduction of beam drift effects in extended patterning runs by automated re-adjustment procedures employing fixed reference marks.
Sample to stage align-ment	– Automatic or manual registration to known global marks on every sample, e.g. complete wafers and fractions of wafers. – Complex navigation within die on wafer is supported by means of two independent coordinate systems. – Alignment allows direct navigation in CAD design and in images.
Dwelltime correction	Automatic dwell time correction by measuring beam current during patterning.
Automatic field stitching	– Online data preparation of hierarchical GDSII layout by fracturing into individual writing fields. – Pre-preparation of large pattern data for faster patterning runs.
GDSII editor and viewer	– View and design structures, e.g. rectangles, polygons, circles, ellipsoids, lines, dots, paths in one or more process levels and hierarchical layers. – The GDSII format has been extended to allow for dose information and further special structure types, e.g. single pixel lines, bitmaps and text formats. – Externally prepared CAD files in AutoCAD DXF-, ASCII-, and CIF-format data can be converted to the GDSII format. – Creation of text pattern and related functions, i.e. patterning time and date for documentation. – Mathematical function generator for arrays of curved lines. – Creating, moving, zooming, deleting, adding, repeating and referencing structures. Undo function. – Post-processing tools, e.g. shrink, frame, overlap removal, etc. – Image overlay options on design for CAD layout navigation.

Parameter	Value/description
Ion column control	– Digital control of column parameters, such as magnification, focus, beam alignments, lens settings, beam voltage, and current settings. – Storing and recalling of complete ion column parameter sets.
Stage control	– Absolute and relative addressing, two coordinate transformations between stage and sample, display of current stage position, storage of positions.
Image acquisition	– Noise reduction: Pixel averaging as well as line and frame averaging. – Displayed on flat panel. – Hardcopy: any printer type can be used. – Archiving as BMP and TIFF files on hard disk, floppy disk, and network connection.
Wafer and CAD layout navigation	– Overlay of CAD layout into all windows like images. – Generation or import of wafermaps with definition of notch, flat, and chip numbering. Several chips can be saved and given a common property, e.g. 'must be inspected'.
Metrology	– Line width, position, and pitch measurements based on real-time line scans or from acquired images. – Pattern placement control across single writefields, single chips/dies or across the whole wafer in conjunction with laser interferometer stage. – Peak detection using a threshold algorithm, cross-correlation, or manual assignment of edge locations.
Protocol and error handling	– Operator and system actions in a rolling protocol. – Error and debug information in a separate file.
Help functions	Complete reference manual with context-sensitive presentation.