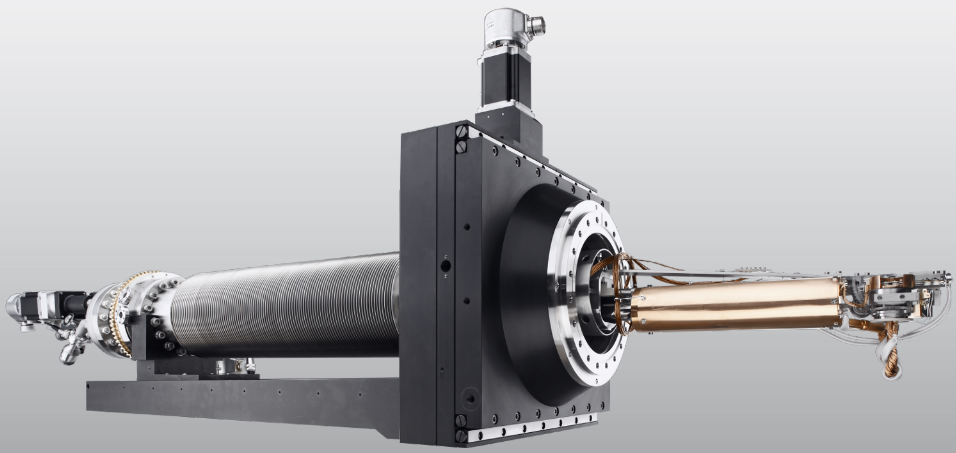
Carving Manipulator

Fitted with Stage for SH2/12 Sample Holders



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ISO 9001 Certificate

SPECS User Manual
Manipulator—Carving manipulator, Version 1.1

July 26, 2013

SPECS order number reference: 78000423

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Chapter 1
Introduction

Welcome to the user manual for the SPECS Carving Manipulator manipulator. This manual describes the features available on your manipulator and points you toward further sources of information.

Most importantly, it contains safety notices that you should read before using the equipment.

1.1 About

The manual is divided into the following chapters:

Chapter 2 describes the construction of the manipulator and its axes of movement.
Chapter 3 has information about the sample holder and sample transfer.
Chapter 4 is an overview of the connections on the manipulator.
Chapter 5 has details about sample cooling and temperature measurement.
Chapter 6 contains information about bakeout conditions.

1.2 Information

The SPECS Carving manipulator is intended for users experienced with UHV systems for surface science experiments. In order to guarantee safe operation, only users with appropriate training should operate the equipment.

This manual describes the manipulator delivered with your SPECS system. Further information is provided in additional manuals:

- MCPS 36 motorization.
- SPECS system manual.

For further advice and assistance, please also contact SPECS support:

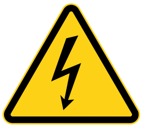
Tel. +49 30 46 78 24-0
email: support@specs.com

If you need to return this SPECS product for repair, service or upgrade, please first contact SPECS support. We will provide you with an RMA as well as details for correct packaging and shipment of the instrument. This will ensure safe transportation and speedy processing.

1.3 Safety

The document "Safety Instructions" is included with this delivery. It contains a number of essential safety instructions. You should read this before using any SPECS equipment.

In addition, this manual contains warnings specific to the use of this manipulator. You should observe these for your own personal safety as well as the integrity of the equipment.



Danger—High Voltages Present!
Potentially lethal high voltages can be present during operation of the manipulator. Always observe the instructions and precautions described in this manual.

Danger—Cryogenic Liquids!
The manipulator can be cooled using cryogenic liquids.

- Always wear gloves and goggles when handling cryogenic liquids.
- Make sure that exhausts are always free—a blocked exhaust can lead to an explosive pressure build-up.
- Make sure the room is well ventilated so that exhaust gas can escape.

Note: If you need to return the manipulator to SPECS for service or repair, please fill out the declaration for hazardous materials at the end of this manual, if necessary.

1.4 Environmental Operating Conditions

The equipment must be installed in a dry, dust free laboratory. The following conditions are required for operation.

Temperature (normal system operation):

- absolute limit range: 15–30 °C (60–85 °F)
- recommended range: 20–25 °C (68–77 °F)

Relative humidity:

- absolute limit values: 40–80%
- recommended range: 50–60%

No condensed water may be present.

Atmospheric pressure:

- 800–1200 mbar

An air conditioning system is advisable in order to ensure the ambient requirements, especially for dissipating heat produced by the equipment.

Chapter 2
Axes of Movement

The major technical advantage of the Carving manipulator is that all three rotational axes intersect at the center of the sample surface. You can thus change any of these axes while keeping the sample center at the focus of your experiment. The three translational axes allow you to move this focal point within the chamber.

This chapter describes all of the axes of movement available on your manipulator, as well as an introduction to the construction and details about the motorization.

Caution!
When you change the manipulator position, all electrical connectors attached to the top of the manipulator move as well. Take care to ensure that cables are not put under strain at any time!

Caution!
The manipulator needs to be mounted vertically on the chamber. The manipulator head is complex and heavy. It does not have any lateral support, and so cannot operate in a horizontal position.

2.1 Construction

The figure below shows a partially assembled Carving manipulator head with some of the major features labeled.

As you can see from the picture, several gears are white, rather than metallic. These are constructed from polyether ether ketone (PEEK), a plastic frequently used for high-performance engineering applications. Being softer than metal, a large force can be applied between the metal and PEEK gears. This guarantees a better mechanical connection, reducing backlash effects and thus increasing the accuracy and reproducibility of the position.

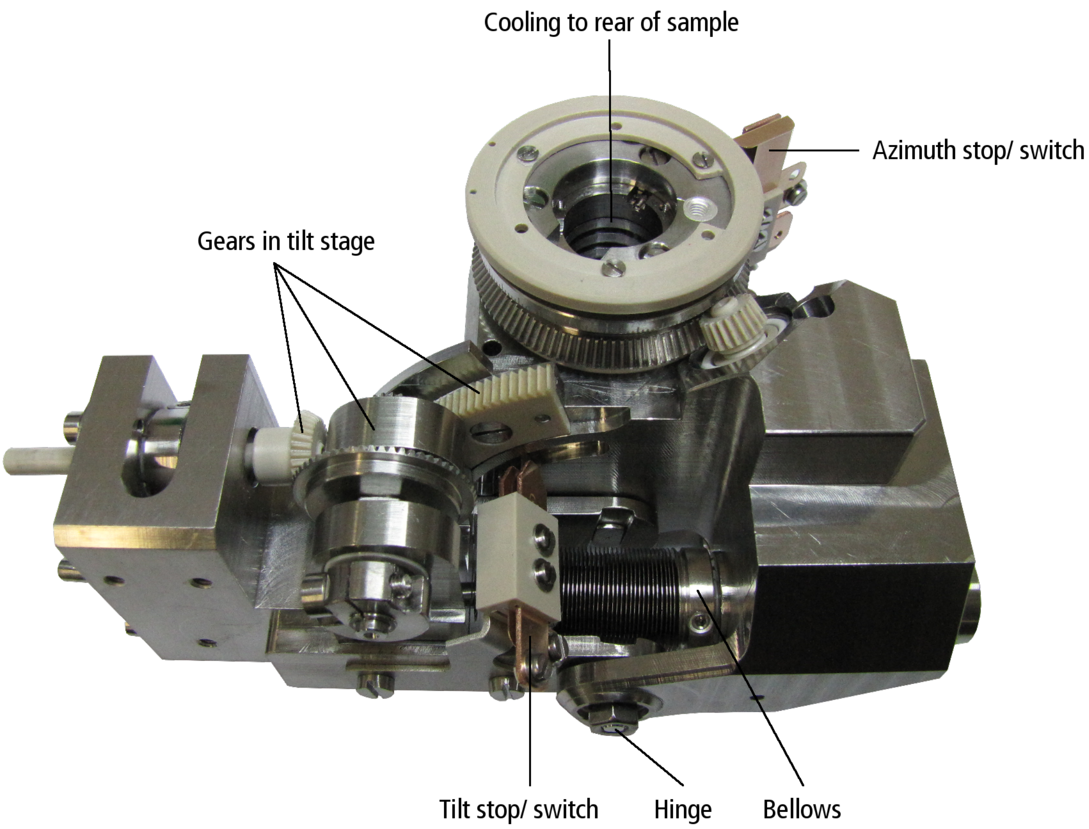


Figure 1: Construction of manipulator head

The tilt gear segment is fitted with stops to prevent damage to the manipulator. When it reaches one of the extremes, the stop pushes a copper leaf in the tilt switch, making contact with one of the copper contacts. This completes a circuit that switches off power to the stepper motor.

Note: The azimuthal rotation also contains limit switches. This prevents the cooling strap from twisting. See "Sample Cooling" on page 21 for more details.

The whole of the sample stage with the azimuth stage is tilted. A small edge welded bellows transmits rotary motion from the stepper motor through the tilt to the azimuth section.

2.2 X-Y Table

The manipulator contains an edge-welded bellows that allows you to translate the sample in the X and Y axes. When setting the position, remember that there is a small degree of backlash in the mechanism. You should therefore always turn the screw gauges in the same direction when setting the position. This results in the maximum accuracy (i.e. reproducibility) of the mechanics.

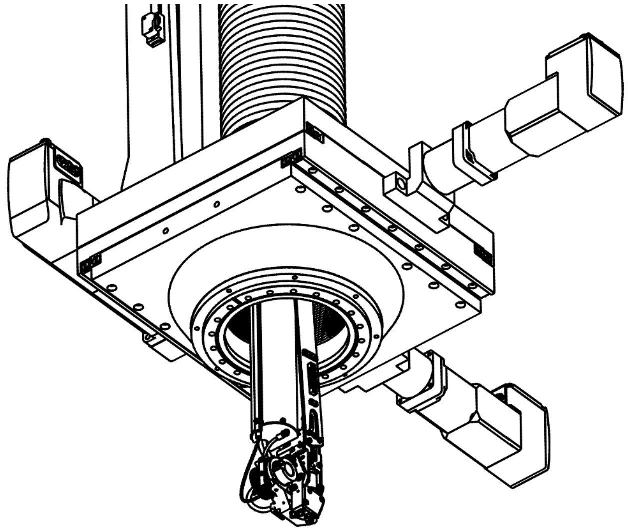


Figure 2: The X-Y table

The X-Y table has the following properties:

- Maximum translation from center (X and Y): ± 25 mm
- Precision: 10 µm

2.3 Z Stage

The Z stage consists of an edge-welded bellows mounted in a supporting frame.

The Z stage has the following properties:

- Z extension: 500 mm
- Precision: 10 µm

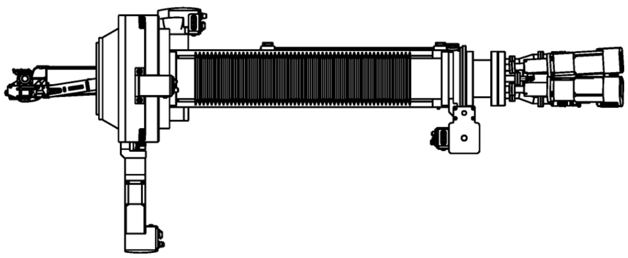


Figure 3: The Z stage

2.4 Polar Rotation (θ)

The polar rotation allows you to rotate the sample around the Z axis. A differentially pumped rotary feedthrough (DPRF) mounted at the top of the Z stage enables the rotary motion. The rotating parts slide over PTFE seals. These seals need to be pumped so that UHV is maintained in the chamber.

Note: Some variations of the manipulator have the DPRF mounted at the bottom of the manipulator, i.e.attached to the chamber. In this case, the entire manipulator turns to set the polar rotation.

Because of the DPRF, the wiring and cooling system also rotates when you change the polar angle. In principle, this axis is freely rotatable. However, the wiring on the top section of the manipulator (in particular for the two motors) also turns. In practice, therefore, you should not rotate this axis too much, in order to avoid tangling or strain.

The polar rotation axis has the following properties:

- Angle of rotation: ±180°
- Precision: 0.05°

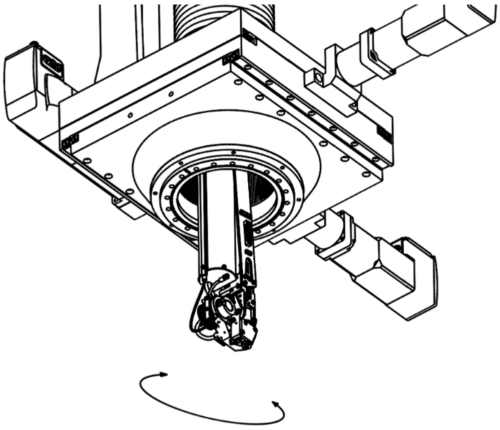


Figure 4: Polar rotation

There are some mechanical limitations that affect polar rotation. The head of the manipulator is braced against a robust tube in order to offer stability along the Z axis. Nevertheless, the center of the sample does wander slightly away from the ideal Z axis. You can see this by examining the position of a sharp tip while rotating the polar axis, as shown in the figure below.

Figure 5: Center position wobble of the polar axis

An accuracy of better than 500 µm is achievable. Due to mechanical tolerances, reproducibility of a better accuracy is not practical.

Note: In this case, the tip is exactly 1.75 mm above the reference level of the sample stage. Please see "Sample Holder" on page 17 for more details.

SPECS calibrates the center point before delivery. This is documented in the test report for your manipulator. If you need to recalibrate the manipulator, please contact SPECS for advice.

2.5 Tilt

The tilt feature allows you to tilt the sample around the x axis, as shown in the figure below.

The tilt axis has the following properties:

- Range: ±30°

- Accuracy: ±0.05°

There are stops built into the tilting mechanism to prevent the stage from moving too far. This completes a circuit that switches off power to the stepper motor.

Caution!
Always make sure that the connector to the 4-pin feedthrough is fitted correctly so that the limit switches can switch off the motor if necessary. The motor produces a lot of torque and can easily damage the stage if they are driven too far.
It is a good idea to use software settings that limit movement to less than the mechnical limits. See the MCPS 36 manual for further details.

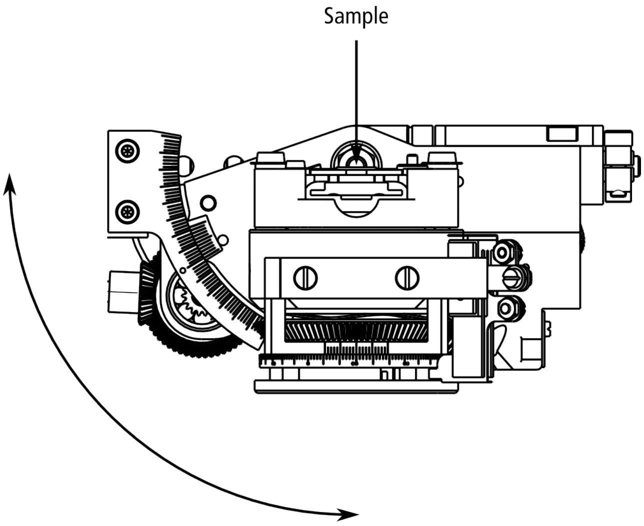


Figure 6: Tilt

A scale allows you to read the angle. There is a vernier scale for additional precision. The scale is useful for confirming the software settings or for calibrating the software.

2.6 Azimuthal Rotation (φ)

The azimuthal rotation axis allows you to rotate the sample around the axis normal to the sample surface. The figure below views the sample from above and shows the rotation.
The azimuthal axis has the following properties:

- Range: ±180°
- Accuracy: ±0.05°

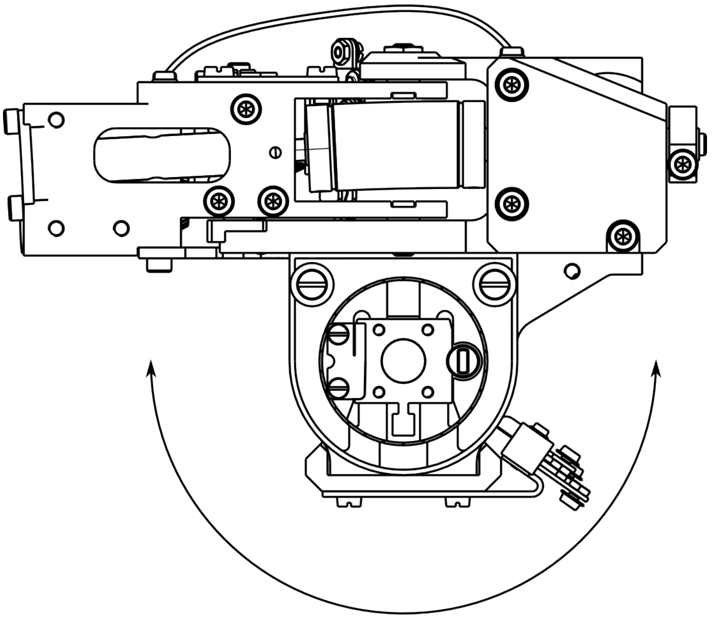


Figure 7: Azimuthal rotation

There is a limit switch to prevent a rotation of more than ±180°.

Caution!
Always make sure that the connector to the 4-pin feedthrough is fitted correctly so that the limit switches can switch off the motor if necessary. The motor produces a lot of torque and can easily damage the stage if they are driven too far.
It is a good idea to use software settings that limit movement to less than the mechnical limits. See the MCPS 36 manual for further details.

2.7 Motorization

Stepper motors are fitted to the manipulator to allow you to set the position of the sample by computer. This has the advantage that manipulator positions can be saved and loaded. A particularly useful aspect of this feature is in the automation of experiments, where the sample can be moved between preparation and measurement positions.

The stepper motors are controlled by the MCPS 36. Please refer to the MCPS 36 manual for further information about installation and operation. The Online Help in SpecsLab Prodigy also contains documentation about the software interface.

The motor drive shaft is fixed to a bearing on the manipulator axis. There is a grub screw accessible through a hole in the side—in this case, an Allen key is shown in the hole. You need to make sure the screw is visible in the hole when mounting or dismounting the motor. Loosen the screw so that the drive shaft is free and the motor can be pulled away.

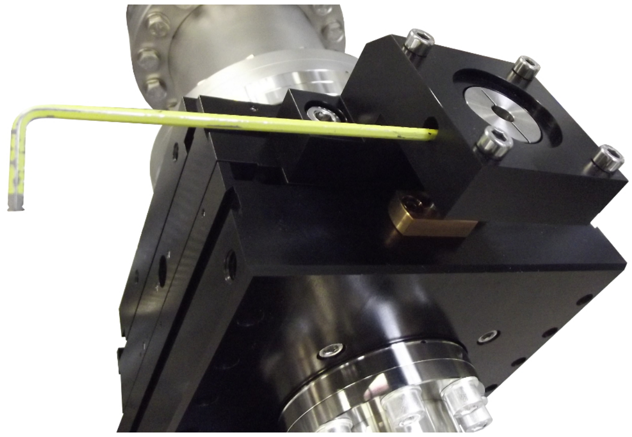


Figure 8: Accessing the clamp grub screw

Four M4 bolts hold the motor in place. The pictures below show motors mounted to X–Y and azimuthal axes on a manipulator, with the hole for the clamping grub screw highlighted. For the Z axis, the motor is mounted on the side and the drive transmitted by gears. You need to remove the lid to access the motor drive.

Caution!
You need to remove the motors before bakeout.

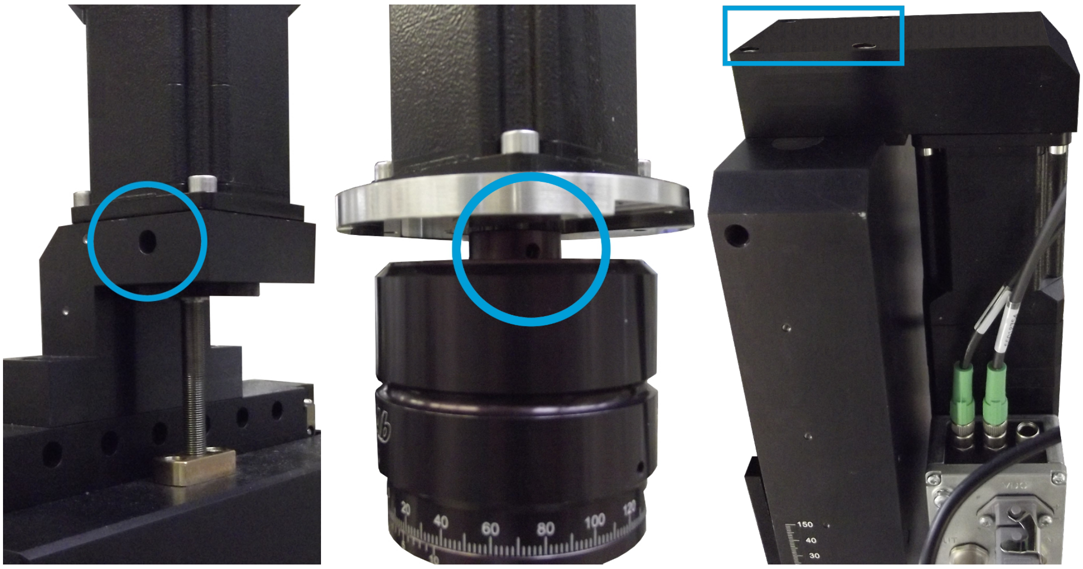


Figure 9: Motors mounted on different axes

After mounting the motor and locking the grub screw into place, the step motor positions may not correspond exactly to the physical positions in the software. You should recalibrate the motor positions in the software. Please see the MCPS 36 manual for this procedure.

Chapter 3
Sample Holder

The sample holder uses the SPECS SH2/12 design and allows you to transfer samples into the manipulator. The holder is clamped into the sample stage, allowing safe motion in all axes as well as good thermal contact. There is an electrical contact to the BNC feedthrough for sample biasing or current measurement.

This chapter covers the most important aspects for preparing the sample holder and transferring it into the manipulator.

3.1 Mounting the Sample

The distance from the reference level on the sample stage to the sample surface must be 1.75 mm in order to guarantee proper sample manipulation. The polar, azimuthal and tilt axes intersect at the center of the sample holder at this distance. Inaccuracies in this distance will cause errors in adjustments of the polar axis in particular.

Figure 10 shows a hat-shaped sample (blue) in a sandwich sample holder (gray). The sample holder is clamped into place in the sample stage. The reference level is the part of the sample stage in contact with the underside of the sample holder. Since the top plate of the sample holder is usually 1 mm thick, the sample should protrude 0.75 mm from the top of the sample holder.

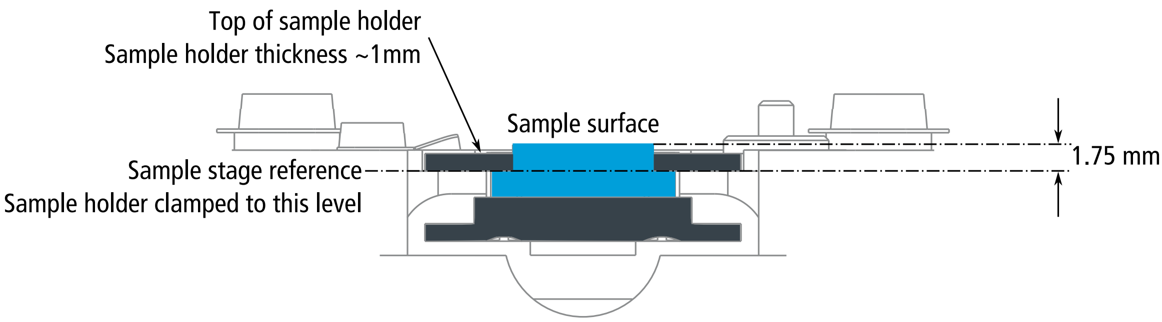


Figure 10: Schematic of sample holder

3.2 Transferring the Sample

The sample holder is carried in the vacuum chamber using a transfer tool on a wobble stick. The transfer tool is able to carry the sample holder as well as tightening the clamp screw.

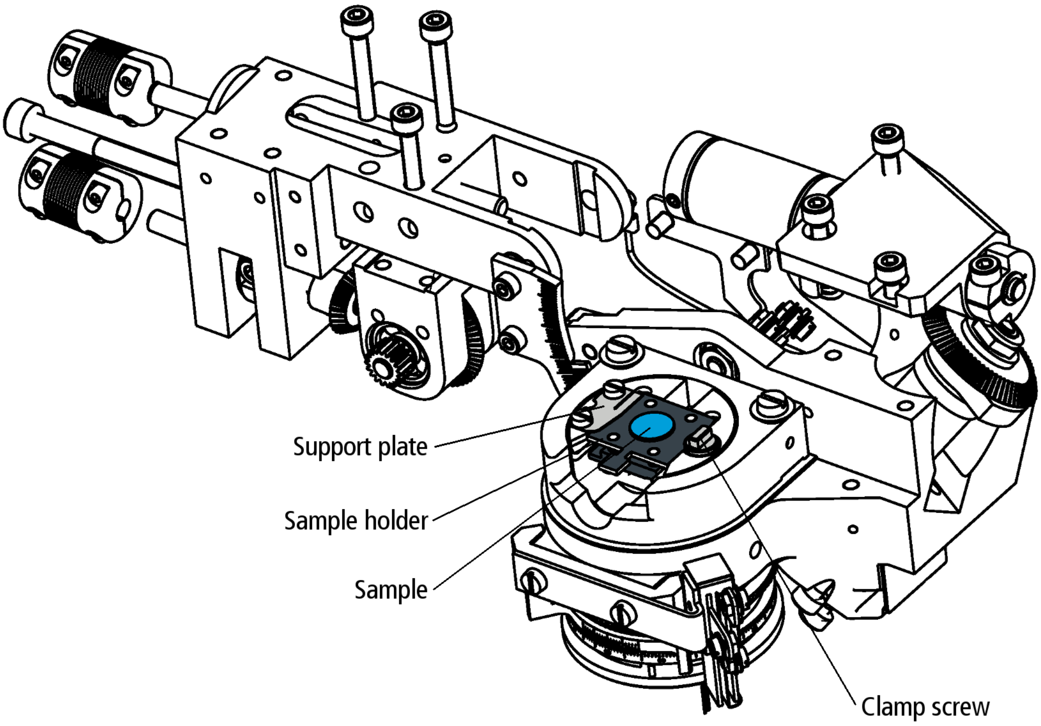


Figure 11: Securing the sample holder

Note the following points:

- The support plate prevents the sample from falling out of the stage before you tighten the clamp.
- The clamp screw only needs a very small torque (0.1 Nm) to clamp the sample holder.
- In addition to securing the sample holder in place, clamping ensures good thermal contact, allowing sample temperatures of <15 K.

Do not:

- Move the manipulator while introducing the sample holder to the stage. Excess pressure on the manipulator head can cause severe damage.
- Overtighten the clamp. Excessive force will damage the sample stage.
- Push the sample stage. A pressing force of over 2 N can damage the stage.

Chapter 4
Feedthroughs

The following sections describe the feedthroughs on the manipulator.

4.1 Electrical Connections

There are a number of electrical feedthroughs. These are described below.

4-pin feedthrough

Pin	Assignment
A	Azimuth limit switch (clockwise)
B	Azimuth limit switch (anti-clockwise)
C	Tilt limit switch (tilt up)
D	Tilt limit switch (tilt down)

6-pin feedthrough

Pin	Assignment
A	Cryostat diode +
B	Cryostat diode −
C	Coldfinger diode +
D	Coldfinger diode −
E	n/c
F	n/c

BNC conncetor.

The BNC connector allows you to apply a sample bias or measure sample current. If this is not used, it should be grounded.

4.2 Differential Pumping

There are two DN16CF pumping ports on the rotary feedthrough. These are identified with engraved numbers:

- 1—High vacuum. The pressure should be 1×10^{-7} mbar or better (deep bore port).
- 2—Low vacuum. The pressure should be 1×10^{-1} mbar or better (less deep bore port).

These conditions ensure optimum vacuum in the chamber.

Note: The rotary feedthrough is normally at the top of the manipulator near the electrical connections. However, some designs feature the rotary feedthrough at the base, i.e. attached directly to the chamber. This does not change the pumping requirements.

It is clear that you need a turbopump for the high vacuum port, while a backing pump will suffice for the low vacuum port. For optimum performance, it is advisable to use separate backing pumps for the turbopump and low vacuum. The pressure in the low vacuum line can cause backstreaming in the turbopump, affecting the pressure in the high vacuum line.

4.3 Helium Exhaust

There is a KF16 flange for the helium exhaust. You can pump this to lower the base temperature slightly.

Chapter 5
Sample Cooling

You can cool the Carving manipulator with liquid helium. A test report is included with the manipulator which details the cooling characteristics of your manipulator and provides calibration of the temperature. This chapter describes the cooling system in the Carving manipulator and the sensors for temperature measurement.

Danger—Helium!
Before using liquid helium, make sure that you are familiar with the necessary safety points:

- Liquid helium is stored under pressure—refer to the manual of the storage vessel.
- When using liquid helium, it boils—allow a suitable exhaust, otherwise equipment containing helium can burst explosively.
- If you are pumping the helium exhaust, always include a T-piece with a safety valve in the pumping line. This provides a failsafe mechanism in the event of pump failure or other form of overpressure.
- Always use gloves and other protective clothing when handling cold surfaces.

5.1 Cooling System

Figure 12 shows the features in the cooling system on the Carving manipulator.

The Carving manipulator contains a cryostat near its base that is cooled with liquid helium. A radiation shield helps to isolate this from the surroundings. A thick copper braid connects the helium cryostat to the sample stage. This is electrically isolated, in order to allow measurements of the sample current. Between the sample stage and the rest of the azimuthal stage is an insulator that thermally isolates the sample. The copper braid is screwed firmly into place to ensure a good thermal connection.

In order to enable a lower base temperature, a second copper braid, insulated with glass braid, leads to the azimuth stage. This provides some cooling to the azimuth stage, i.e. the area that surrounds the sample. The temperature gradient from the sample to its surroundings is therefore not so steep.

This arrangement means that most of the cooling is concentrated on the sample stage, without cooling large sections of the manipulator. The gearing systems for changing the azimuthal and tilt angles are not cooled, reducing the mechanical demands on the materials and components. In addition, thermal contraction along the Z direction is kept to a minimum.

A further advantage is that the sample cools rapidly, with a temperature of ~20 K after around 15 minutes. However, it will take a further 30–45 minutes before the manipulator reaches its equilibrium. At this time, all parts are cold and the values included in the test report are valid.

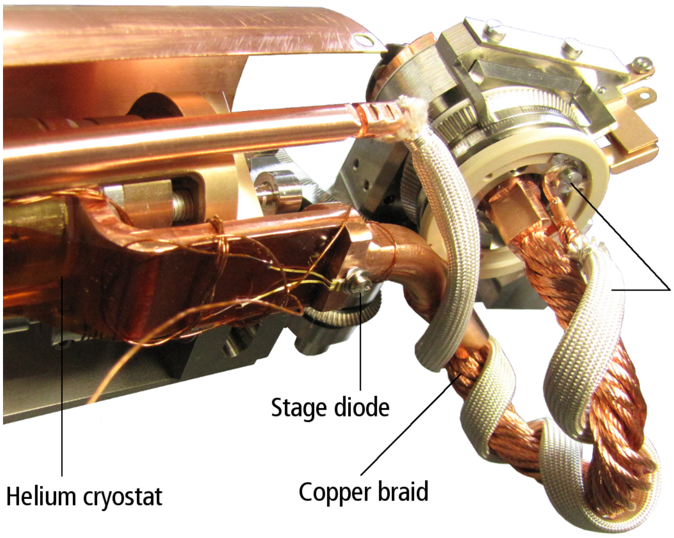


Figure 12: Cooling system on the Carving manipulator head

5.2 Temperature Measurement

For temperature measurements, a silicon diode (DT470) is fitted on the copper block, just before the point where the copper braid is attached. Clearly, this point is colder than the sample when cooling is in operation.

The test report contains a calibration curve for the temperature reading of your manipulator. For this measurement, a silicon diode was fitted on a sample plate and the plate mounted in the sample stage, as with normal operation. The temperature at this sample diode can be compared to the temperature on the stage diode. Using the calibration curve, you can therefore find the real sample temperature by monitoring the stage temperature.

Note: This "sample" diode is part of the factory calibration setup and is not delivered with the manipulator.

The calibration curve is valid after ~1 hour of cooling. By this time, the manipulator is in thermal equilibrium.

Note: There is also a second diode fitted to the cryostat. The cryostat temperature is even lower than the stage temperature. The test report also includes calibration data for this cryostat diode. However, it is advisable to refer to the calibration data for the stage temperature rather than that for the cryostat. Although both can be used for the sample temperature calibration, the stage temperature is closer to the sample temperature, so there will be less uncertainty in applying a correction to the observed temperature.

Chapter 6
Bakeout

You need to bake out the manipulator in order to achieve UHV pressure. Please observe the following points:

- Maximum temperature is 130 °C
- Remove all motors, electrical connectors and external limit switches before baking out.

Caution!
If you are using heating tapes, make sure they do not create any local hot spots on the manipulator!

Please refer to the SPECS Systems Manual for details about connecting the bakeout heaters and operating the controller.

Index

Health and Safety Declaration for used Vacuum Equipment and Components

The repair and/or service of vacuum equipment/components can only be carried out if a correctly completed declaration has been submitted for every component.

1. Description of components: ____

Type: ____ Serial number: ____________

2. Reasons for return: ____

3. Equipment Condition

Has the equipment ever come into contact with the following (e.g. gases, liquids, evaporation products, sputtering products…)

	Yes	No
• toxic substances?	□	□
• corrosive substances?	□	□
• microbiological substances (incl. sample material)?	□	□
• radioactive substances (incl. sample material)?	□	□
• ionizing particles/radiation (α, β, γ, neutrons, ...)?	□	□
Is the equipment free from potentially harmful and hazardous substances?	□	□

4. Decontamination Procedure

Please list all harmful substances, gases and by-products which have come into contact with the vacuum equipment/component during the decontamination method used.

Substance	Decontamination Method

5. Legally Binding Declaration

Organization ____

Address ____

Phone/Fax ____

Name/Position ____

I hereby declare that the information supplied on this form is complete and accurate.

Date: ____________	Signature: ________________________	Company Stamp