

EPFL



CIME - Plasma FIB

MSE-704

Carsten Putzke

Quantum Materials Laboratory

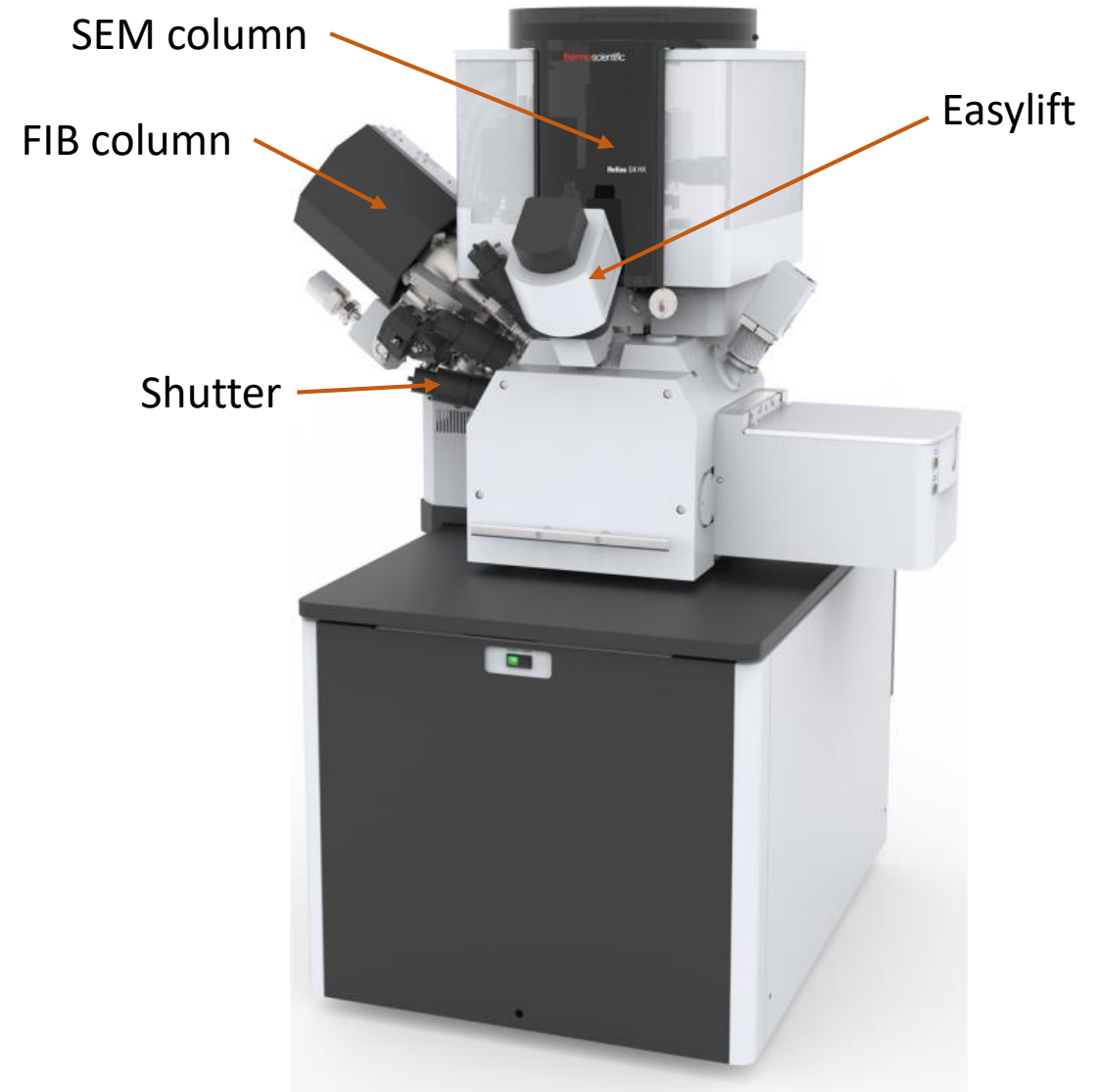
@EPFL_QMAT

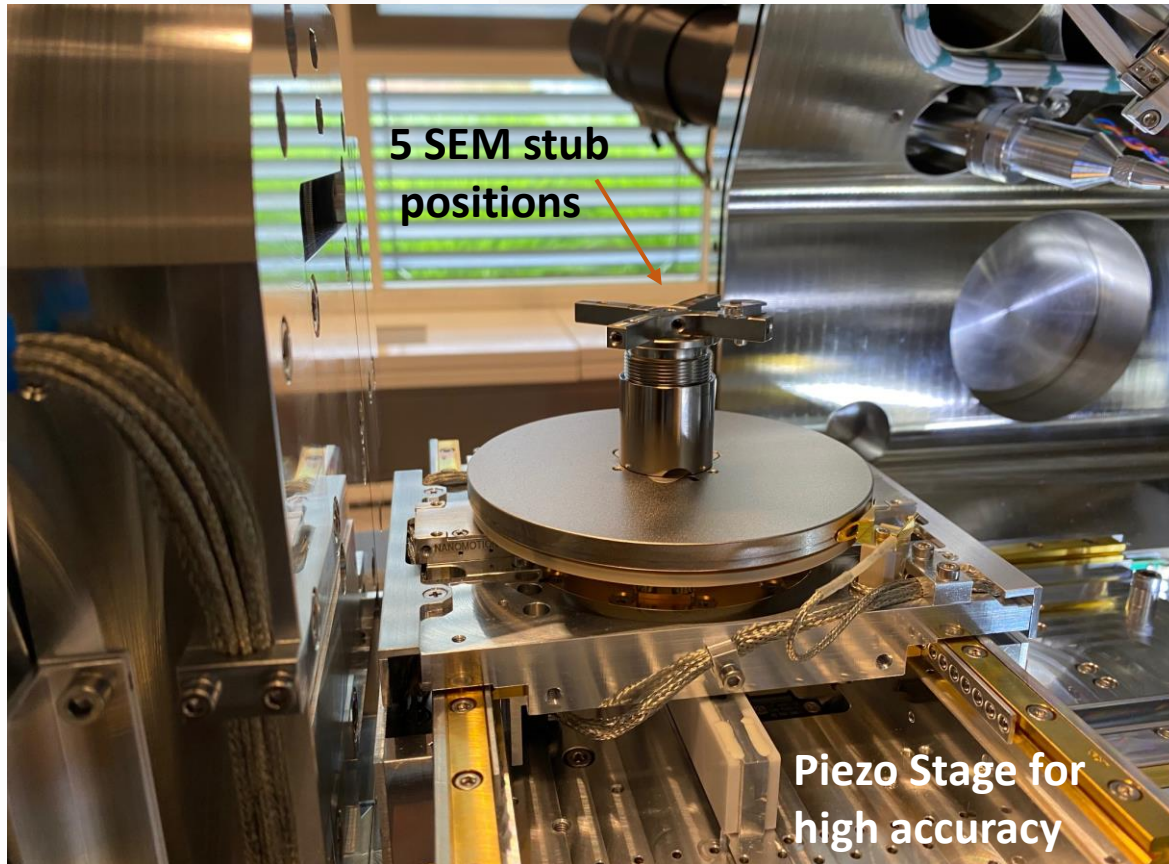
qmat.epfl.ch

Helios G4 Plasma FIB

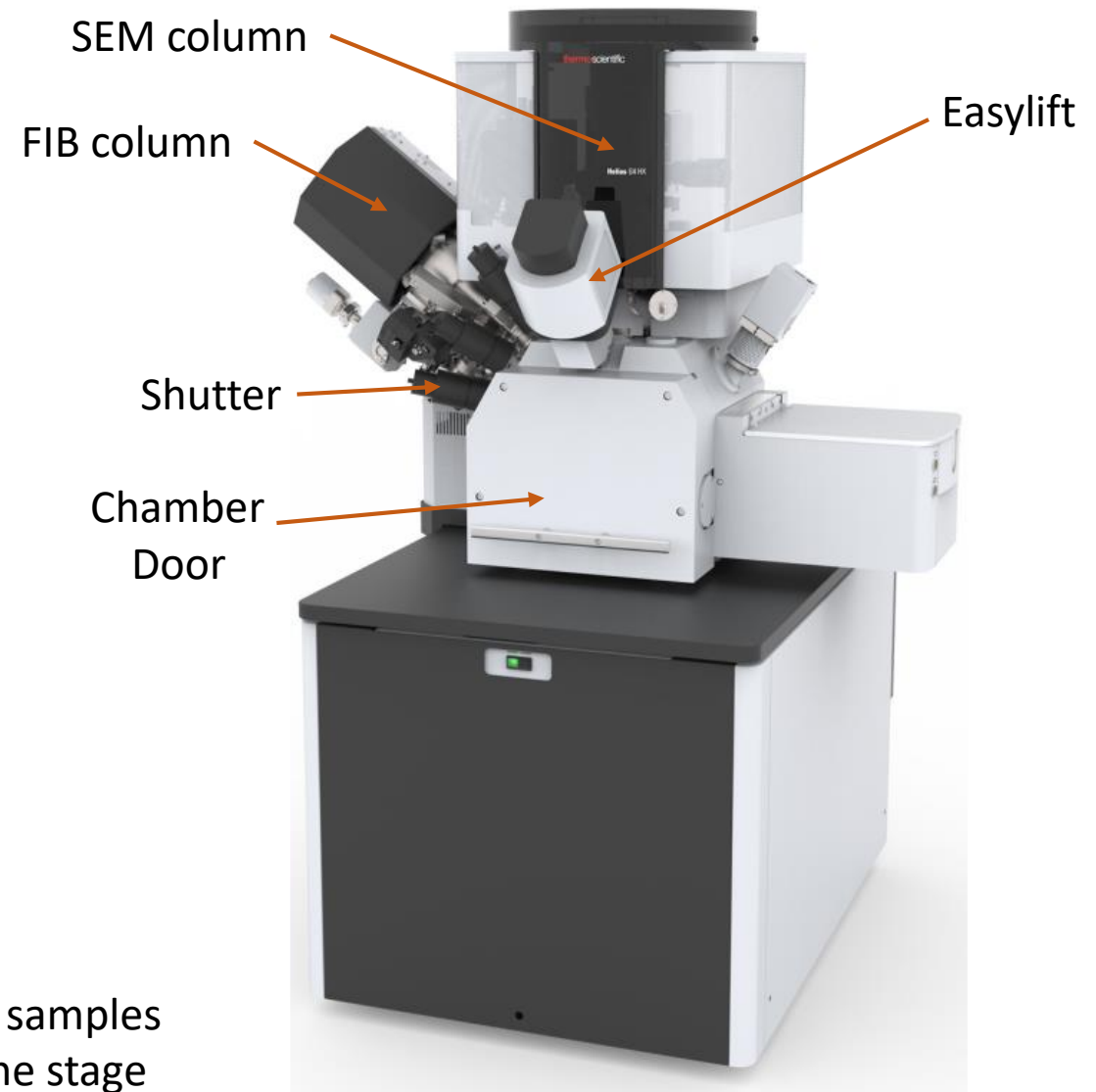
- Dual Beam System
 - SEM
 - Xe-ion beam
- Build In detectors
 - ICE (secondary electrons and ions)
 - ETD (Everhart Thornley detector)
 - TLD (through lense detector)
 - optical camera
- MultiGIS (multi gas injection system)
 - Pt,C,W
- Easylift
- EDX

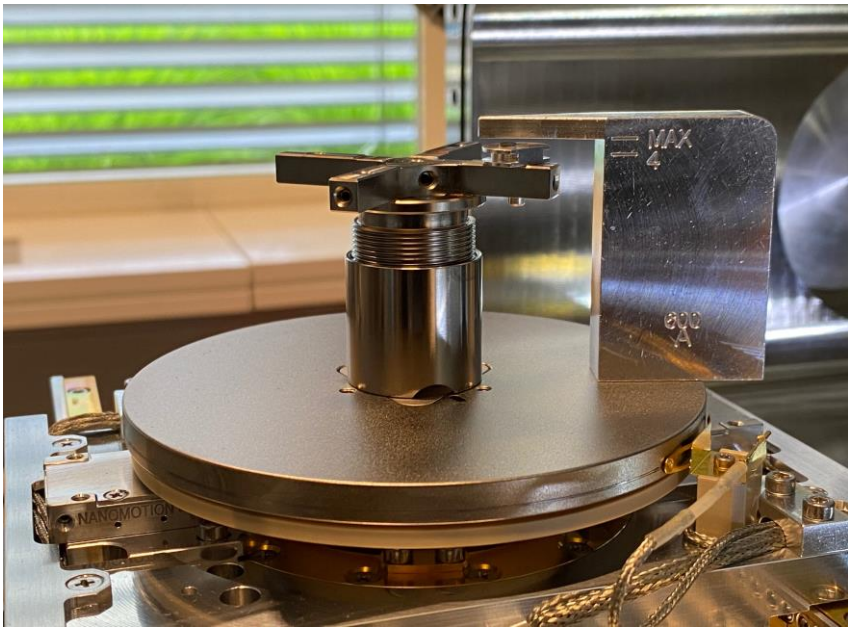






The piezo stage is limited to 9mm z-motion. When mounting tall samples the stub holder cross can be adjusted. Due to the sensitivity of the stage one needs to be extra careful.

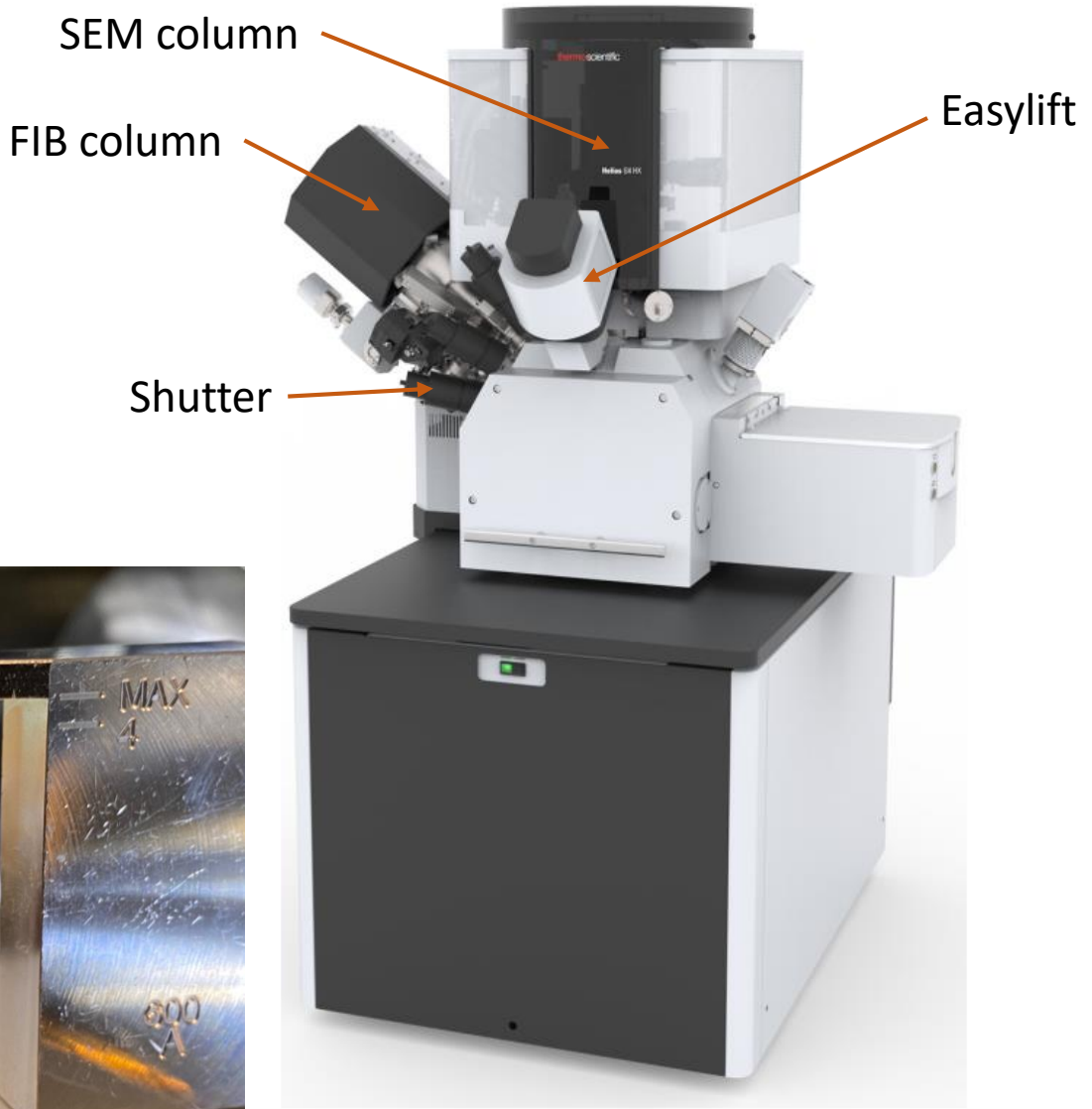
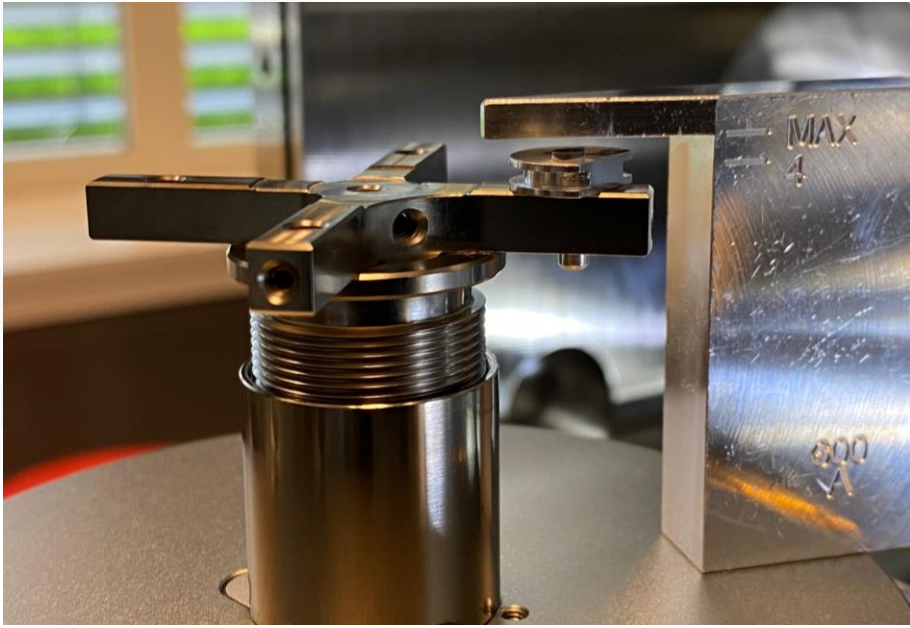


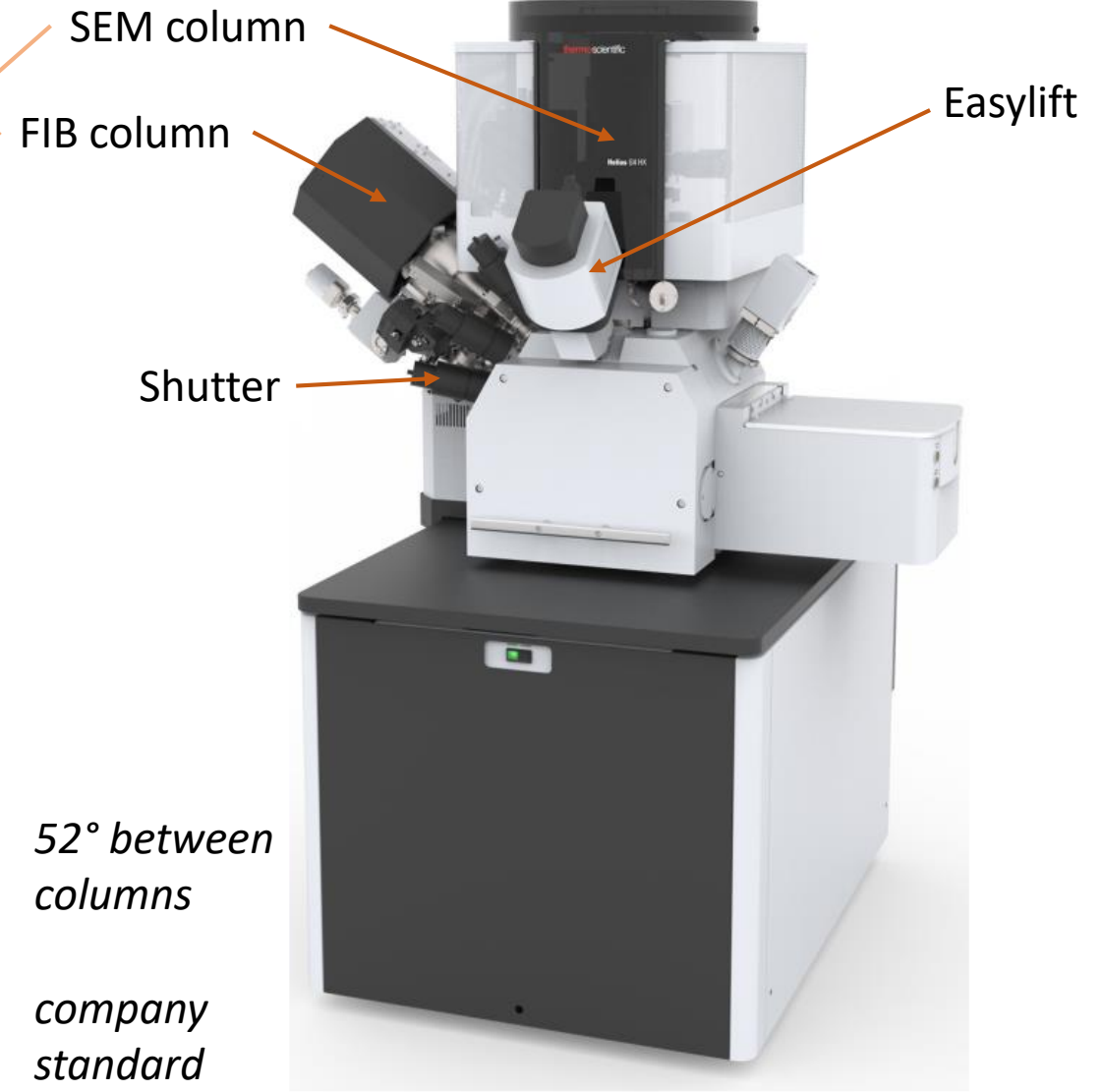


To prevent the sample from damaging the column while closing the door a reference is provided.

It is important to place the sample between the 4mm mark and the MAX position.

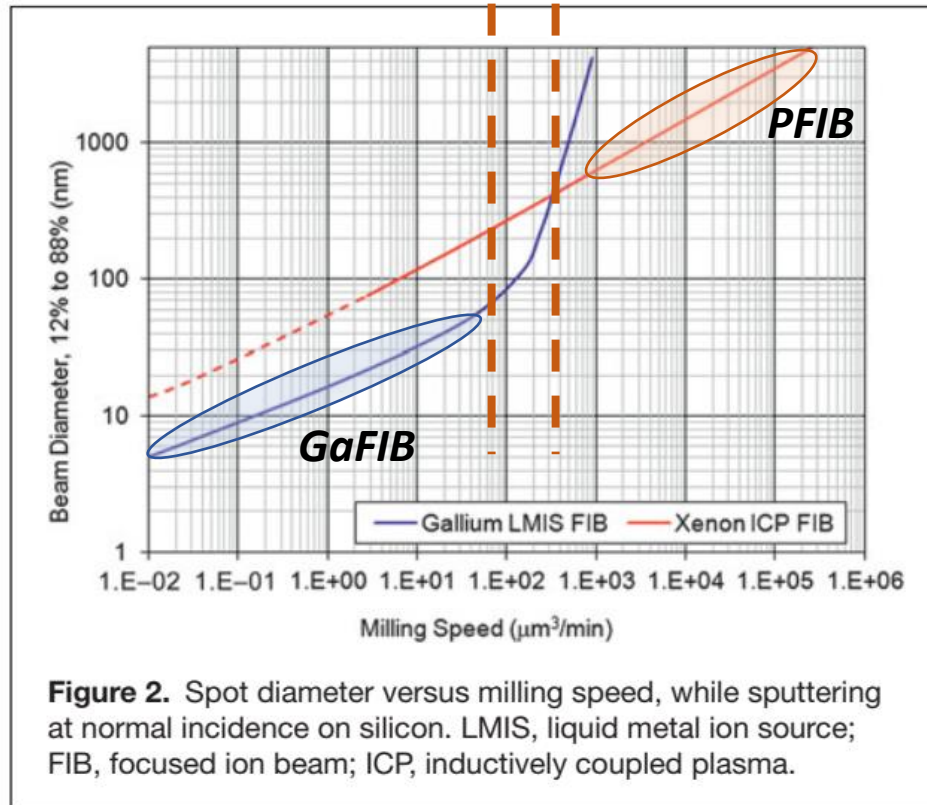
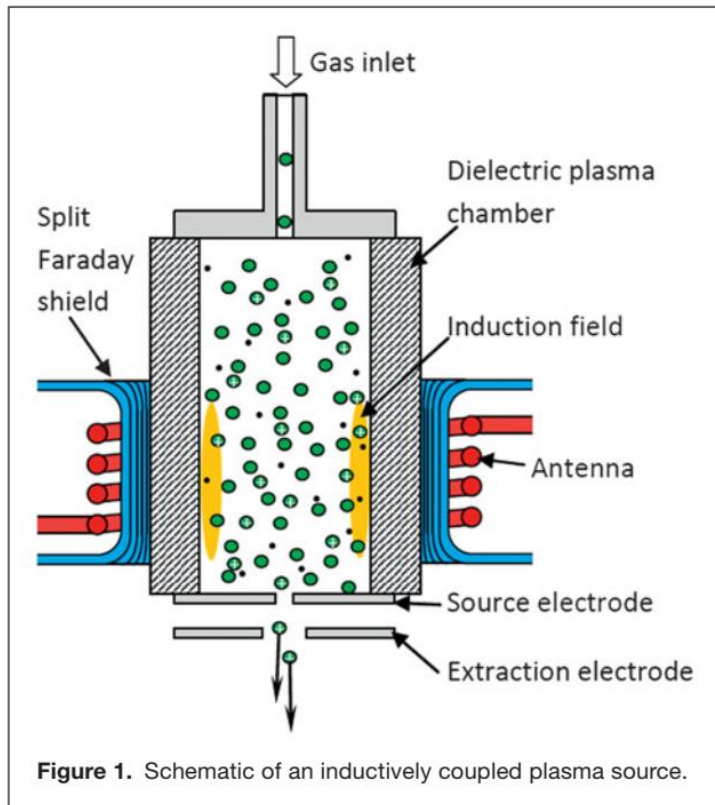
We will discuss the 4mm when looking at the software.



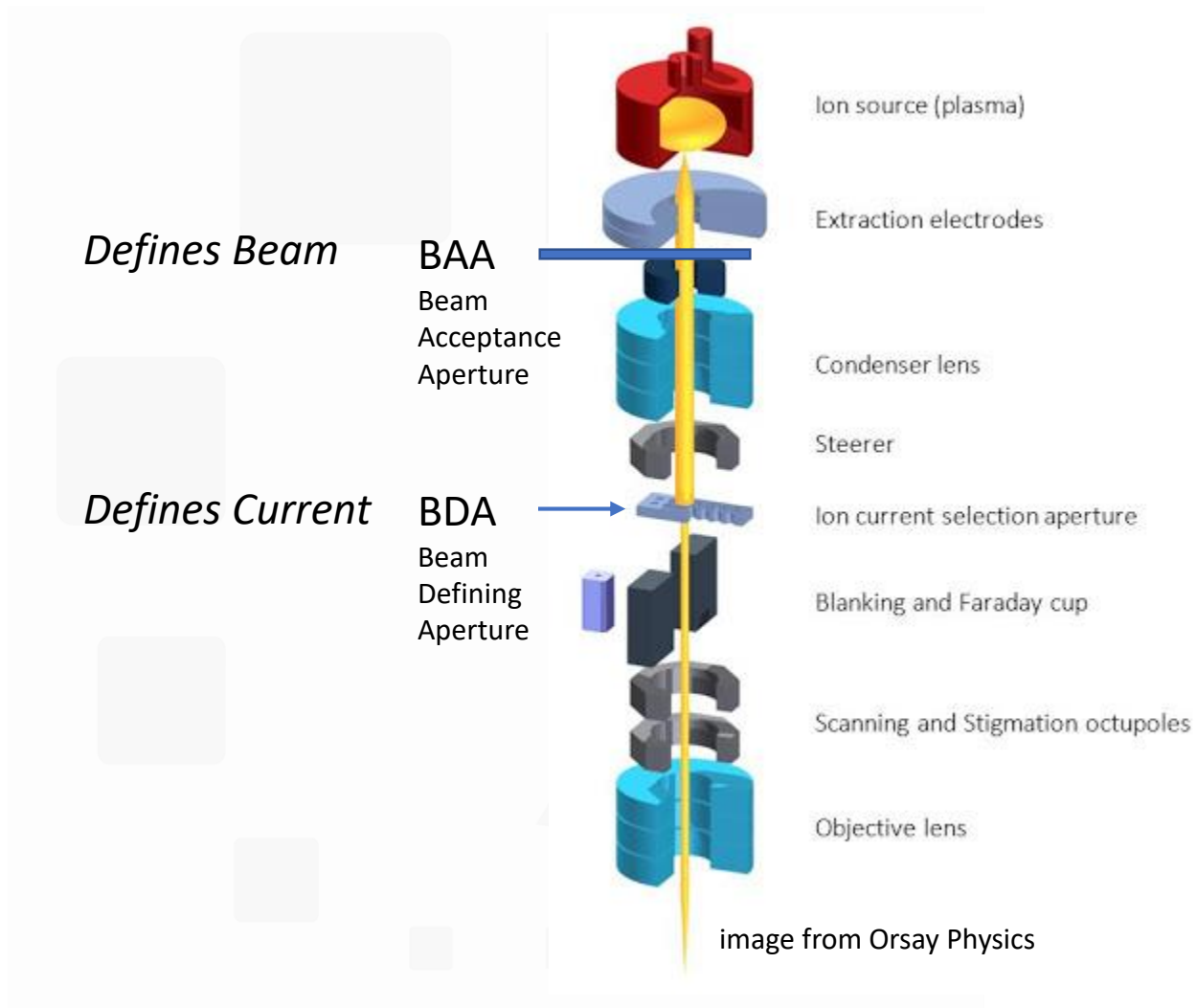


*52° between
columns*

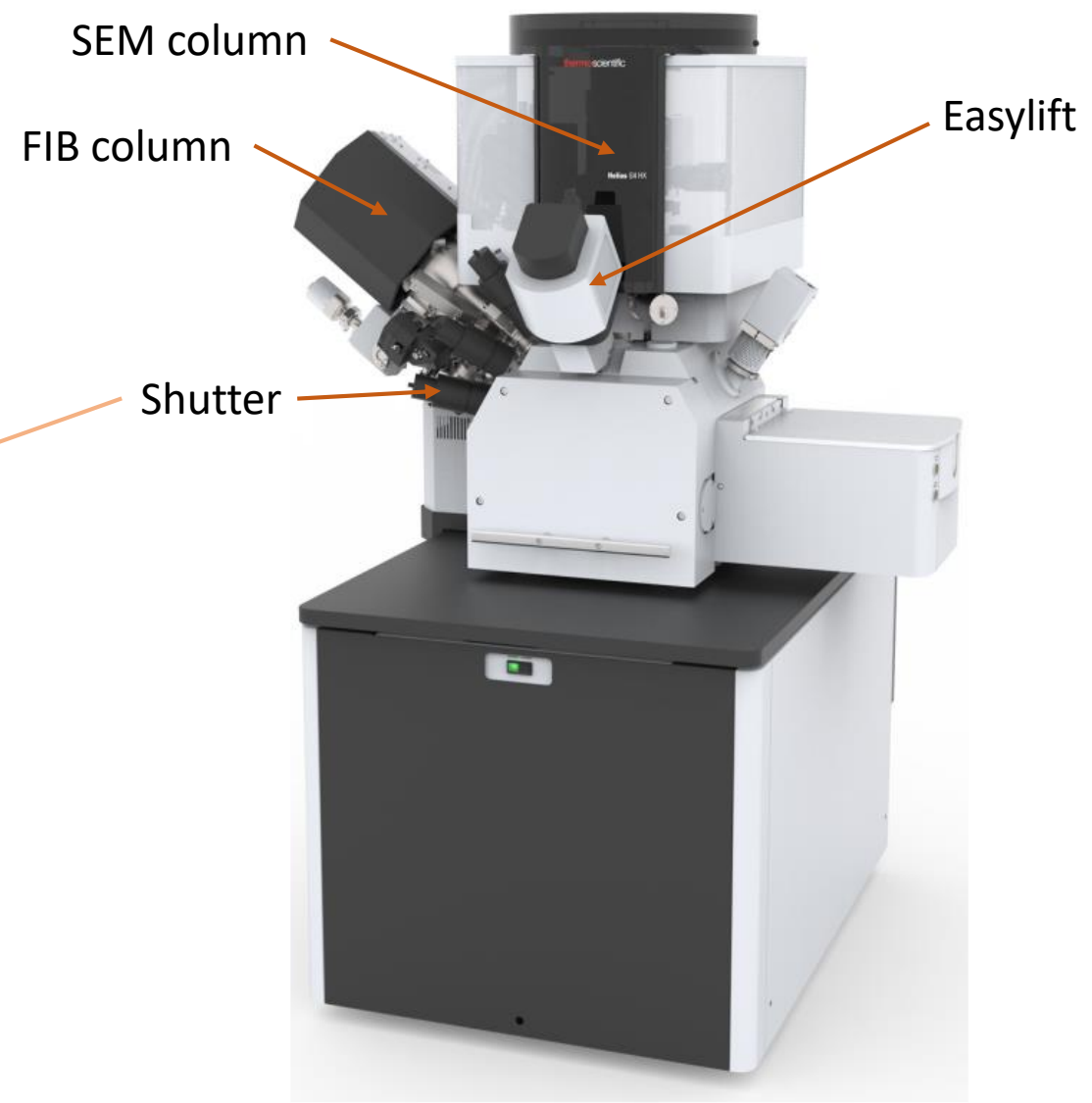
*company
standard*

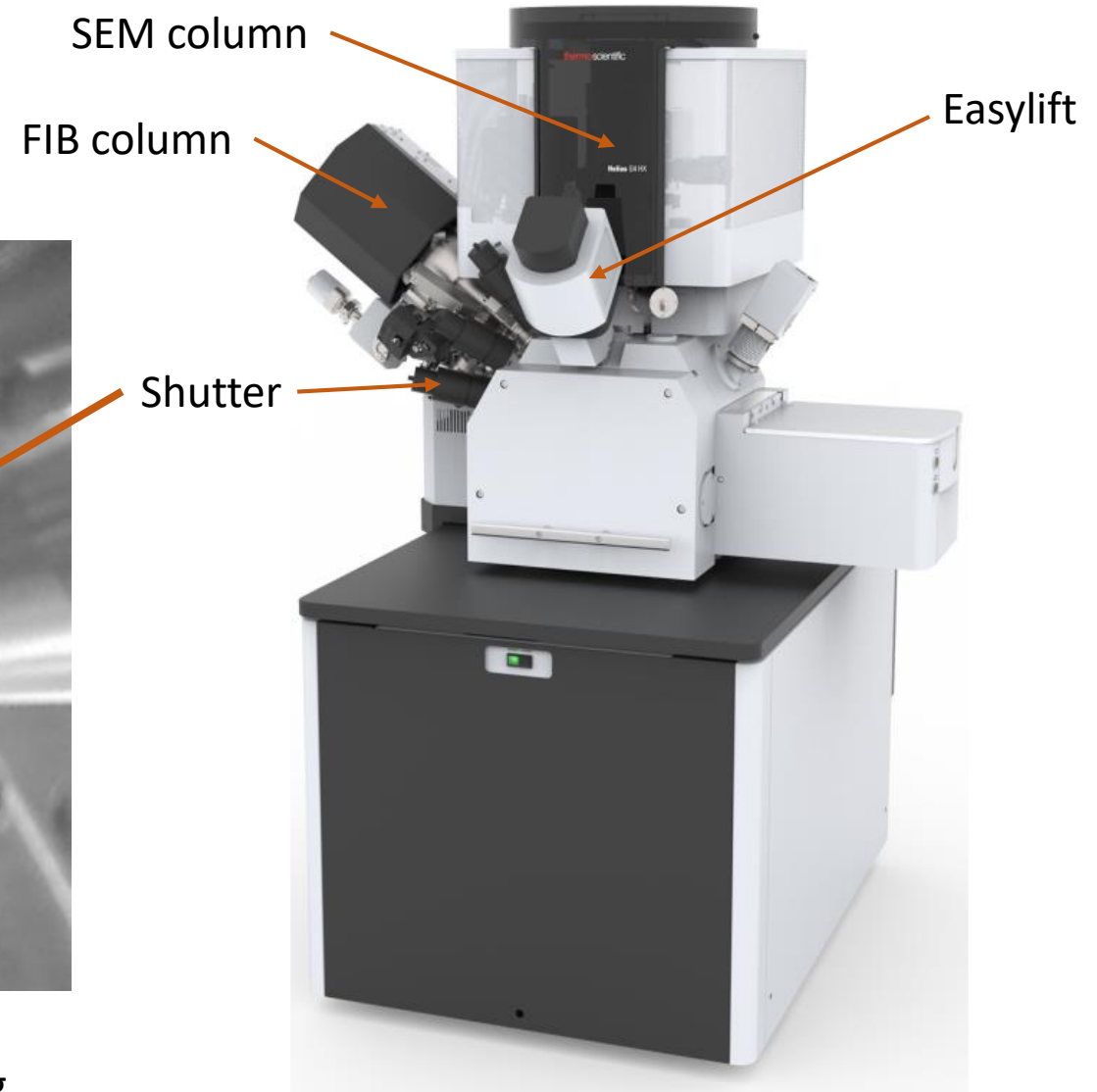
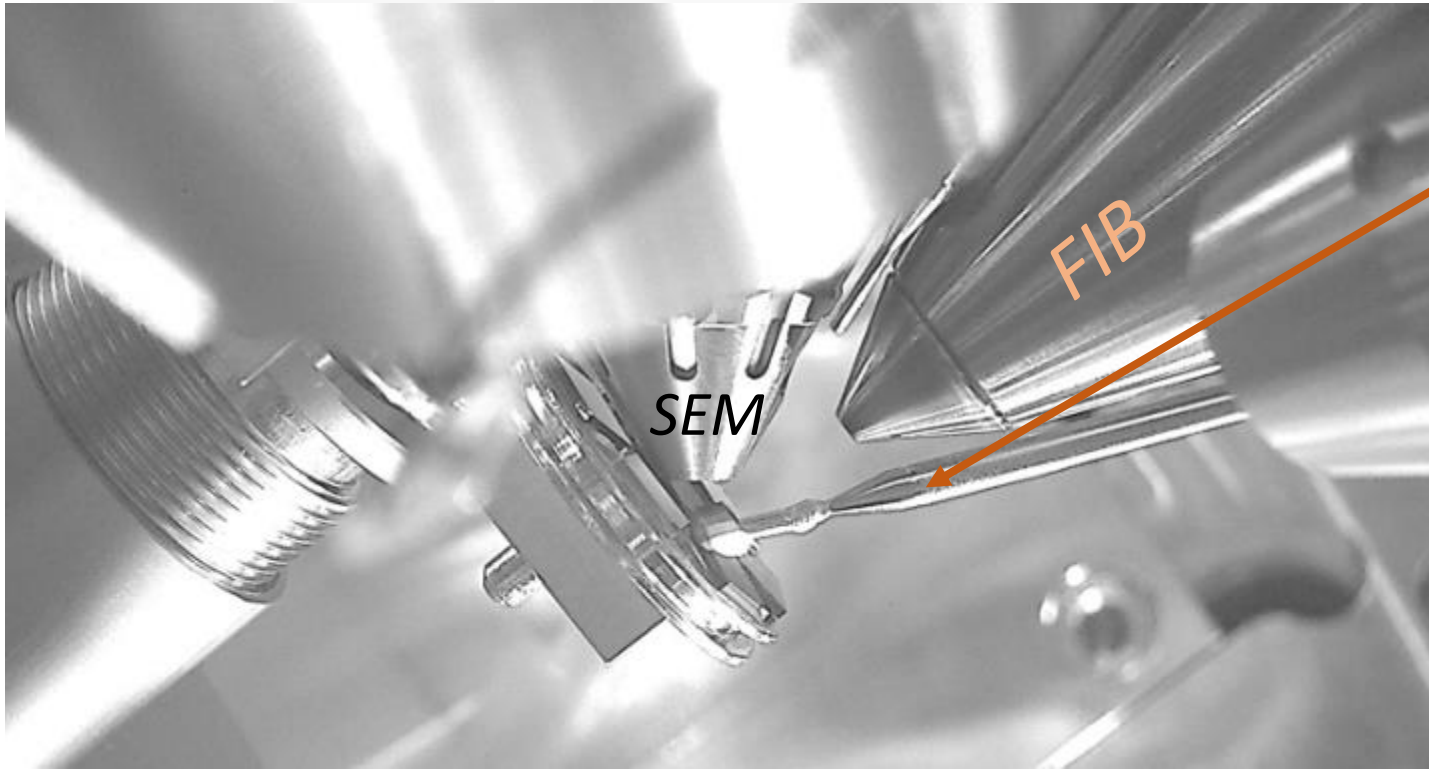


N.S. Smith et al. MSR Bulletin 39, 329

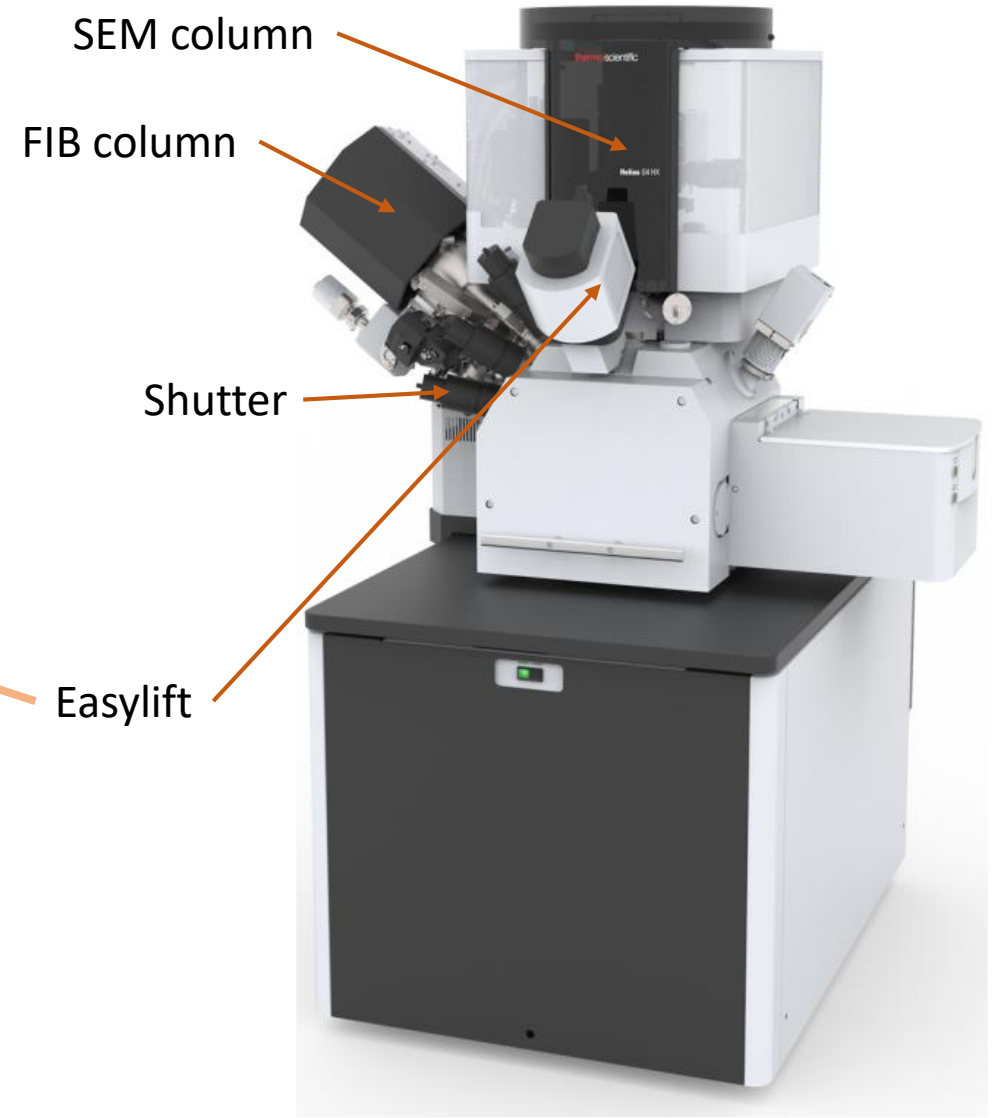


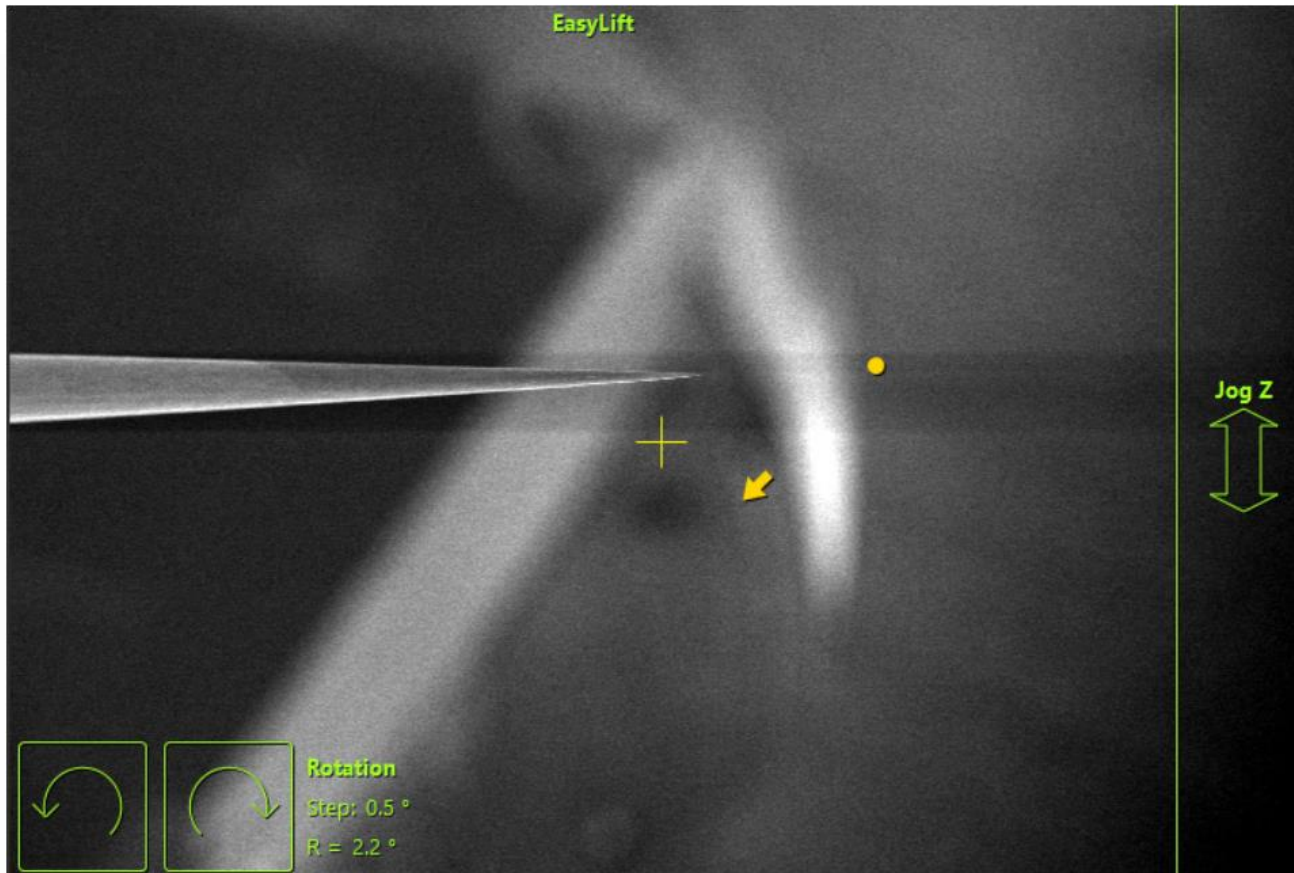
For $I > 4nA$: only a spot burn test can tell beam condition.



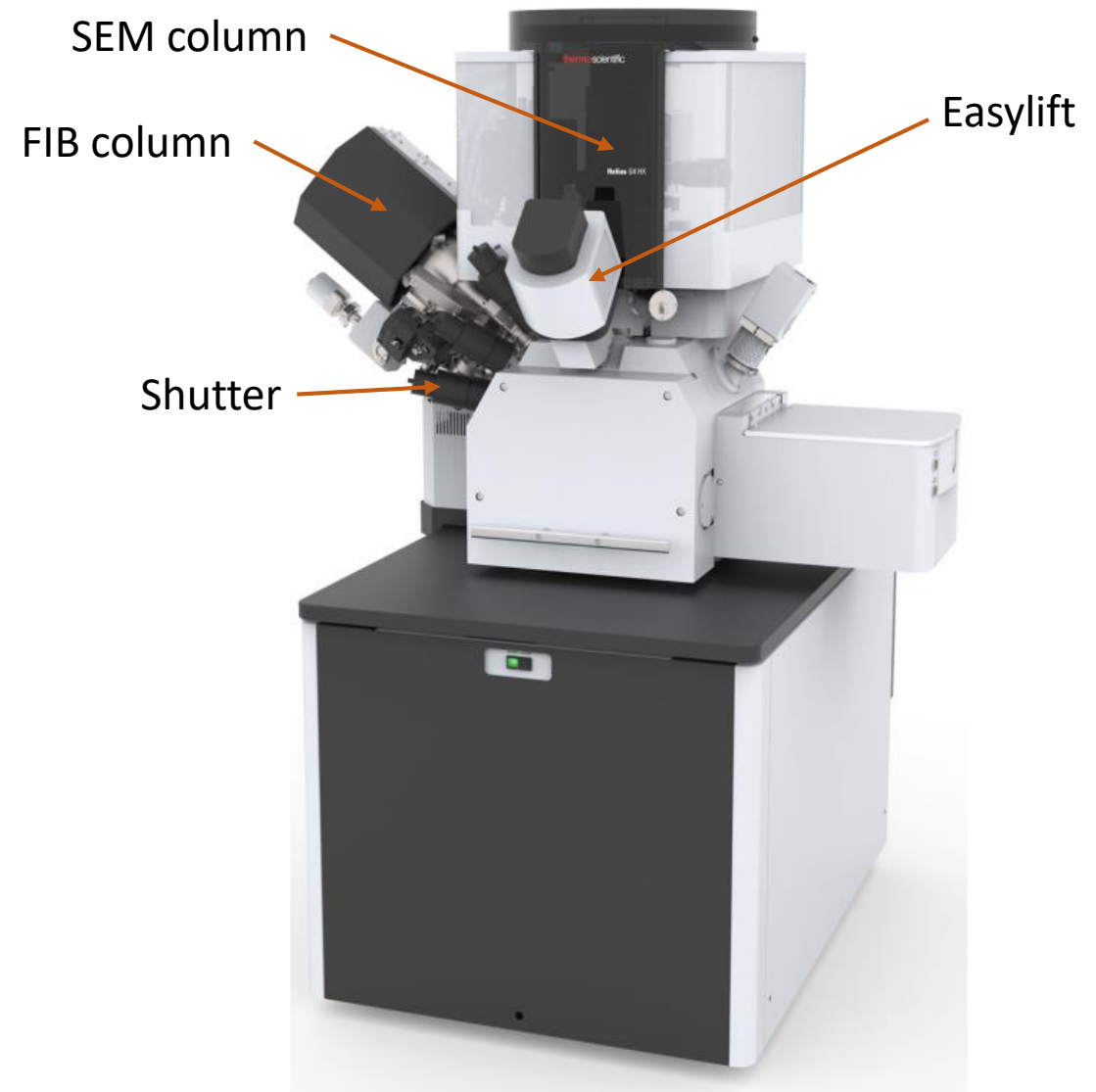


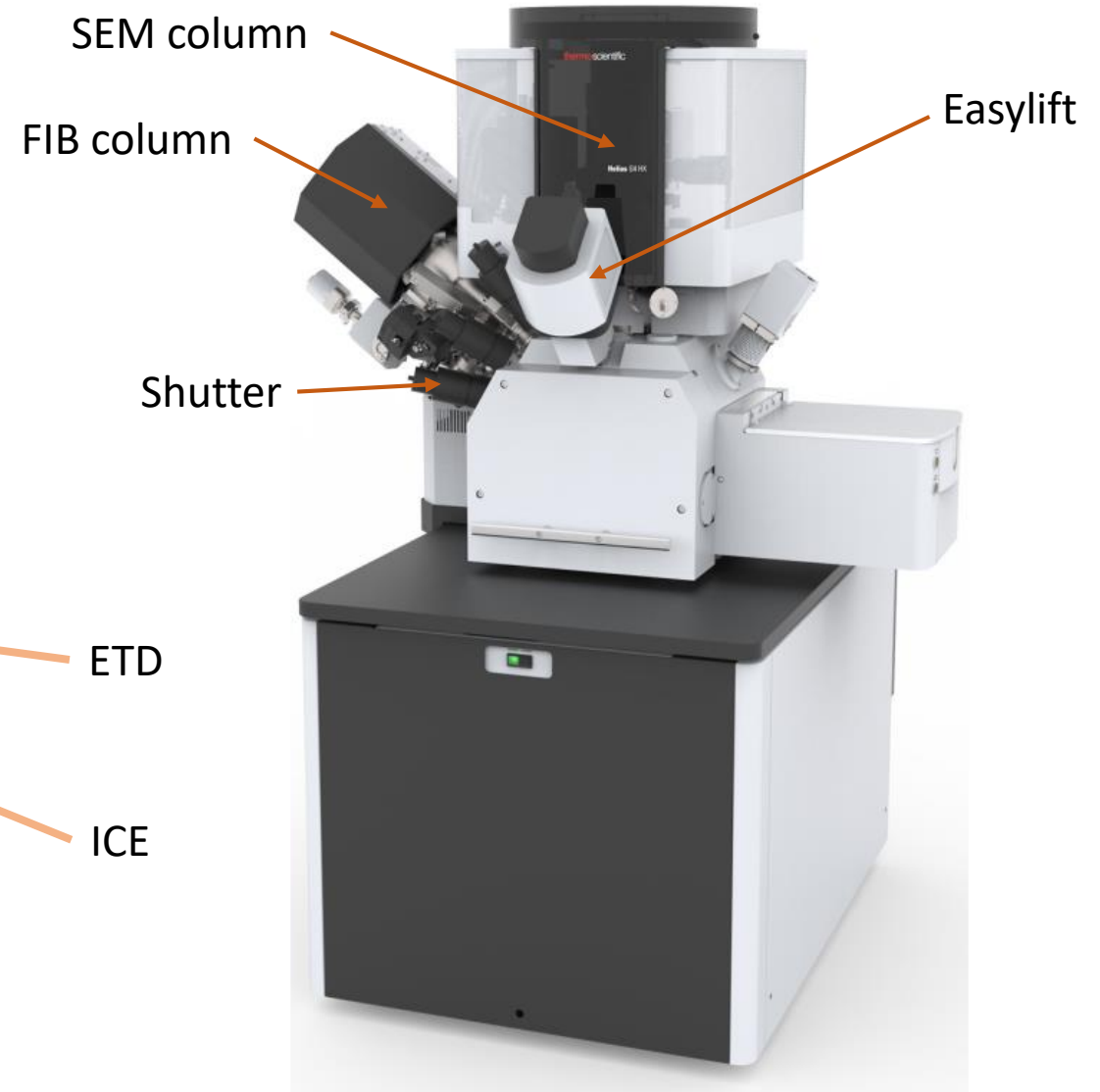
- Automatically inserted at currents $>0.2\mu\text{A}$.
- Prevents contamination of the SEM column at large volume milling.
- Inserted with reference to the coincidence point!

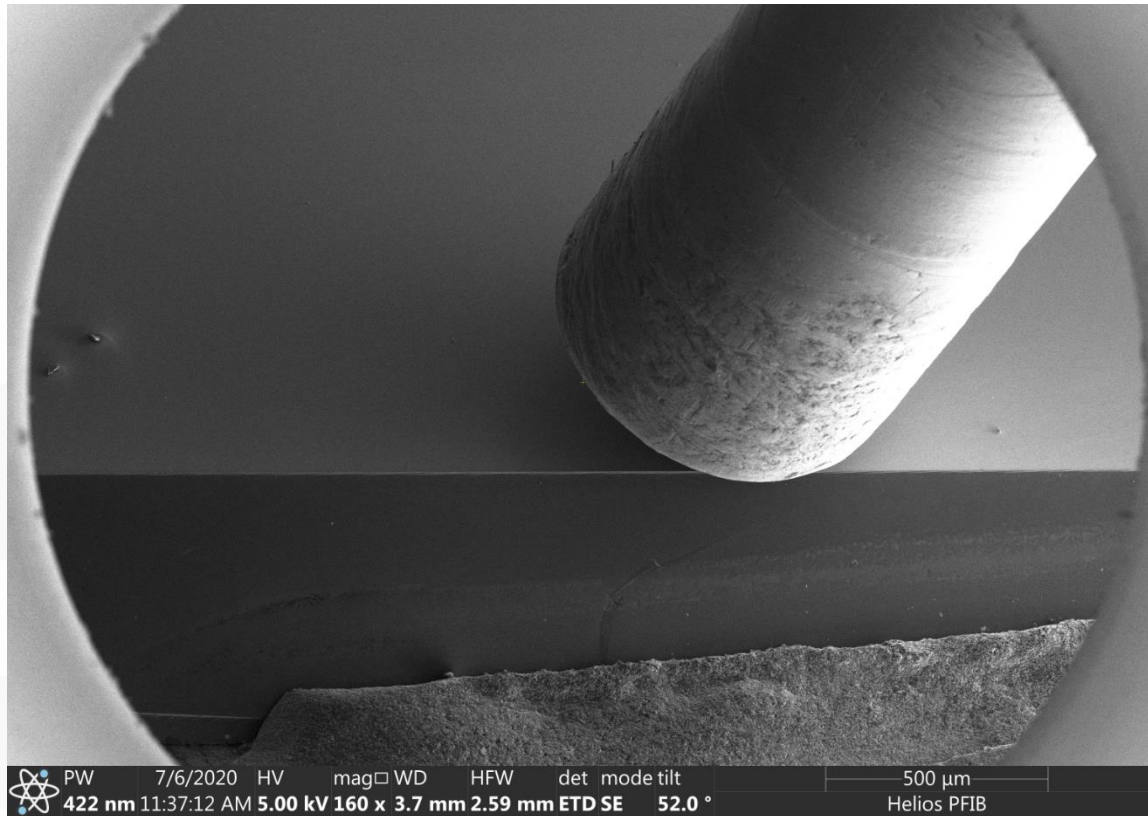




- 3 axis control + rotation
- X,Y-axis are relative to beam used for image
- Z-axis always parallel to SEM
- Movement controlled by dragging the mouse on the screen.
- Speed control by mouse movement.





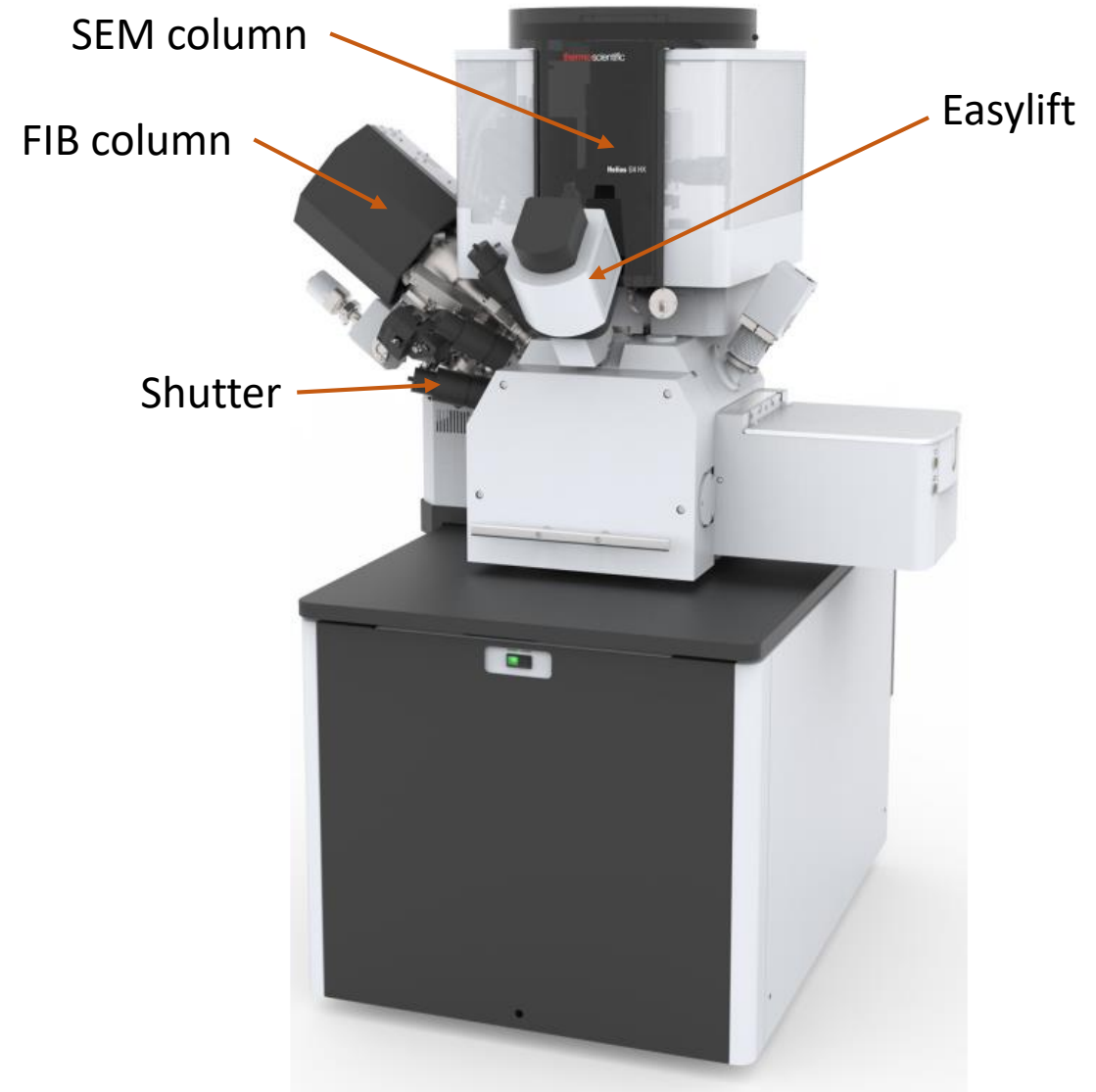


MultiGIS (Gas Injection System)

Allows deposition of Pt, C, W and mixtures of those.



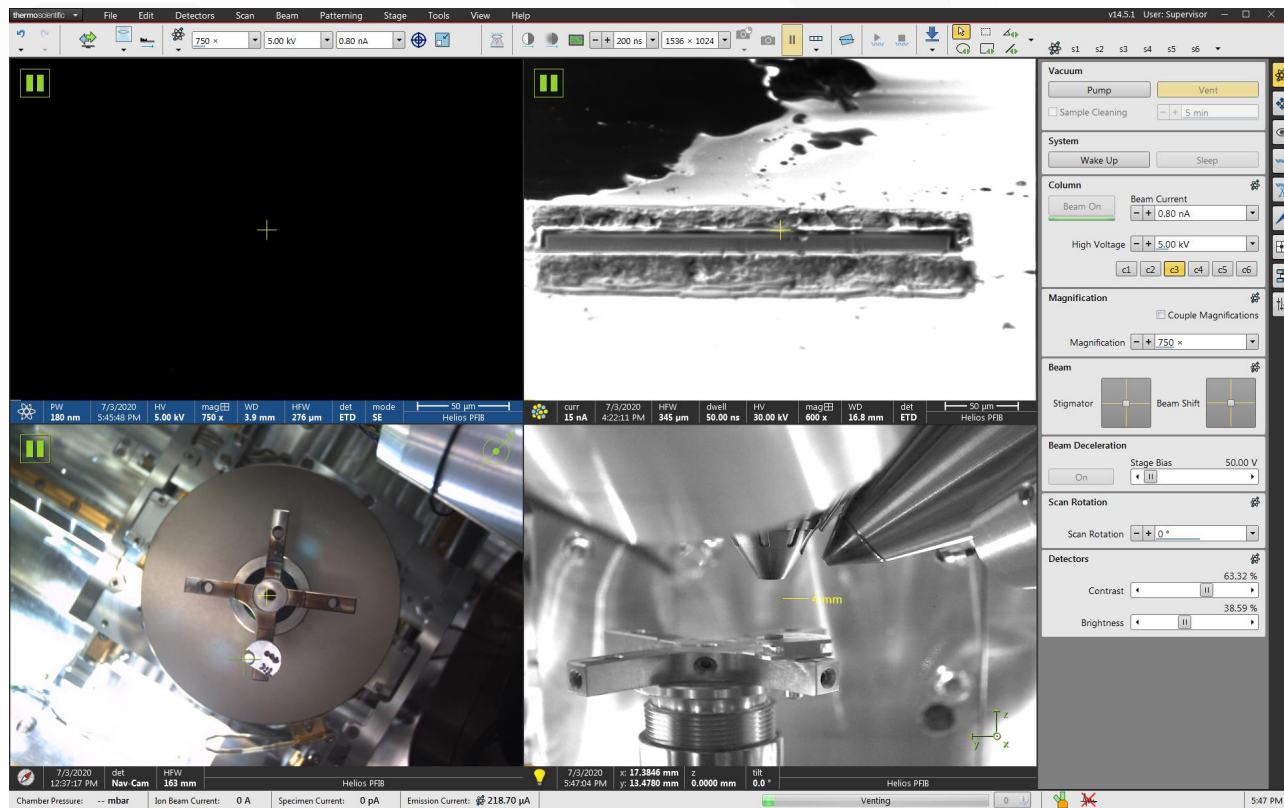
*Lets close the door
and switch to the
computer.*



xT Microscope Server



Microscope Control Software



Microscope Control Software

The screenshot displays the ThermoFisher Helios PFIB microscope control software interface. The main window is divided into four quadrants:

- Top Left:** Labeled "SEM" in large white text. It shows a secondary SEM image of a sample.
- Top Right:** Labeled "FIB" in large red text. It shows a primary FIB image of a sample.
- Bottom Left:** Labeled "NavCam" in large white text. It shows a camera view of the microscope's internal stage.
- Bottom Right:** Labeled "Live Image" in large black text. It shows a real-time view of the FIB tip and the sample.

On the right side of the interface is a control panel with the following sections:

- Vacuum:** Pump, Vent, Sample Cleaning (+5 min).
- System:** Wake Up, Sleep.
- Column:** Beam On, Beam Current (0.80 nA), High Voltage (5.00 kV), and column selection buttons (c1-c6).
- Magnification:** Magnification (750x), Couple Magnifications checkbox.
- Beam:** Stigmator and Beam Shift controls.
- Beam Deceleration:** On, Stage Bias (50.00 V).
- Scan Rotation:** Scan Rotation (0°).
- Detectors:** Contrast (63.32%), Brightness (38.59%).

At the bottom, a status bar provides detailed parameters:

- Chamber Pressure: -- mbar
- Ion Beam Current: 0 A
- Specimen Current: 0 pA
- Emission Current: 218.70 μ A
- Venting: 0
- Time: 5:47 PM



Microscope Control Software

Submenu

The screenshot displays the microscope control software interface. On the left, a vertical toolbar contains icons for different functions. The main area is divided into several panels:

- Beam Settings**: Located at the top left, it includes a yellow atom icon.
- Stage Settings**: Below Beam Settings, featuring a blue crosshair icon.
- Camera/Detector Settings**: Below Stage Settings, featuring an eye icon.
- Patterning**: Below Camera/Detector Settings, featuring a blue waveform icon.
- Rocking Mill**: Below Patterning, featuring a blue icon of a mill.
- EasyLift**: Below Rocking Mill, featuring a blue icon of a lift mechanism.
- Alignment Tools**: A bracket on the left groups the EasyLift and the bottom two icons (a crosshair and a magnifying glass).

The central image shows a grayscale micrograph of a sample. The right side of the interface contains a control panel with various settings and buttons:

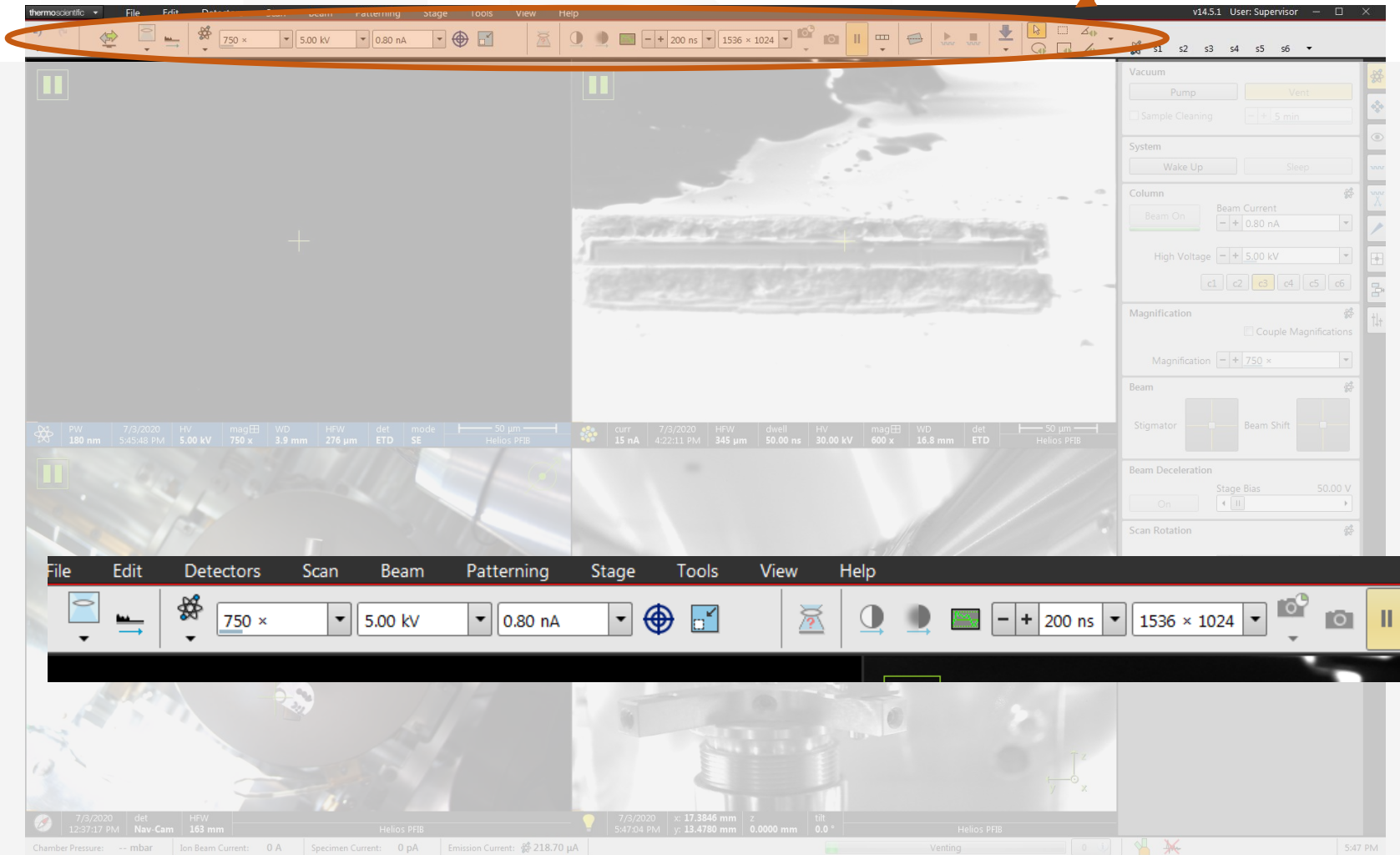
- Vacuum**: Includes buttons for Pump and Vent.
- System**: Includes buttons for Wake Up and Sleep.
- Column**: Includes Beam On, Beam Current (0.80 nA), and High Voltage (5.00 kV) controls.
- Magnification**: Includes Magnification (750x) and Couple Magnifications.
- Beam**: Includes Stigmator and Beam Shift controls.
- Beam Deceleration**: Includes Stage Bias (50.00 V) and On/Off controls.
- Scan Rotation**: Includes Scan Rotation (0°) controls.
- Detectors**: Includes Contrast (63.32%) and Brightness (38.59%) controls.

The bottom status bar displays various parameters such as Chamber Pressure, Ion Beam Current, Emission Current, and Venting status.

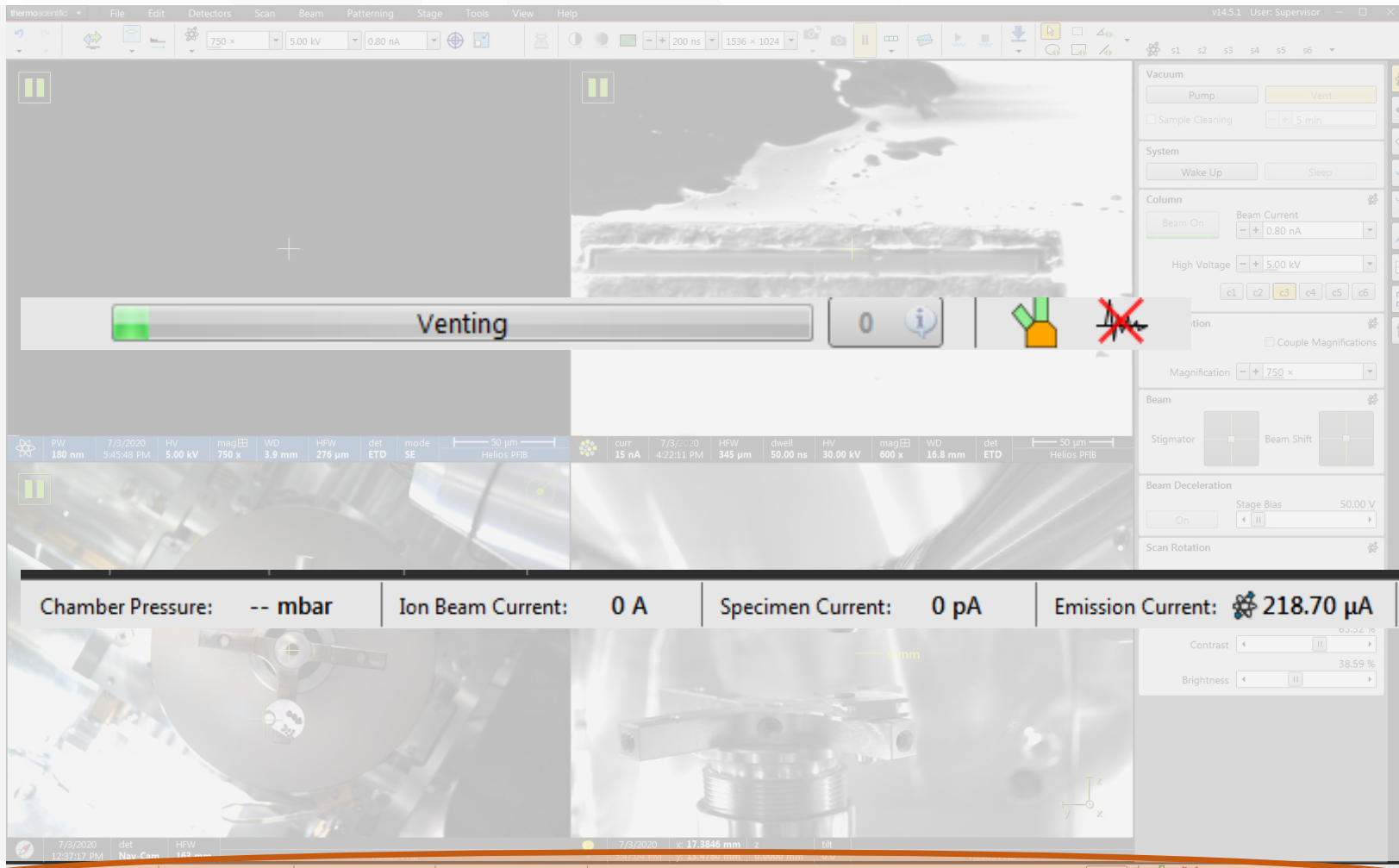


Microscope Control Software

Parameter

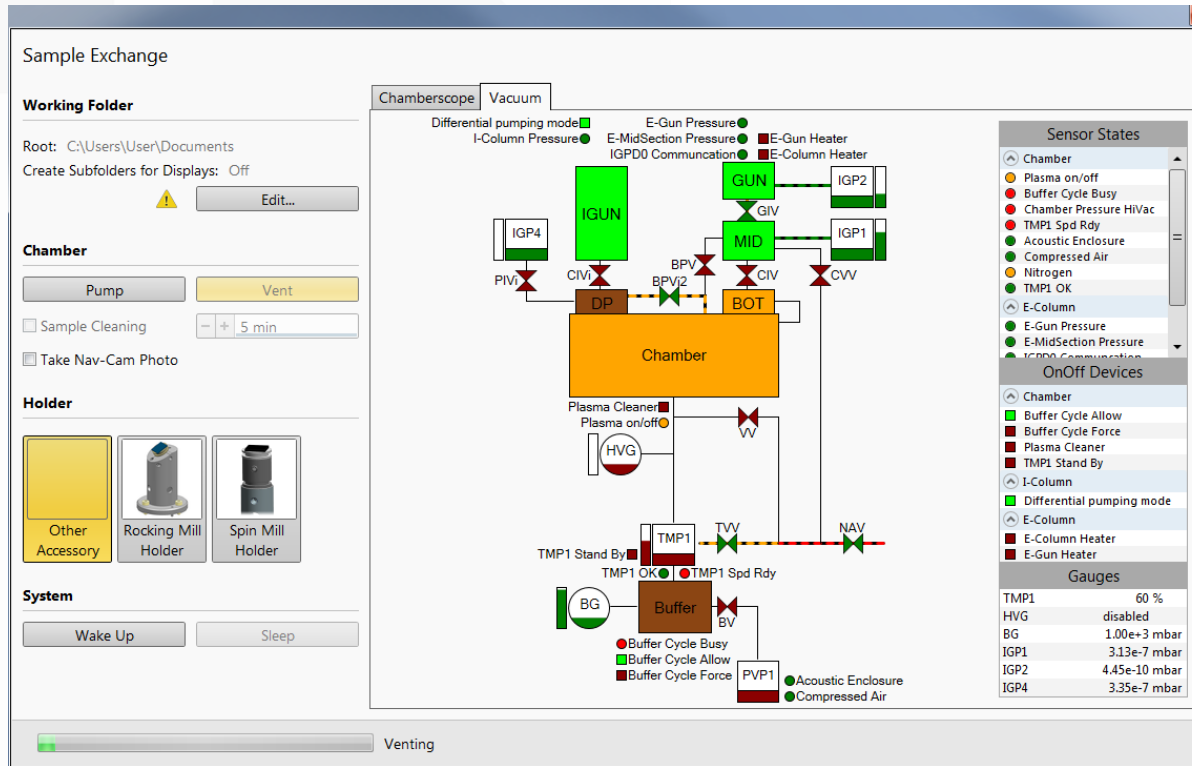


Microscope Control Software



← Status bar

Microscope Control Software



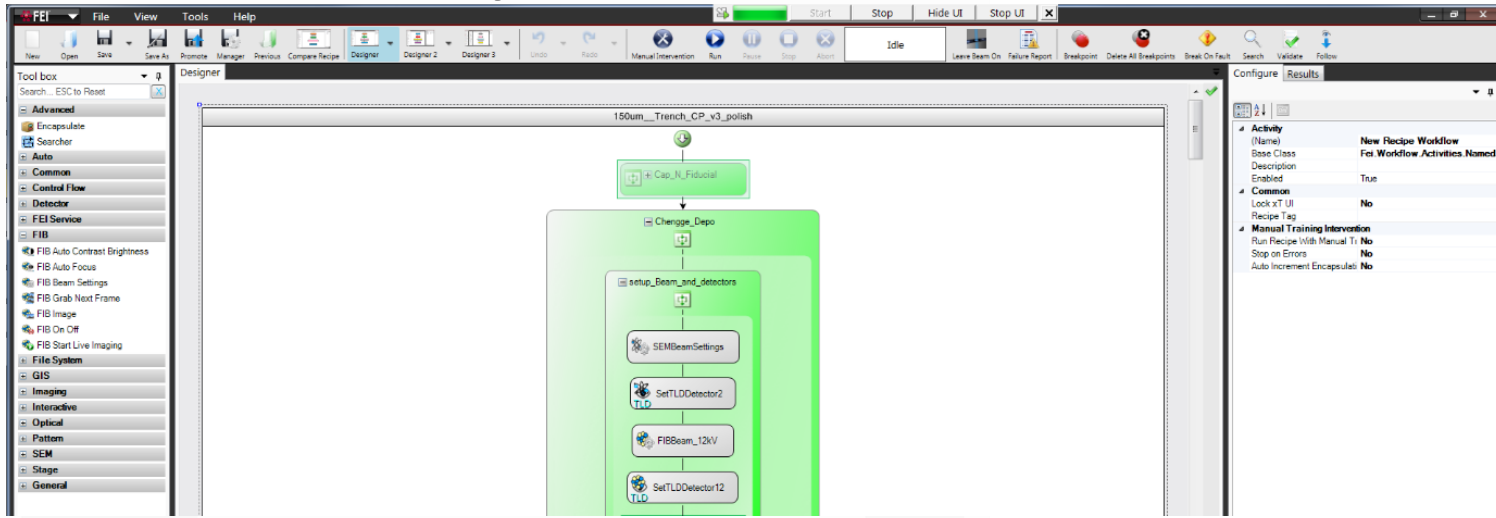
The screenshot displays the 'Sample Exchange' control window. On the left, a 'Working Folder' section shows the root path 'C:\Users\User\Documents' and an 'Edit...' button. Below this, the 'Chamber' section includes 'Pump' and 'Vent' buttons, a 'Sample Cleaning' checkbox with a '5 min' timer, and a 'Take Nav-Cam Photo' checkbox. The 'Holder' section features three icons: 'Other Accessory', 'Rocking Mill Holder', and 'Spin Mill Holder'. The 'System' section has 'Wake Up' and 'Sleep' buttons. A progress bar at the bottom indicates 'Venting'.

The central part of the window shows a schematic diagram of the microscope's vacuum system. It includes components like 'IGUN', 'GUN', 'MID', 'IGP1', 'IGP2', 'IGP4', 'DP', 'BOT', 'Chamber', 'Plasma Cleaner', 'HVG', 'TVP1', 'NAV', 'BG', and 'Buffer'. A legend at the bottom of the diagram defines symbols for 'Buffer Cycle Busy', 'Buffer Cycle Allow', 'Buffer Cycle Force', 'PVP1', 'Acoustic Enclosure', and 'Compressed Air'.

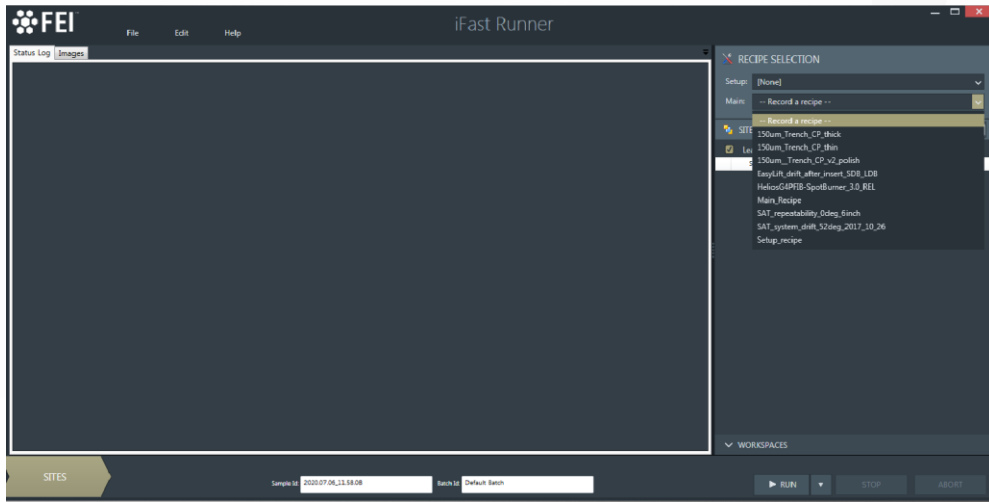
On the right side, there are two panels: 'Sensor States' and 'OnOff Devices'. The 'Sensor States' panel lists various sensors with their current status (e.g., Chamber, Plasma on/off, Buffer Cycle Busy, Chamber Pressure HiVac, TMP1 Spd Rdy, Acoustic Enclosure, Compressed Air, Nitrogen, TMP1 OK, E-Column, E-Gun Pressure, E-MidSection Pressure, I-Column). The 'OnOff Devices' panel lists devices that can be turned on or off (e.g., Chamber, Buffer Cycle Allow, Buffer Cycle Force, Plasma Cleaner, TMP1 Stand By, I-Column, Differential pumping mode, E-Column, E-Column Heater, E-Gun Heater). Below these panels is a 'Gauges' section showing real-time pressure readings: TMP1 (60 %), HVG (disabled), BG (1.00e+3 mbar), IGP1 (3.13e-7 mbar), IGP2 (4.45e-10 mbar), and IGP4 (3.35e-7 mbar).



iFast Developer



iFast Runner



Allows easy execution at multiple sites.



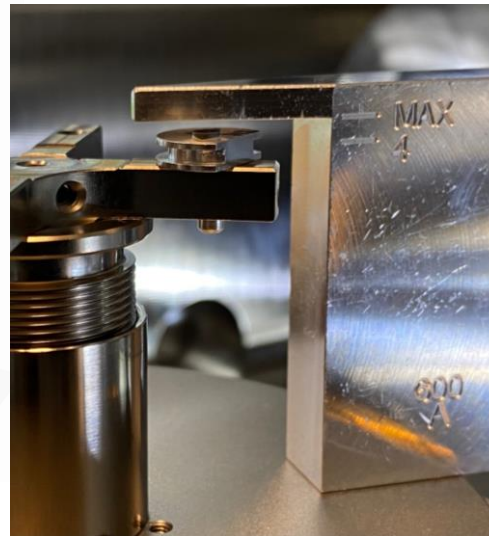
Python Autoscript

```
Tests - [C:\Users\User\PycharmProjects\Carsten\Tests] - ...\settingparameter.py - PyCharm Community Edition 2017.2.2
File Edit View Navigate Code Refactor Run Tools VCS Window Help
Tests > settingparameter.py
Project settingparameter.py x
Tests C:\Users\User\PycharmProjects\
  drill_holes_constants current.py
  drill_holes_diffCurrentsLoop.py
  drill_holes_diffCurrentsLoop_andcr
  example.py
  example.pz
  Michal_Array_Pattern.py
  settingparameter.py
  testmove.py
External Libraries
1 from autoscript_sdb_microscope_client import SdbMicroscopeClient
2 from autoscript_sdb_microscope_client.enumerations import *
3 from autoscript_sdb_microscope_client.structures import *
4
5 microscope = SdbMicroscopeClient()
6 microscope.connect()
7
8
9 lx = 1e-6
10 ly = 1e-6
11
12 patt_dwell_time = 10e-6
13
14 rp = microscope.patterning.create_rectangle(0, 0, lx, ly, 1e-6)
15
16 rp.dwell_time = patt_dwell_time
17
18 no_px = lx/rp.pitch_x*ly/rp.pitch_y
19
20 patt_time = no_px*patt_dwell_time
21
22 rp.time = patt_time
```

Enables combination of microscope control, image recognition and numerical calculations.



4mm Marker



4mm Marker



- indicates the WD=4mm.
- after focusing the stage needs to be linked
- z(absolute) → z(Full Working Distance)



Link the stage after focusing.



4mm Marker

if the sample is too low

- it is not possible to bring sample into coincidence
- GIS system will be too far from sample for good deposition

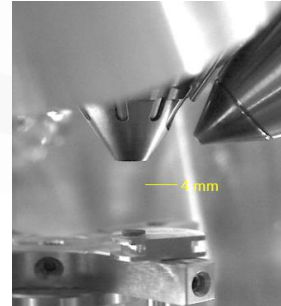
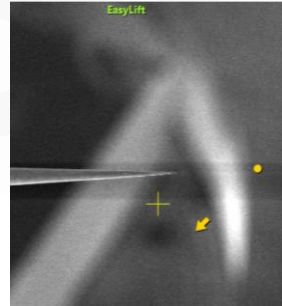
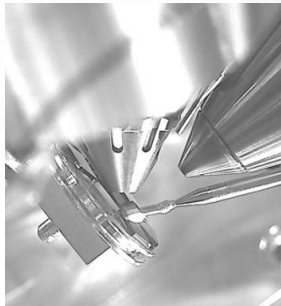
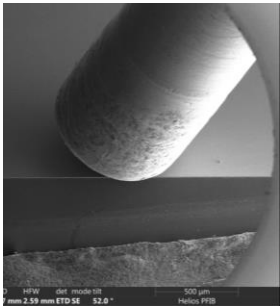
if the sample is too high

- **risk of damaging the system**



- **Shutter**
- **EasyLift**
- **GIS**
- **SEM**

- **your sample will be damaged**



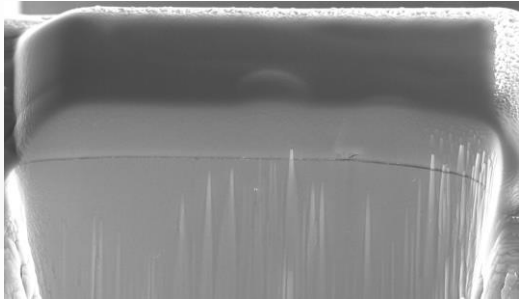
Applications and Examples



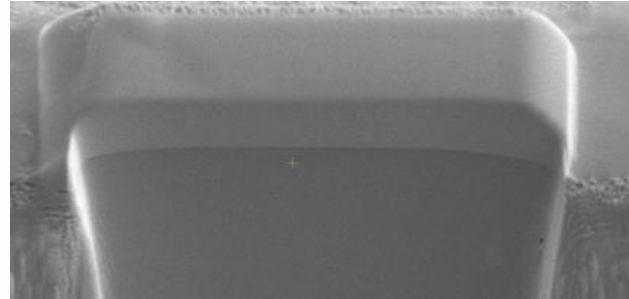
MultiGIS

Combining Pt and C allows for variation in hardness and growth speed.

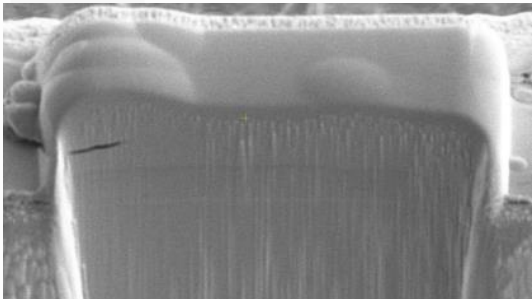
1%C:100%Pt



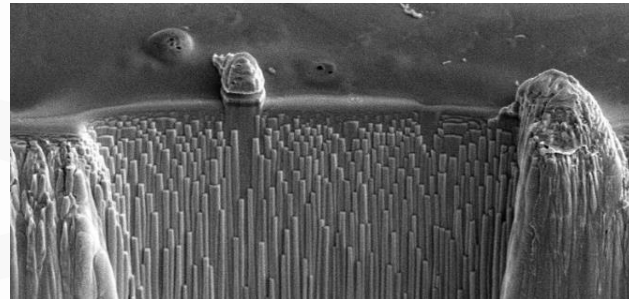
2%C:100%Pt



4%C:100%Pt

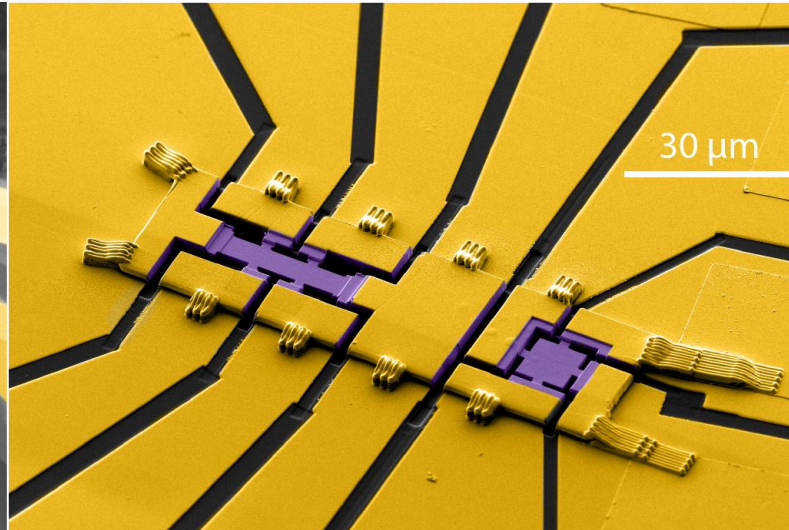
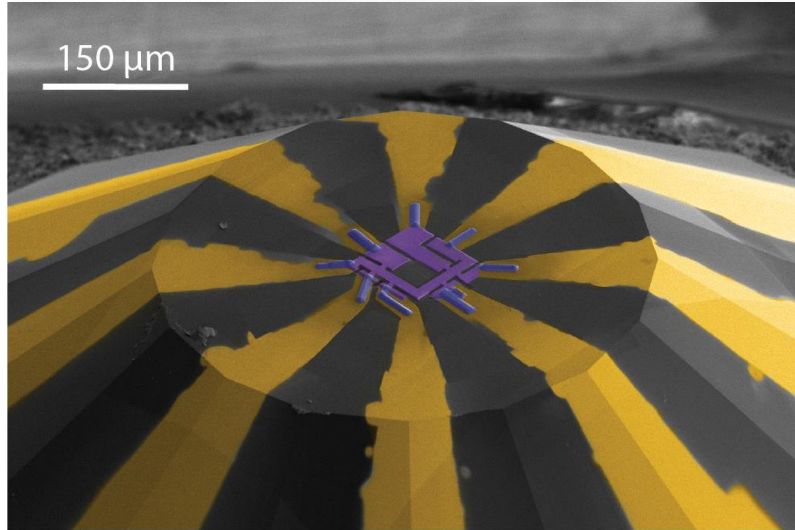


without protection layer

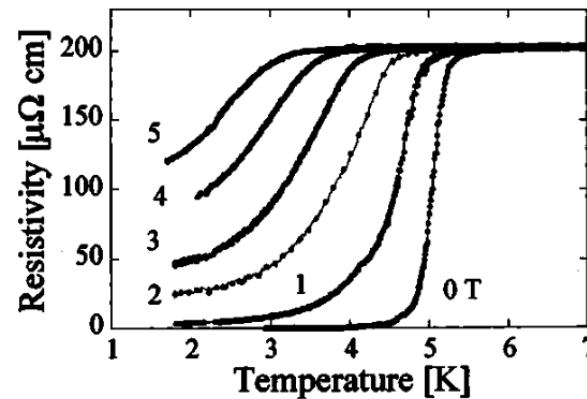


MultiGIS

Pt as electrical contact.



W as superconducting contacts and reduced cross contamination.



Appl. Phys. Lett. **85**, 6206 (2004)



Studying Electrical Properties

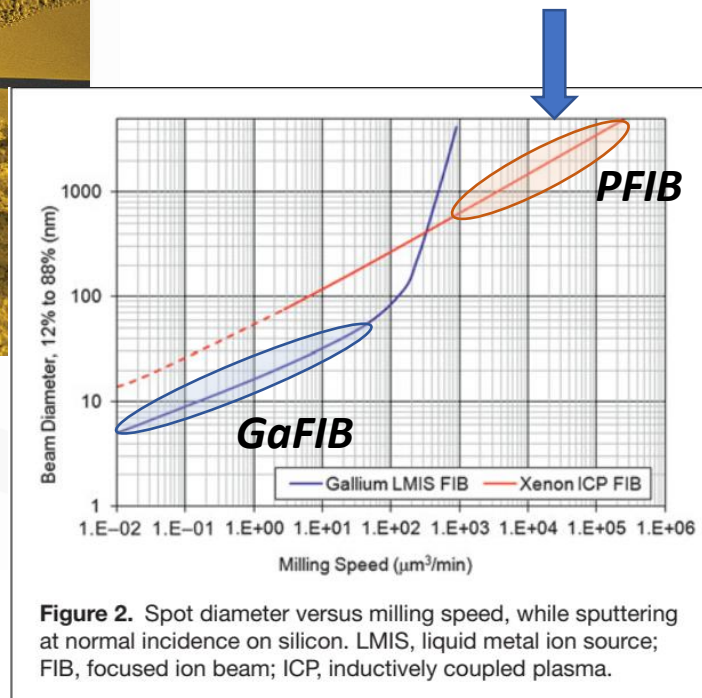
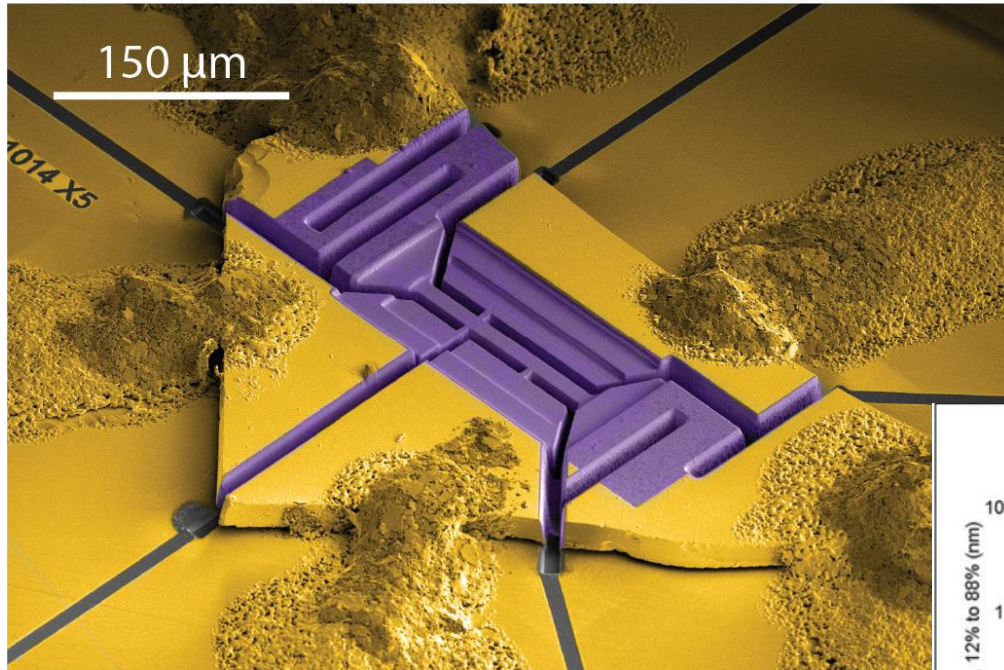
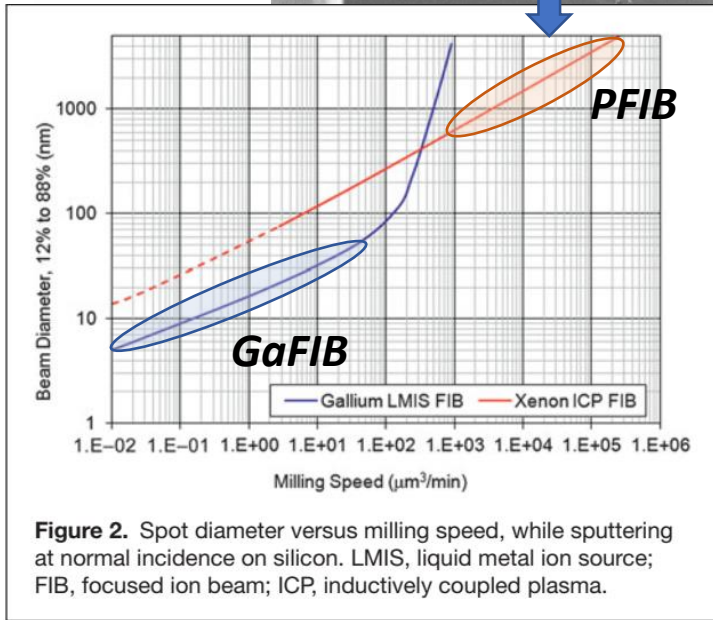
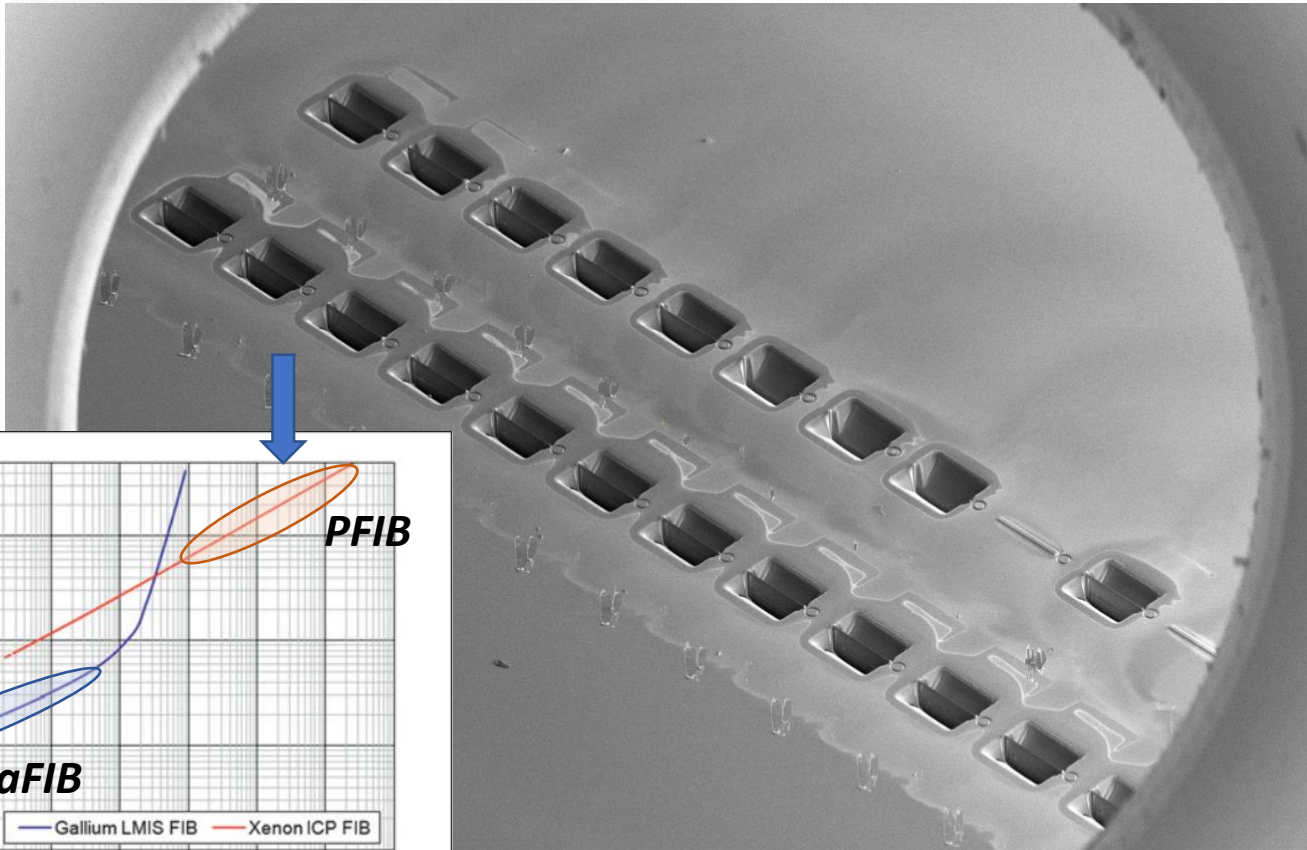


Figure 2. Spot diameter versus milling speed, while sputtering at normal incidence on silicon. LMIS, liquid metal ion source; FIB, focused ion beam; ICP, inductively coupled plasma.

Studying Electrical Properties

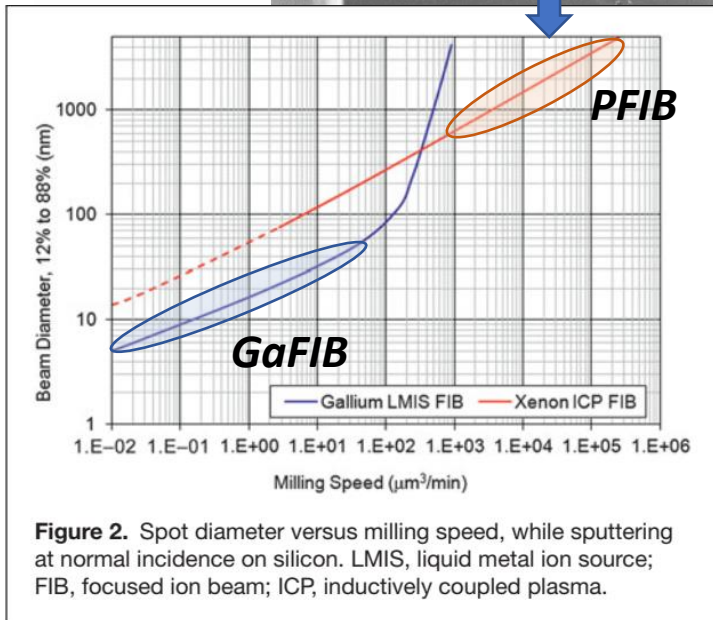
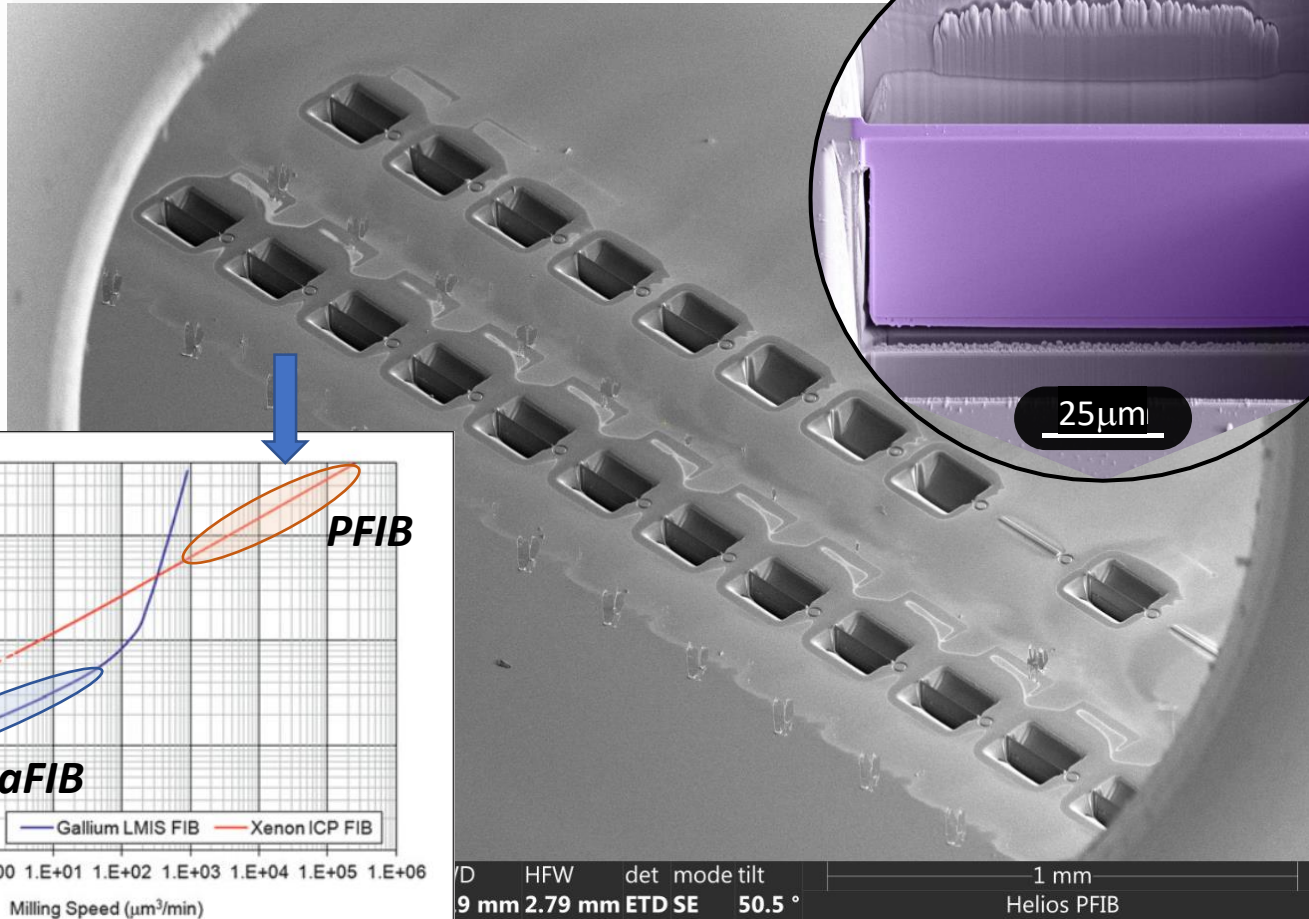


D HFW det mode tilt 1 mm
 9 mm 2.79 mm ETD SE 50.5 ° Helios PFIB

iFast Automation
 ~1h per lamella

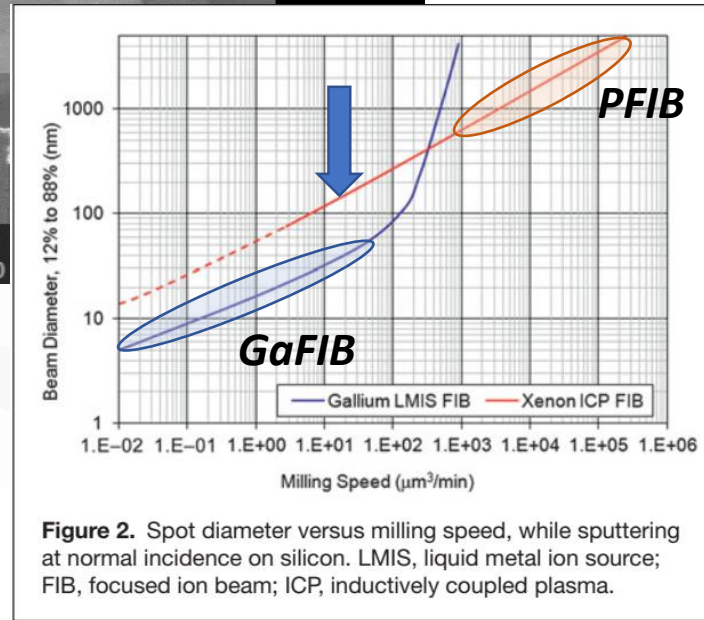
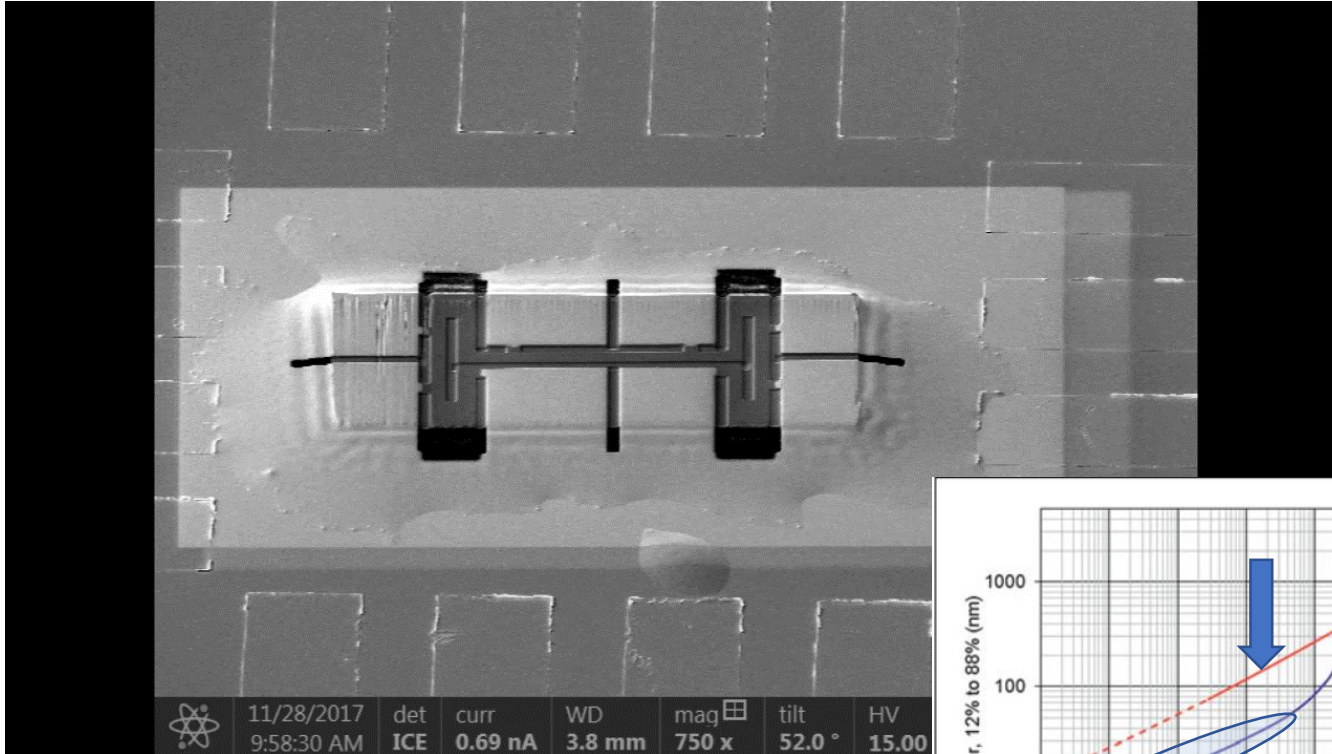


Studying Electrical Properties



iFast Automation
~1h per lamella

Studying Electrical Properties



Studying Electrical Properties

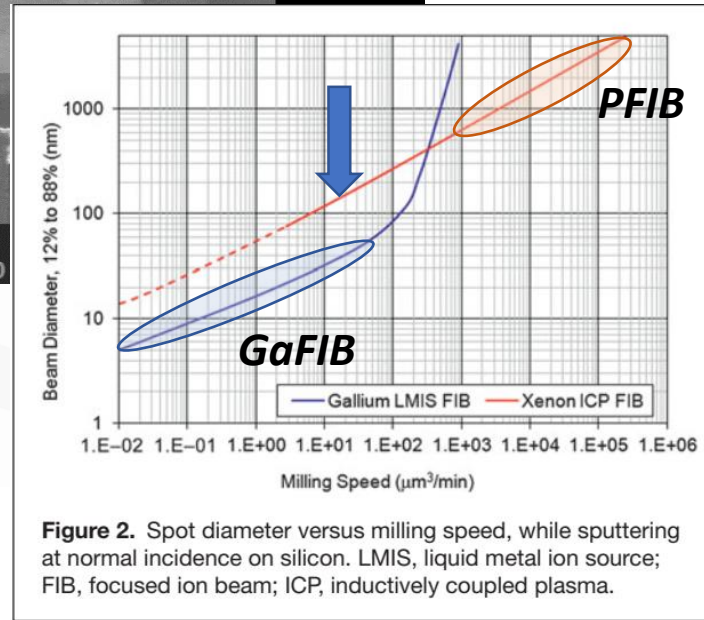
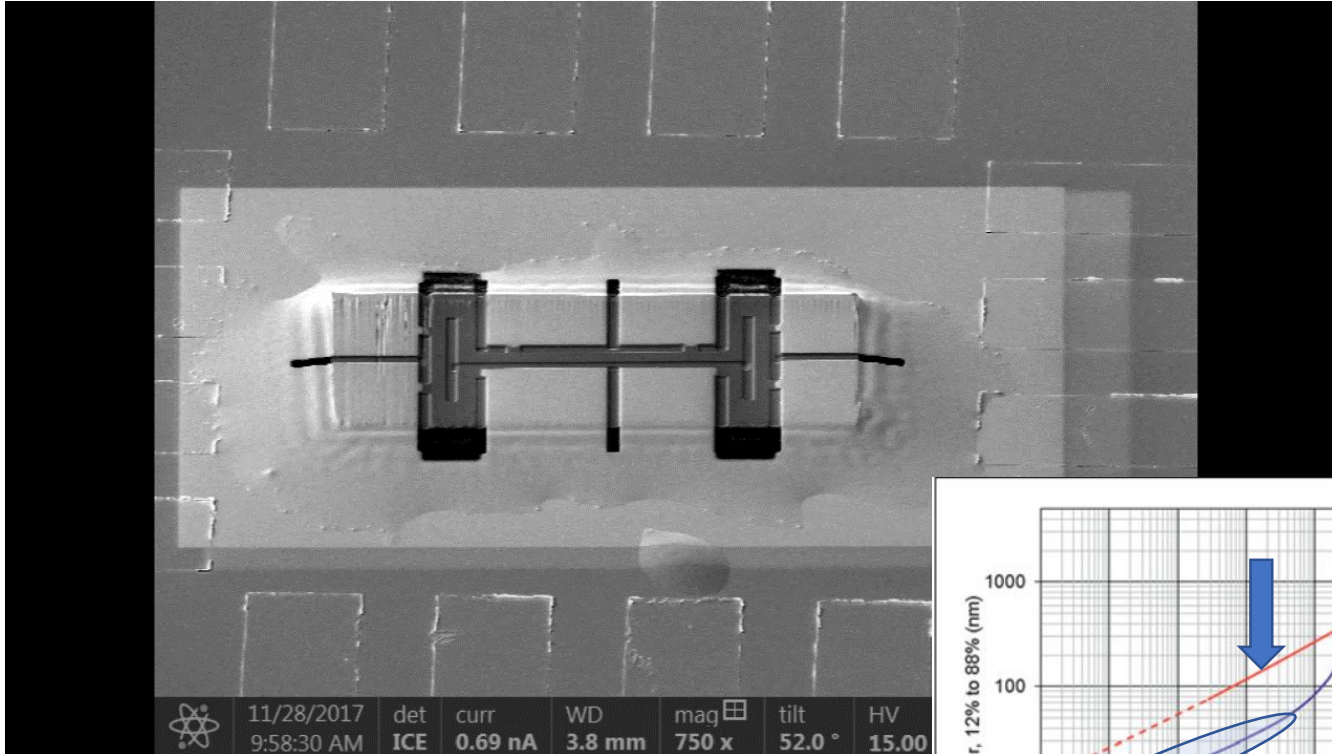
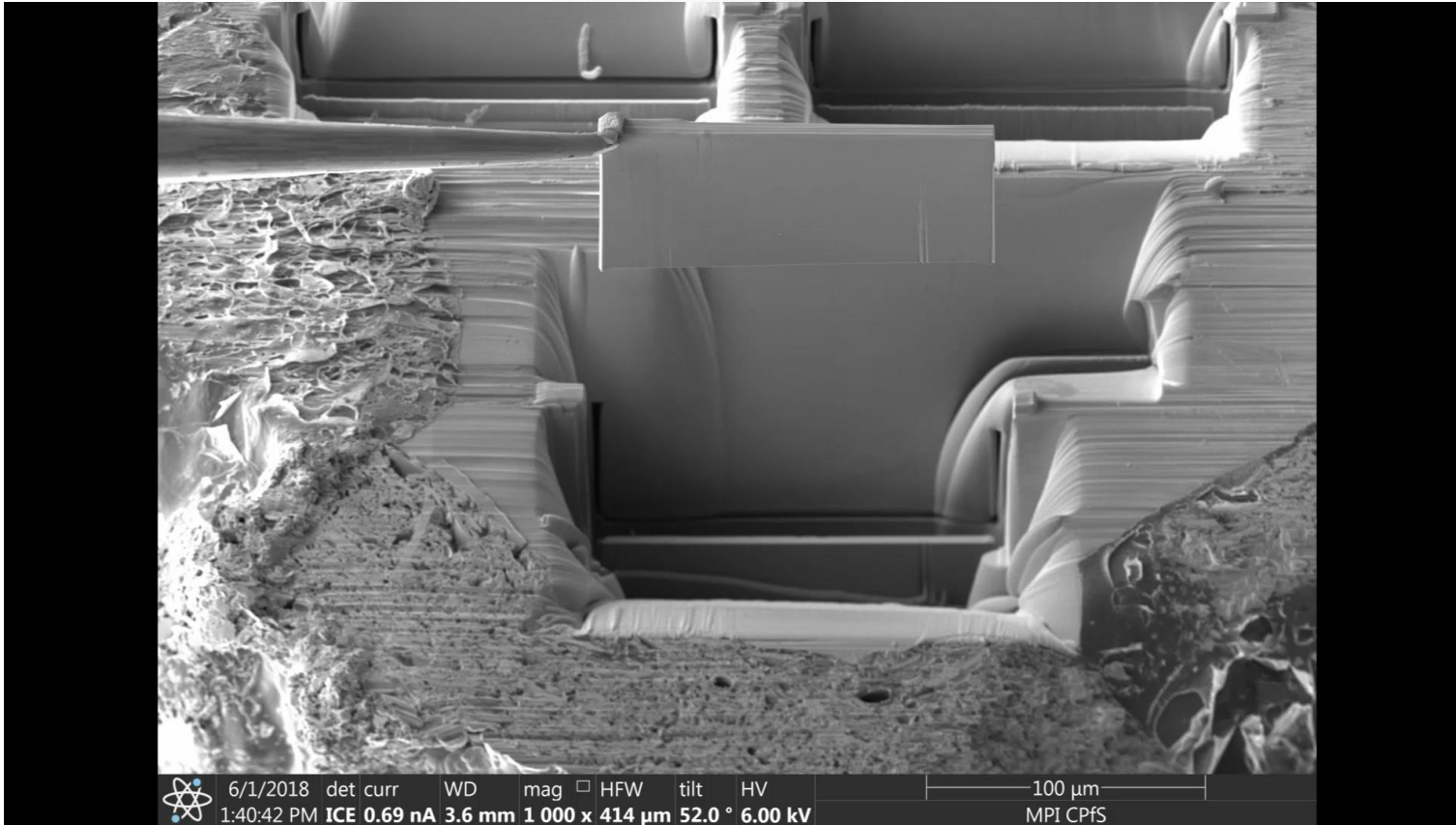


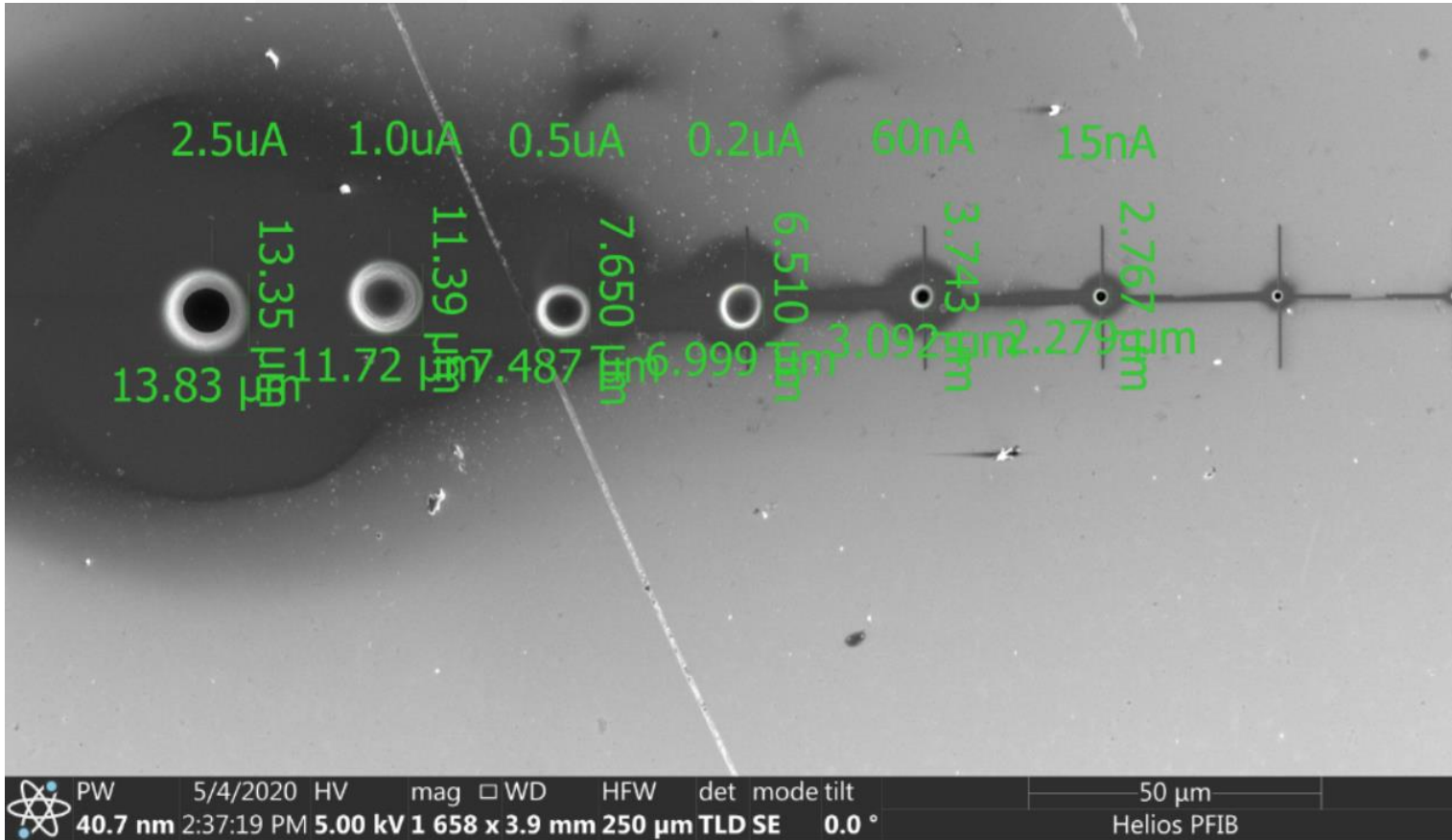
Figure 2. Spot diameter versus milling speed, while sputtering at normal incidence on silicon. LMIS, liquid metal ion source; FIB, focused ion beam; ICP, inductively coupled plasma.



Microelectronic Strain

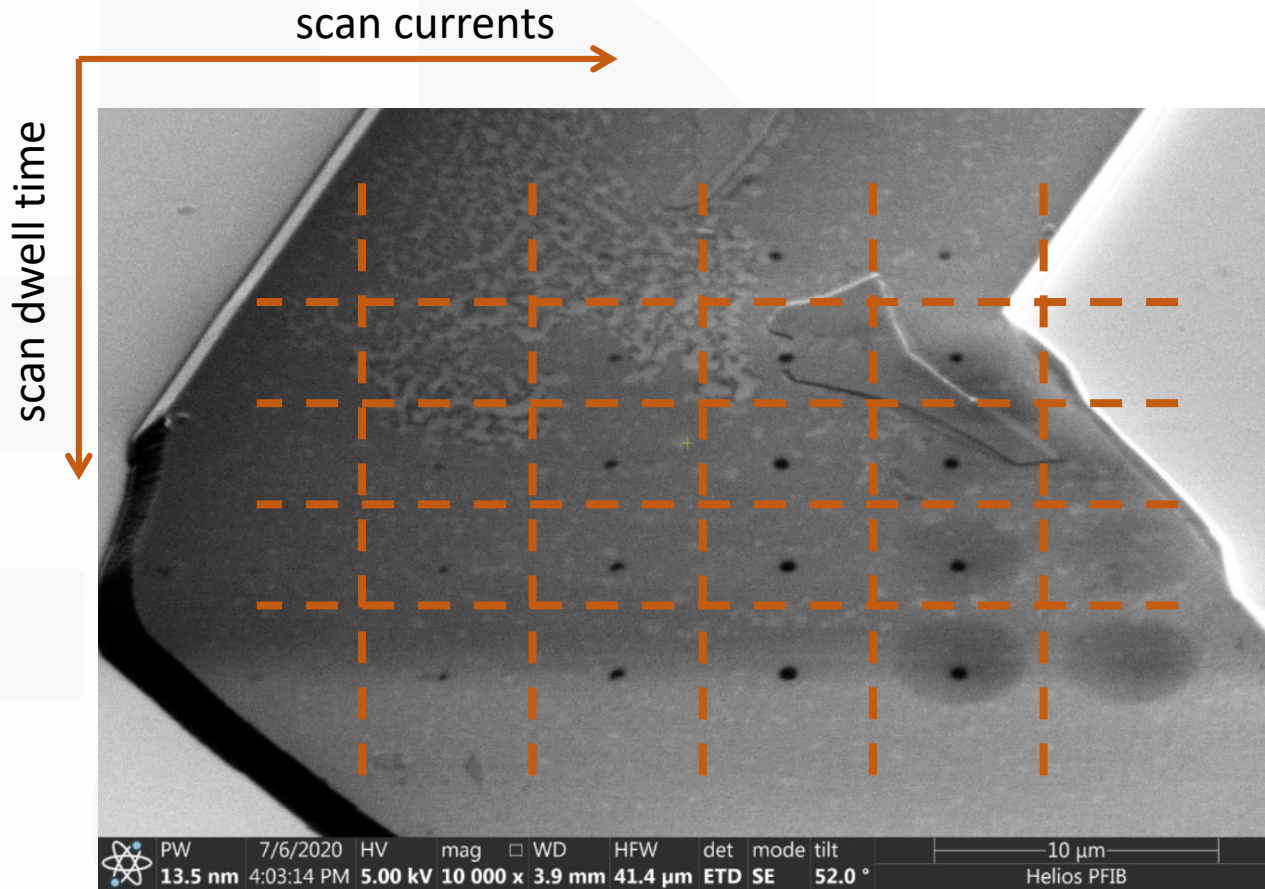


Automated System Check



Python Script lets you automatically check the system for spot size and alignment.

Automated Irradiation Study



Automated parameter scan. Picture taken by Michal Macha.

