From Nanorobotics to Microproduction

... Know-how transfer between dimensions

Klocke Nanotechnik

Pascalstr. 17
Aachen, Germany

One of 279 members in a

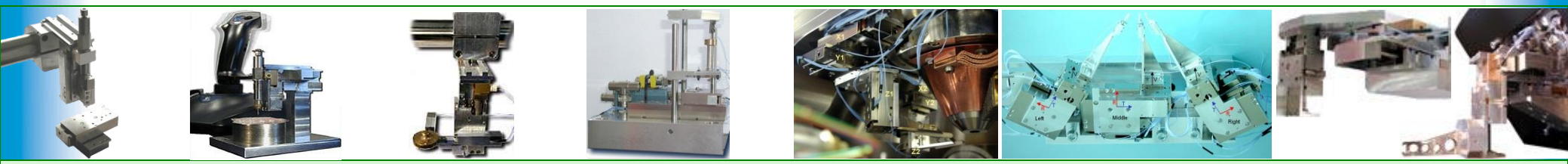
Microtechnology Network

Modular Nanorobotics

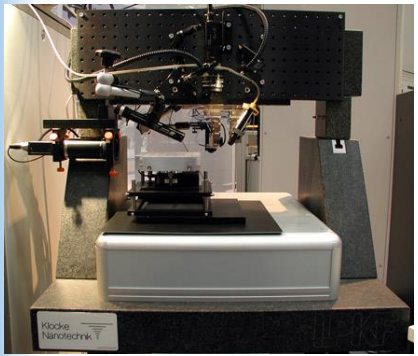
Configuration instead of Development

Pool of more than 200 Nanorobotics Components

Configuration to individual machines



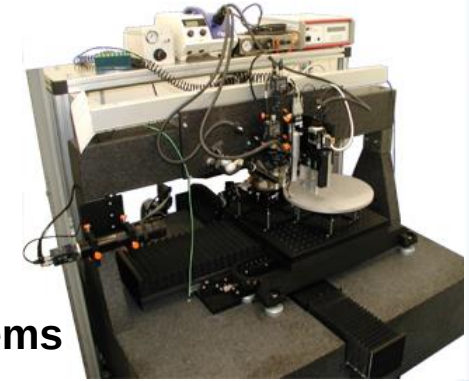
µ-Assembly, µ-Tensile-Machine, 3D-Nanofinger, SPM-Lithographer, ... **The SEM/FIB Workbench**



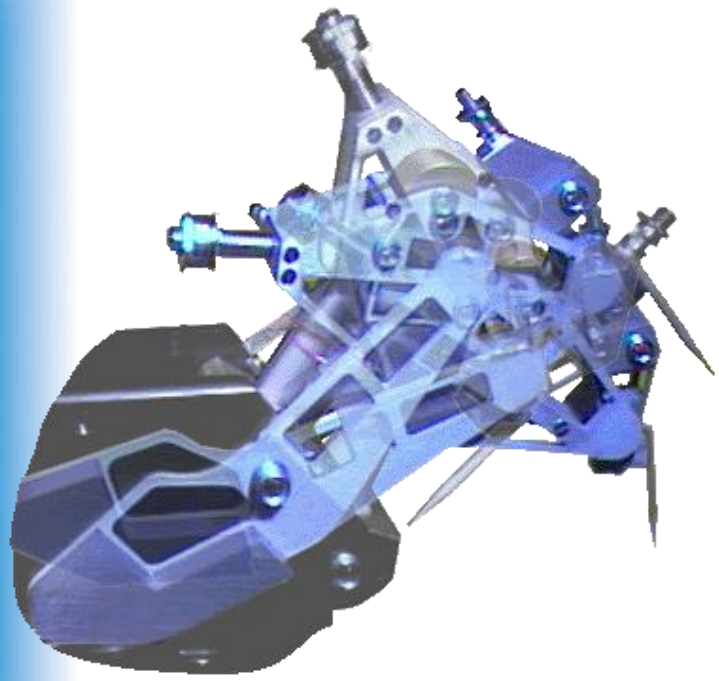
Integration in Nanorobotics systems

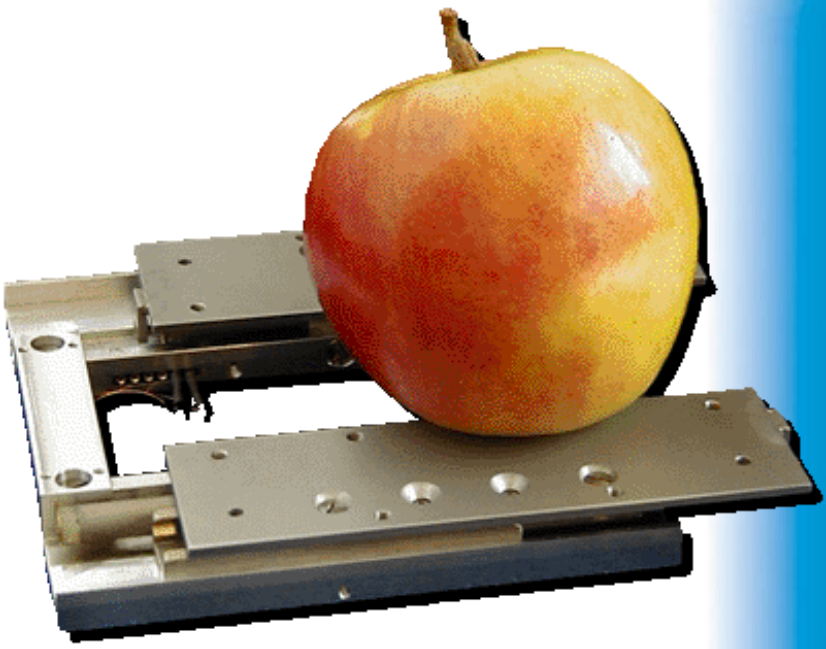
Universal Testing Benches

Micro Production Systems

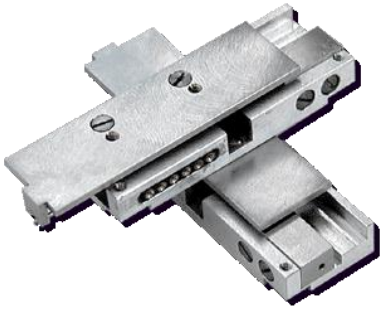


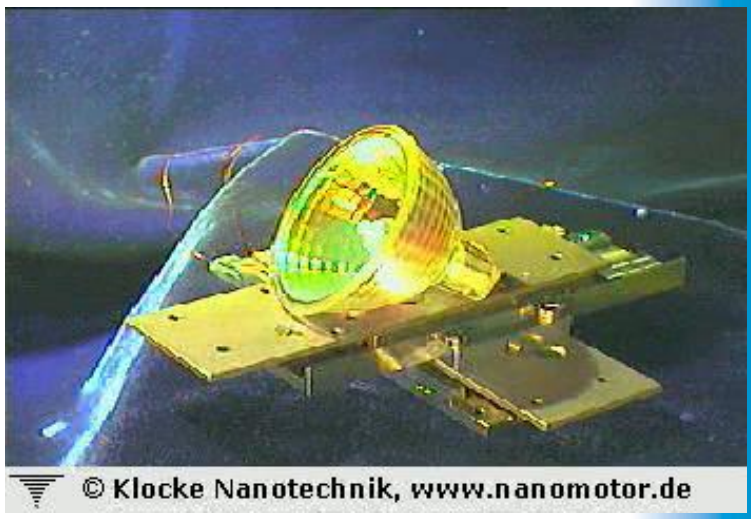
Nanorobotics





5 - 50 mm stroke
Loads up to 2 Kg
1 nm resolution
No backlash





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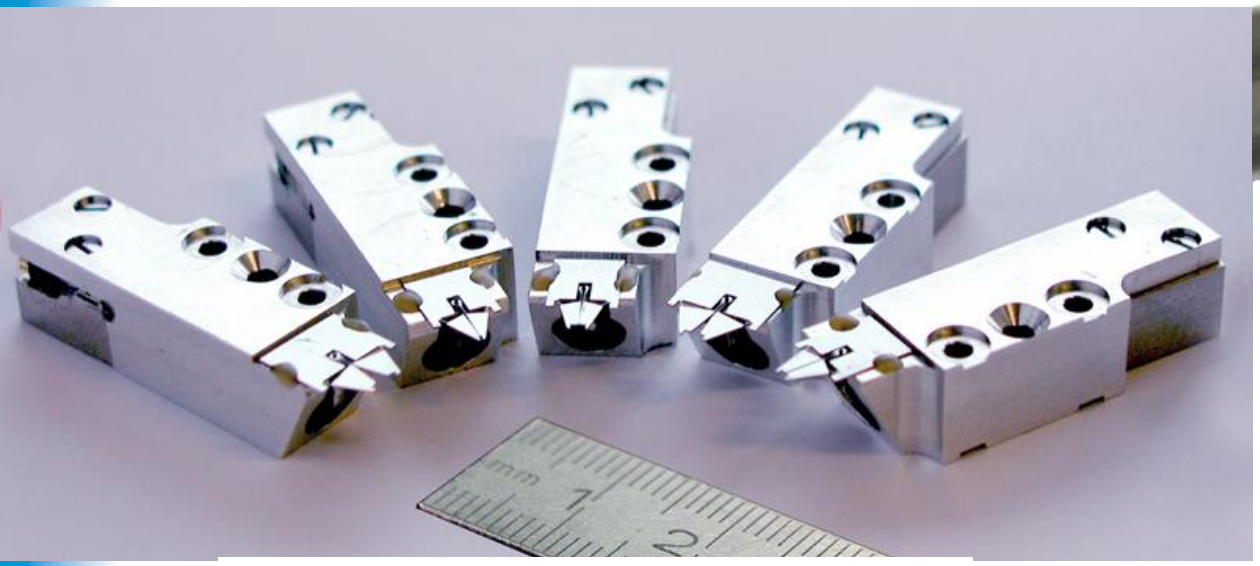
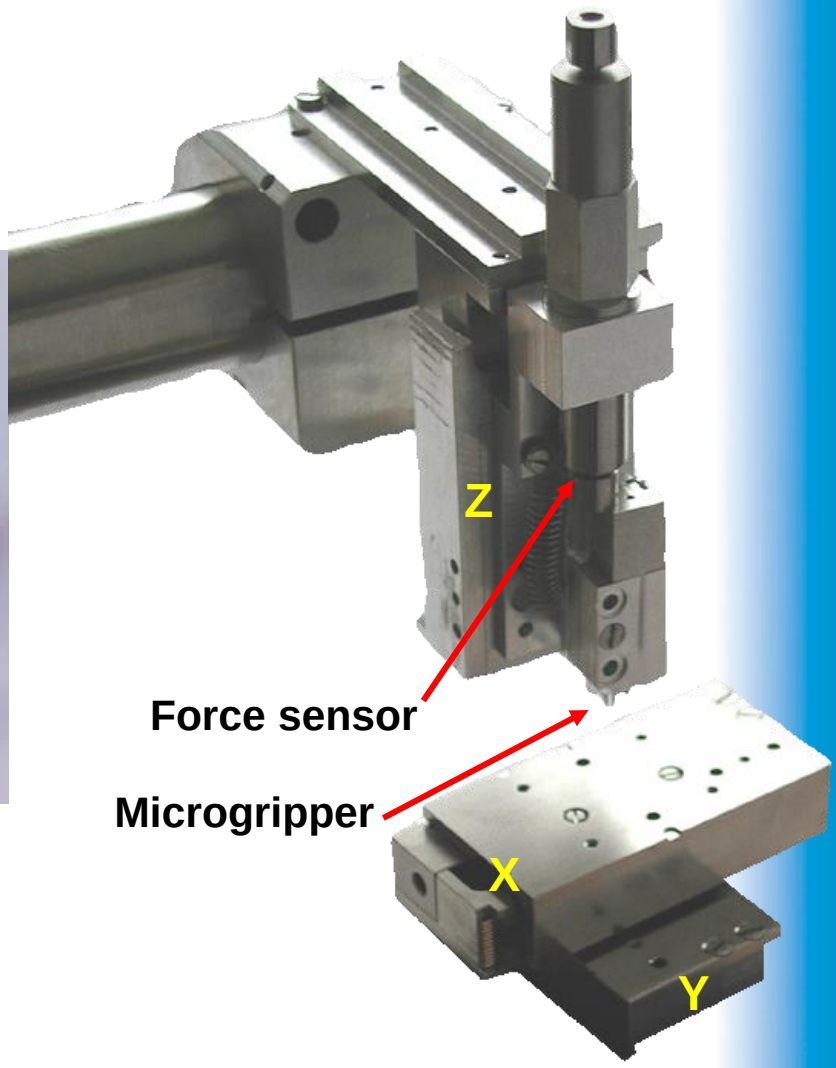
Microassembly-Module

with < 1 nm resolution



Microgripper with 1 nm resolution

and different tip shapes



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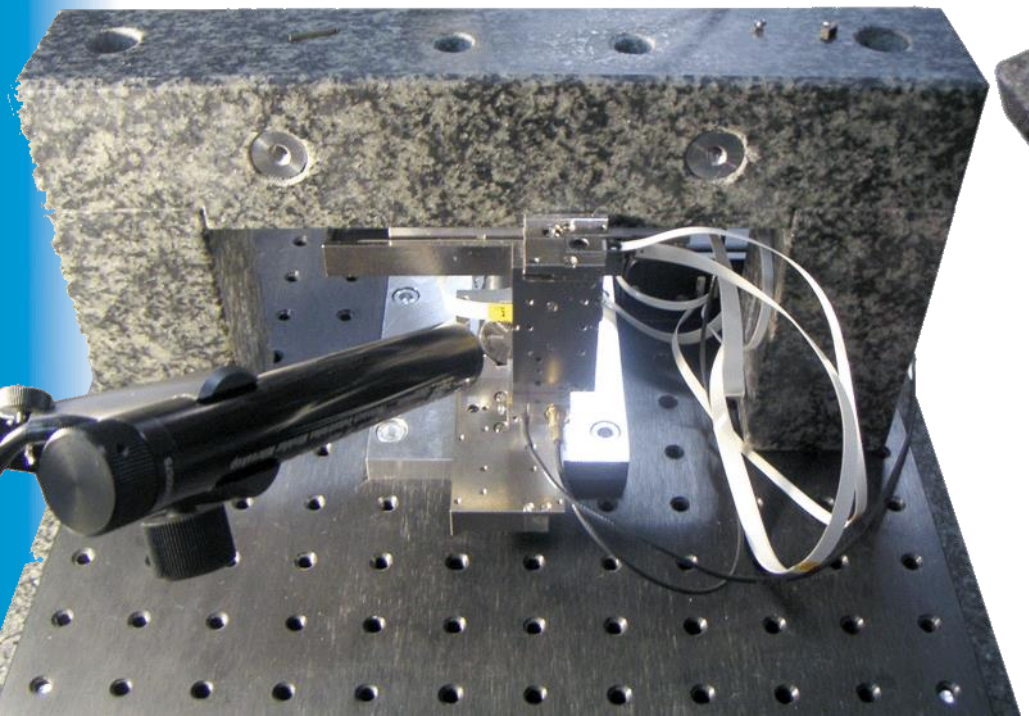
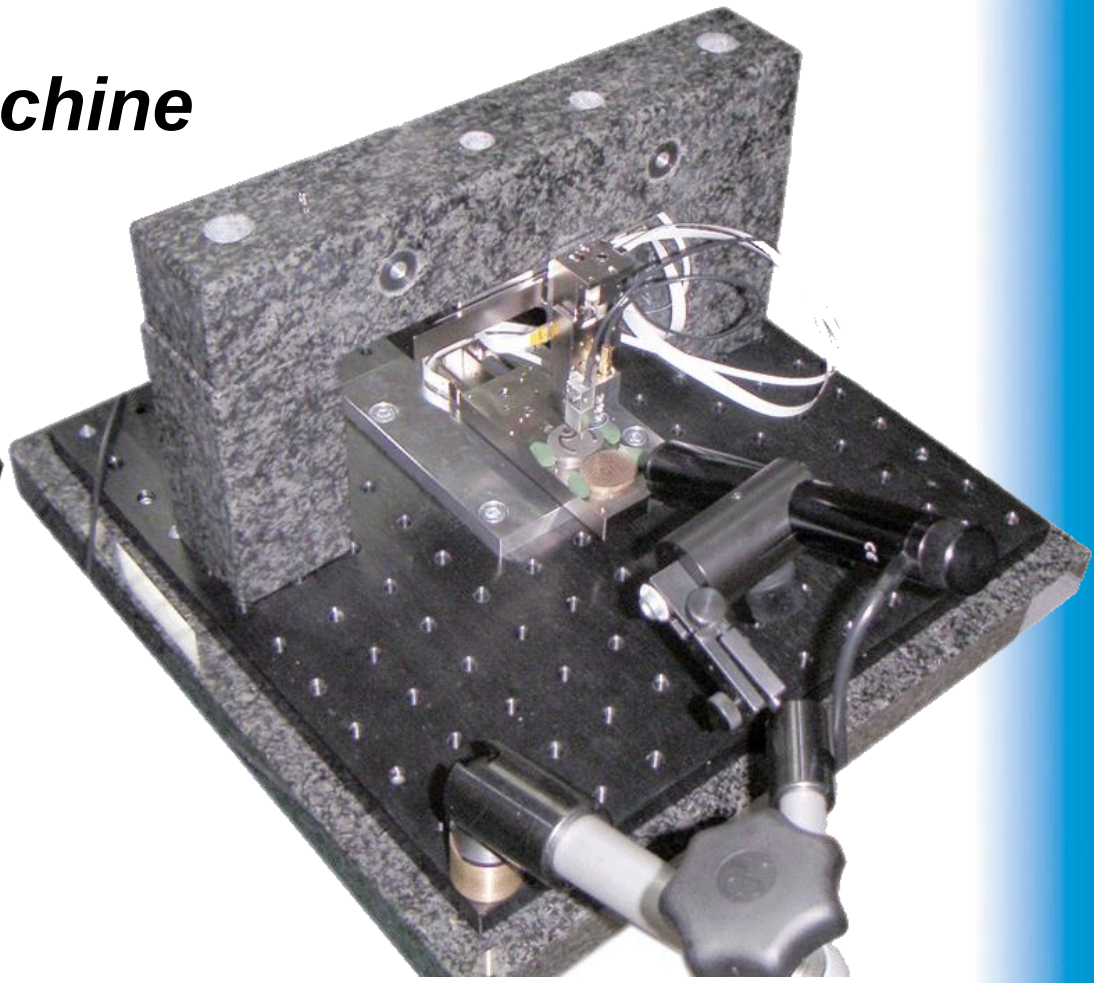
3D-Nanofinger®

A new instrument between Profilometer and Coordinate Measuring Machine





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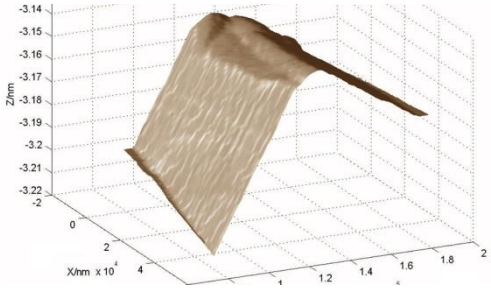
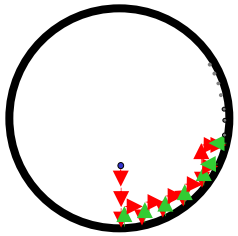
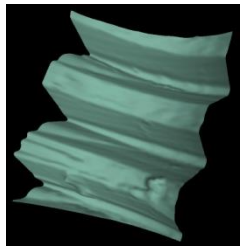
3D-Nanofinger®

•3D Topography

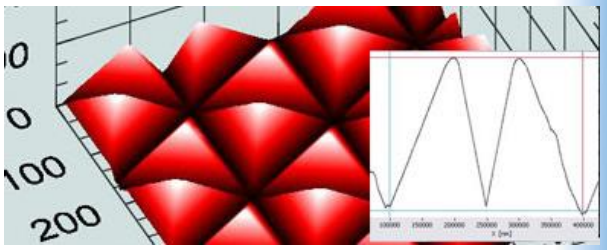


• Contours

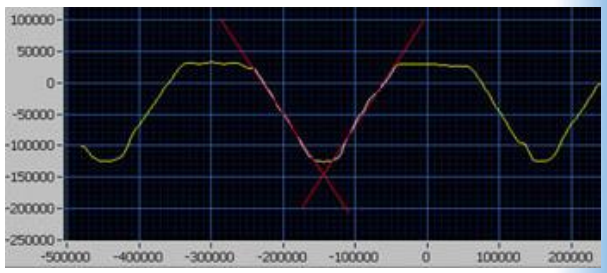




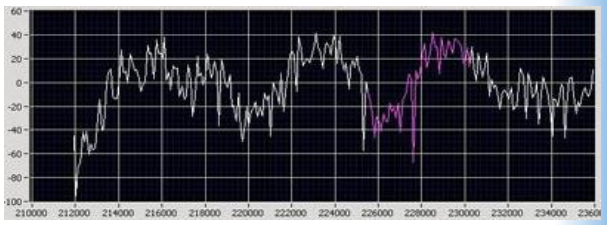
•Dimensions



• Angles



• Roughness



- **Stroke:**
  Up to 50 mm in XY and 20 mm in Z

- **Resolution of movement: 1 nm**
  Sensor resolution: 0.5 nm
  Smallest structure size: < 100 nm

- **Automation**

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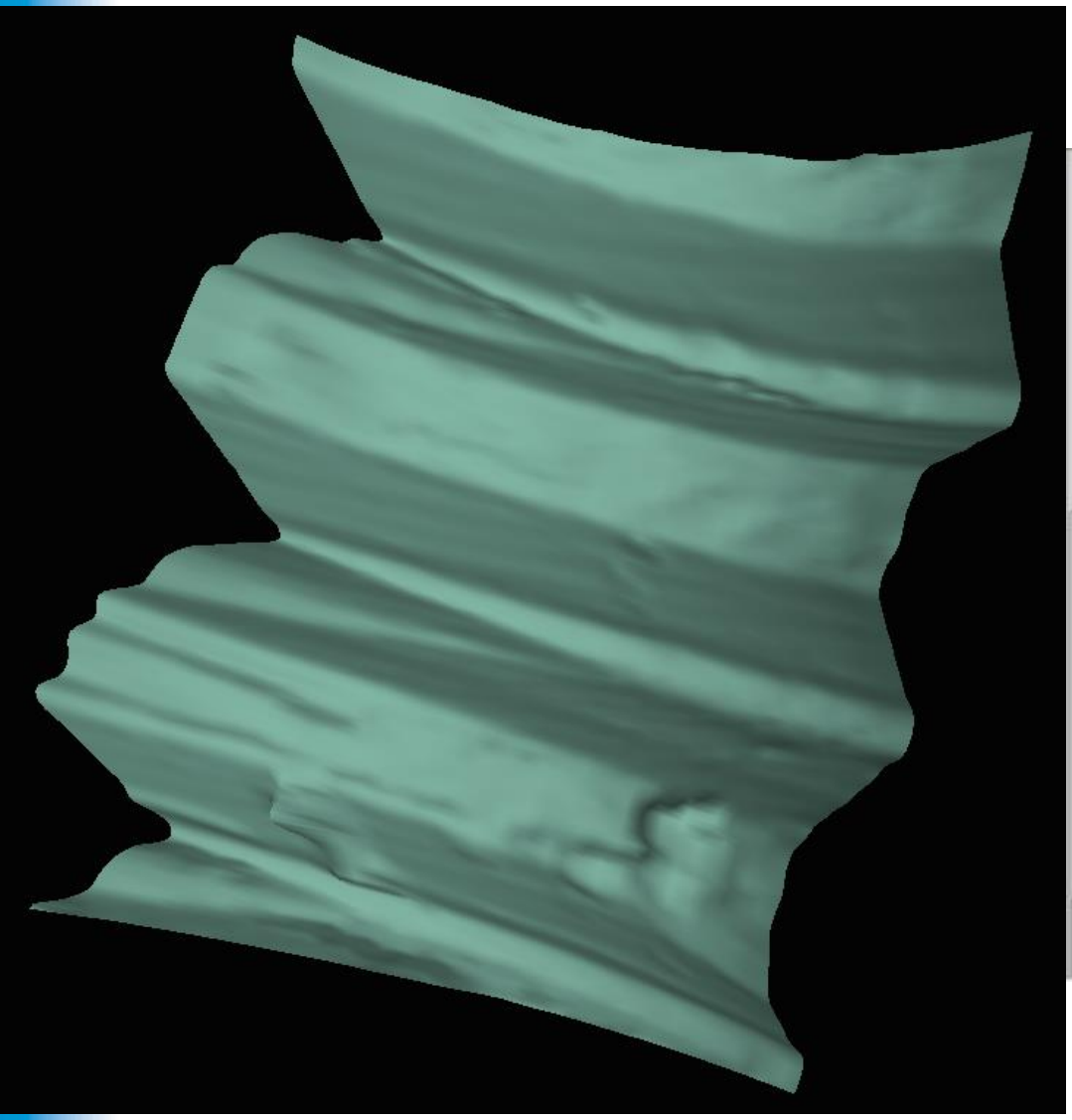
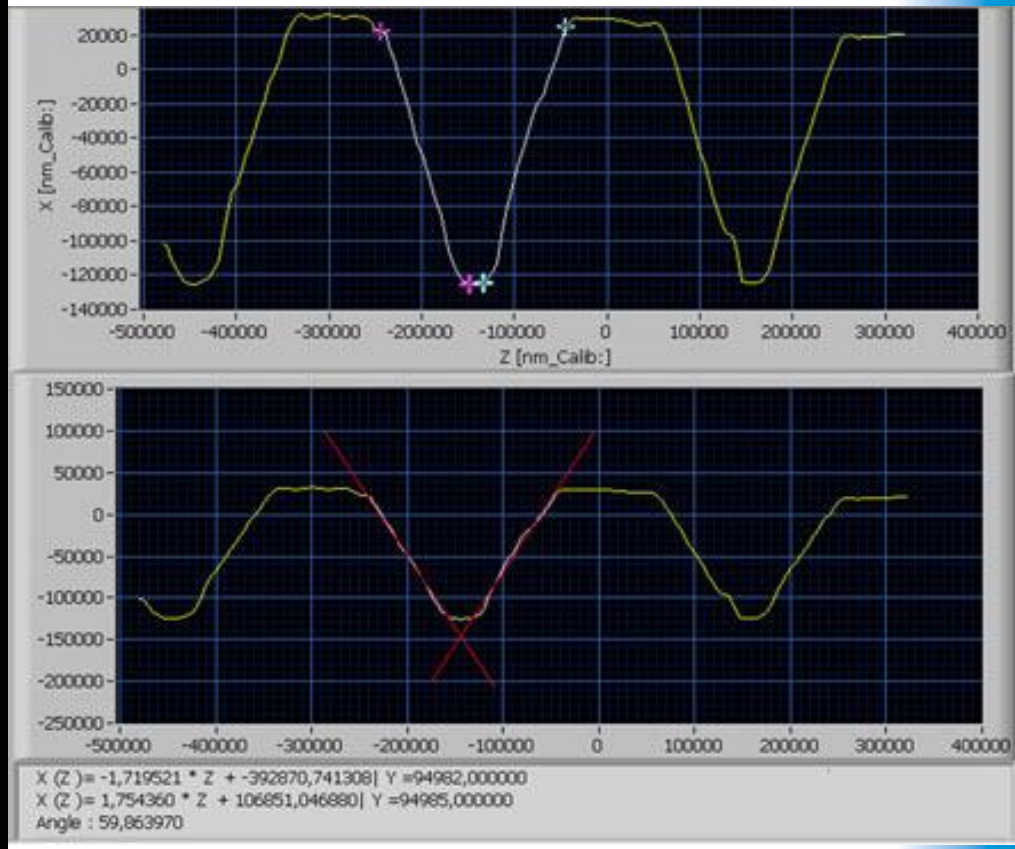
1 Example

Measurements in small holes



Internal screw thread with 1.4 mm diameter



Linescan to determine the winding angle

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The SEM-FIB Workbench

Handling in SEM/FIB, as easy as at a Light microscope:

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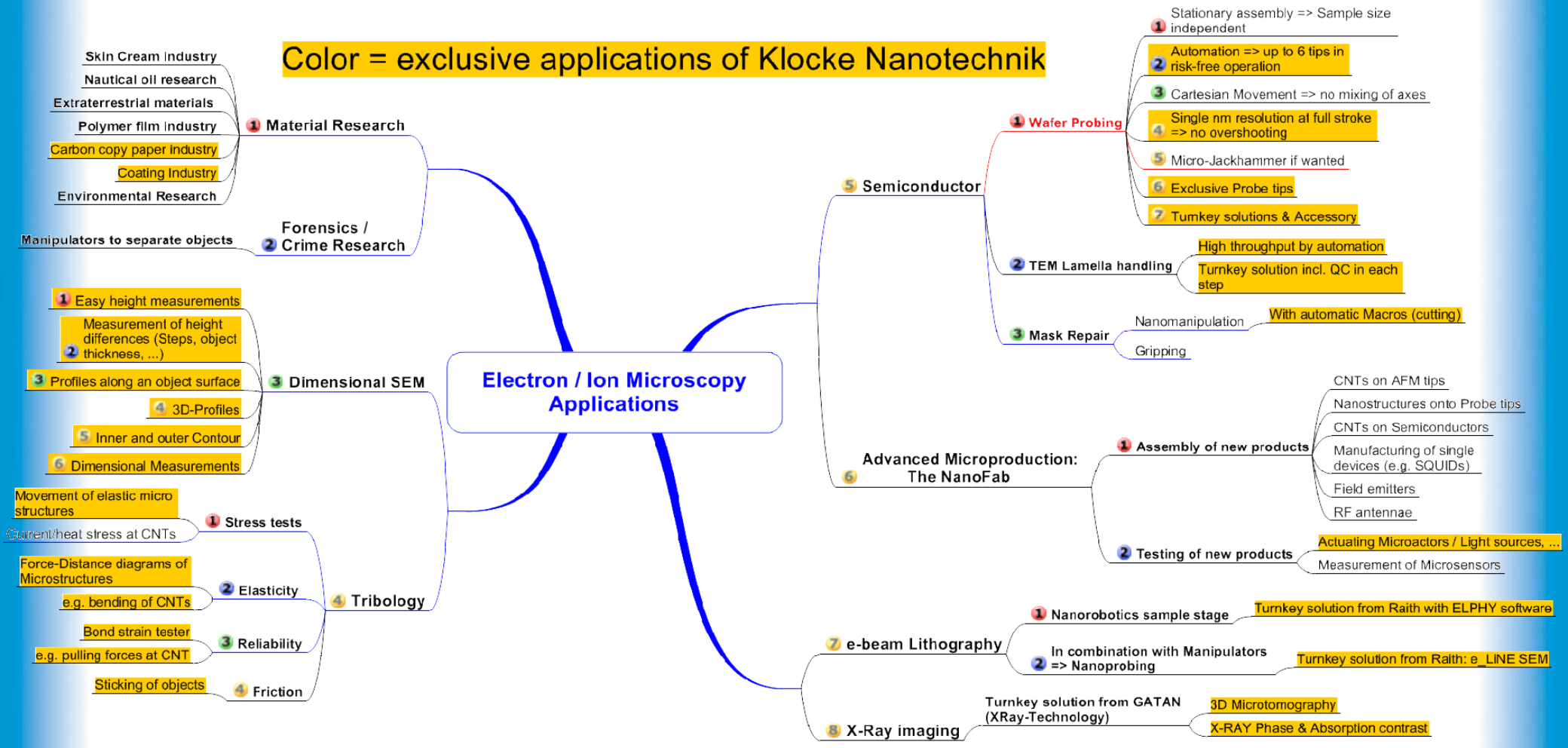
The SEM-FIB Workbench

Applications



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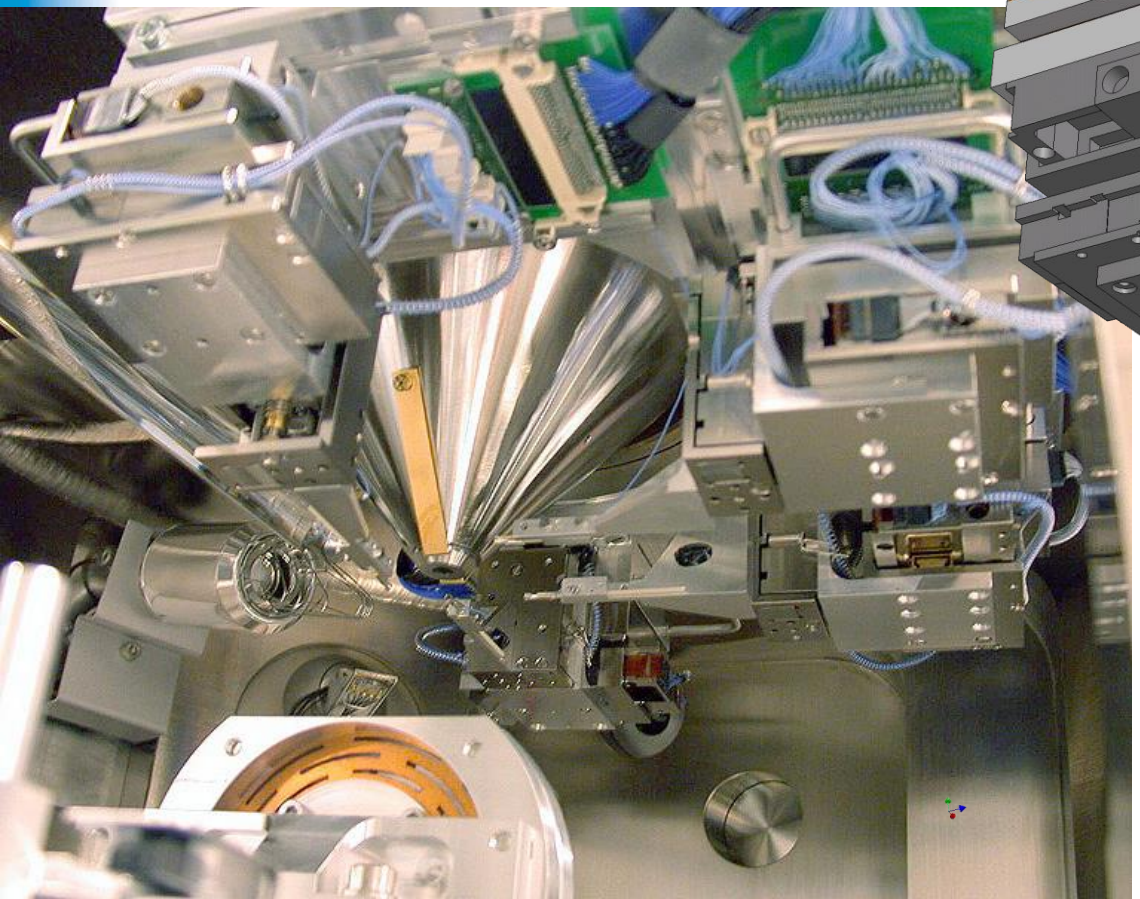
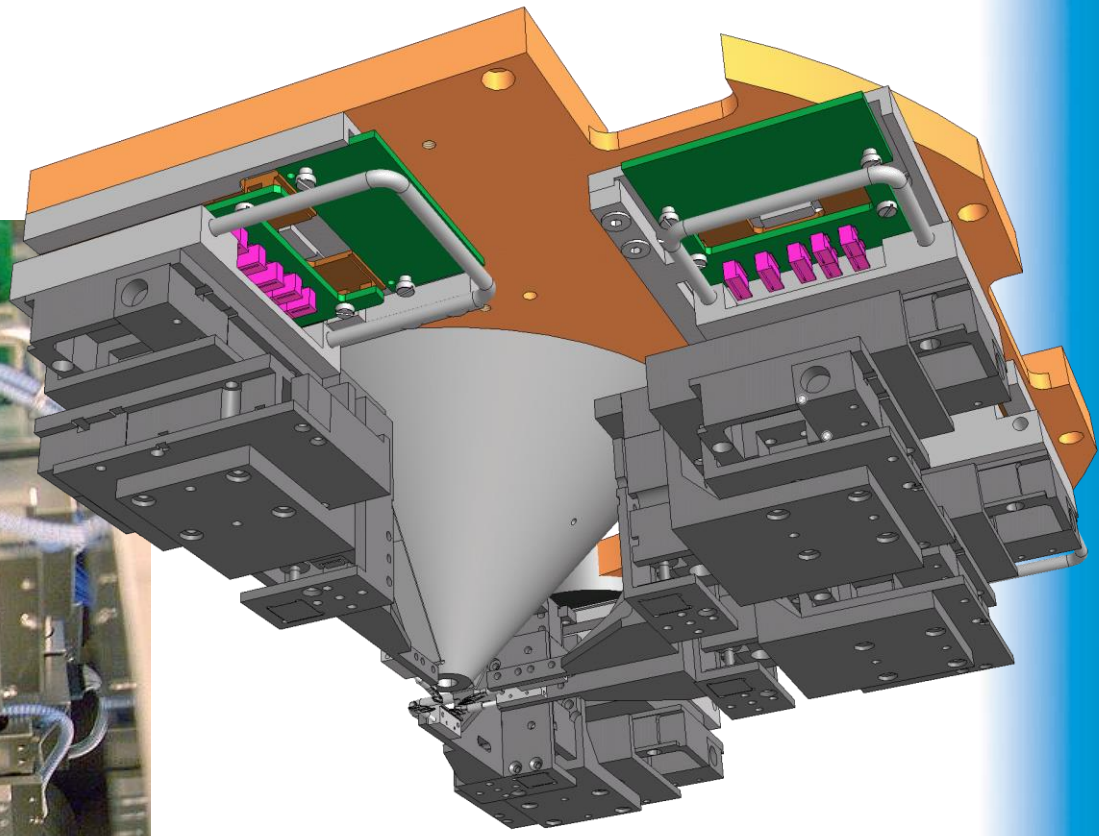
4 Nanorobotics Manipulators

Typical SEM-Integration





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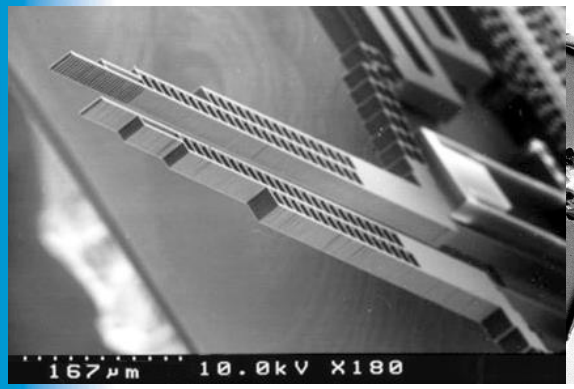
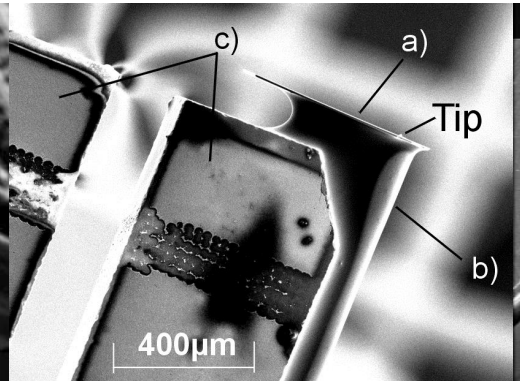
Proof of precision:

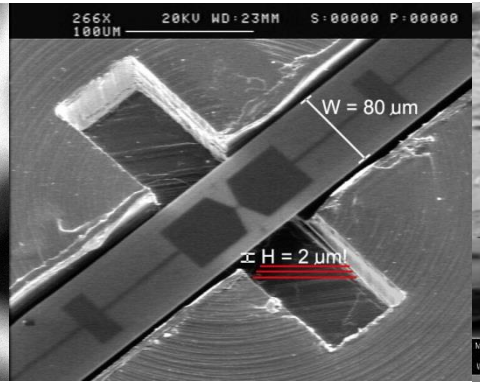
The in-SEM "NanoFab"

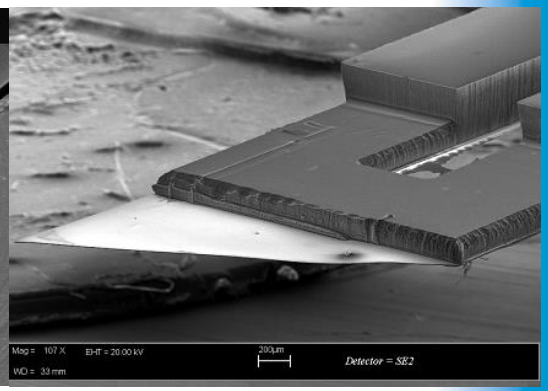
Automatic microassembly of smallest components

- Production of Carbon Nanotube transistors
- AFM tips sharpened by CNTs
- Production of GHz antennas …









The "NanoFab" from Klocke Nanotechnik in a network of partners:

NanoHand · OFFIS · Nascatec Nanoscale Technologies GmbH · EMPA Materials Science & Technology · Institut for Mikro- og Nanoteknologi · ST · csem · VDI|VDE|IT · EurExcel · TESCAN · EPFL École Polytechnique Fédérale de Lausanne · Klocke Nanotechnik · FUTUREtec Gesellschaft für angewandte Informatik mbH

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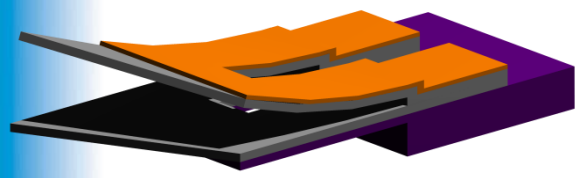
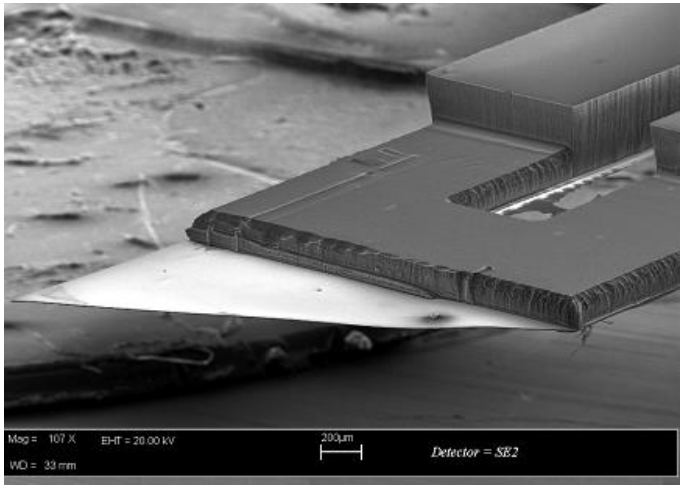
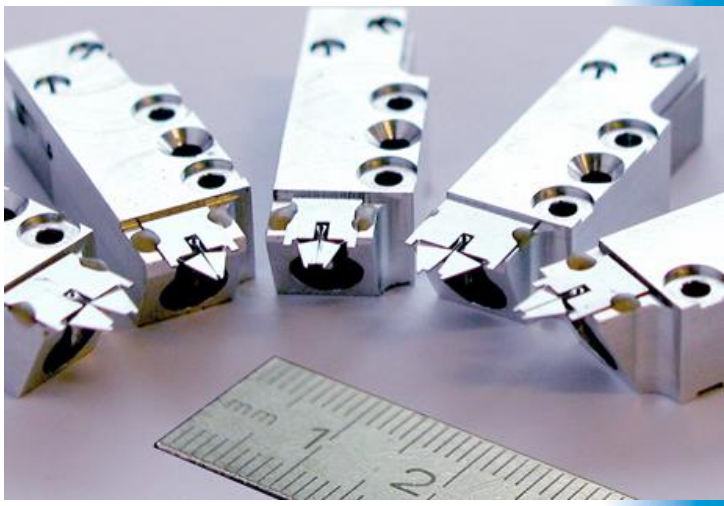
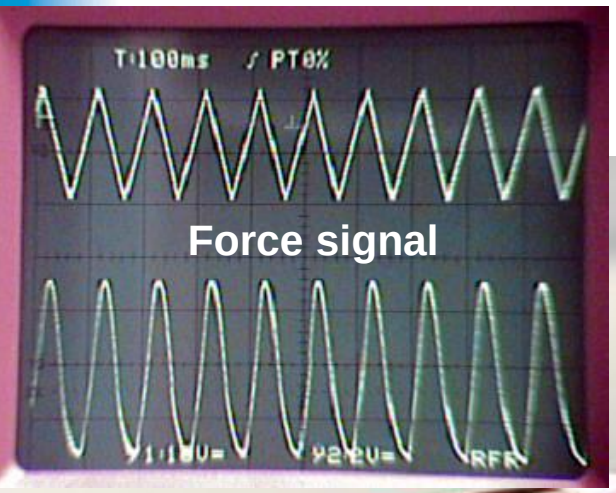
The “NanoFab” in your SEM

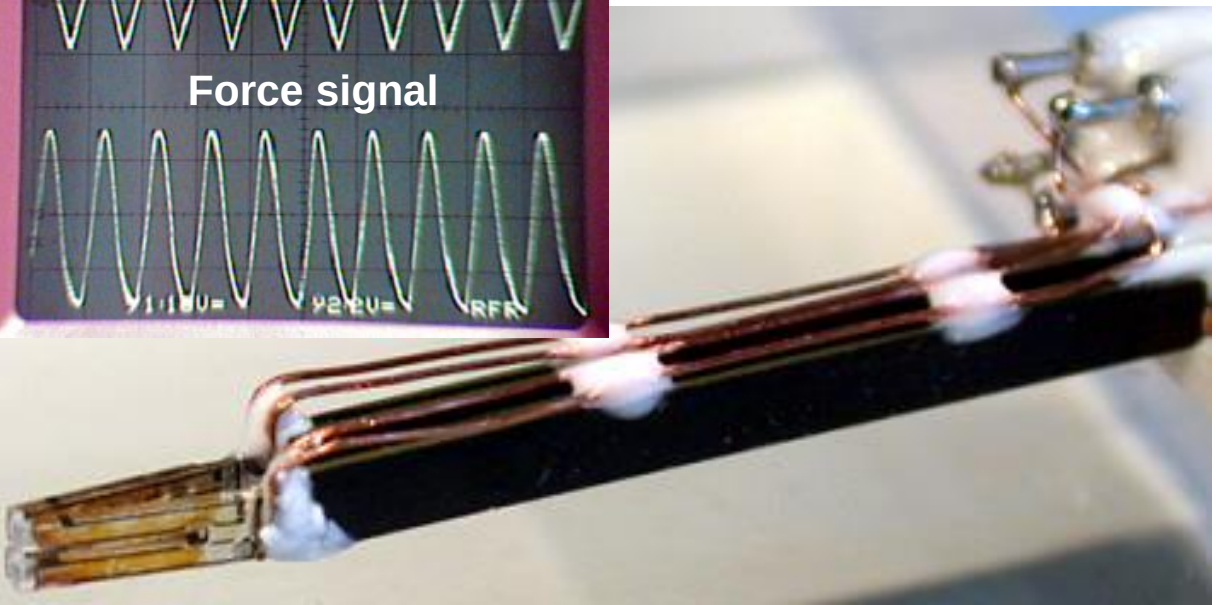
… including several different Microgripper series

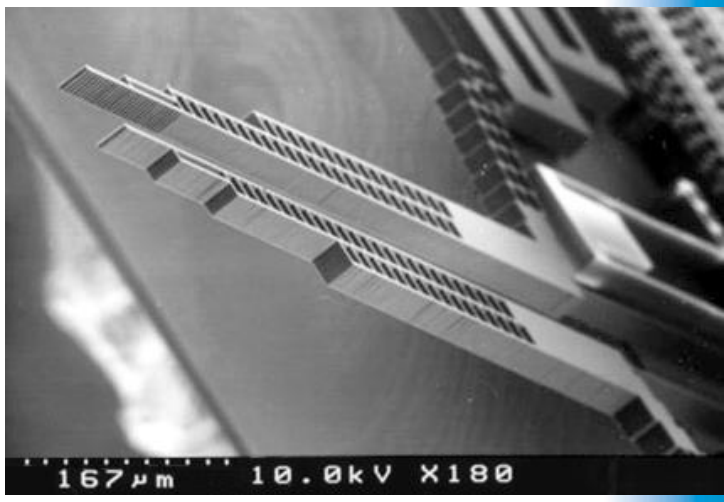












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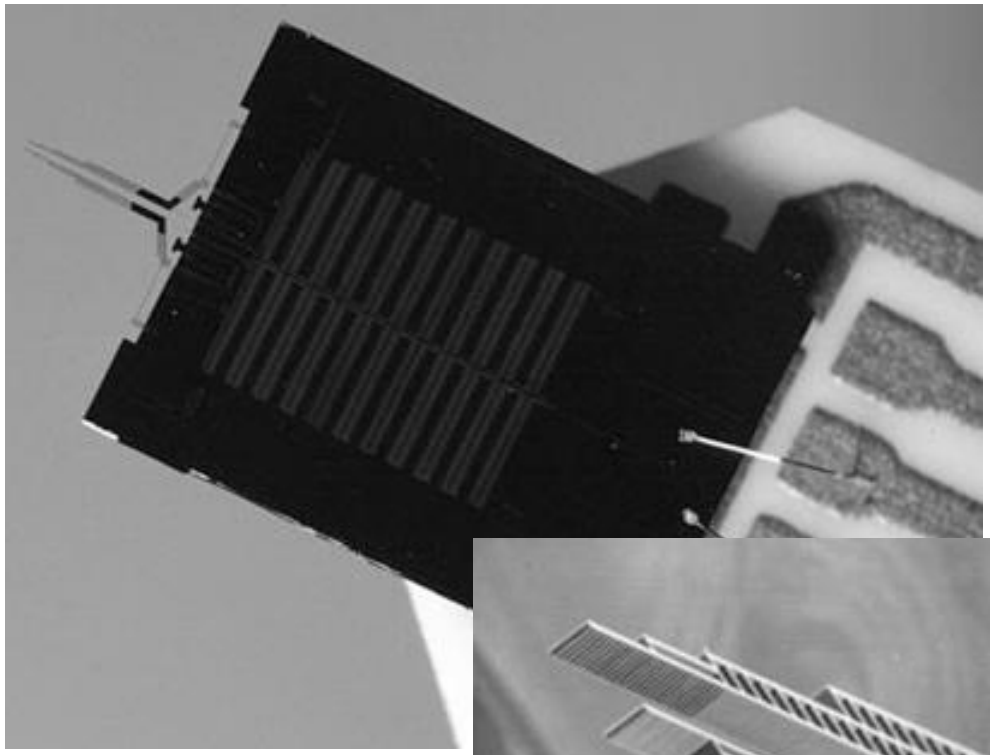
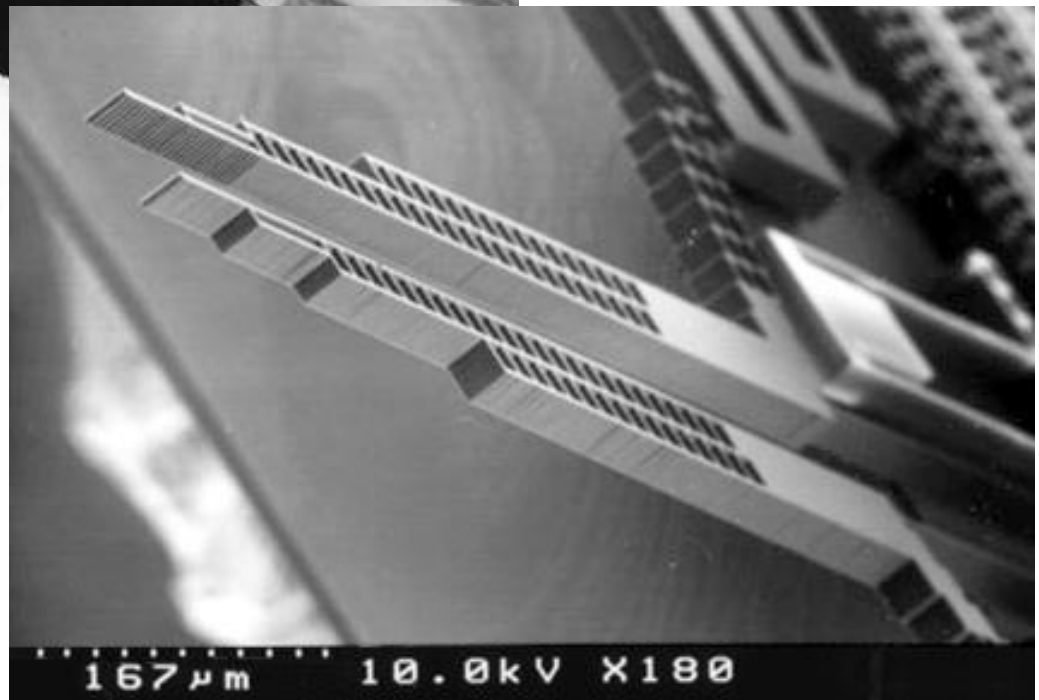
Electrostatic Gripper





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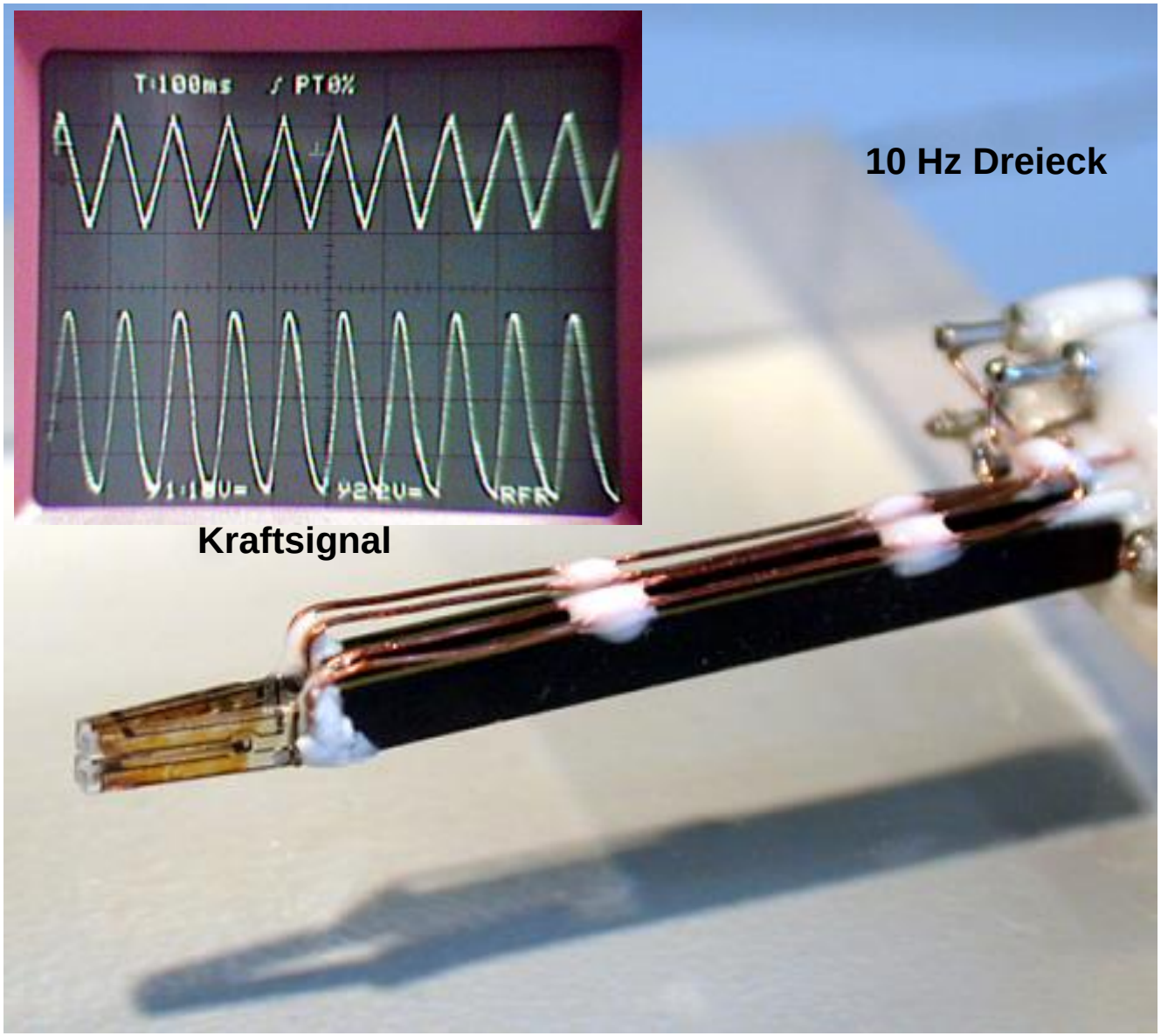
Force Feedback Gripper



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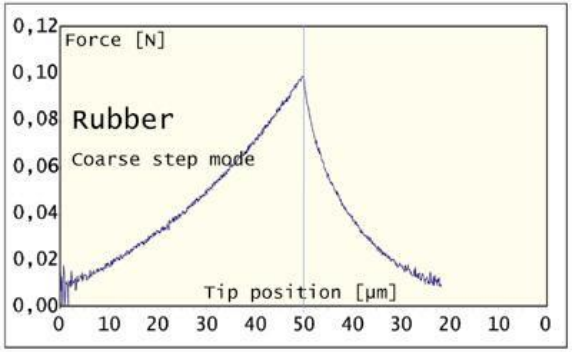
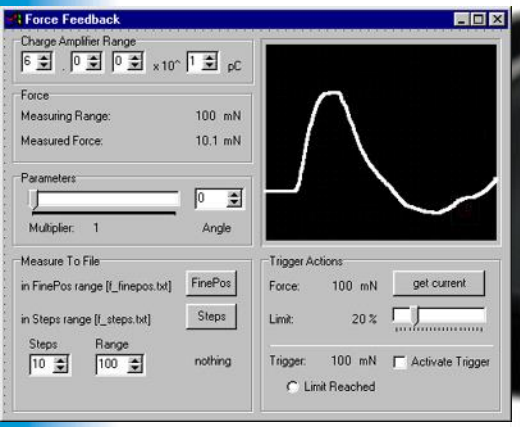
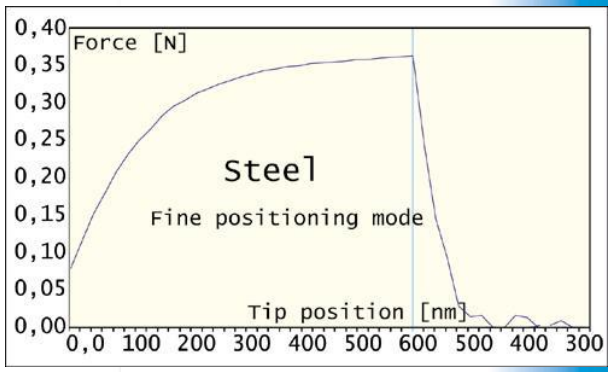
Force Measurement

Haptic interface







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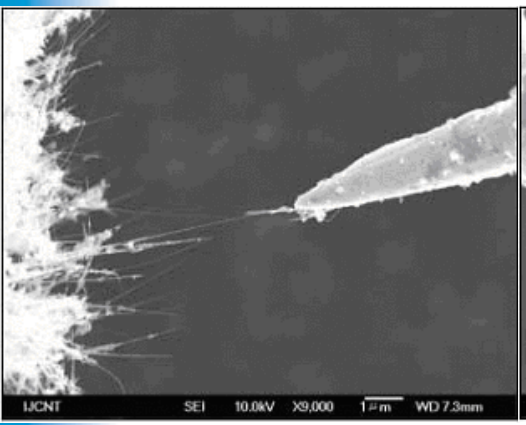

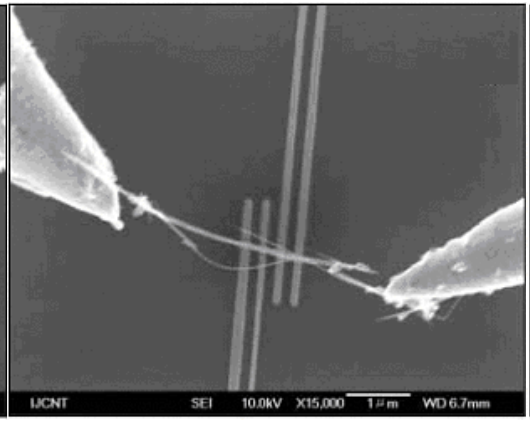

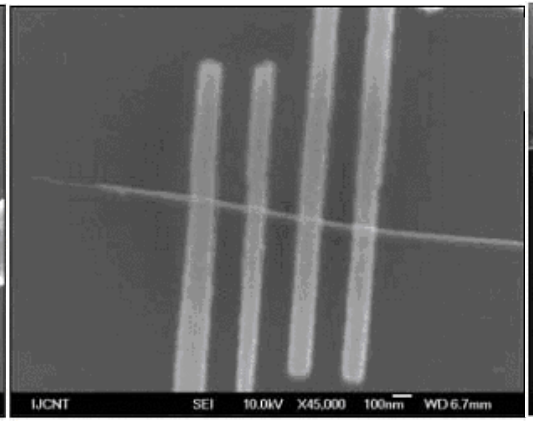

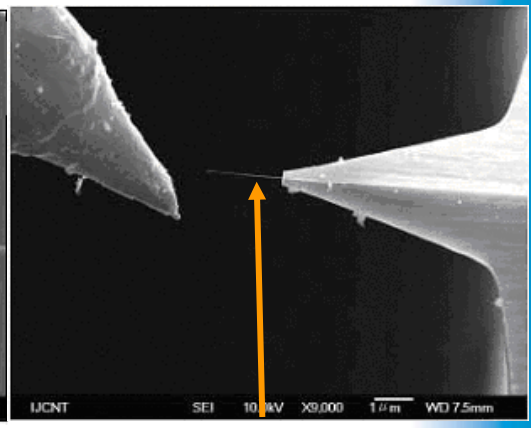

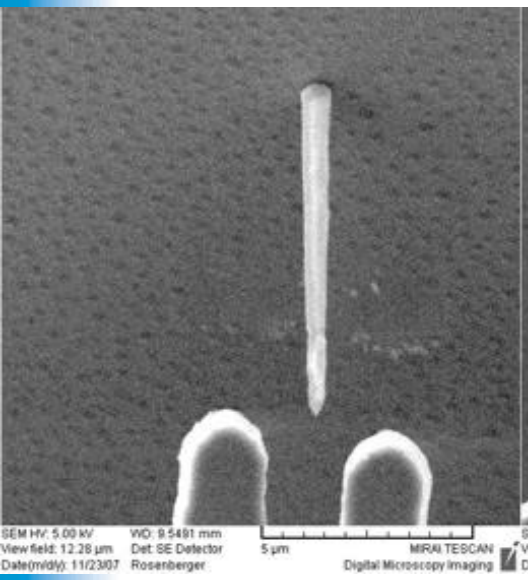

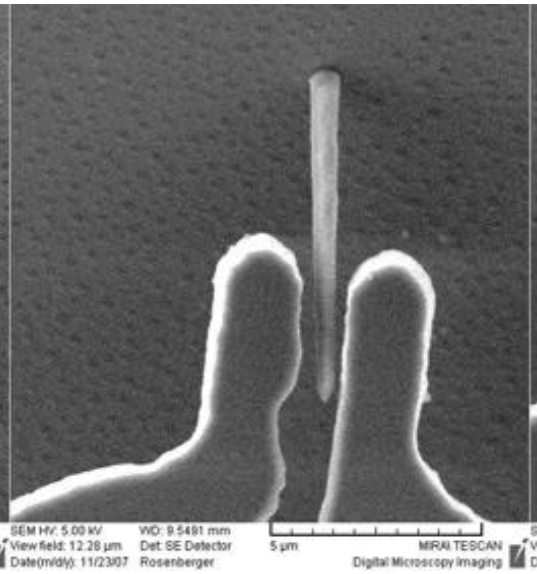

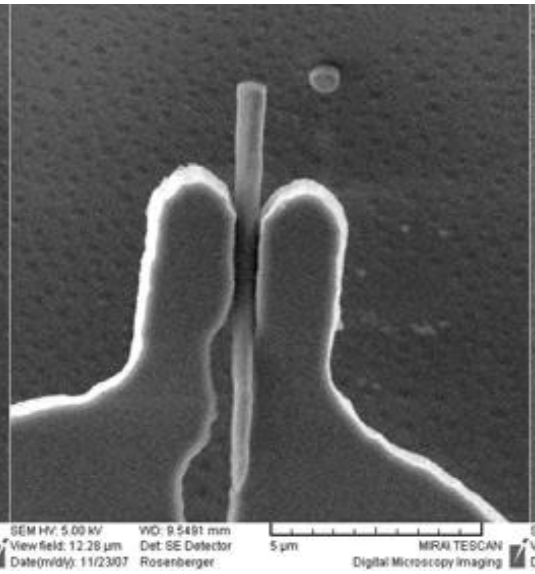

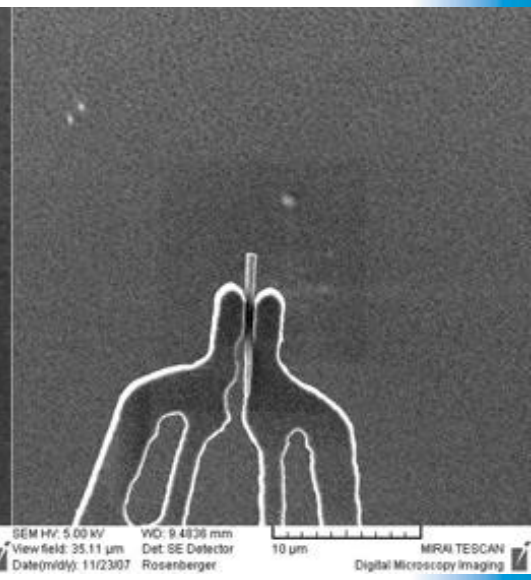

Nanoassembly of Carbon Nanotubes

Handling & assembly of a CNT with 2 manipulators

Assembly of a CNT at an AFM-Tip

Handling & assembly of a CNT with a microgripper

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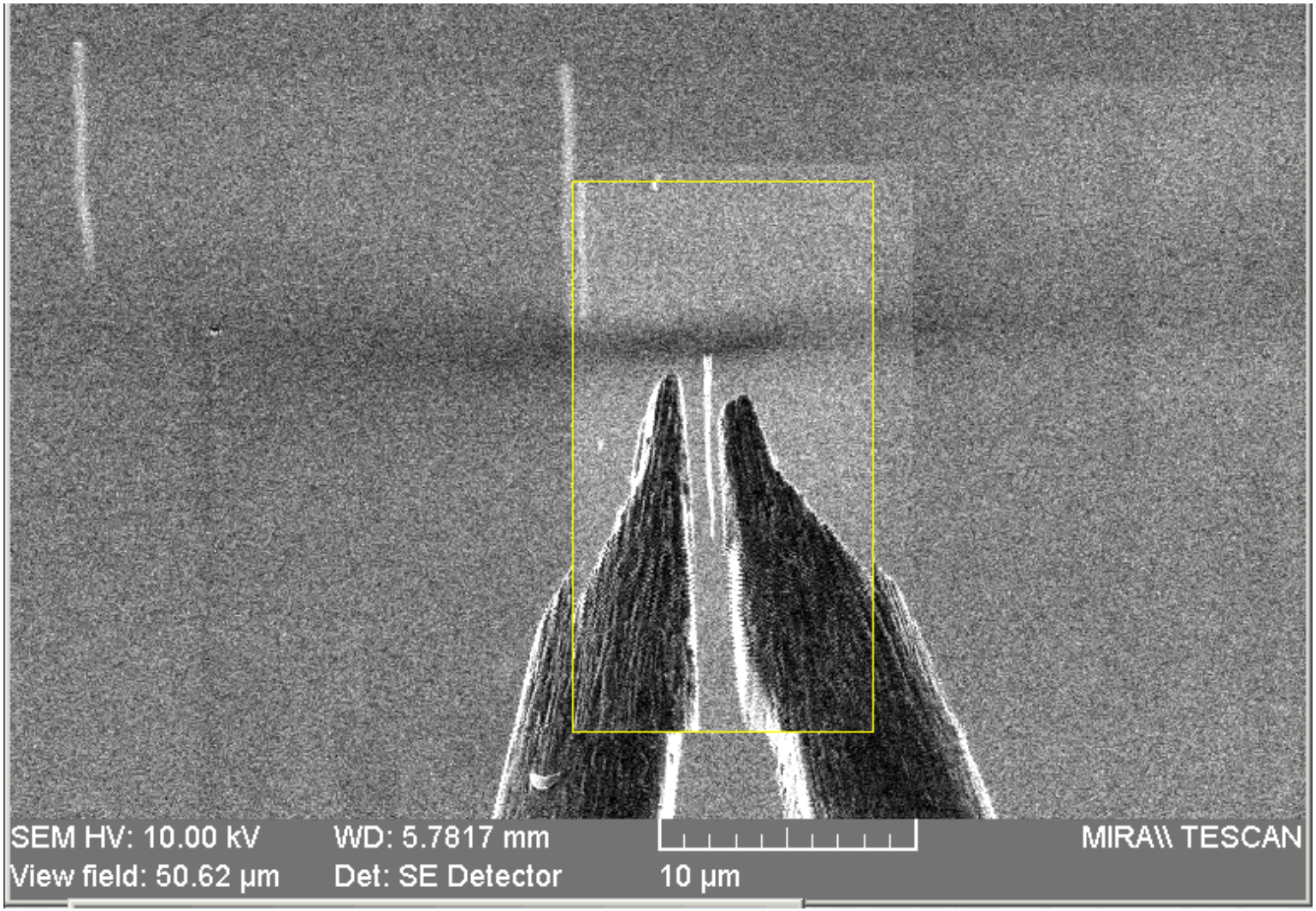
Particle sorting



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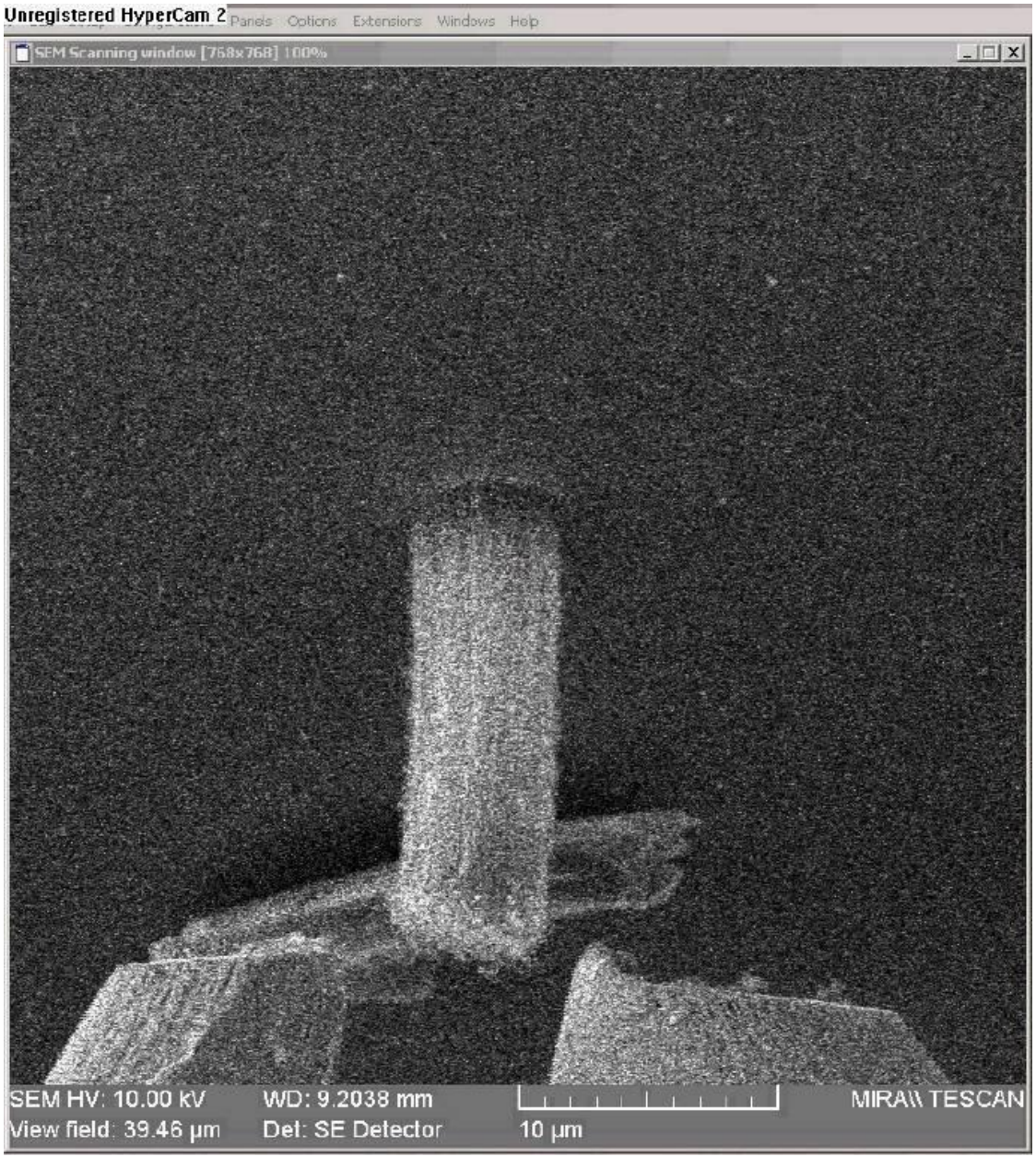
Particle sorting



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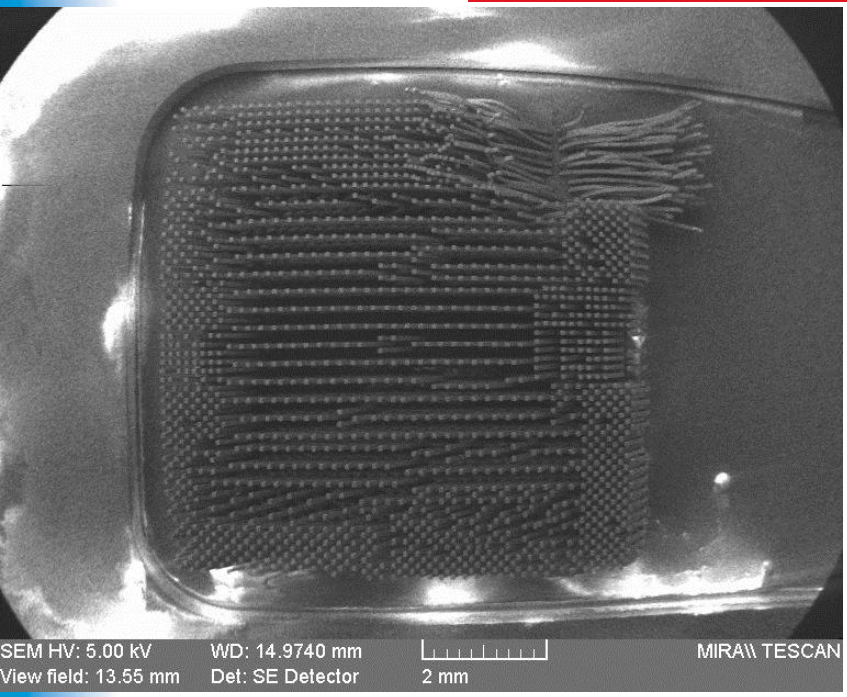
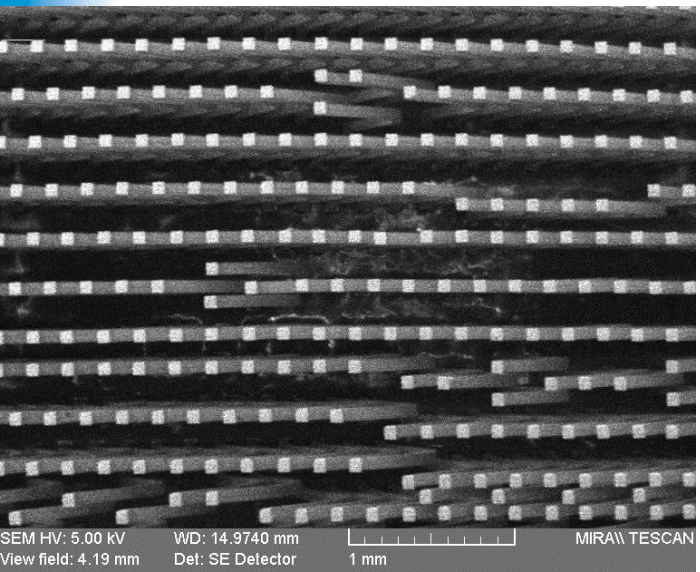
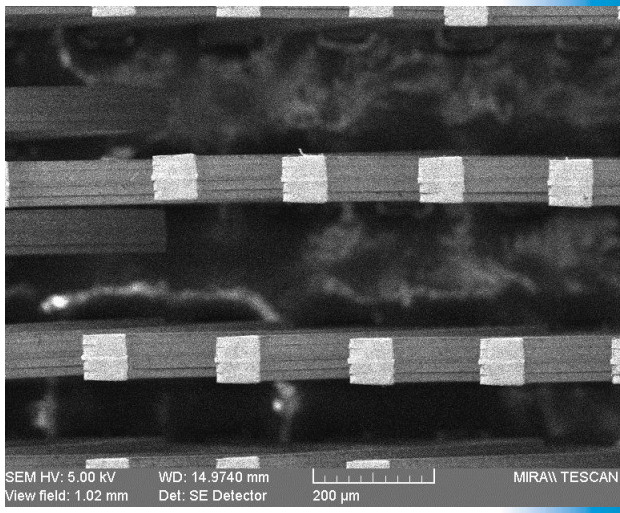
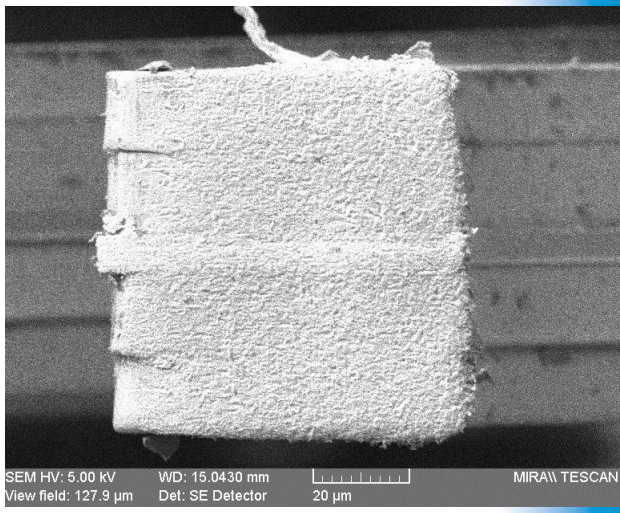
In-SEM development

Probe Card Repair









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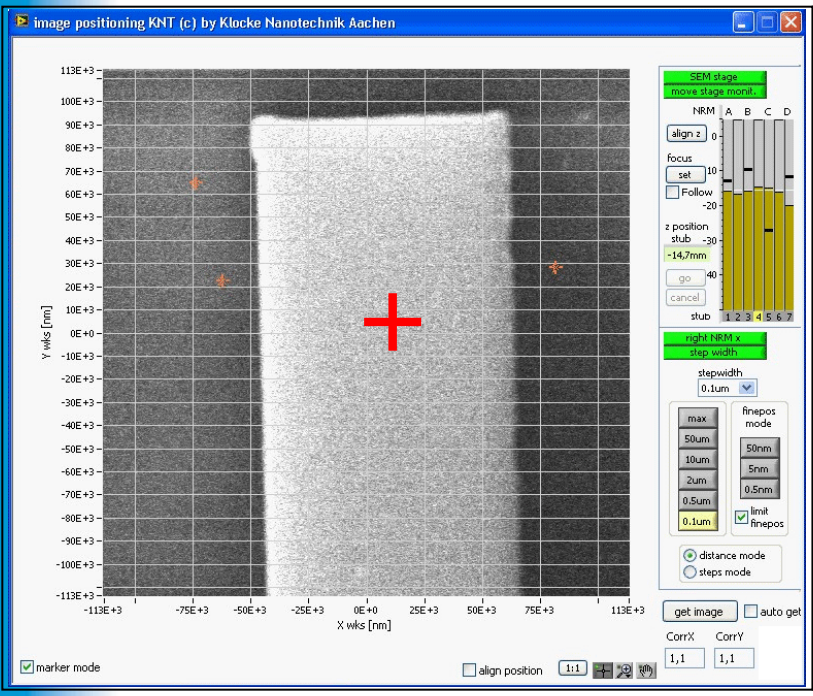
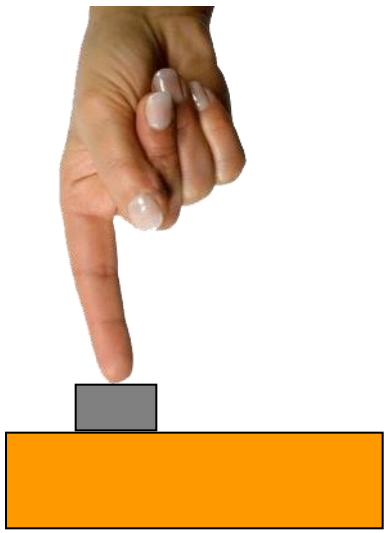
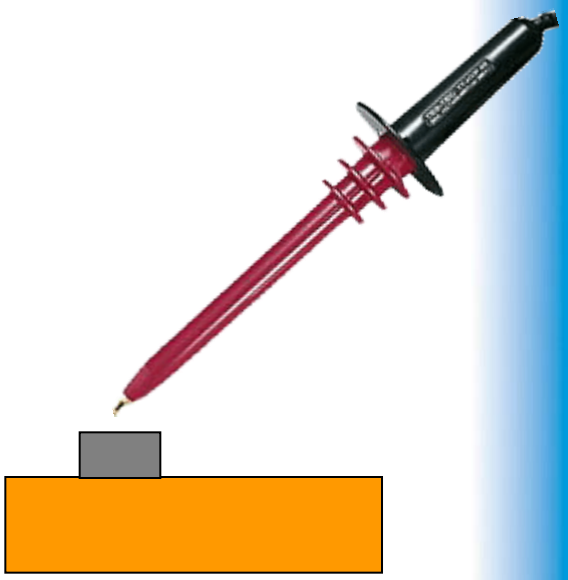
In-SEM development

Probe Card Repair







Live Image Positioning:

Select target

1D-Nanofinger®:

finds target, measures position

Tip:

bending tests

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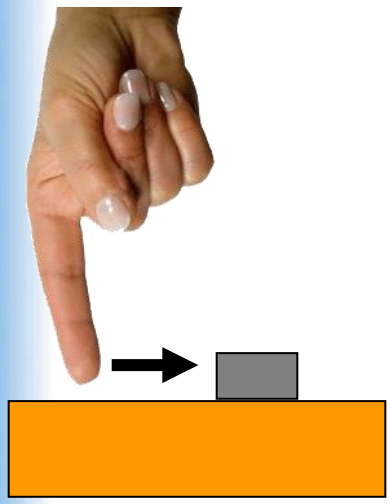
Nanotechnik

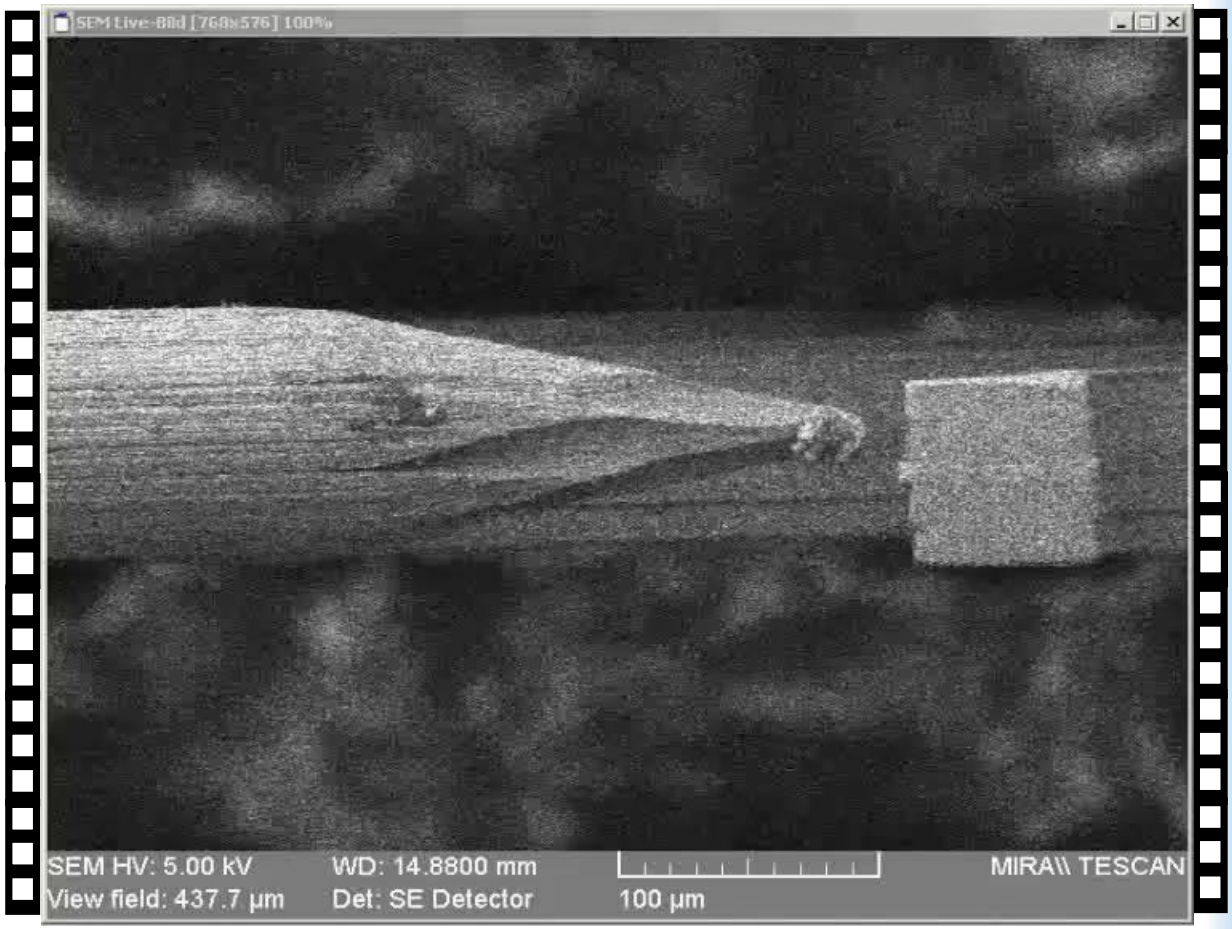
In-SEM development

Probe Card Repair



1D-Nanofinger®:

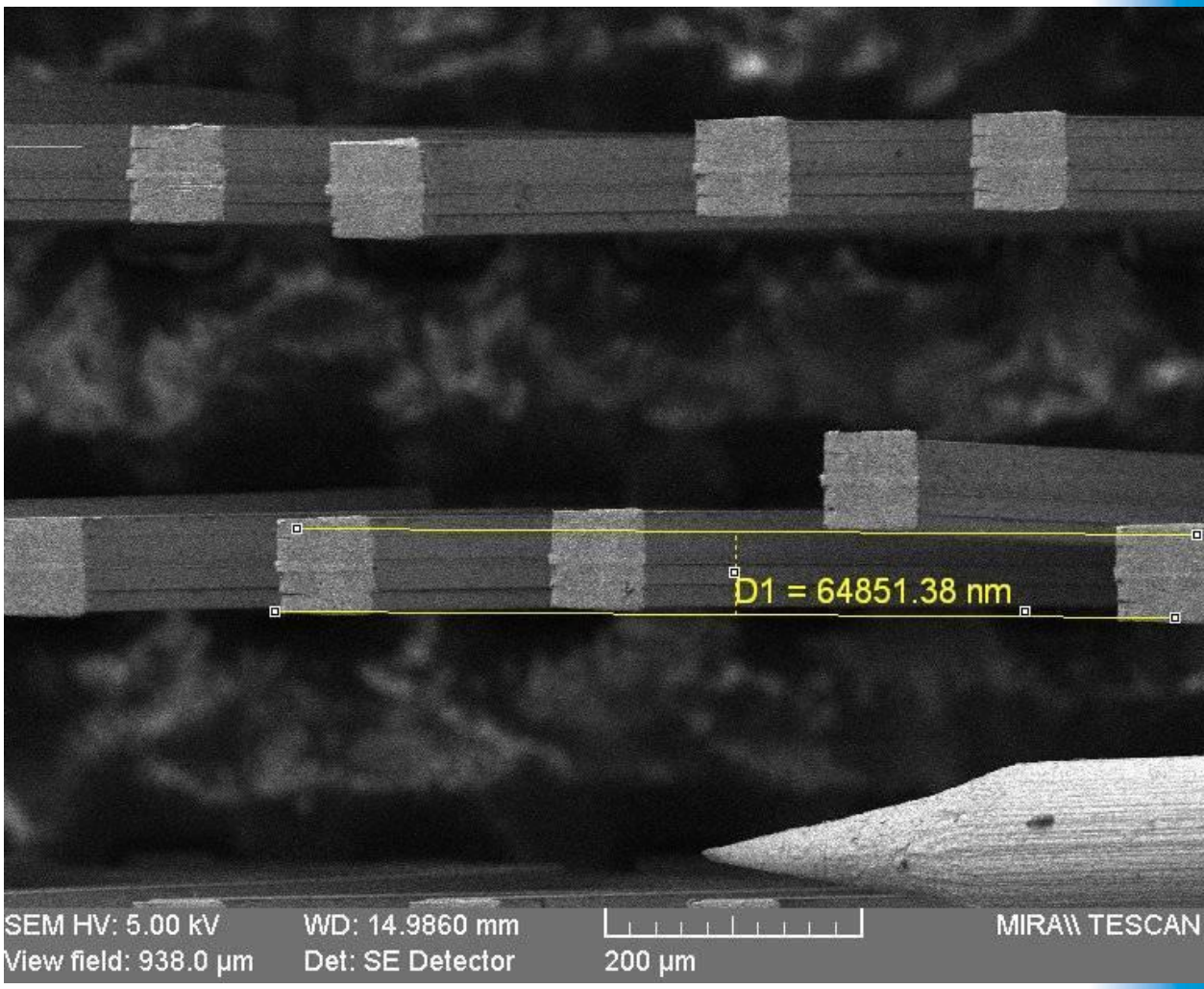
finds soft target



In-SEM development

Probe Card Repair

Bending Experiments



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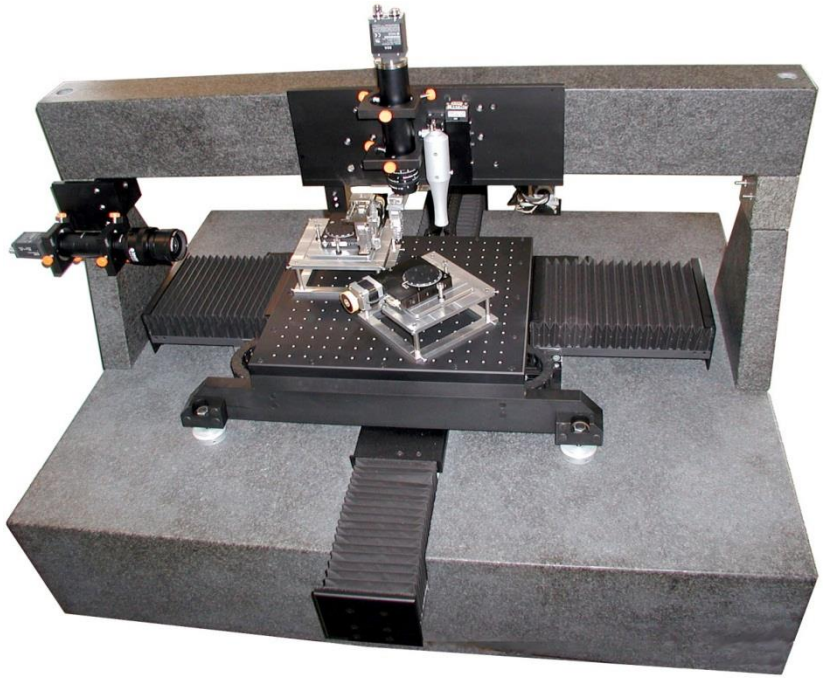
Micro Production Systems

The bridge between
Nanotechnology and mechanical
Engineering:



Production island with Nanometer-
resolution for up to Kilograms of load

Operation modes:

- Manual mode with Joysticks
- Automatic functions & manual operation
- Completely automatic process
- Closed loop process with vision control

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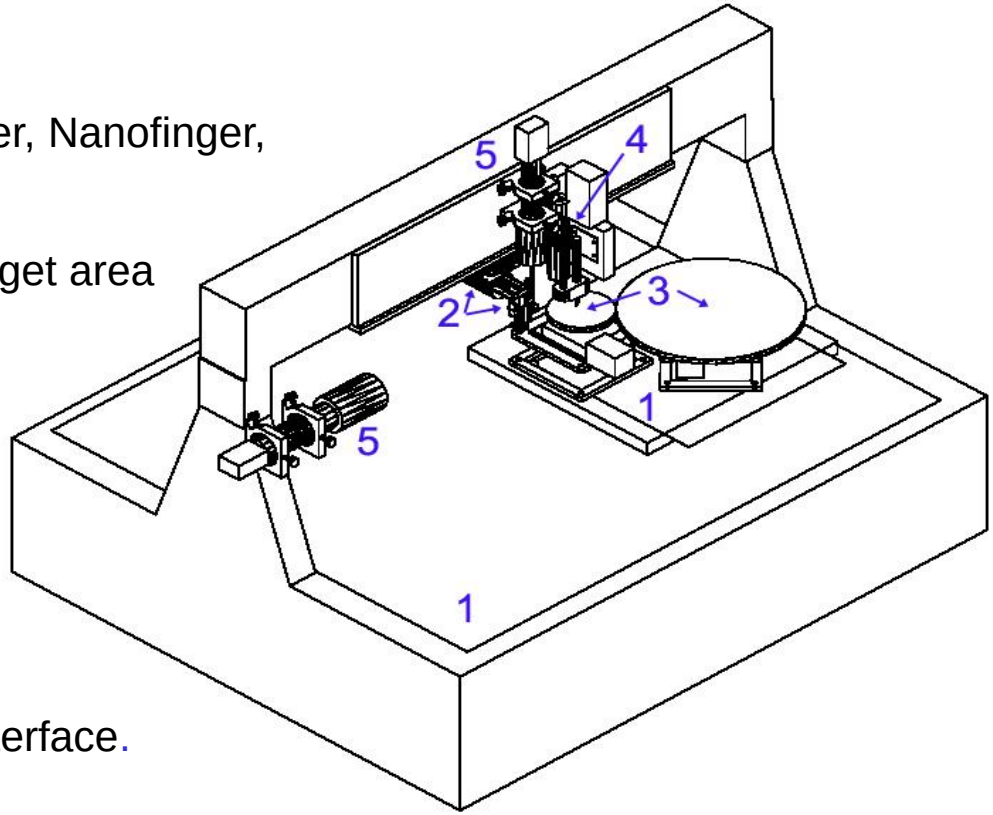
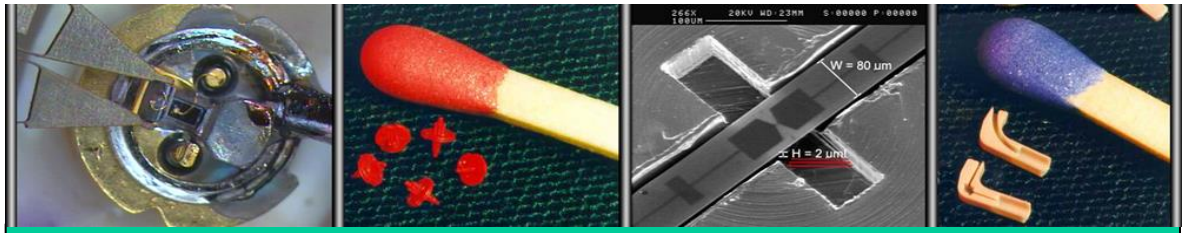
Principle

of setup

1. High precision xy-stage
2. Nanorobotics modules [2], microgripper, Nanofinger, Wafer Prober, ...
3. Two rotation stages for source and target area
4. Adhesive dispenser, Nanomanipulators, Scanning Probe Microscopes, MicroProf®
5. Video cameras with vision software for pattern recognition
6. Process control with graphical user interface.





Laserdiode, Zahnrad mit Welle, HF-Mischer, Sensorgehäuse

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Flexible System Configuration

From Nanomanipulator with Gripper up to:

The most precise production cell available in the market:

- **3D Microassembly and interconnection technology, e.g. including:**
- **Micro Adhesive Bonding, Pattern recognition and Quality Control**

... or a "Universal Testing Bench":

- **For analysis, quality control, reverse engineering, prototyping and repair, incl.:**
- **Nanomanipulators, Wafer Prober, Force Sensors, Inspection Systems for:**
- **I/V or force measurements, failure analysis, prototype development or repair**

... or both, configured by yourself:

- **Choose components out of a wide range of our kit, we deliver that special system.**
- **Change and add components later as you like**

In any case:

- **It's 10 – 100 times more precise than other solutions!**

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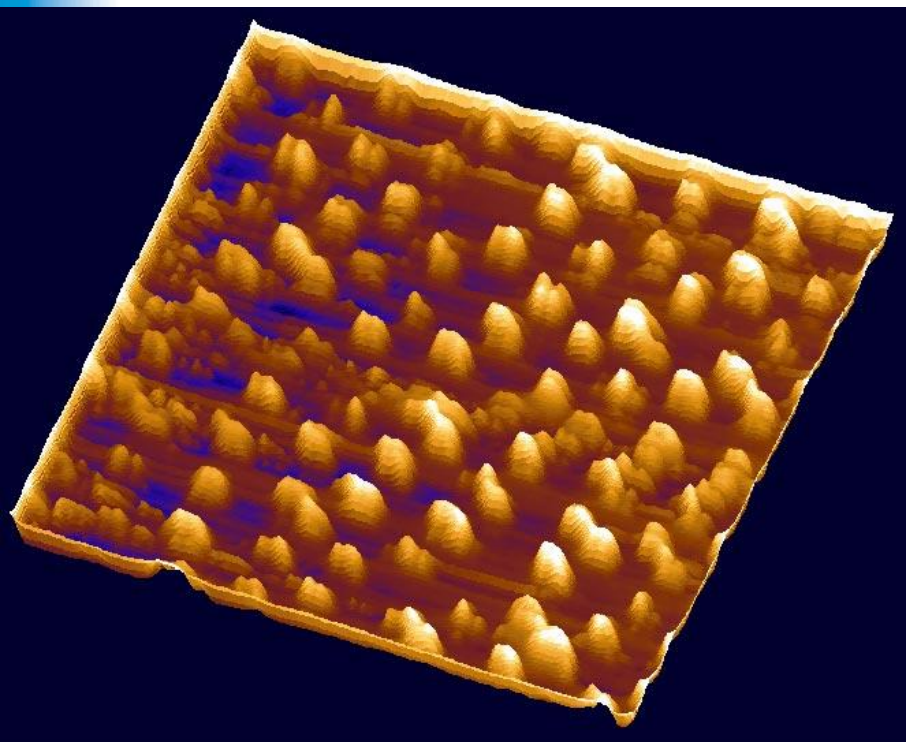
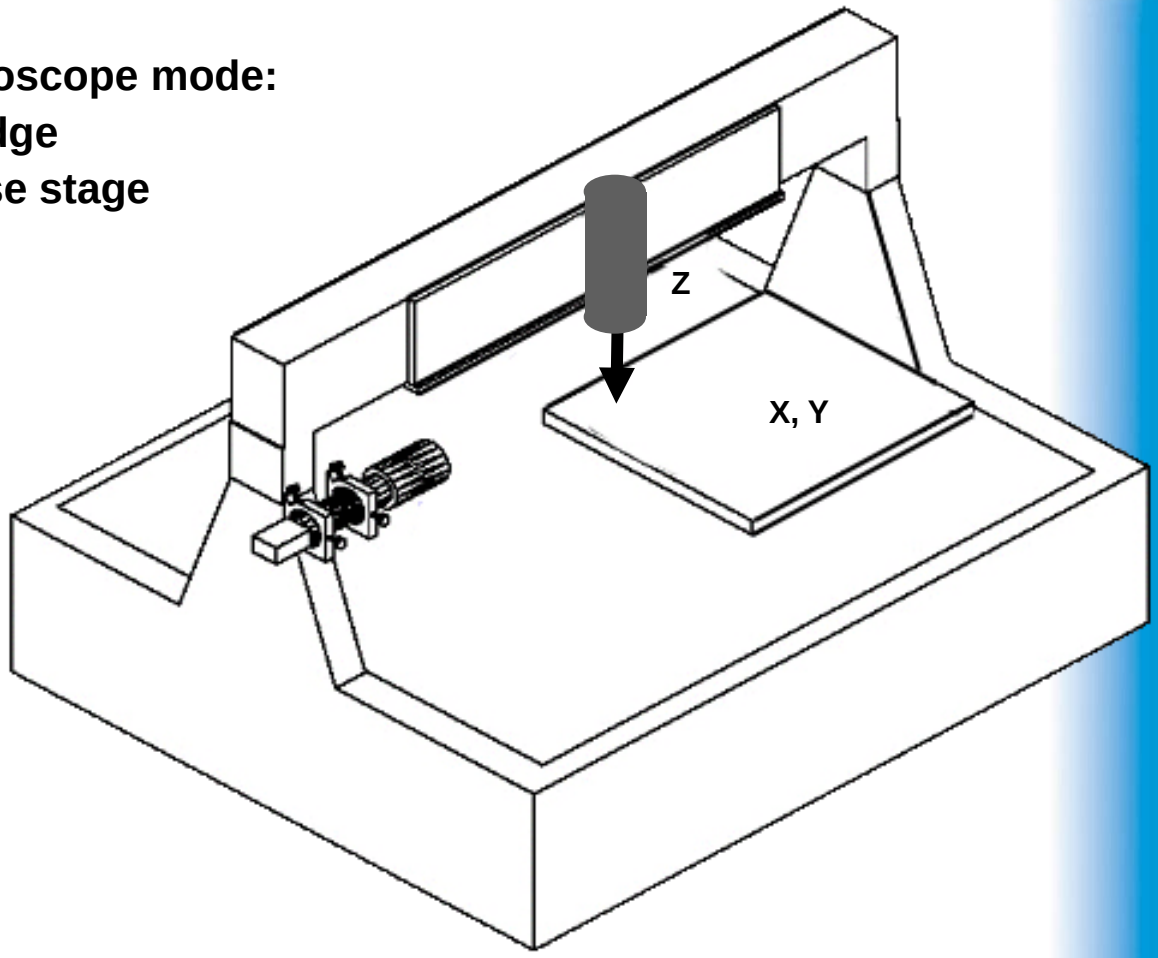
Resolution of the Base Stage

Test in Scanning Tunneling Microscope mode:
Z-axis of an STM fixed at the bridge
XY-movement made with the base stage

=> 3D image of CD bits





Noise in the image: about 50 nm!

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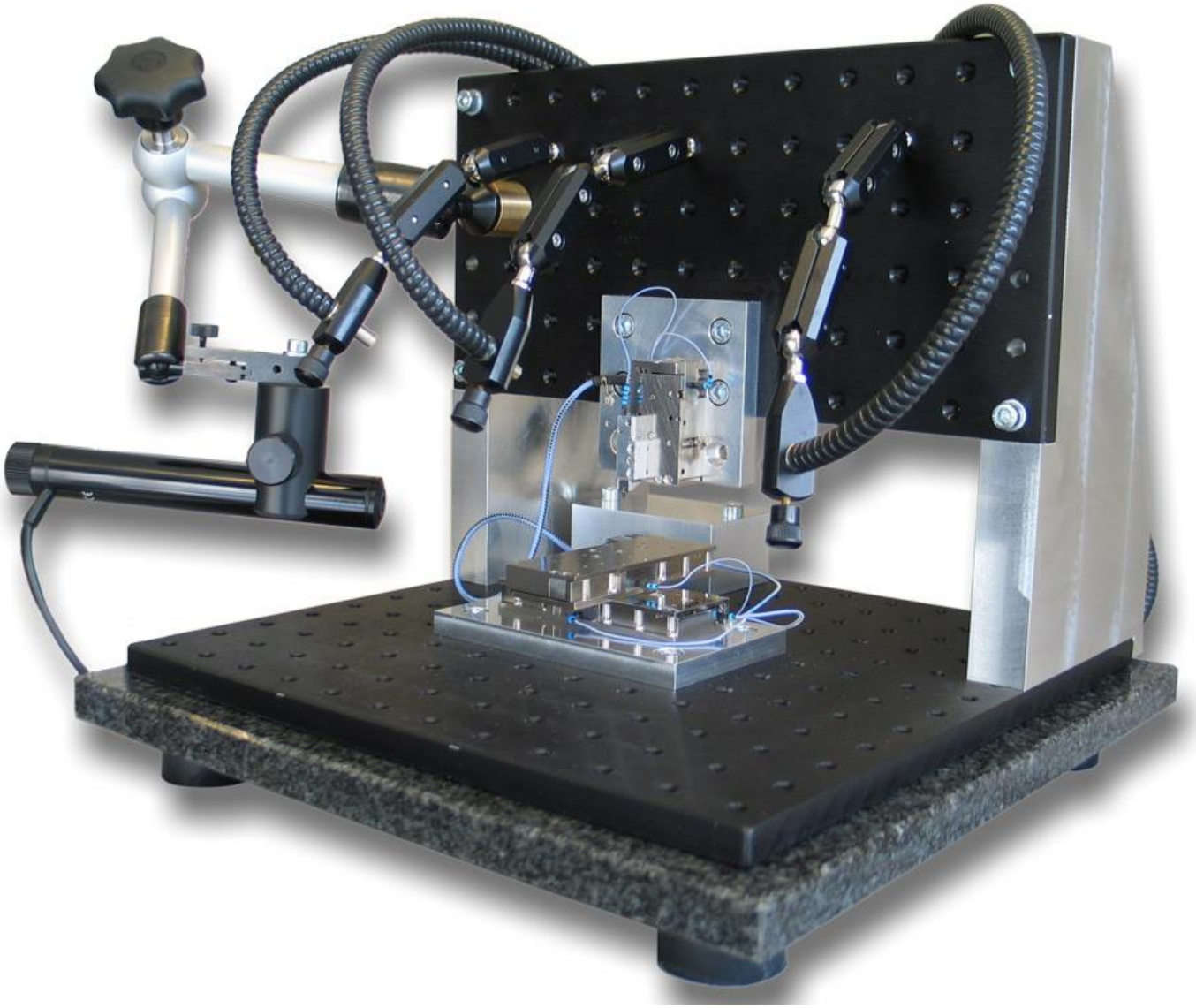
First Expansion Step

with 1 nm resolution



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Second Expansion Step

Including Automation

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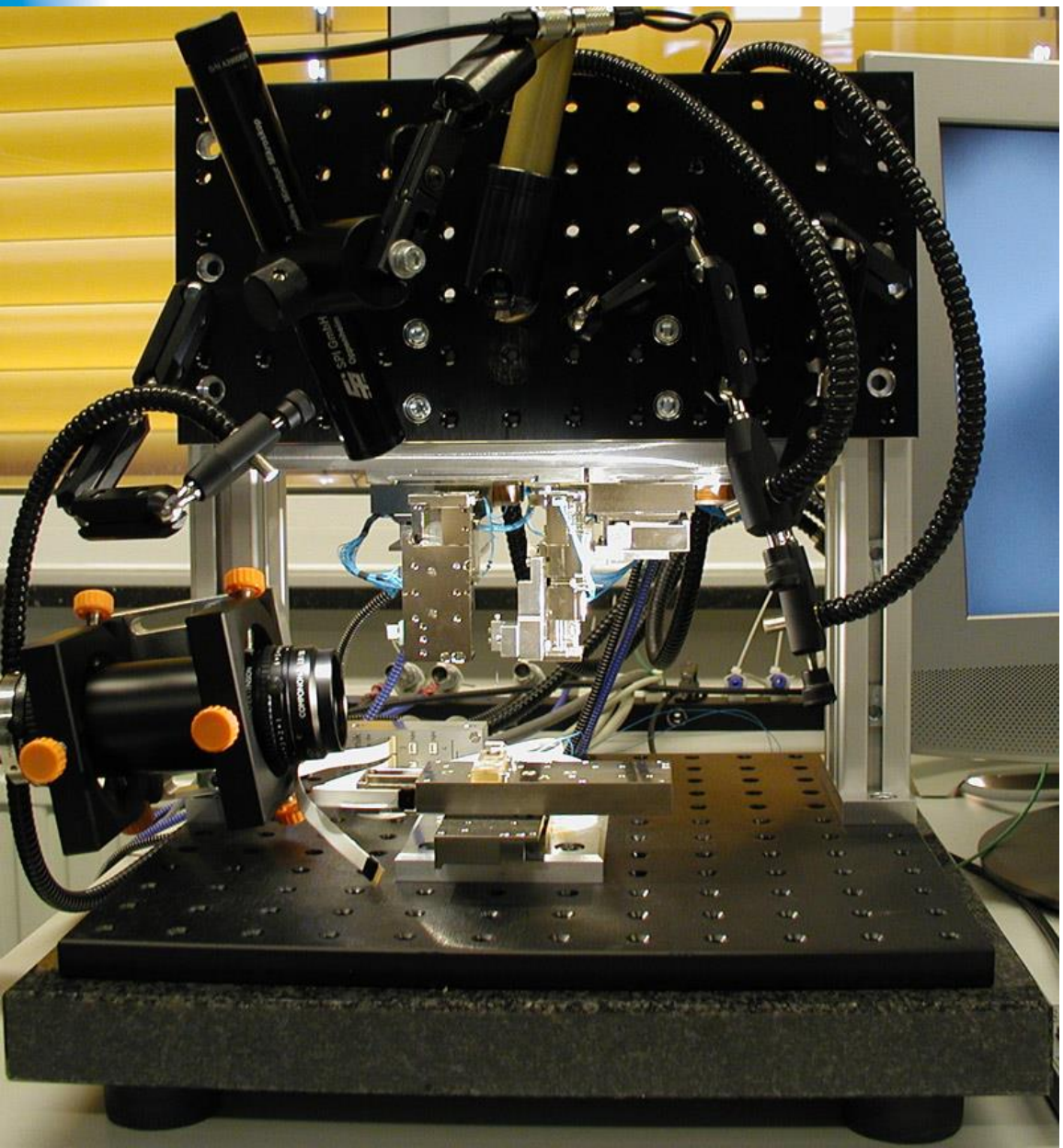
Second Expansion Step

with more D.O.F.



- **Base stage: X, Y, rotation**
- **2 XYZ Manipulators**
- **3 different Microgrippers**
- **Micro adhesive bonding dispenser**
- **Micro Tensile Testing modules**
- **Wide range zoom video microscope**
- **High resolution video microscope**
- **3 Cold light sources**
- **Sequencer for automation**

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The small System

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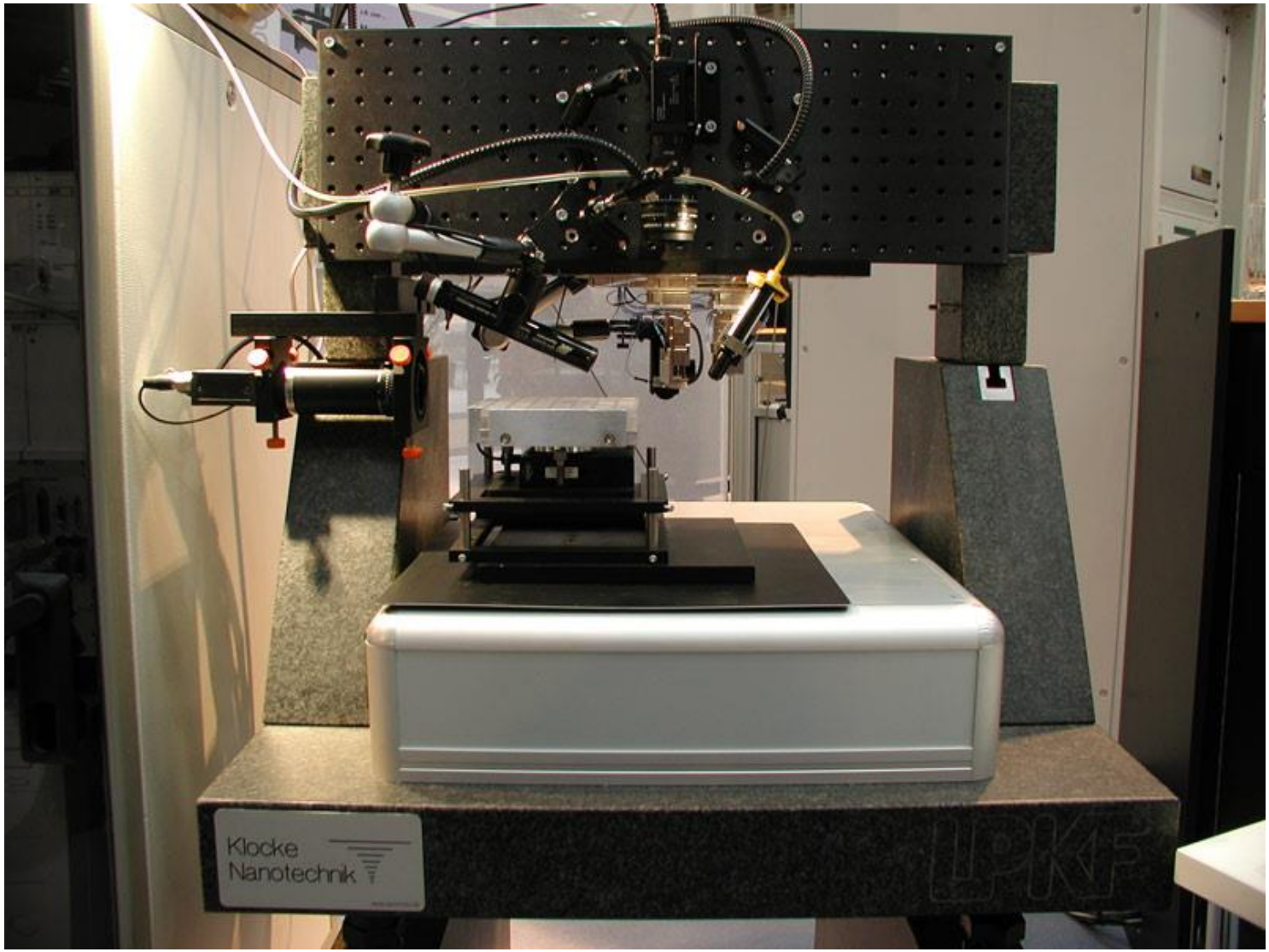
... with 100x100 mm² Stroke



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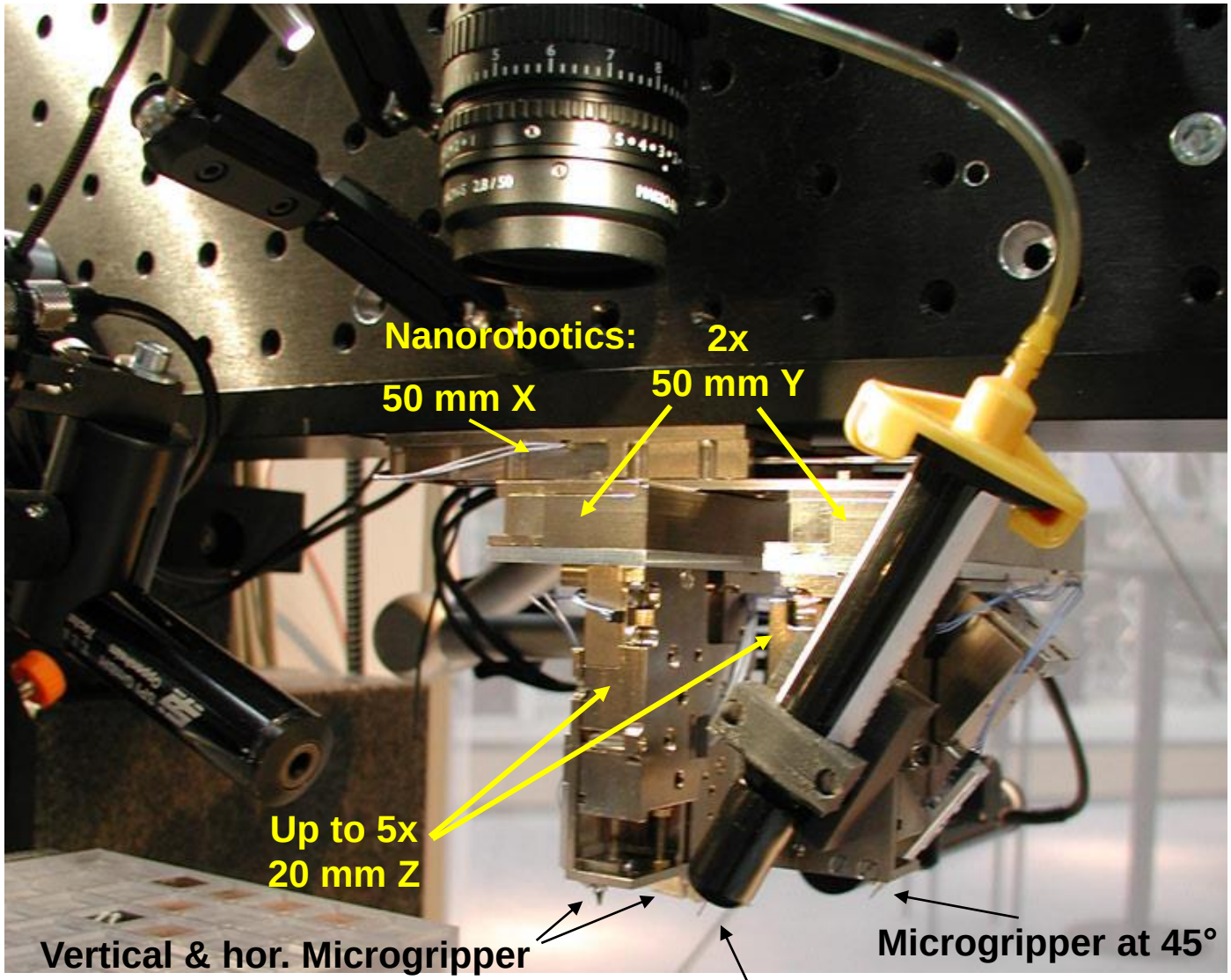
... in Detail



Micro Adhesive Dispenser

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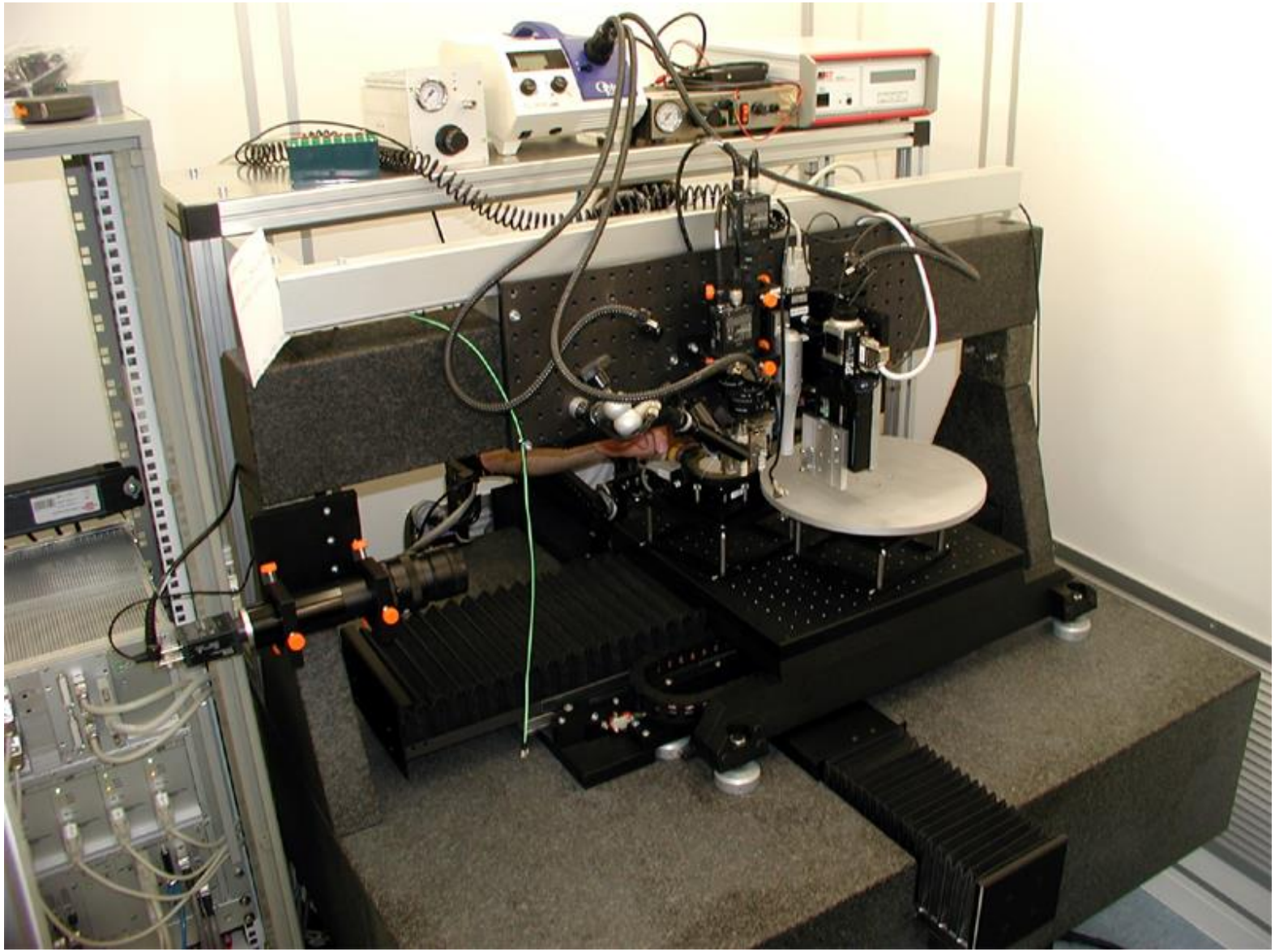
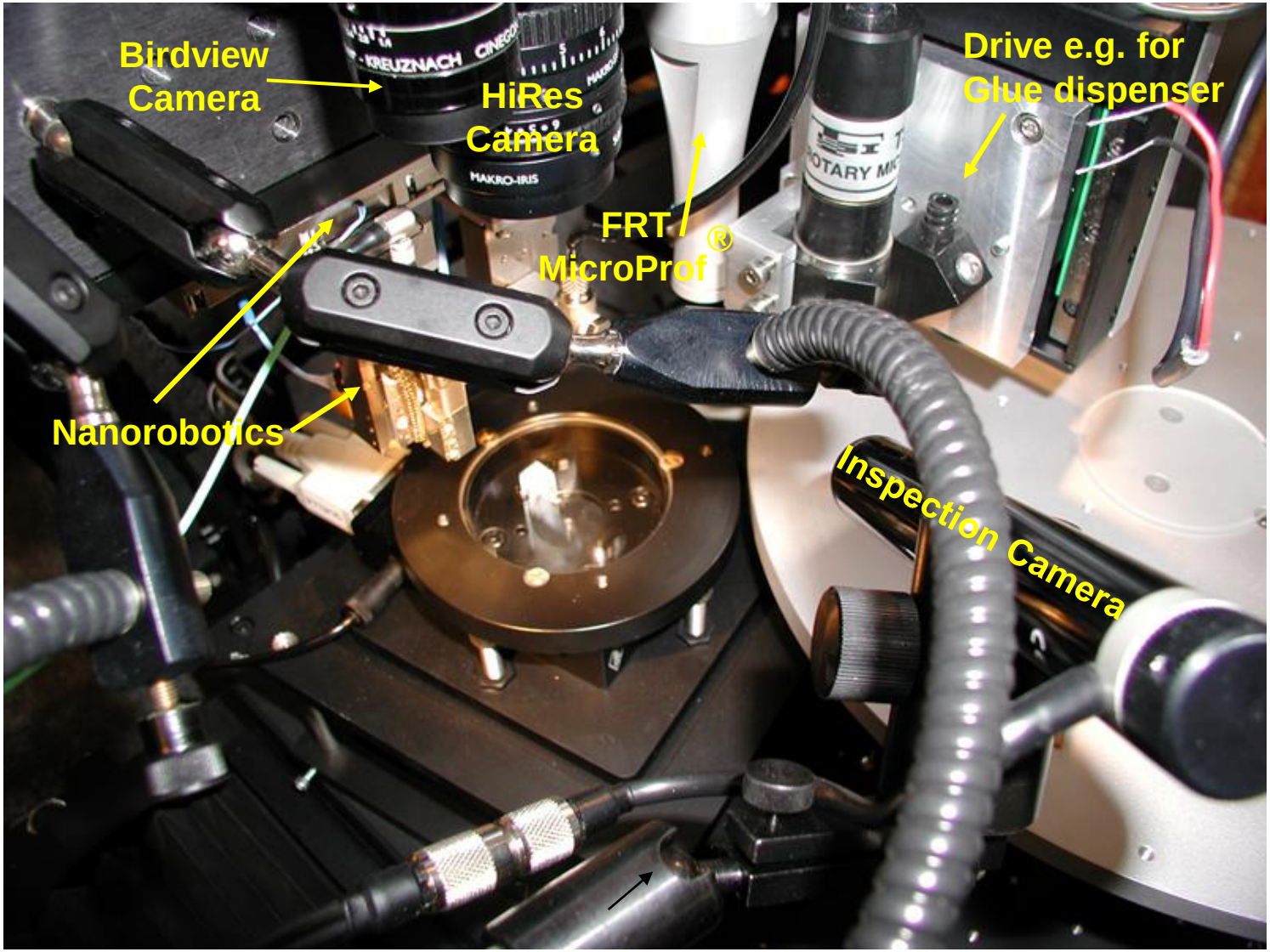
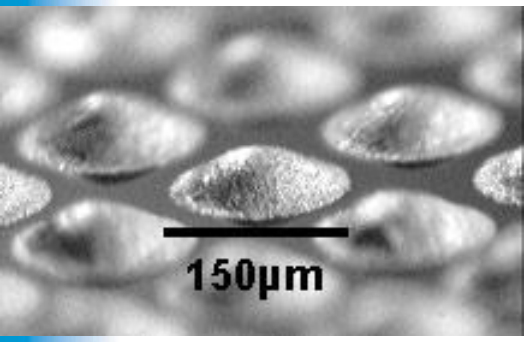
The big System



... some components

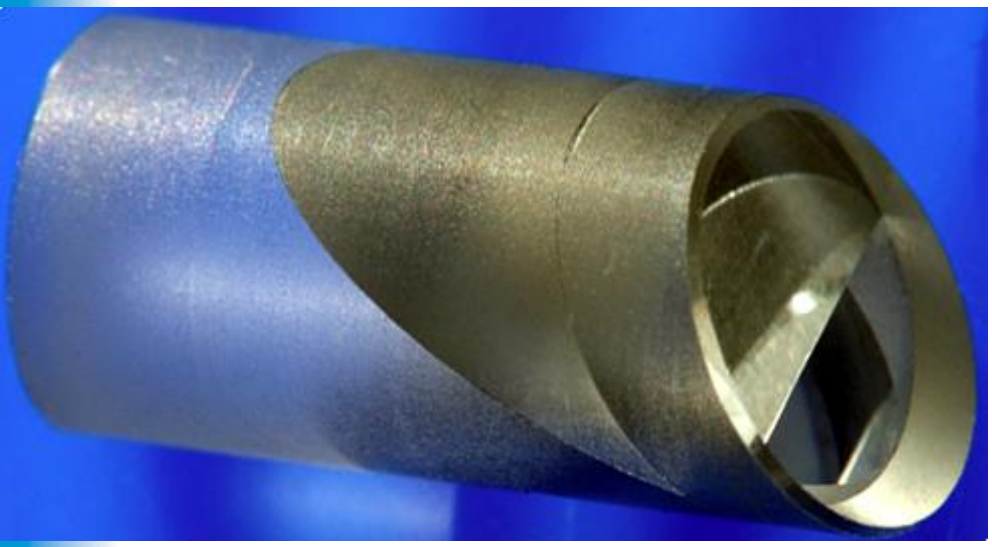


…including Micro Adhesive Bonding,



Conductive adhesive

- Joining of many different materials
- Multi-functionality of the joint (e.g. mechanical fastening plus conductivity)
- Low heat / cold joining
- Low mechanical stress, uniform stress distribution
- Galvanic isolation of the parts (no contact corrosion)
- Small solutions and new freedom for design



Endoscope Objective,
Ø 1,85 mm (Wolf GmbH)

VCSEL diode after active alignment glued into SMD housing. Coupler to glass fiber (Spinner GmbH)

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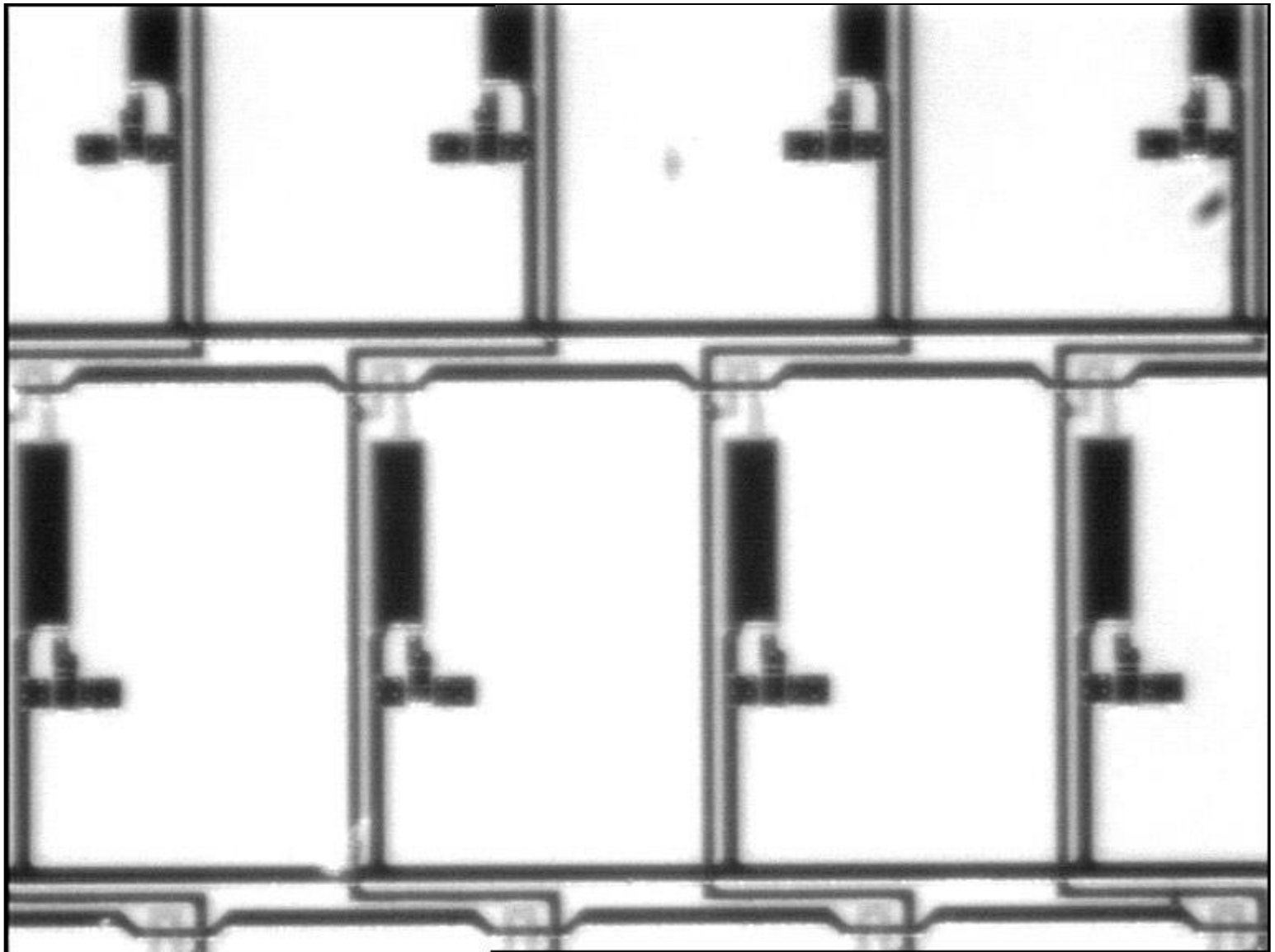
… with Pattern Recognition

of single pixels



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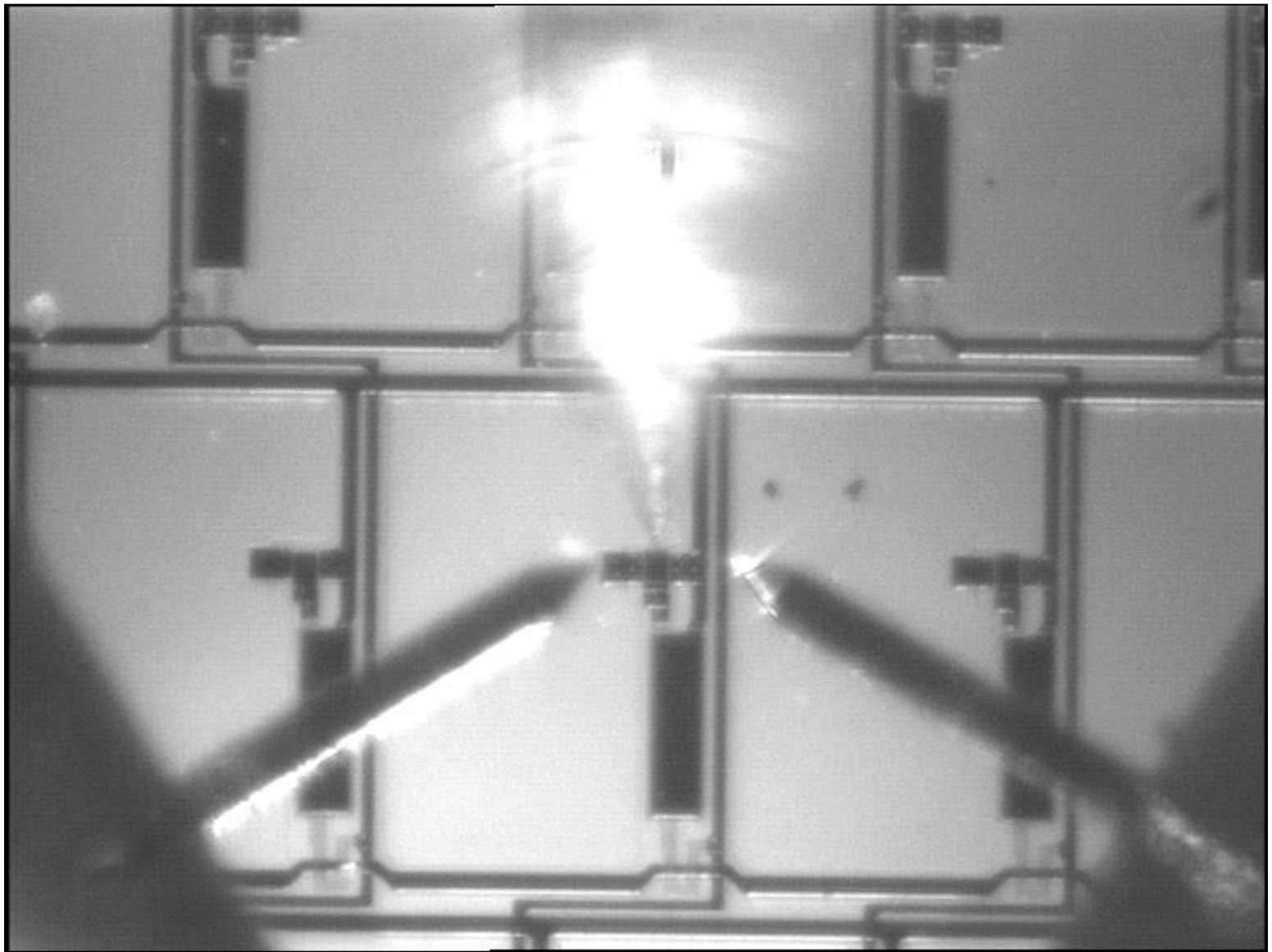
… probe tip approach

For current measurement



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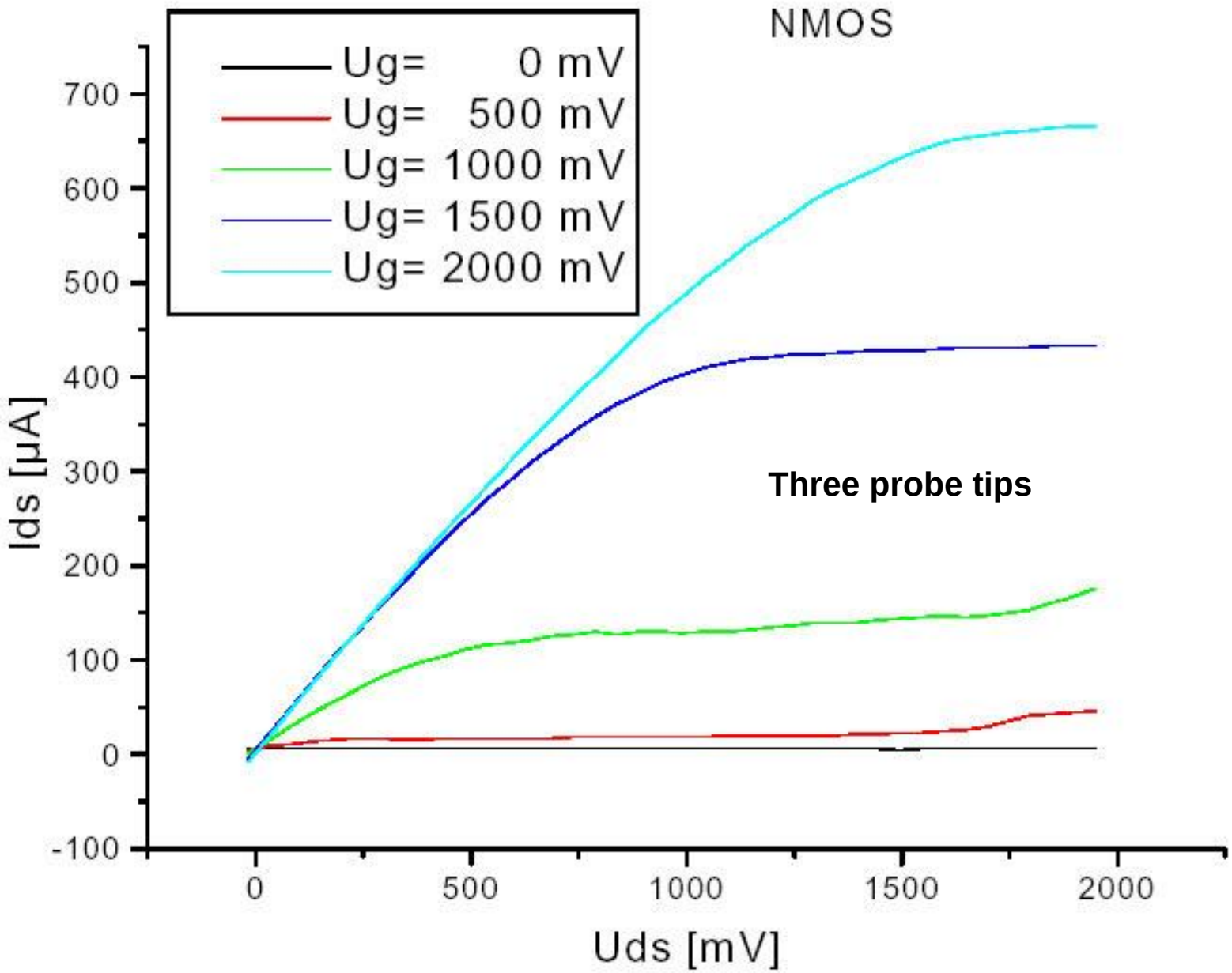
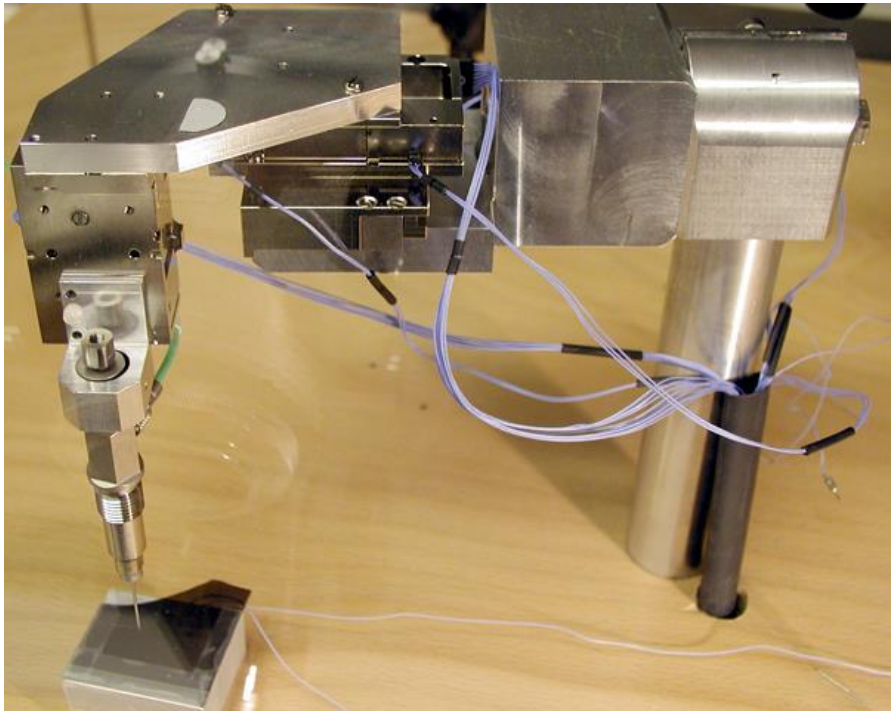
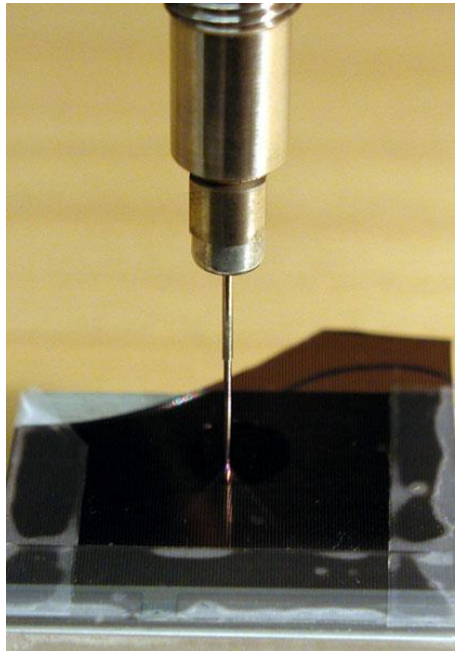
… Current Measurement

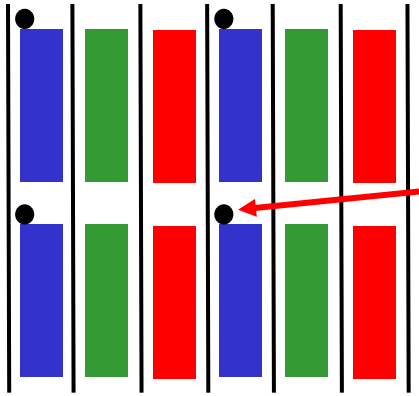


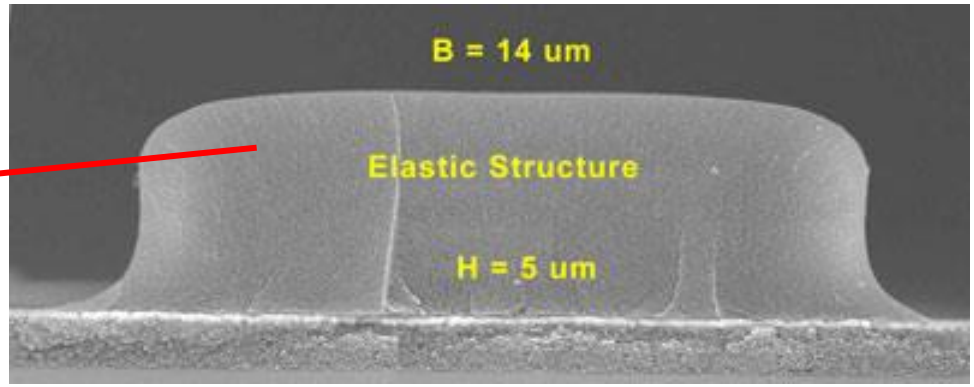
… Force Measurement

at Microstructures









On arrays in automatic measurement: Alignment by pattern recognition

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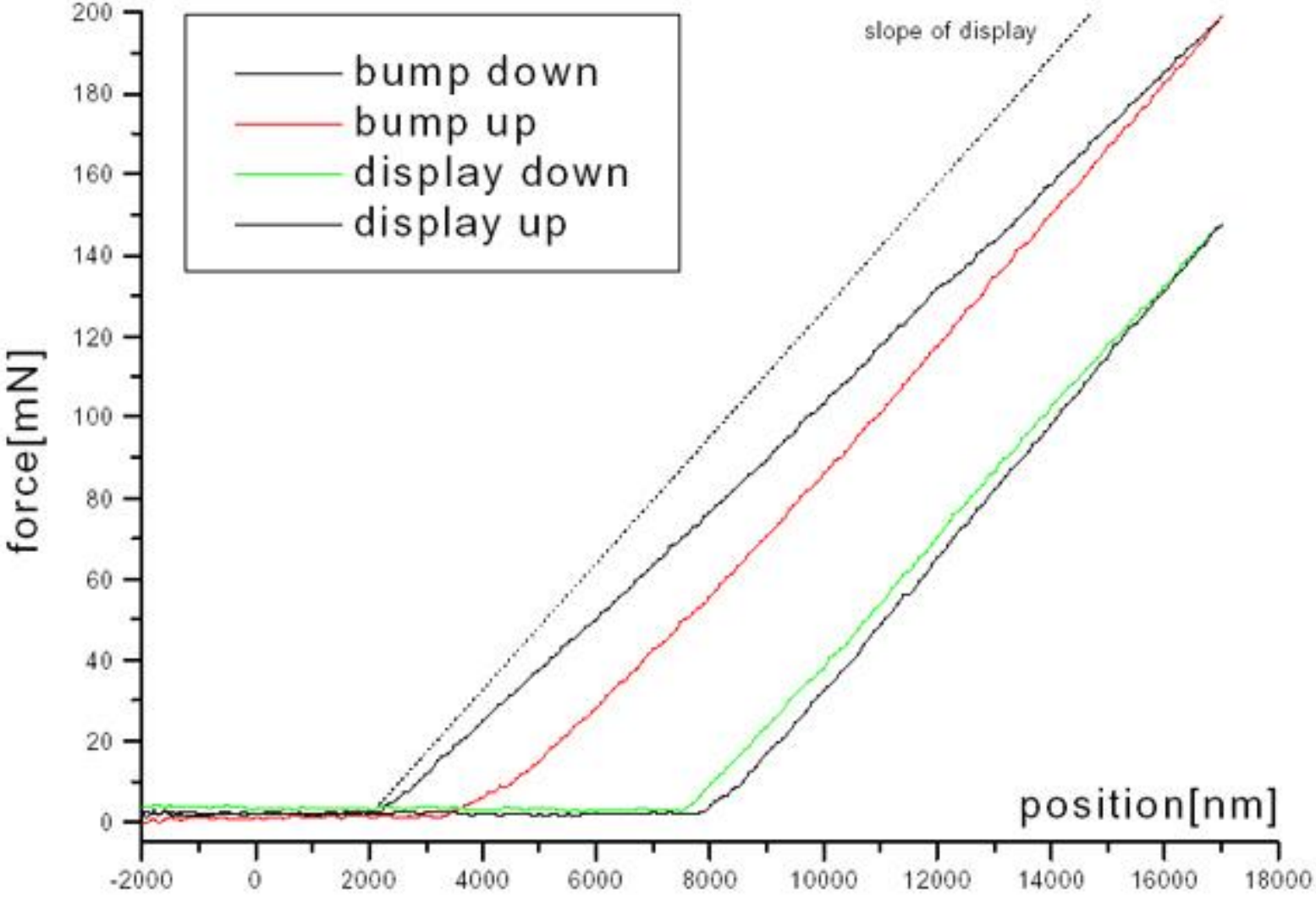
… Force-Distance Diagrams

at Microstructures



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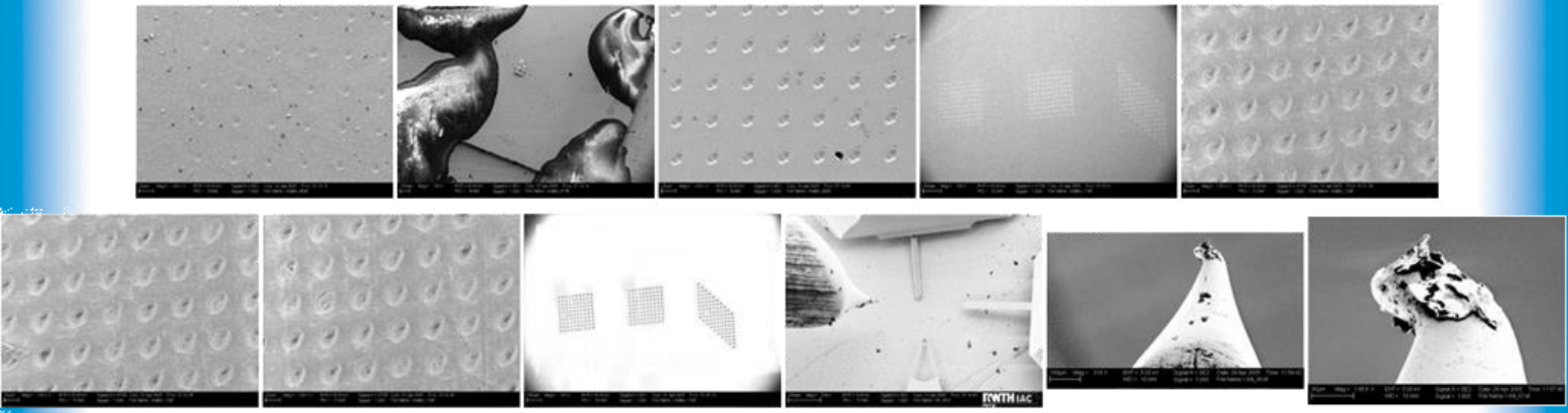
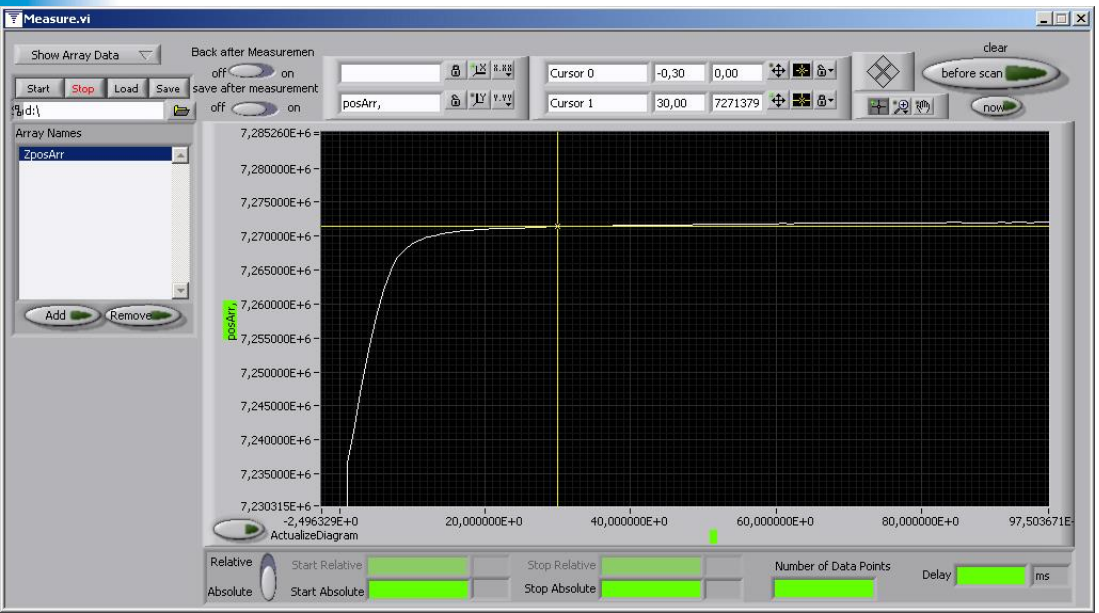
… Nanoindentation

to form structures





Depth measurement for each indent

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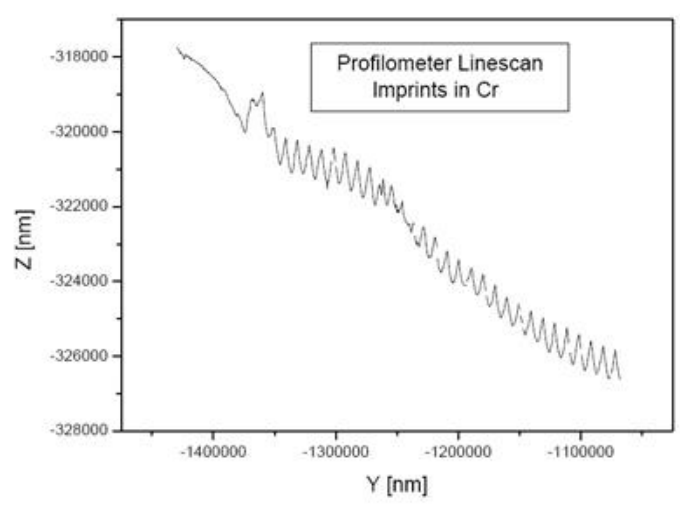
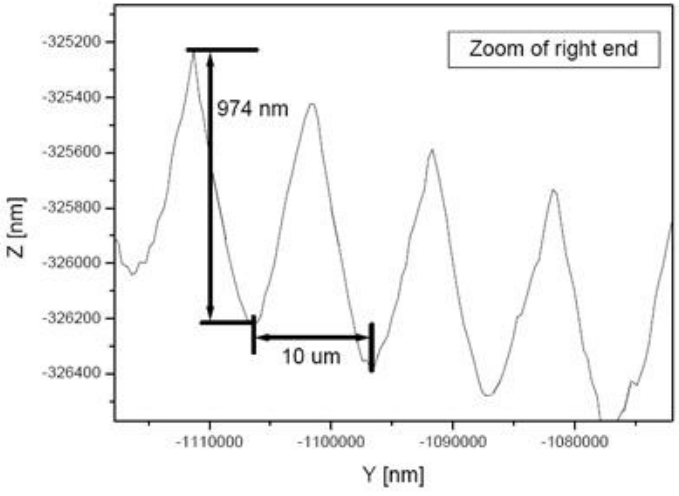
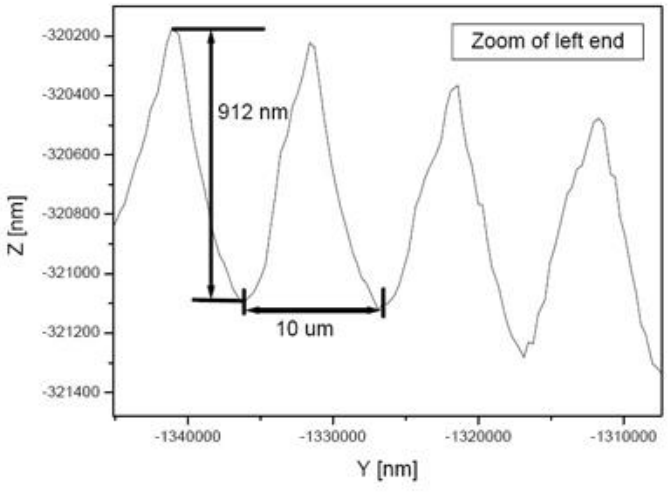
… Nanoindentation

measured with the 3D-Nanofinger







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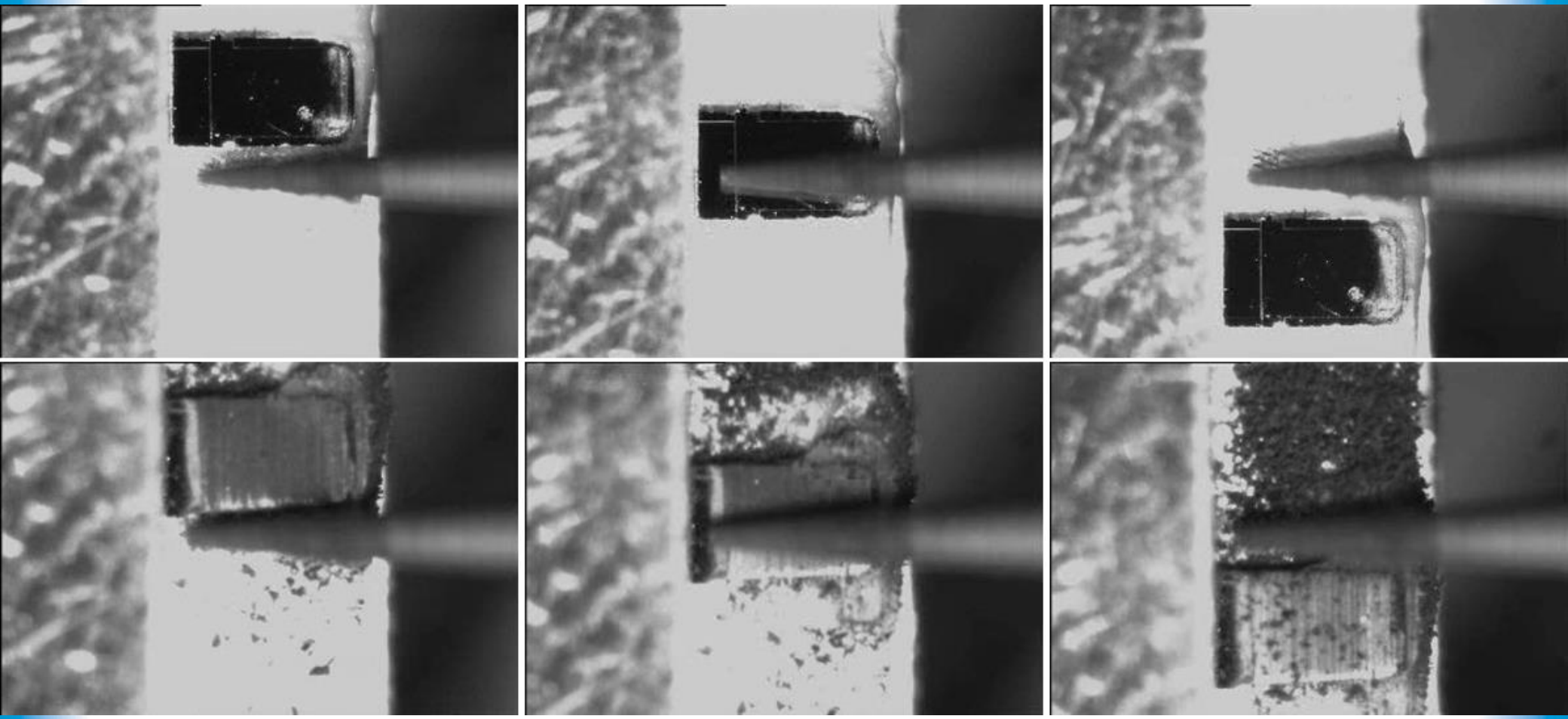
… incl. Nanomachining

by grinding



Grinding of a wedge structure into Silicon

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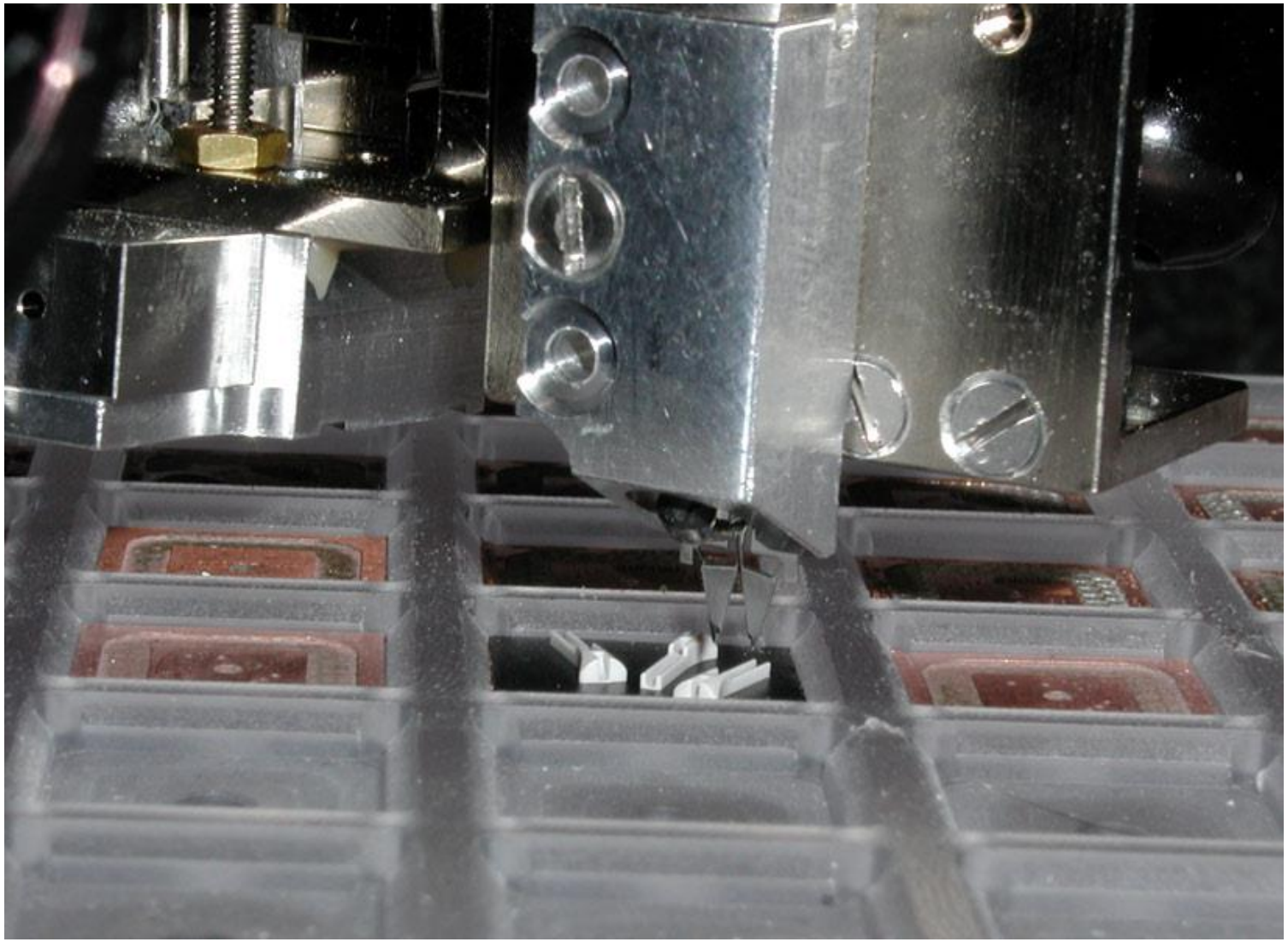
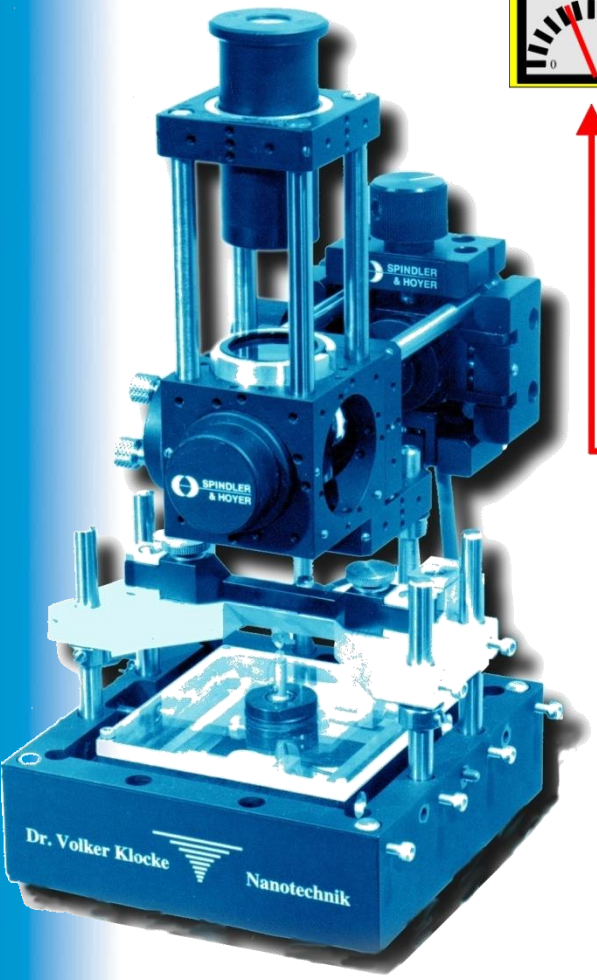
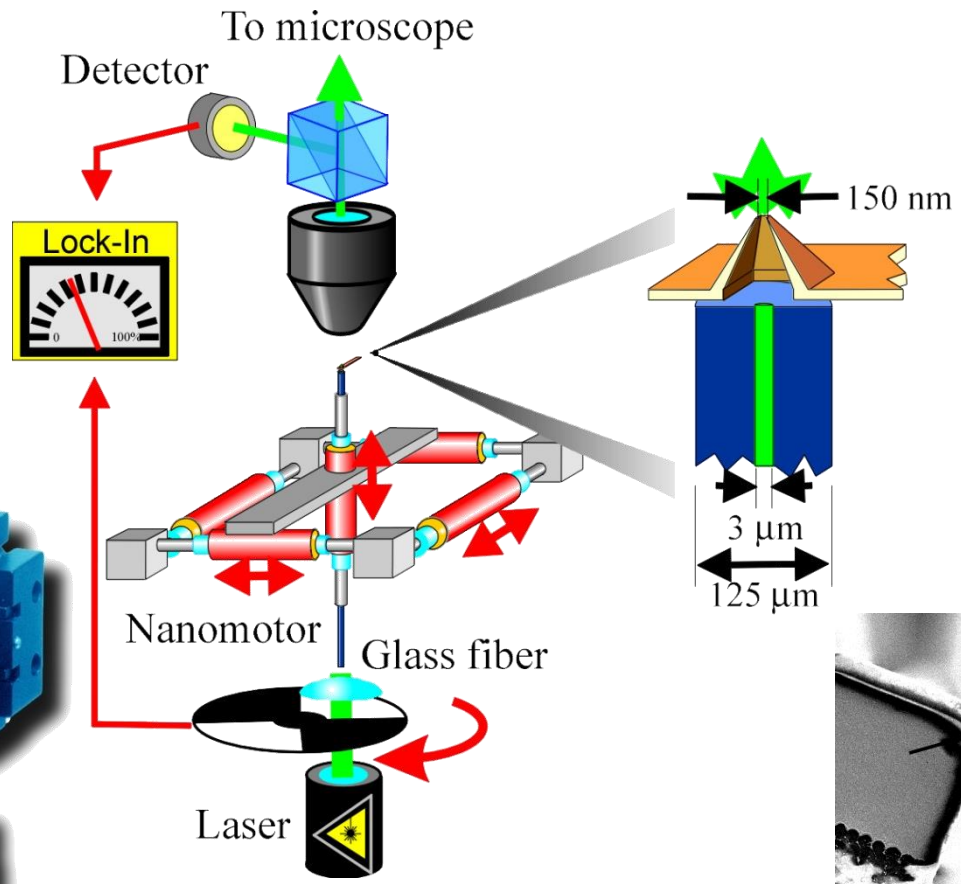
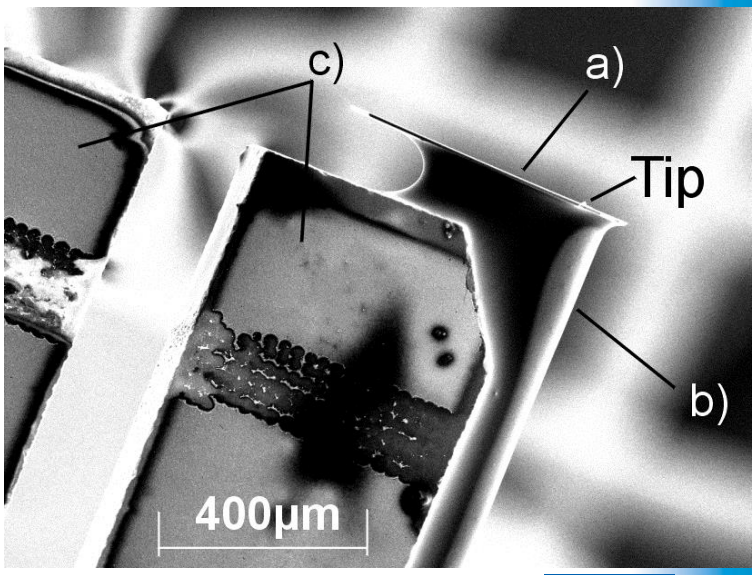
... or Automatic Microassembly



e.g. to „sharpen hairs“







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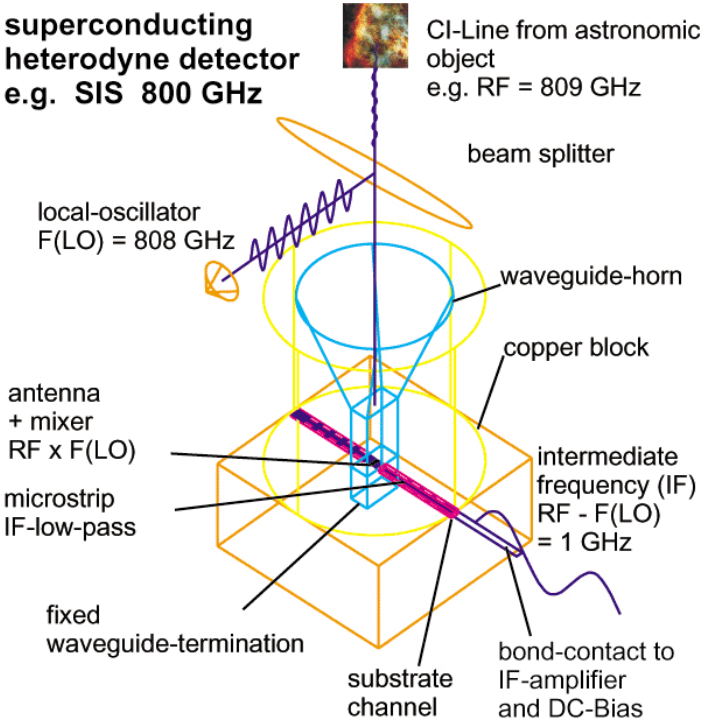
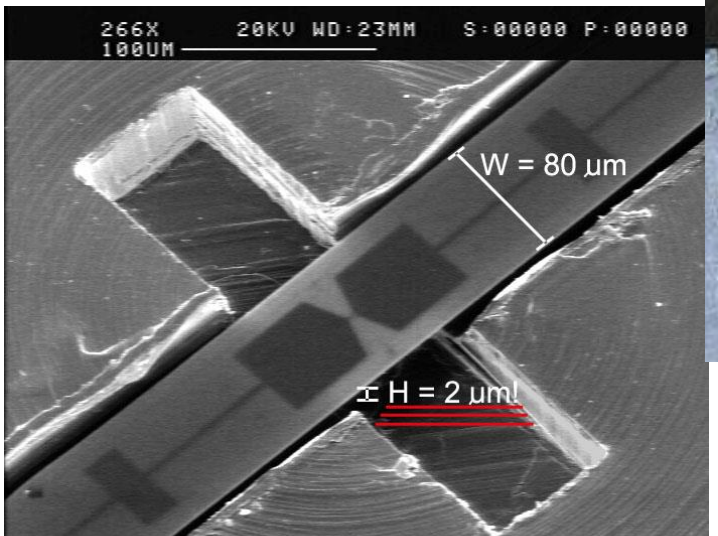
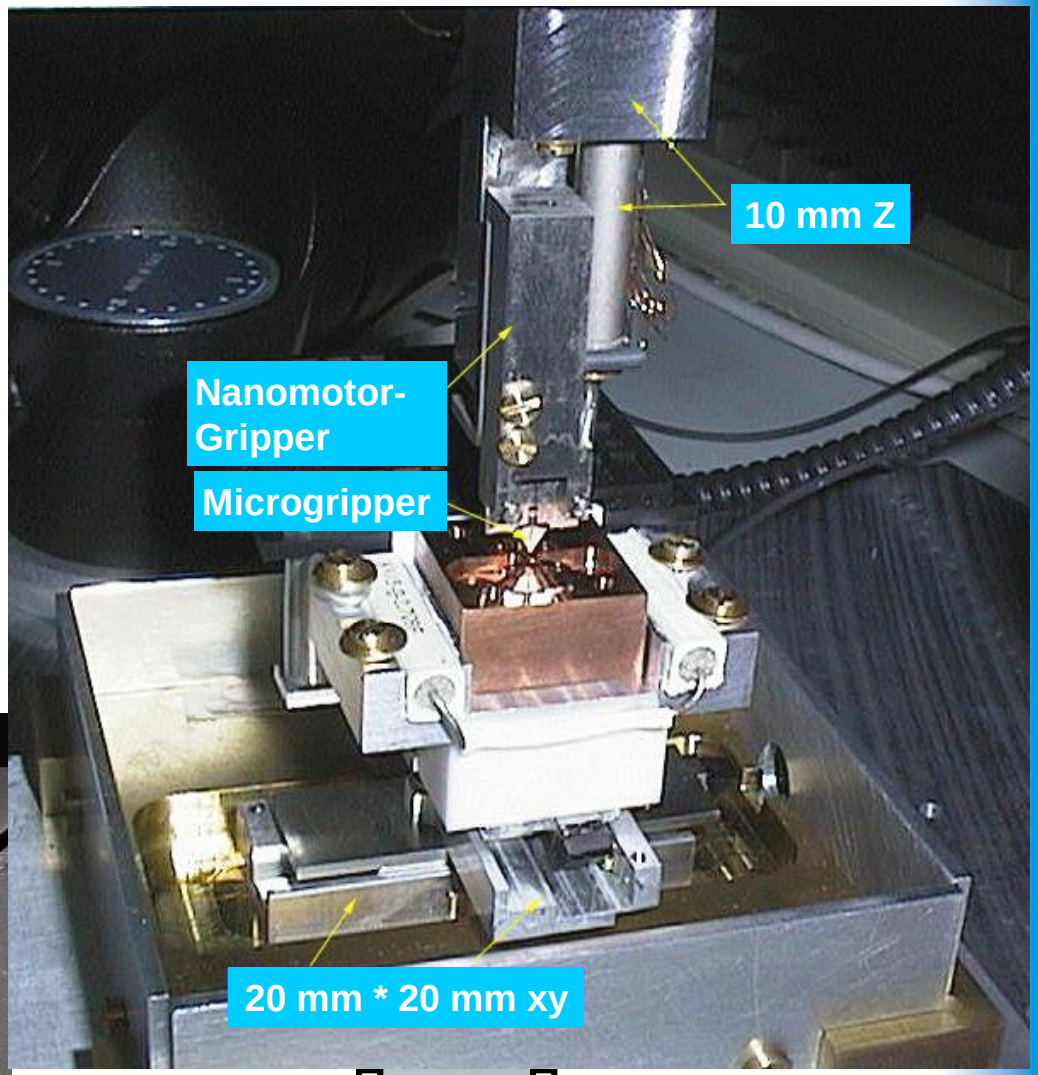
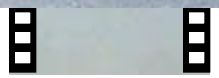
e.g. Microassembly of RF-Modules









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Micro Production Systems:

Link:

http://www.nanomotor.de/aa_production_system.htm

Strength:

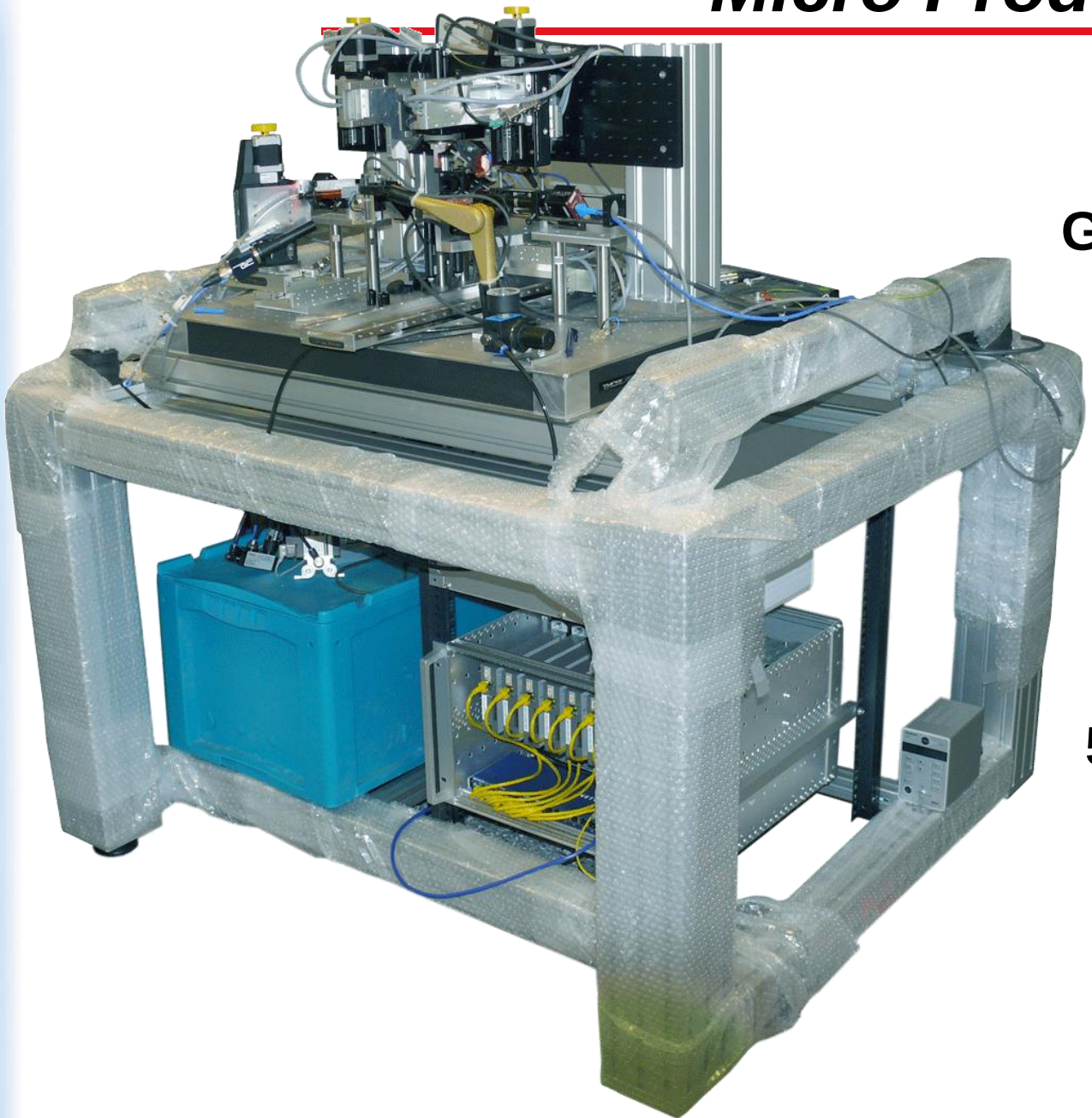
- flexible configuration, also by user
- ideal for changing production tasks
- Flexible upgrade options avoid investment risks

Weakness:

- not developed for single type mass production ***(…. ?!)***

Micro Production System

for mass production



Glass fiber assembly

in

mass production:

500-700 good parts

per week

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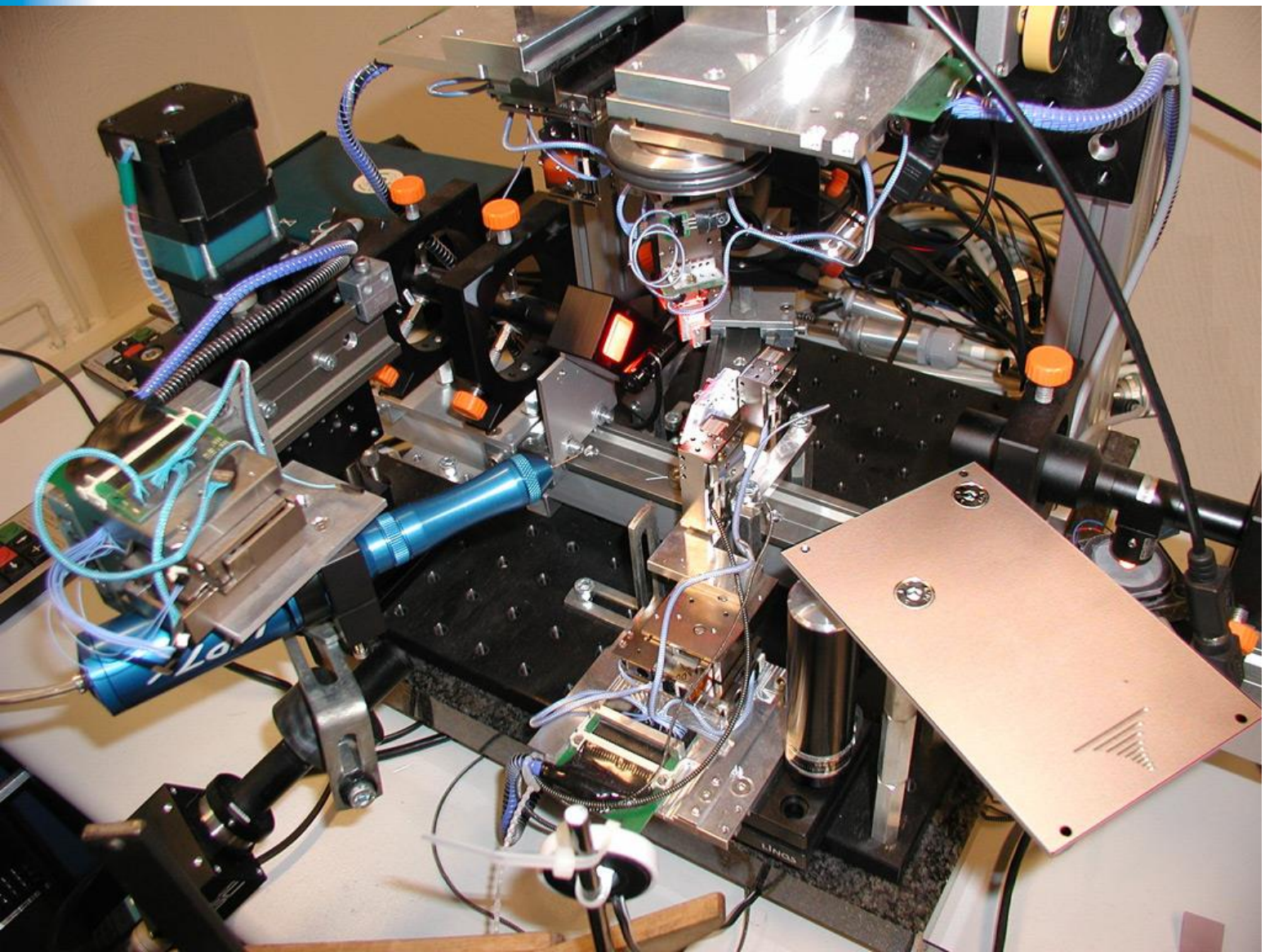
Micro Production System

First Prototype, upgraded to Service machine



Made for first process development

Produced 24.250 good parts: 400-500 per week

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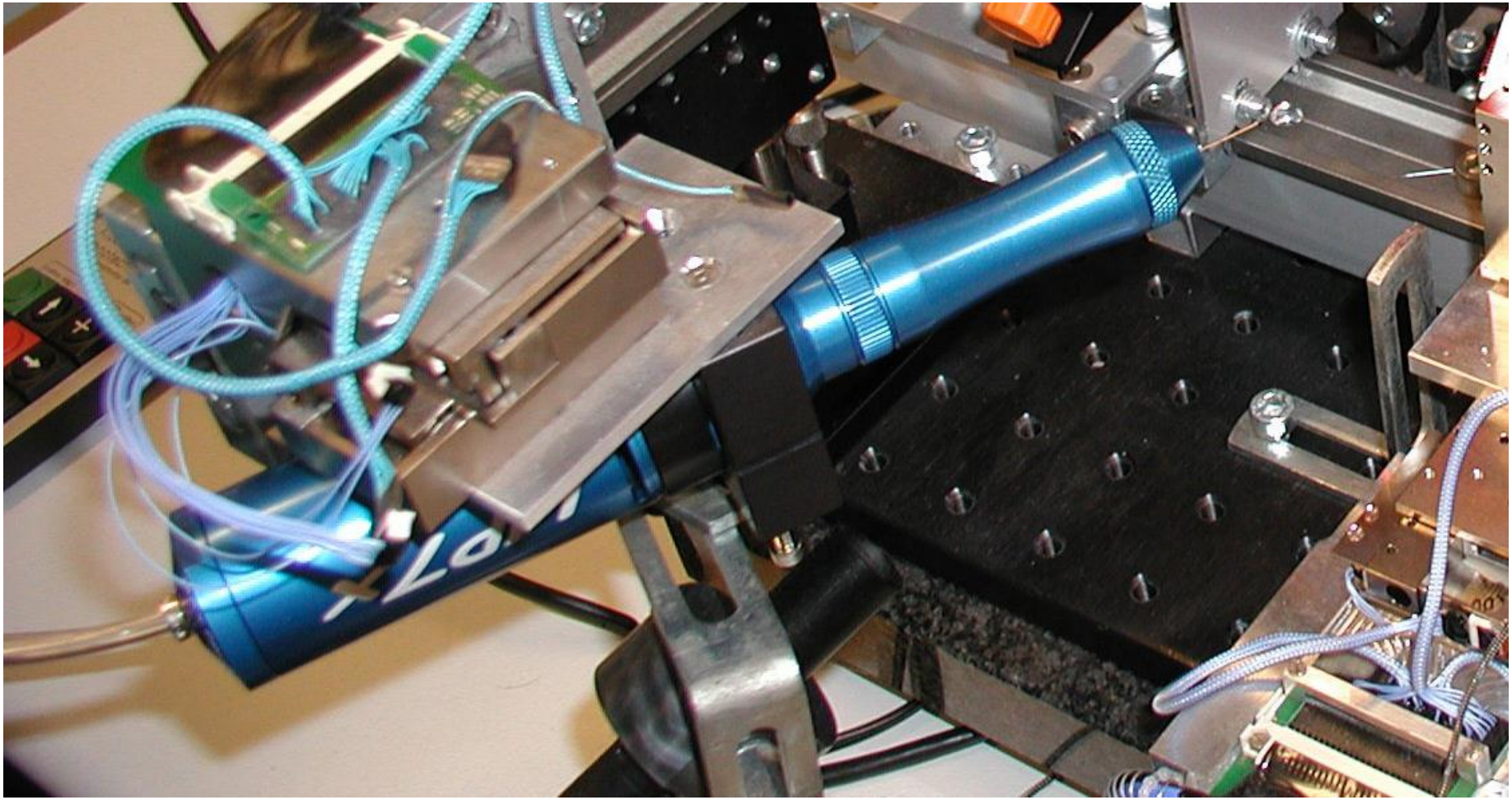
Micro Production System

Service machine, future backup system



All commercial dispensers failed => own development

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Micro Production System

Production machine

… just a box …

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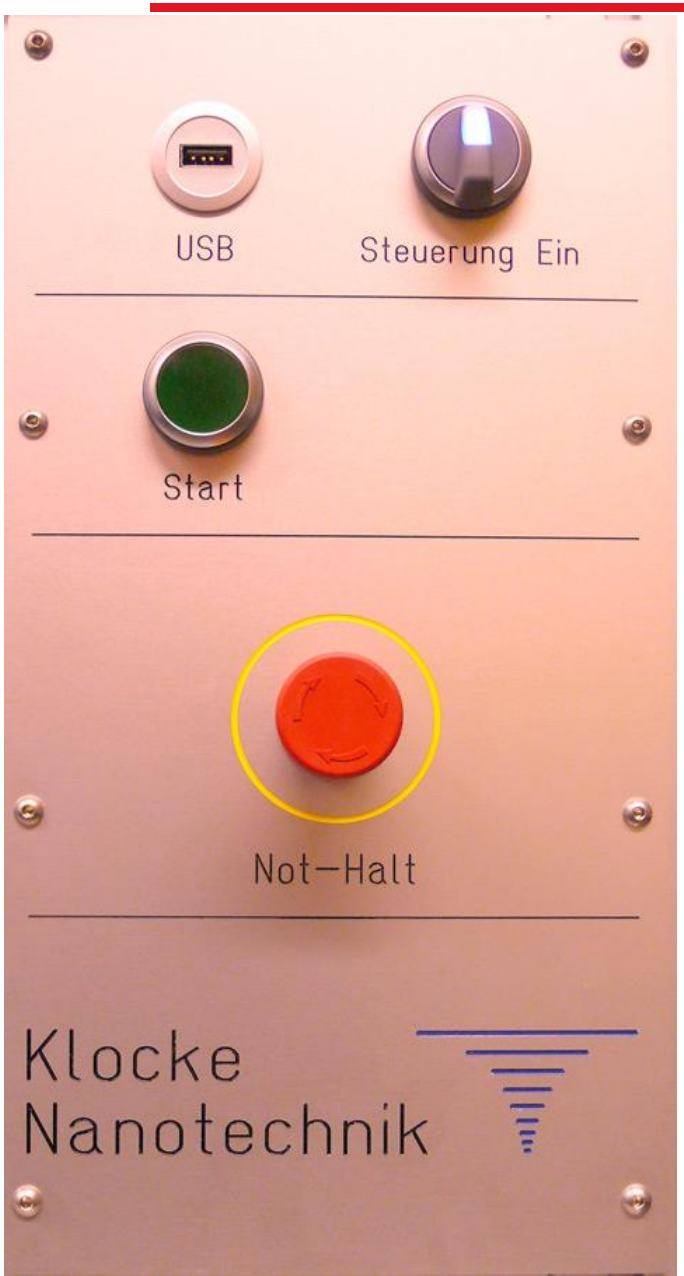
Micro Production System

Production machine



Degree of Automation…

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Micro Production System

Production machine

What's inside?

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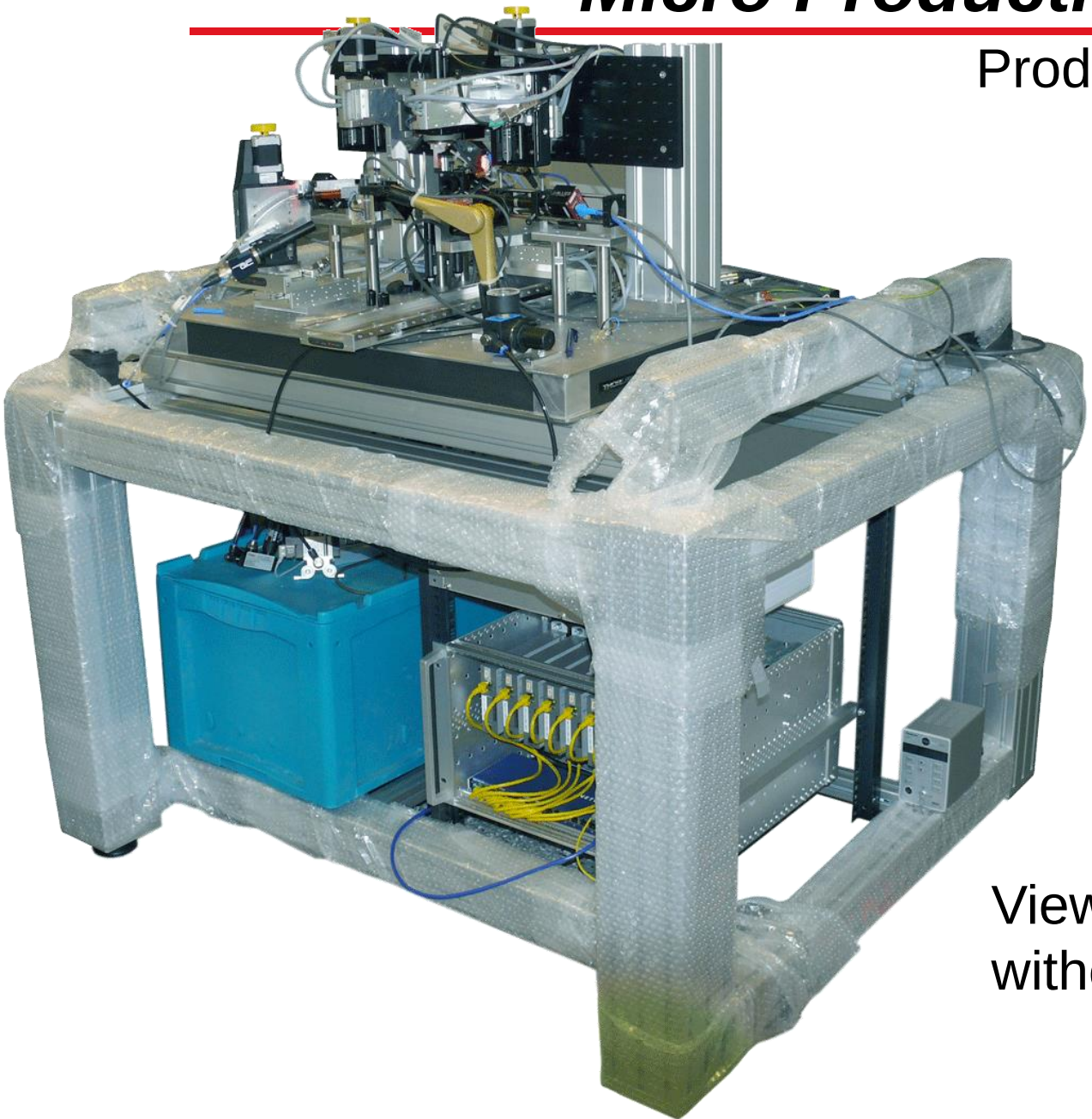
Micro Production System

Production machine



View at the machine without housing

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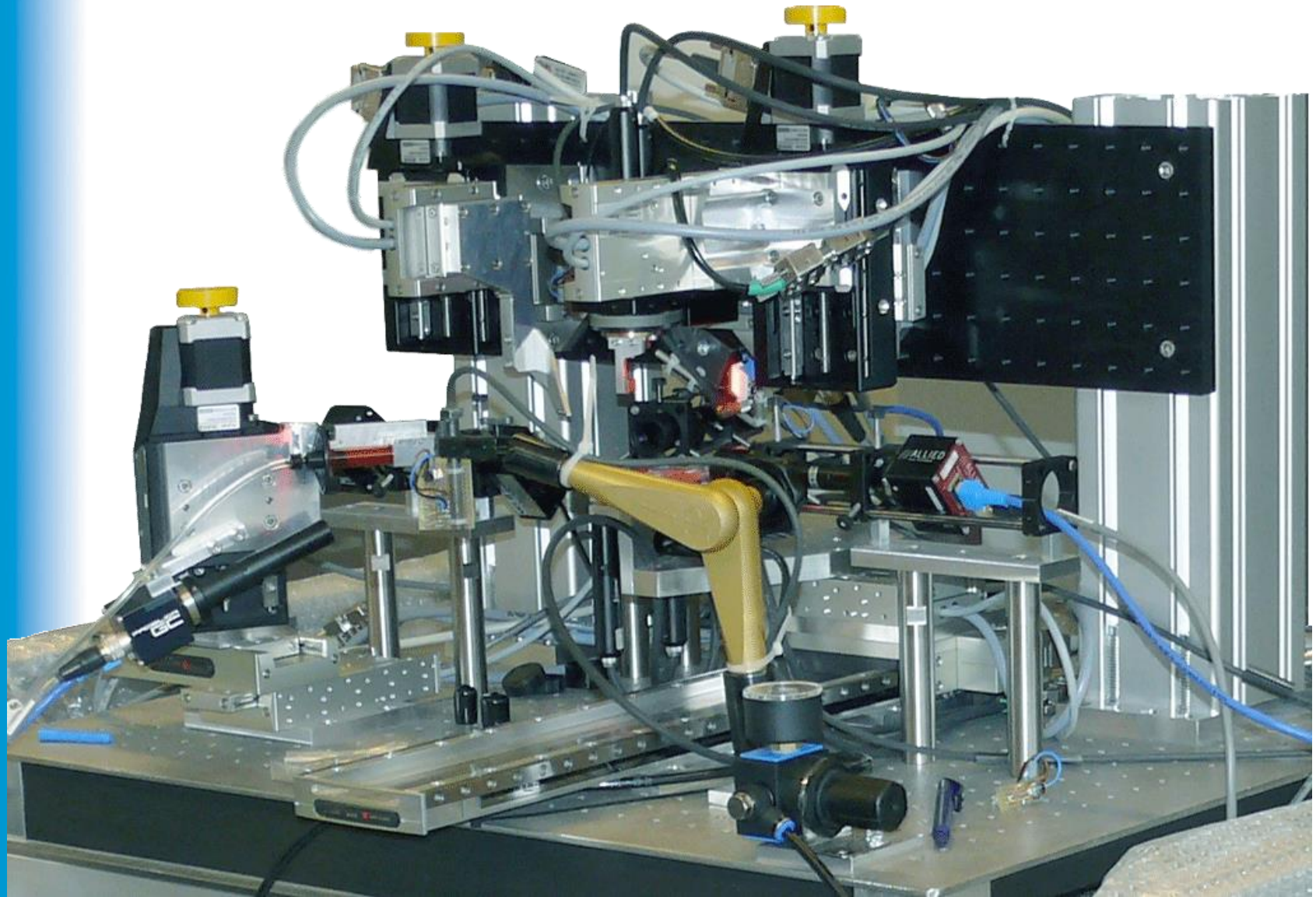
Micro Production System

Production machine



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Micro Production System

Specification

- 87 good parts per day
- Cycle time < 3,5 minutes
- Yield > 80% measured during production
- Light point position +- 5µm
- Adhesive & fiber position error < 2µm at 15mm length
- Axial Fiber rotation < +-5°
- Varying fiber diameter: 27µm - 45µm

- Several different pre-defined production processes
- Data base interface
- Remote service
- Operation possible by „everybody“
- Replacement machine ready in < 3 days

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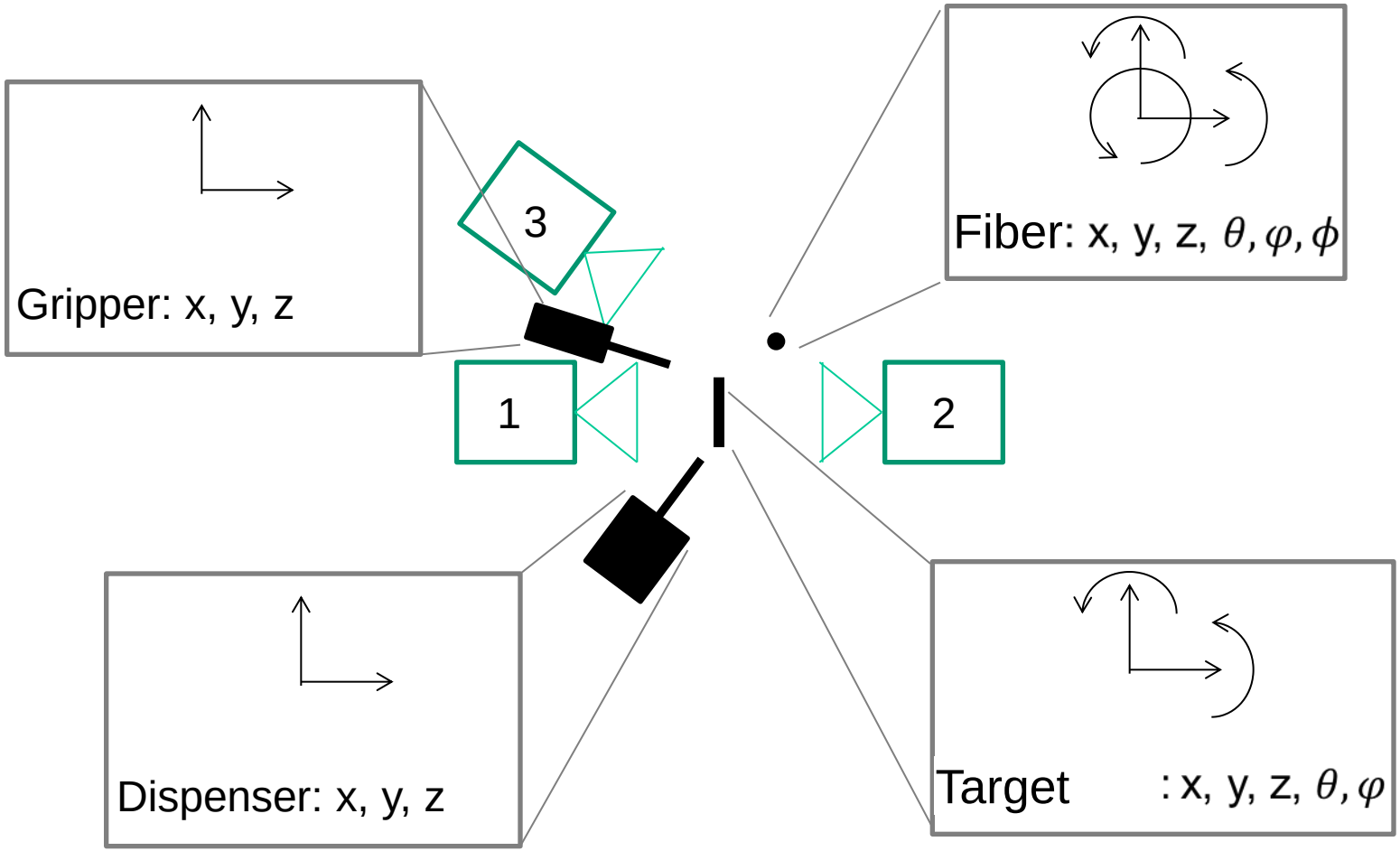
Micro Production System

D.O.F.

3 Cameras
17 Degrees of Freedom



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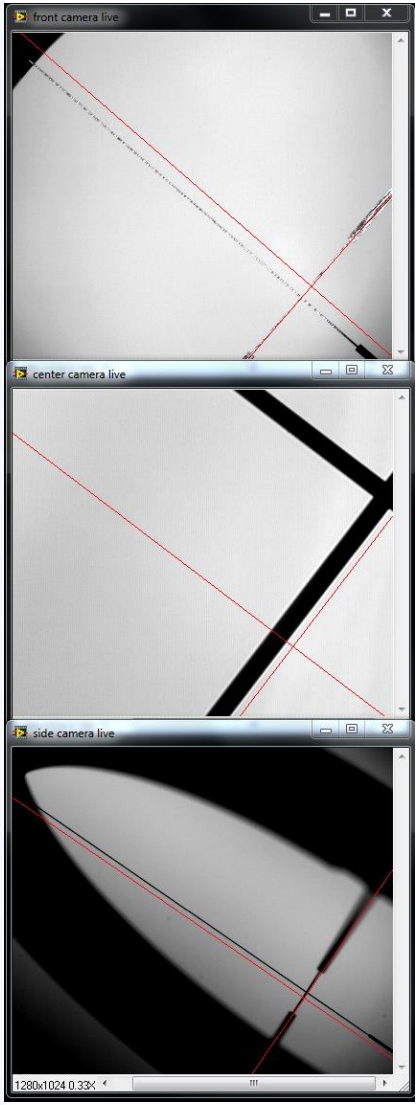
Micro Production System

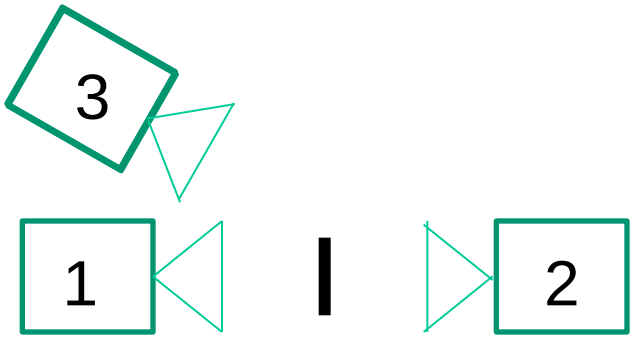
Coordinate systems



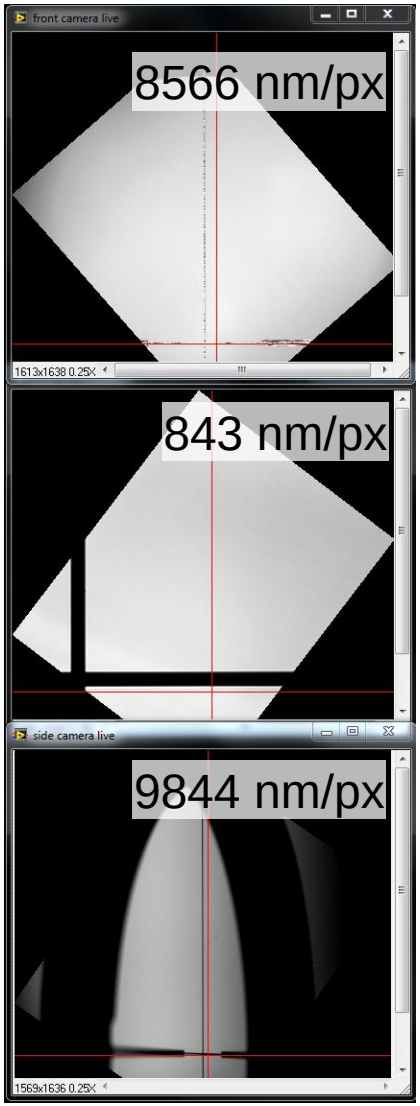
1

2

3



Automatic Calibration



Micro Production System

Data rates and precision

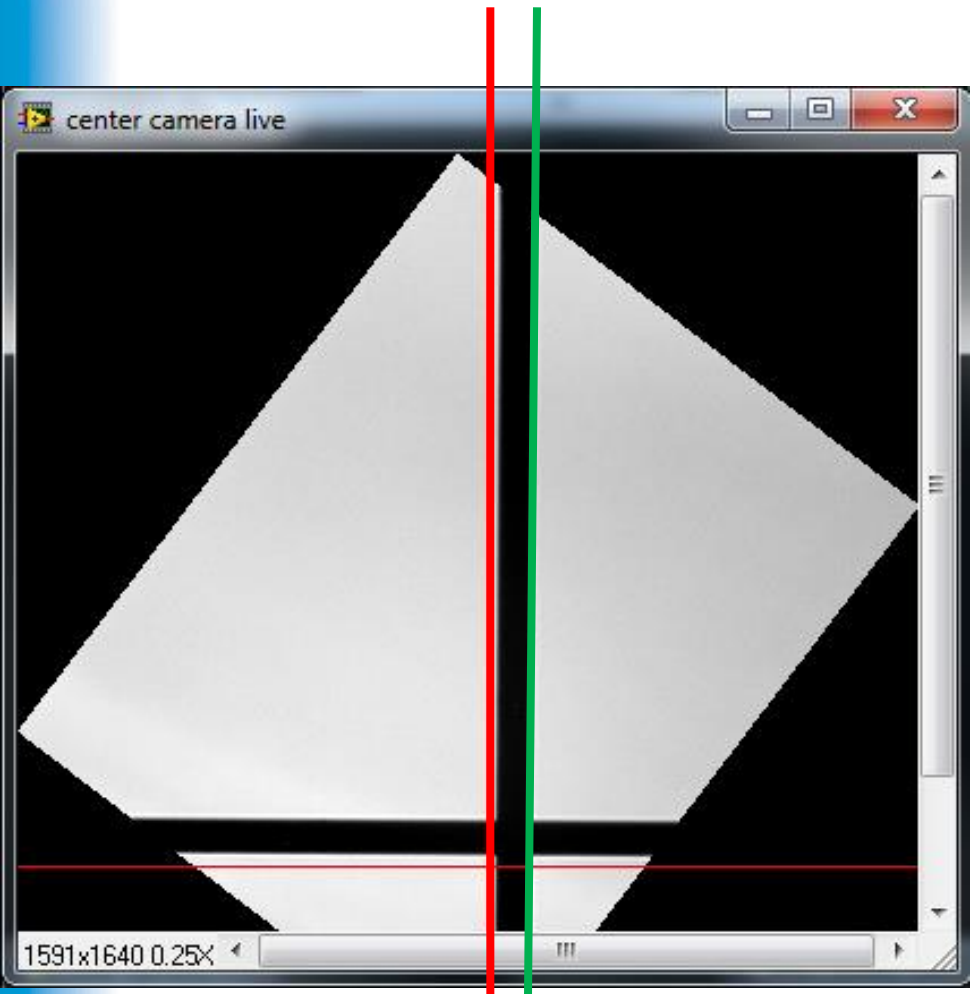
256 gray scales with 1280x1024	→	1.3 MB
30 pictures per second	→	39 MB/s
4 Cameras	→	156 MB/s
		= 1,25 GBits/s

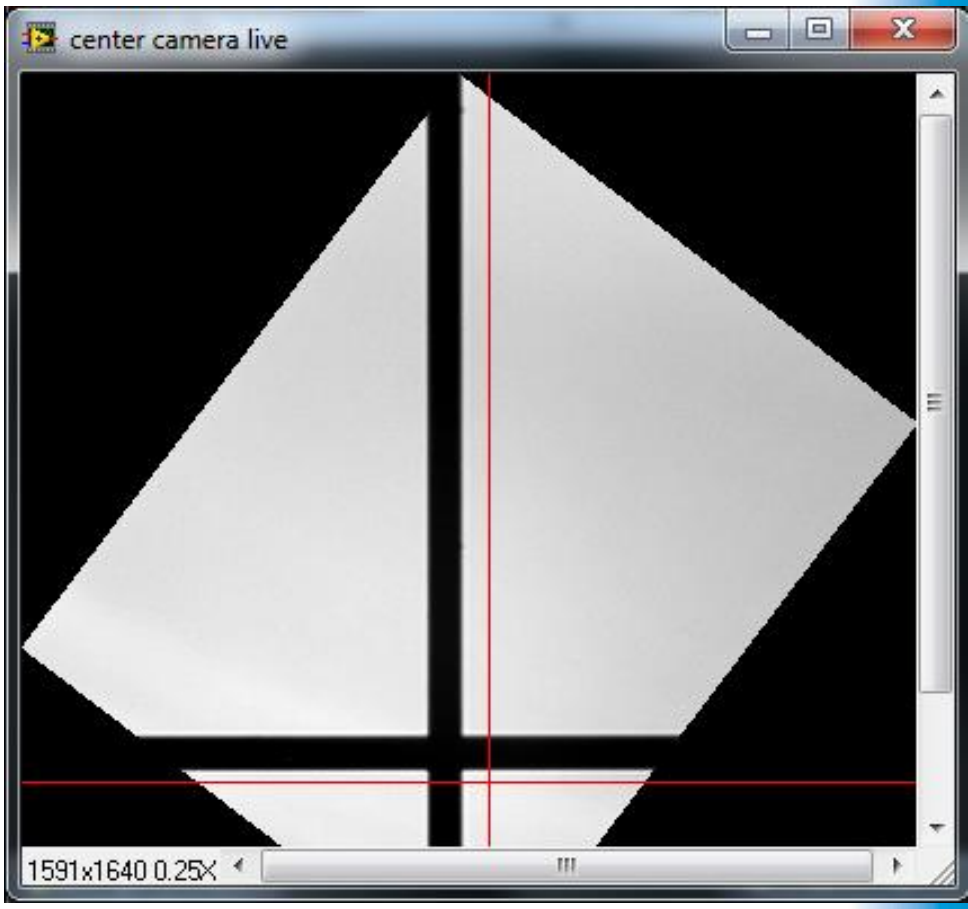
Bandwidth must be dispersed to the cameras,

depending on speed and optical parameters.

Micro Production System

Positioning the target structure





Angle correction: -0,4855°
Axes: z1, z2

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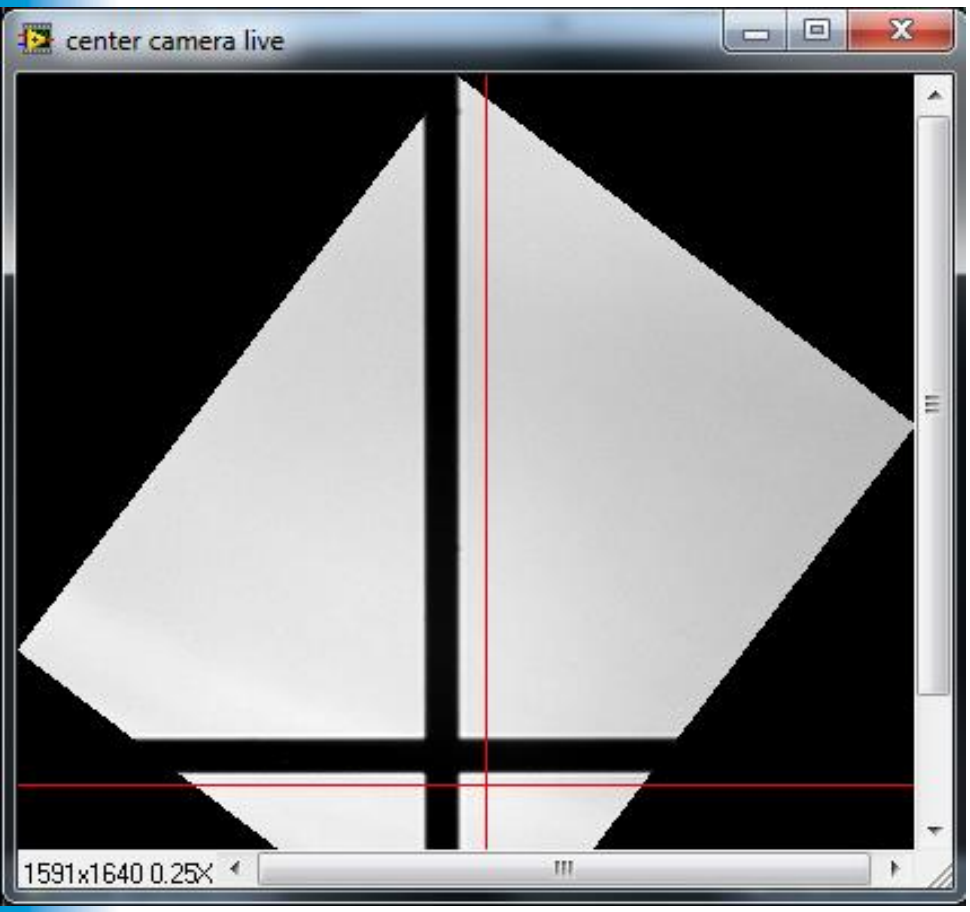
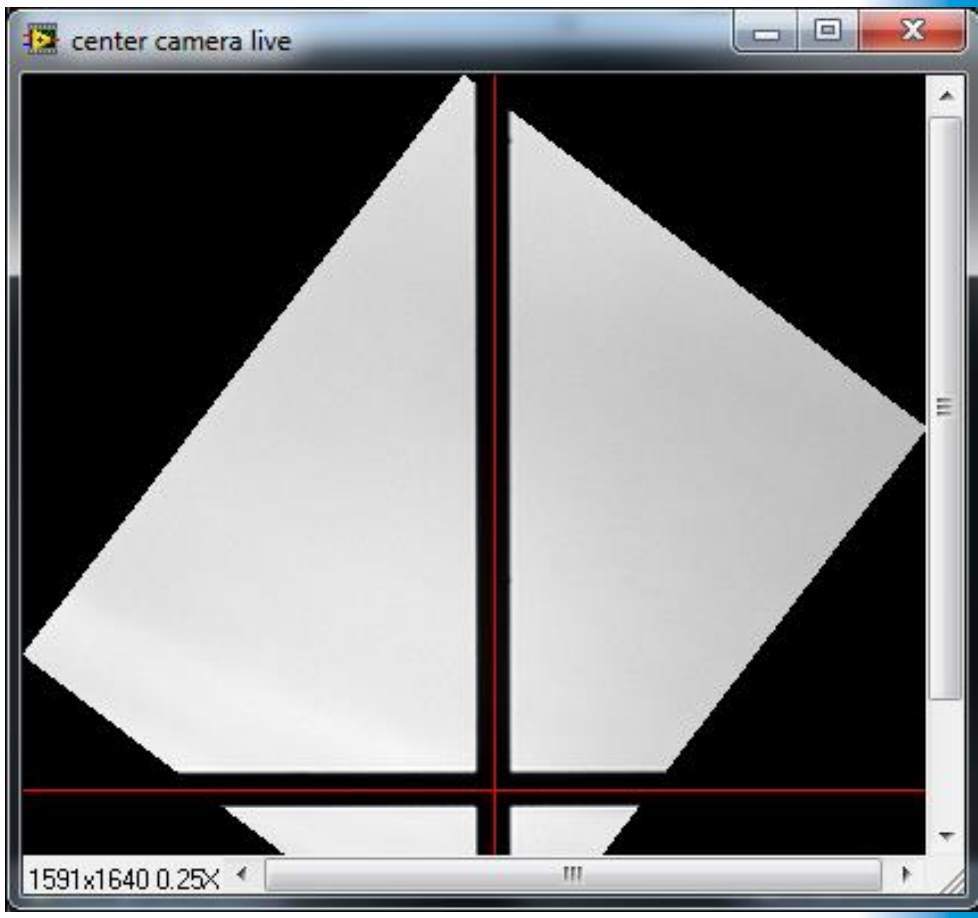
Micro Production System

Positioning the target structure





Position correction: +68800nm, -57432nm
Axes: y, z1, z2

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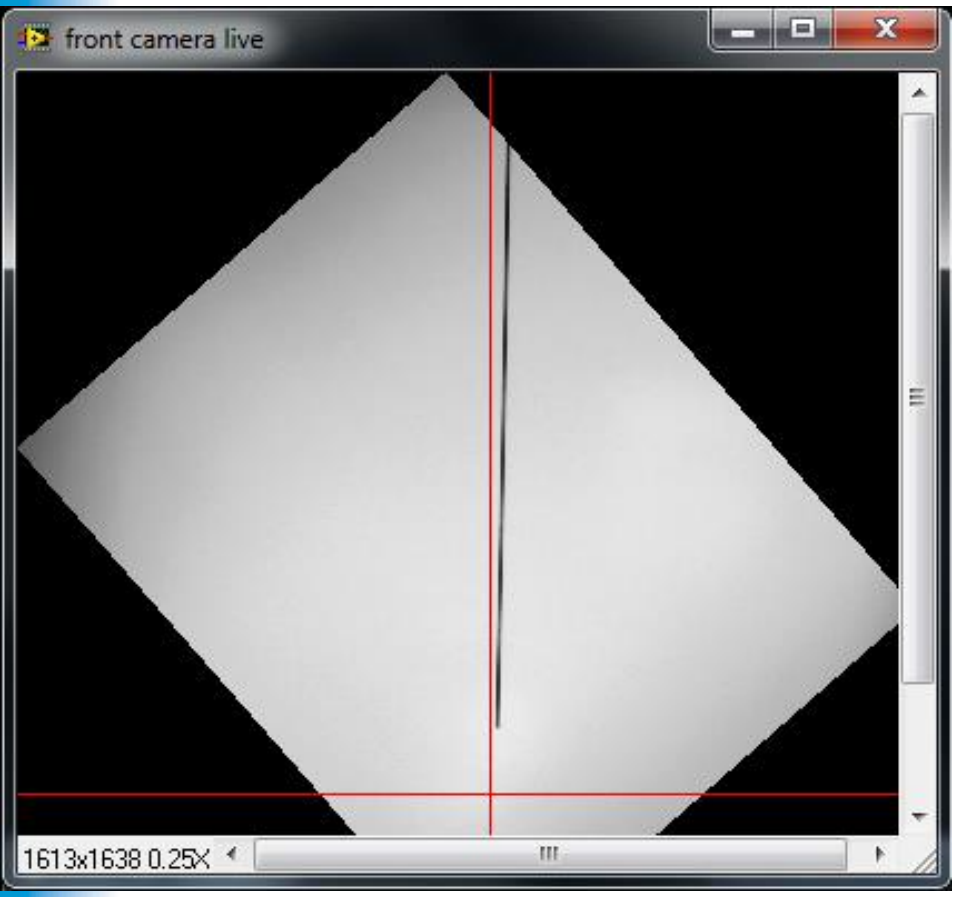
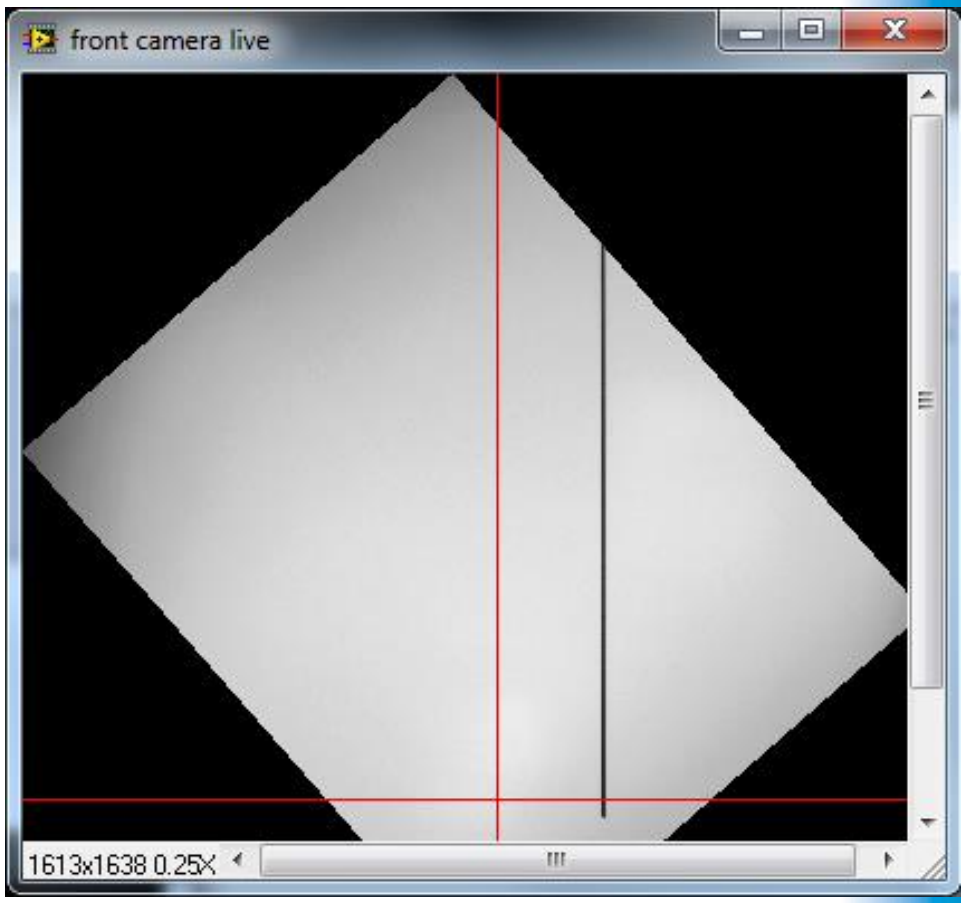
Micro Production System

Positioning of Fiber





Angle correction: Axis: θ

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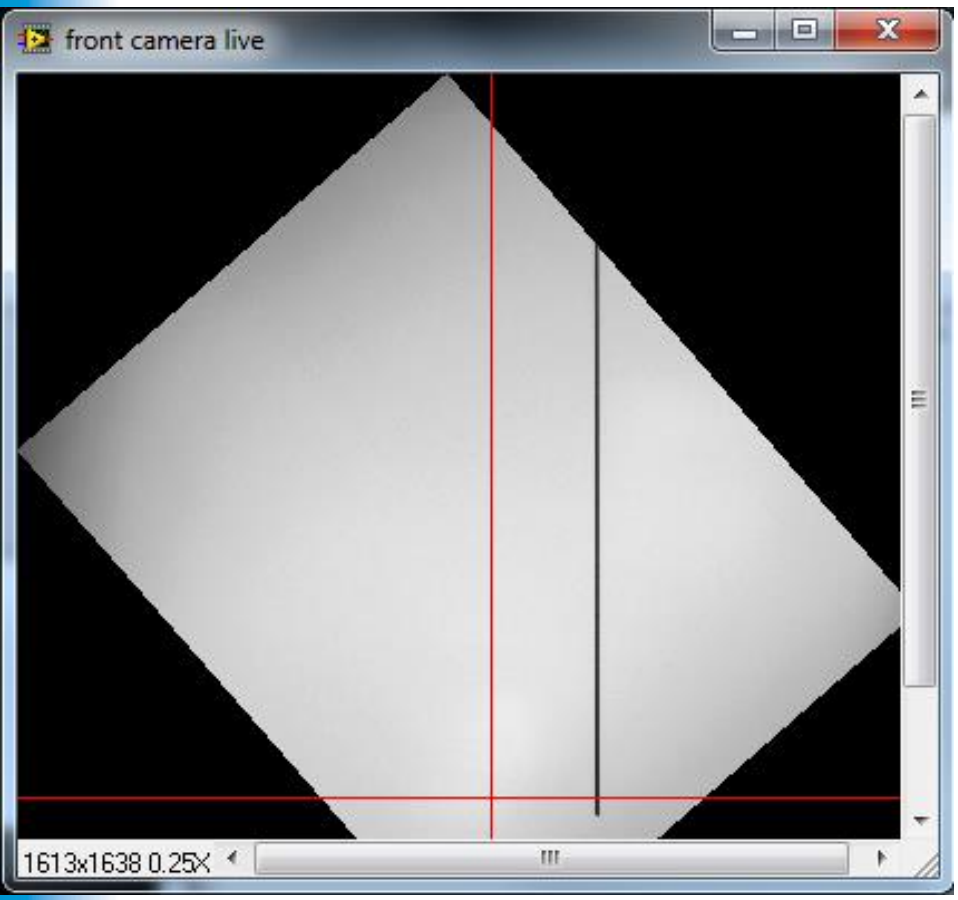
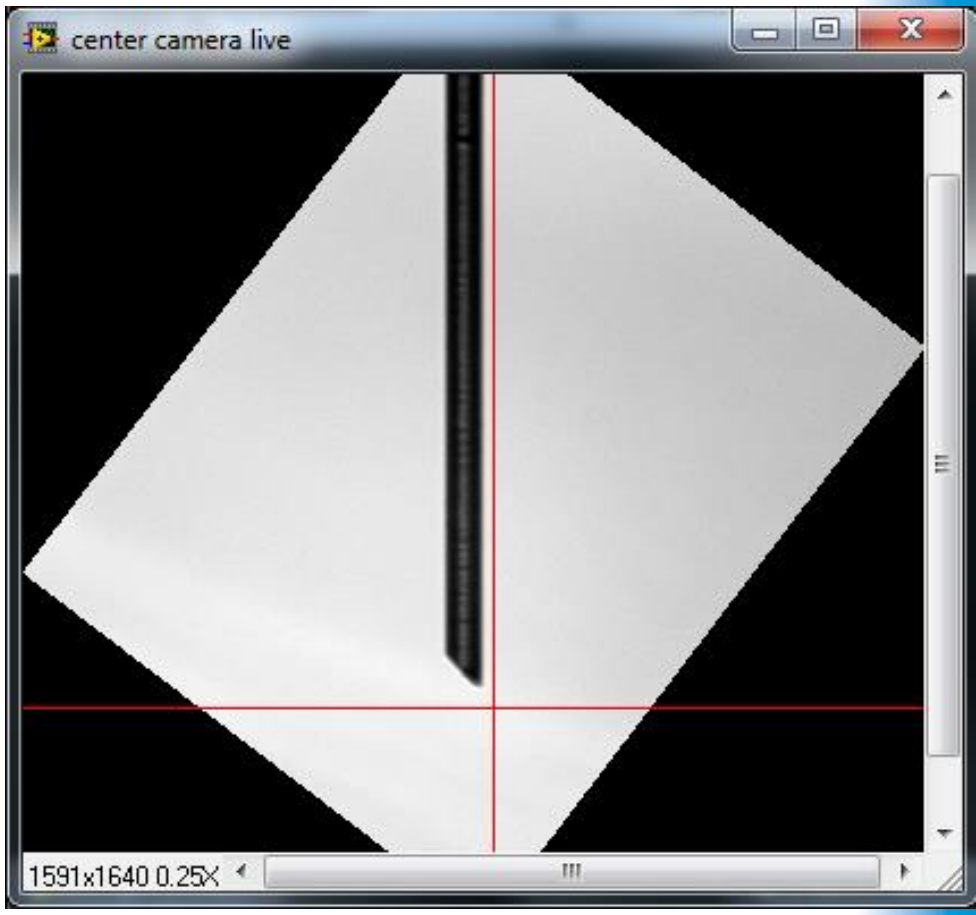
Micro Production System

Positioning of Fiber





Position correction: Axes: x, y, z

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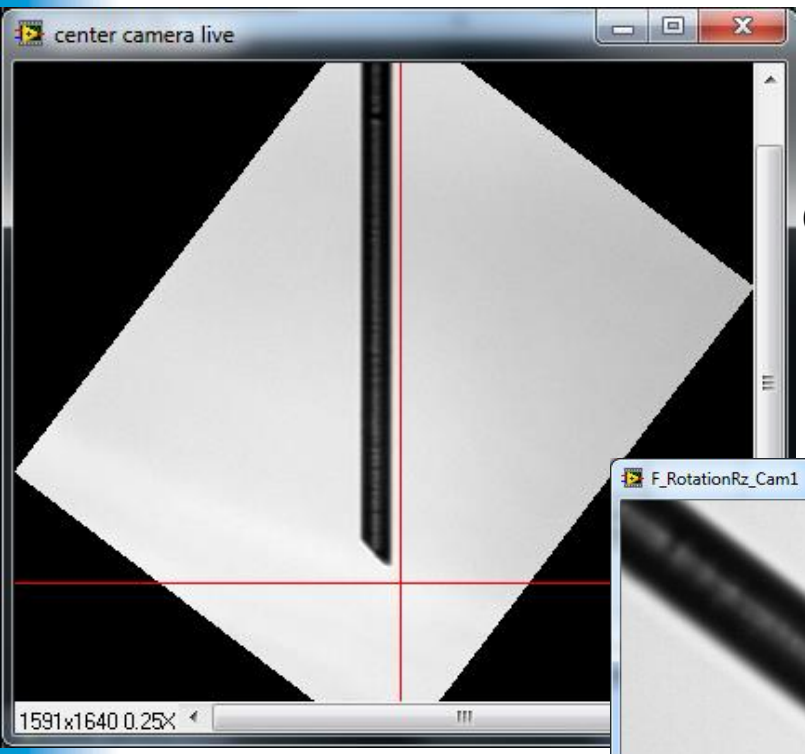
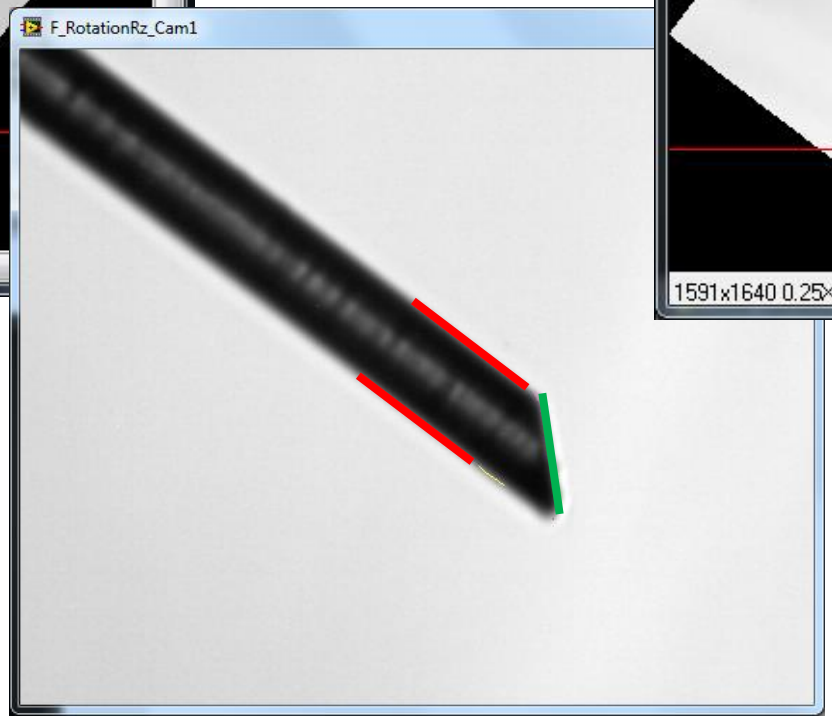
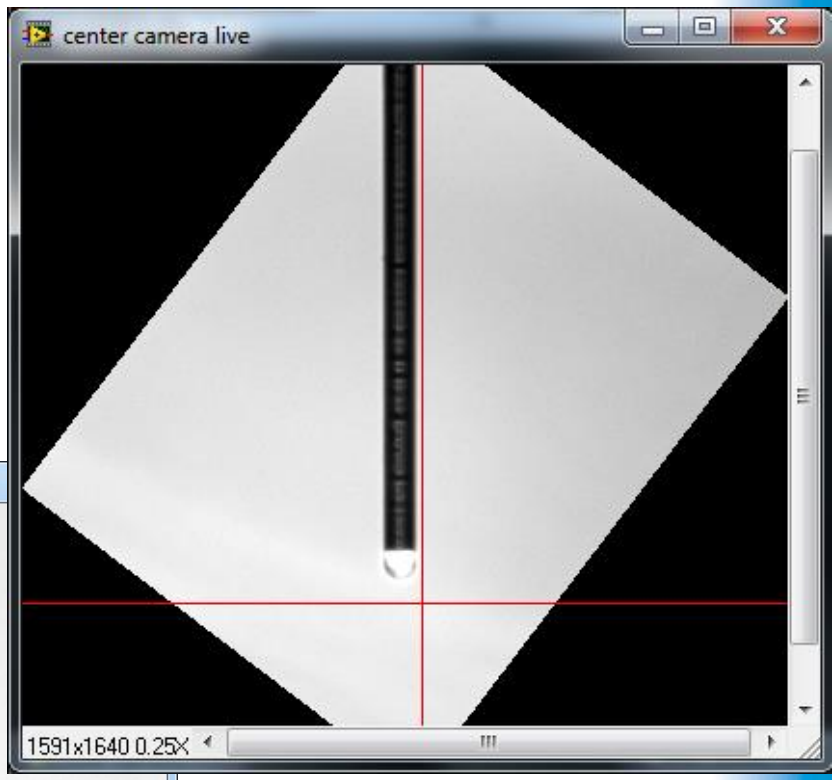
Micro Production System

Positioning of Fiber



Correction of rotation
Axes: x, y, z, ϕ





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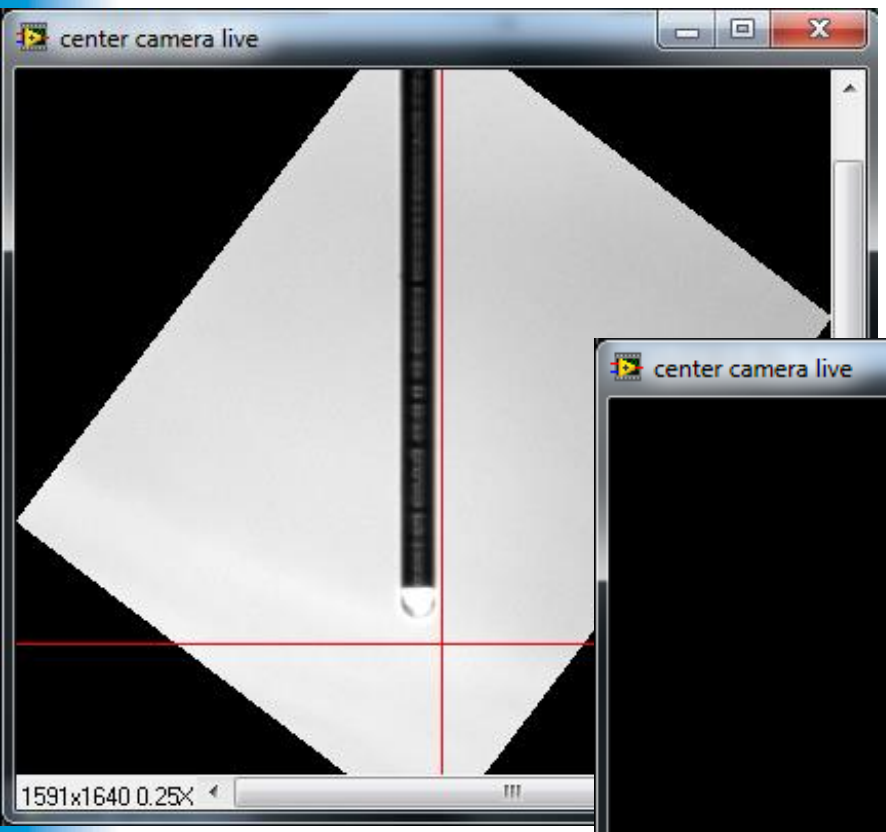
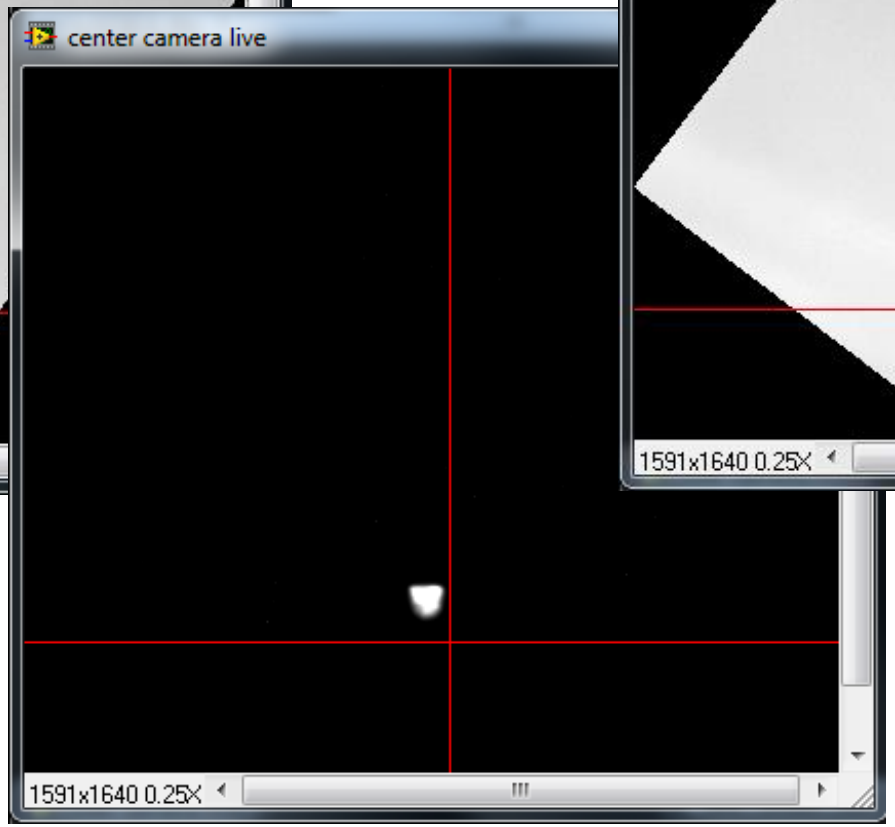
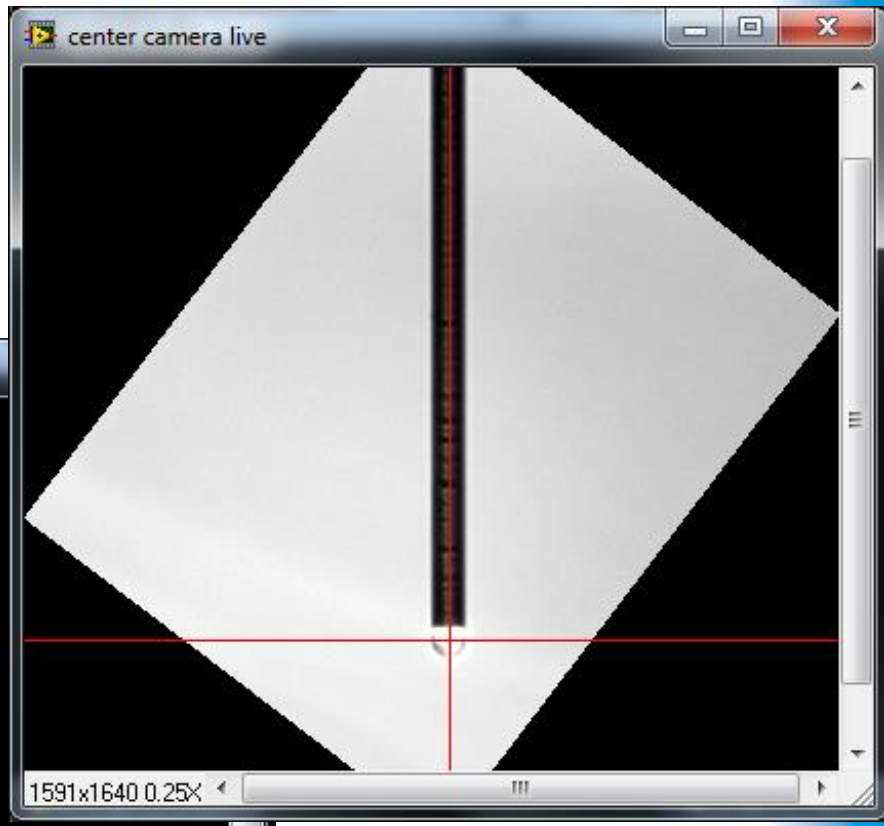
Micro Production System

Positioning of Fiber



Correction of fiber end
Axes: y, z





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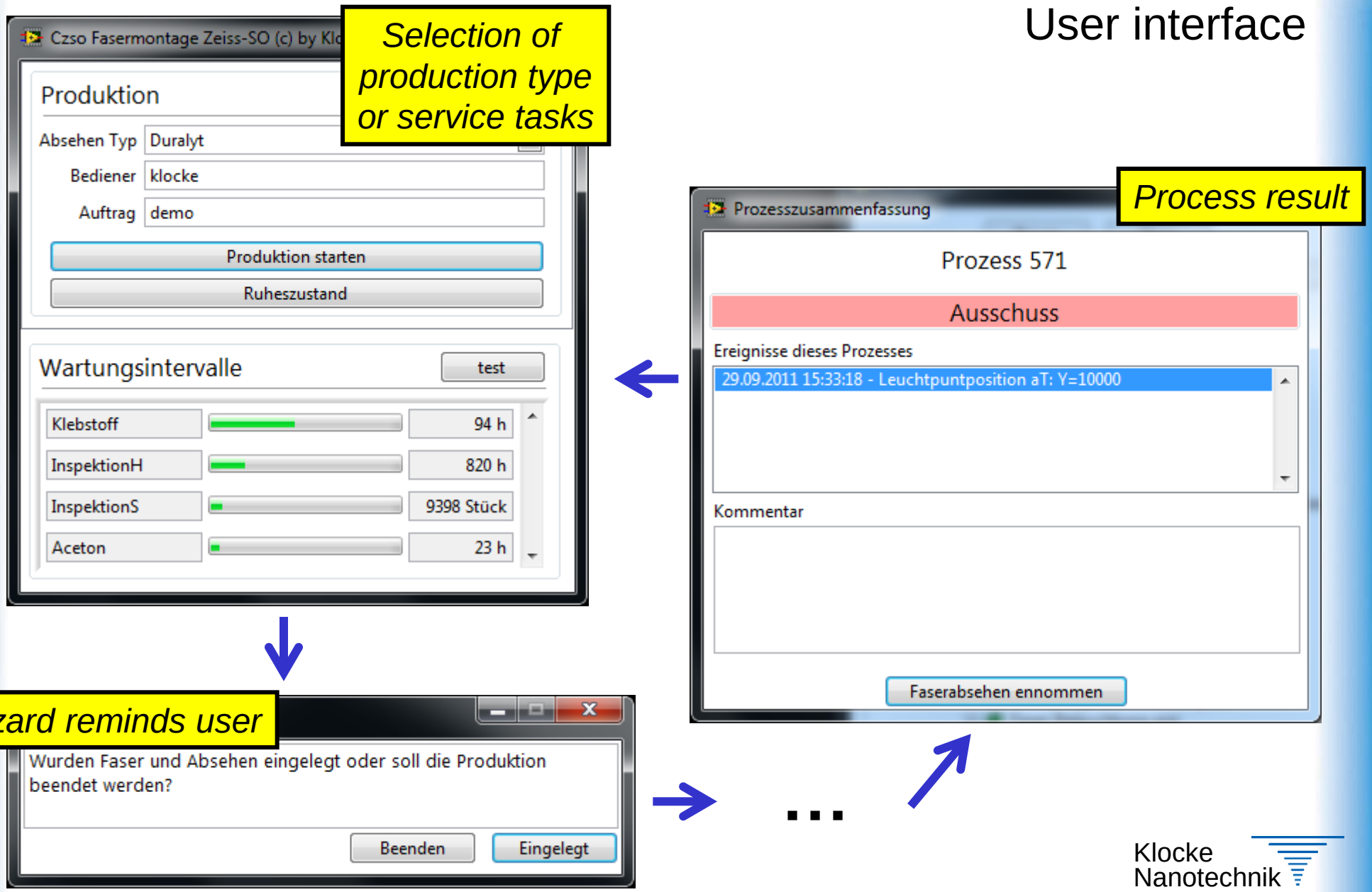
Micro Production System

User interface



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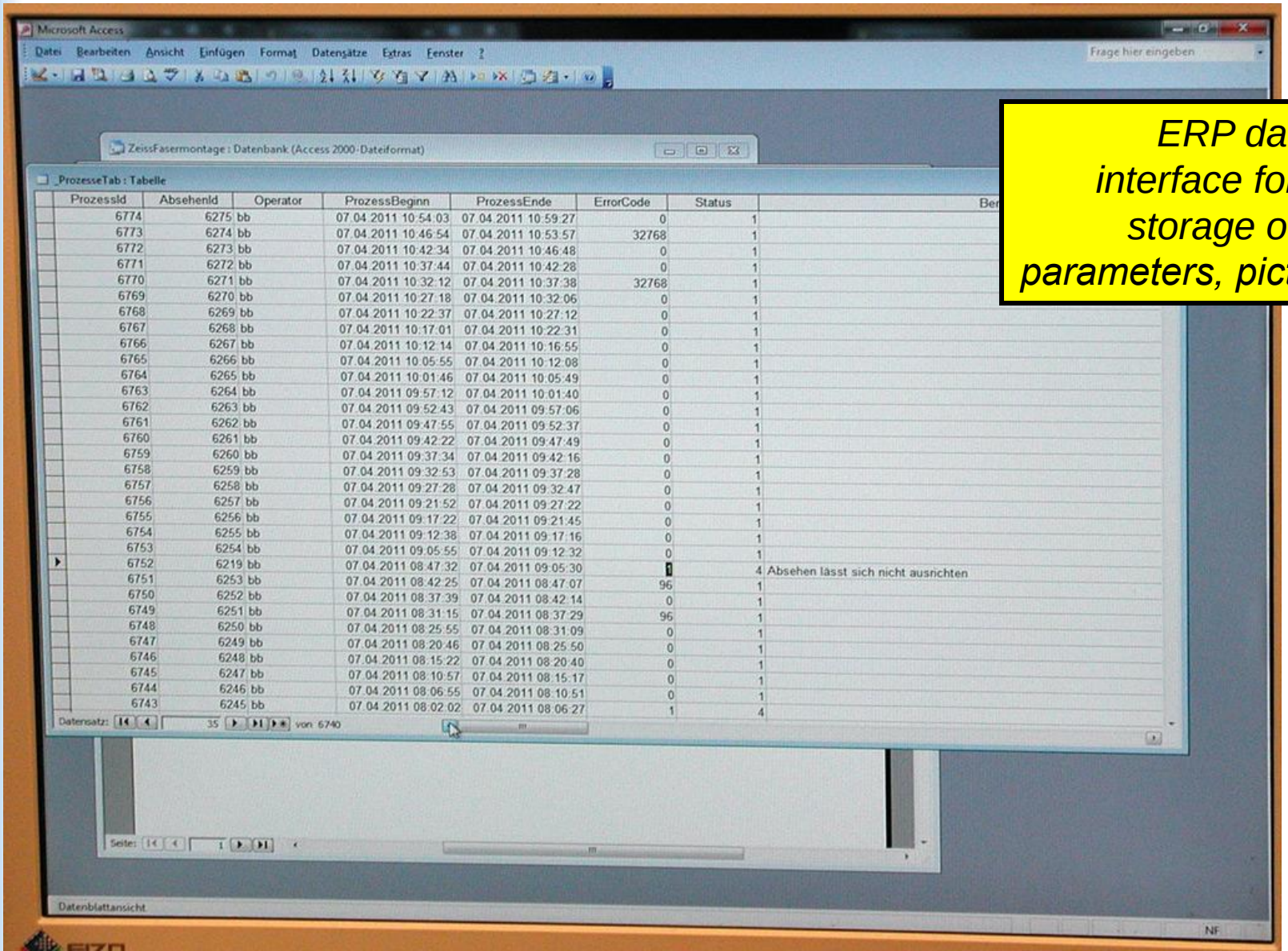
Micro Production System

Database interface



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6773	6274	bb	07.04.2011 10:46:54	07.04.2011 10:53:57	32768	1	
6772	6273	bb	07.04.2011 10:42:34	07.04.2011 10:46:48	0	1	
6771	6272	bb	07.04.2011 10:37:44	07.04.2011 10:42:28	0	1	
6770	6271	bb	07.04.2011 10:32:12	07.04.2011 10:37:38	32768	1	
6769	6270	bb	07.04.2011 10:27:18	07.04.2011 10:32:06	0	1	
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6767	6268	bb	07.04.2011 10:17:01	07.04.2011 10:22:31	0	1	
6766	6267	bb	07.04.2011 10:12:14	07.04.2011 10:16:55	0	1	
6765	6266	bb	07.04.2011 10:05:55	07.04.2011 10:12:08	0	1	
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6754	6255	bb	07.04.2011 09:12:38	07.04.2011 09:17:16	0	1	
6753	6254	bb	07.04.2011 09:05:55	07.04.2011 09:12:32	0	1	
6752	6219	bb	07.04.2011 08:47:32	07.04.2011 09:05:30	1	4	Absehen lässt sich nicht ausrichten
6751	6253	bb	07.04.2011 08:42:25	07.04.2011 08:47:07	96	1	
6750	6252	bb	07.04.2011 08:37:39	07.04.2011 08:42:14	0	1	
6749	6251	bb	07.04.2011 08:31:15	07.04.2011 08:37:29	96	1	
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6743	6245	bb	07.04.2011 08:02:02	07.04.2011 08:06:27	1	4	

ERP data base interface for automatic storage of process parameters, pictures, movies…

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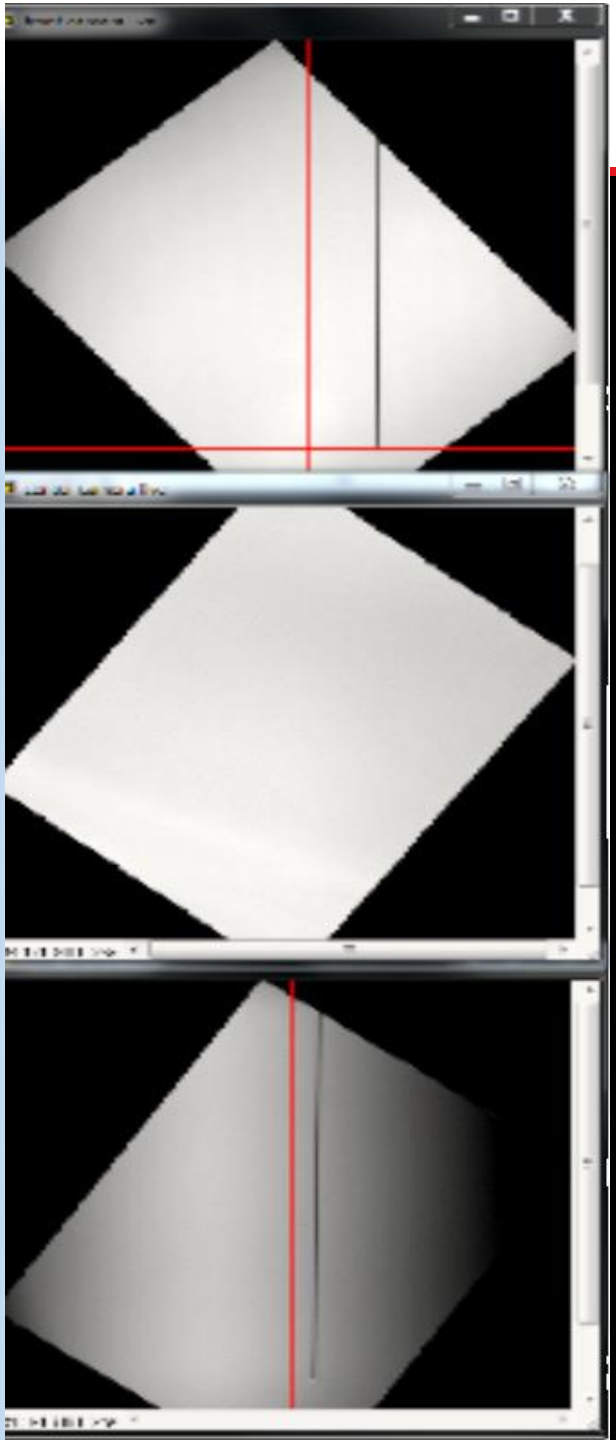
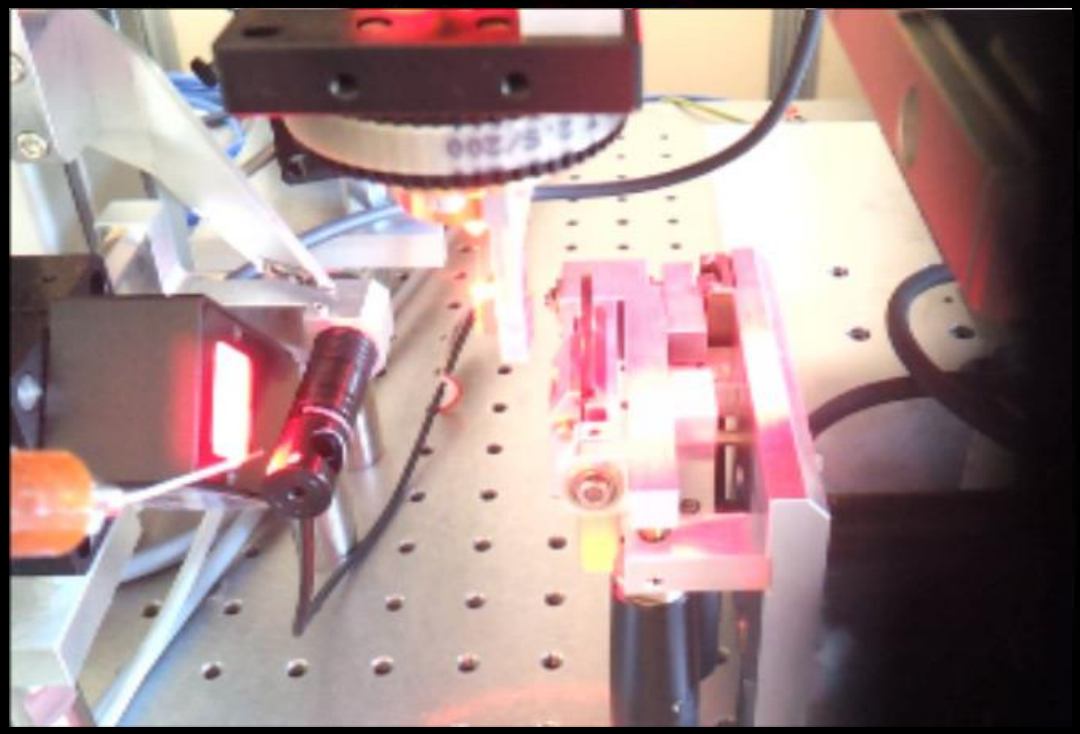


Micro Production System

The assembly process

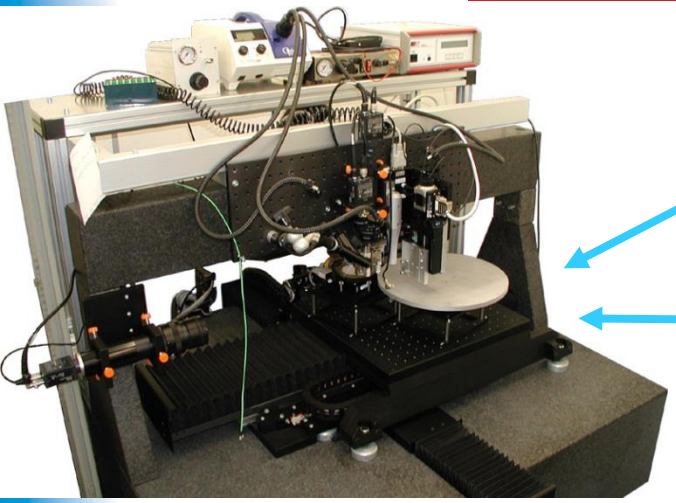
Process Control



Hardware

Click 2 times onto this background to see the movie

Complete Micro Production Line



IFAM

Institut Fertigungstechnik Materialforschung

LPKF Laser & Electronics

LPKF Motion & Control GmbH

Organisation: VDMA

IBM

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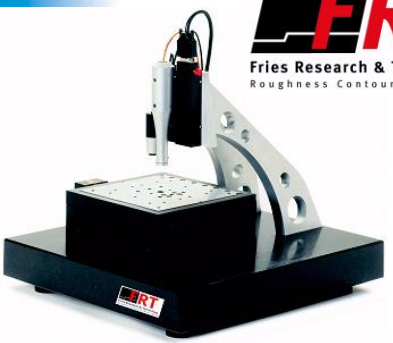


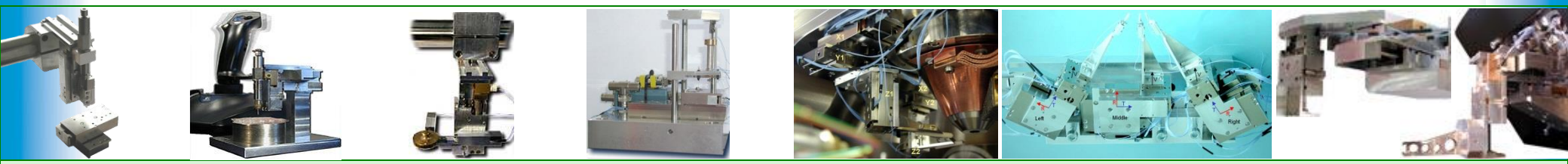
FRT Fries Research & Technology
Roughness Contour Topography

Summary

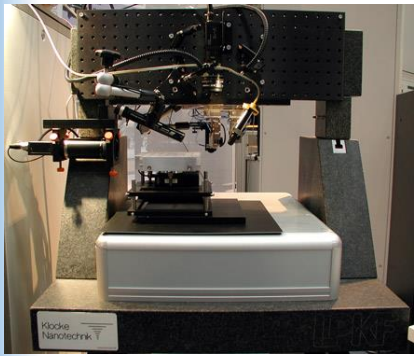
Modular Nanorobotics

Pool of more than 200 Nanorobotics Components

Configuration to individual machines



µ-Assembly, µ-Tensile-Machine, 3D-Nanofinger, SPM-Lithographer, ... **The SEM/FIB Workbench**



Integration in Nanorobotics systems

Universal Testing Benches

Micro Production Systems