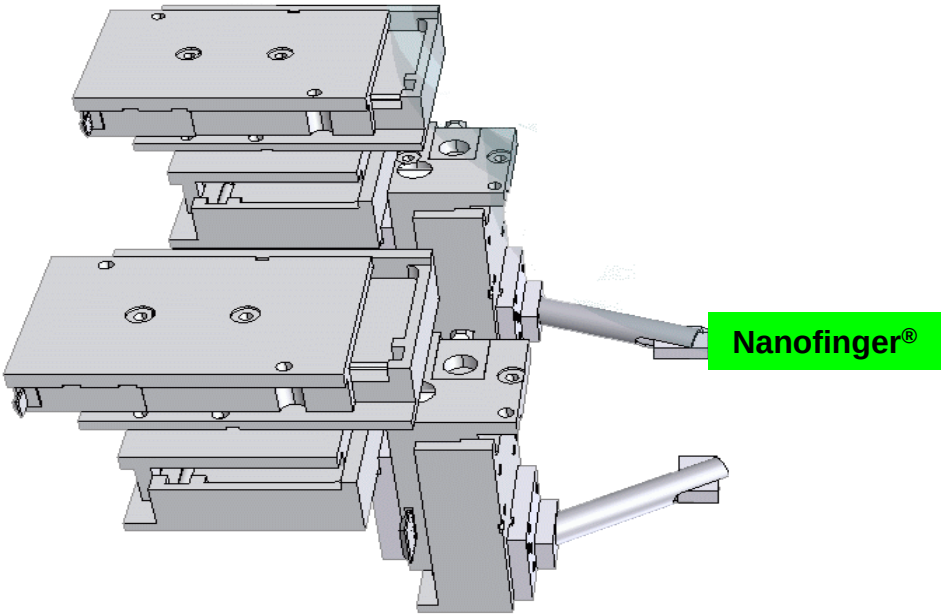
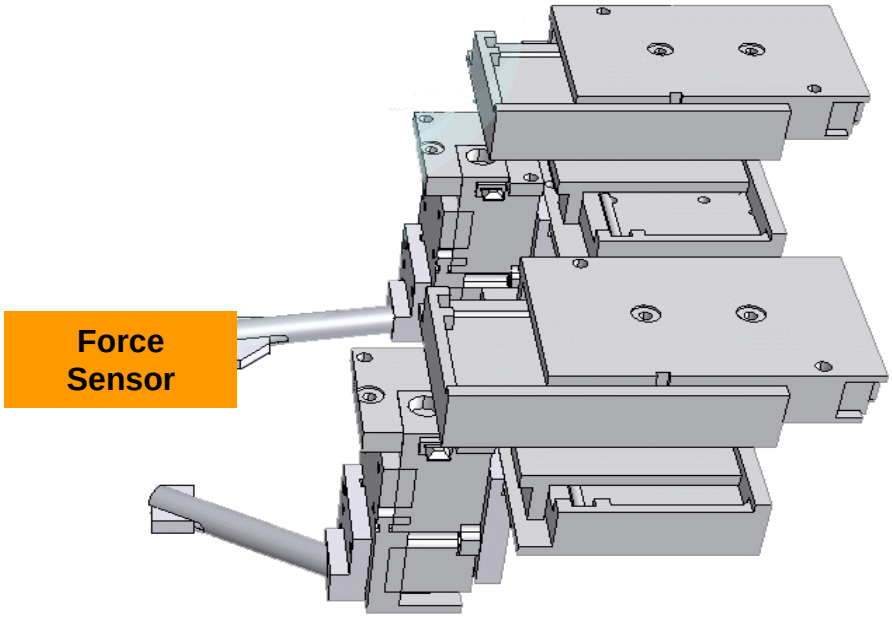
Force-Distance Measurements:

Force-Distance Measurements inside SEM/FIB systems with the Nanoworkbench from Klocke Nanotechnik

Force-Distance Measurements

Nanoworkbench Configuration





1. Nanomanipulator equipped with: 1D-Nanofinger® as Scout, Tip Cleaning Module, or Discharge Module for working on isolating samples

2. Nanomanipulator equipped with: Force Sensor

- Standard Software Package: Macro Executor, Live Image Positioning, Assistants, Sequencer

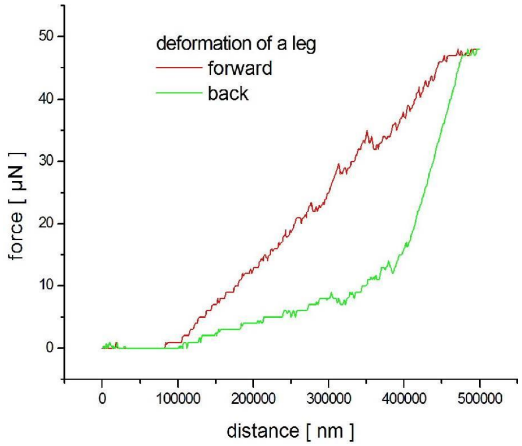
Force-Distance Measurements

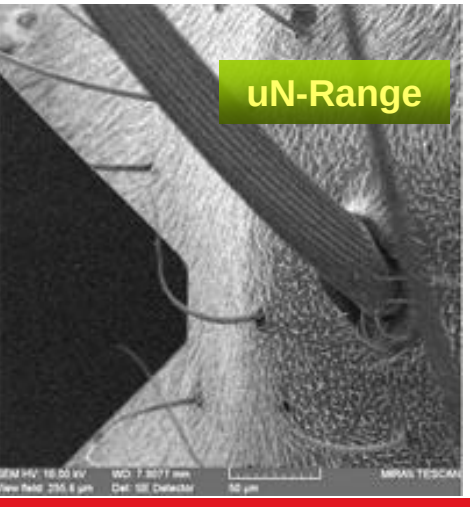
is more than just force!

Force – Distance Measurements need:

- Absolute positioning accuracy with single nm resolution
  ➔ Most manipulators can only carry a force sensor without knowing its position: No option for Force-Distance and e.g. Elasticity measurements

- The force and stroke range depends on the used sensor:





Sensors with different resolution for elastic samples

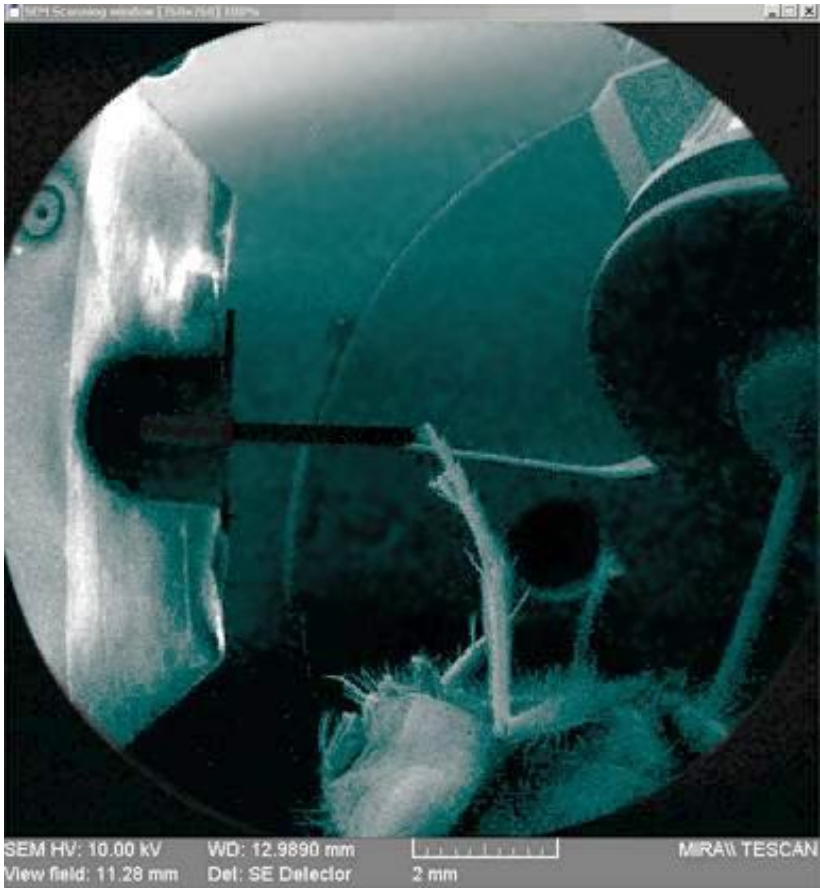
High Stiffness sensors for harder samples

Force-Distance Measurements

Live Science Applications

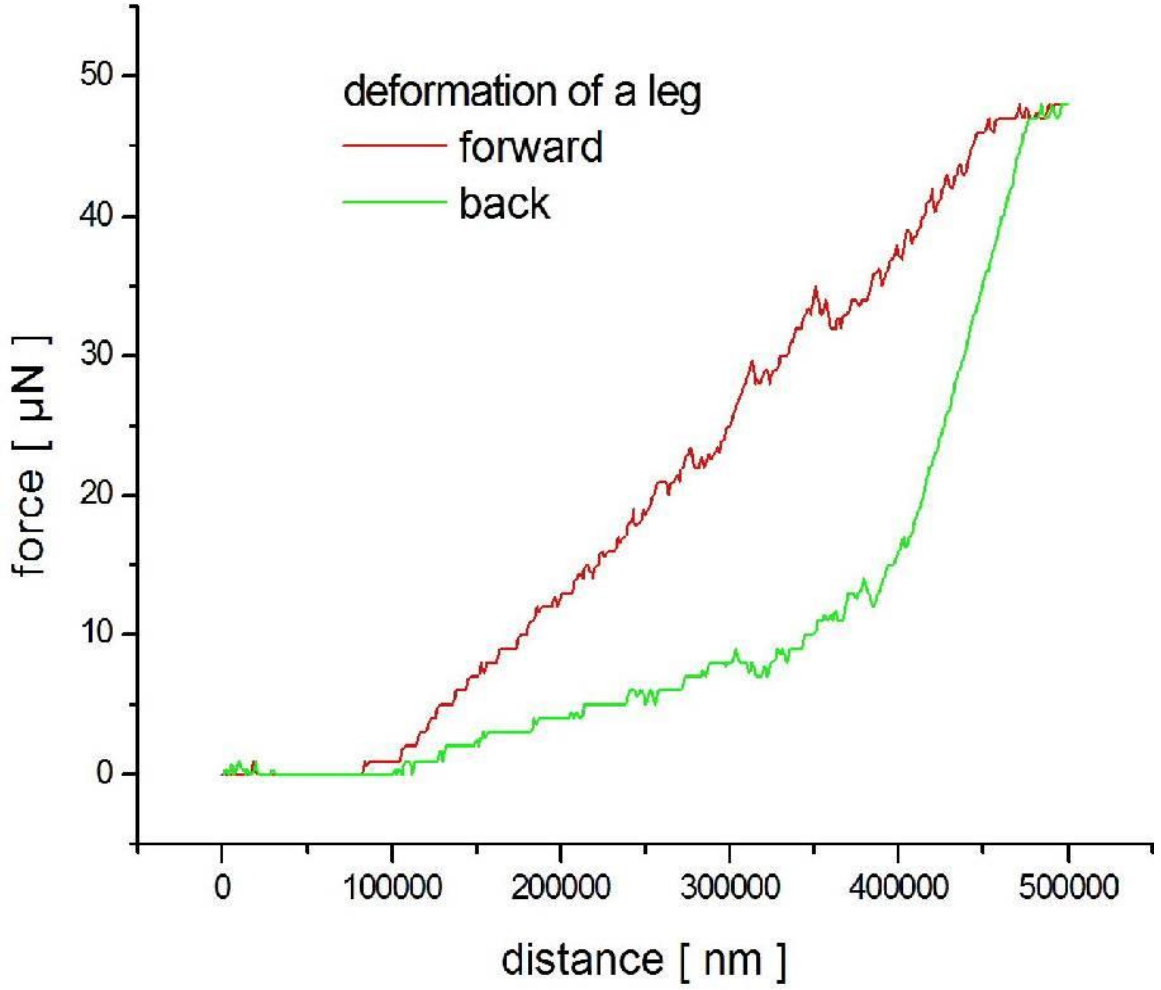
SEM image in Wide Field mode:

- A Nanorobotic Manipulator from Klocke Nanotechnik is equipped with a force sensor for elastic samples.
- The force sensor is moved from the left side towards the leg of a fly (center of the image)



Force-Distance Measurements

Live Science Applications



Force – Distance Diagram:

- Single nm resolution in displacement
- Force range depending on used sensor
- The hysteresis allows to determine the elasticity

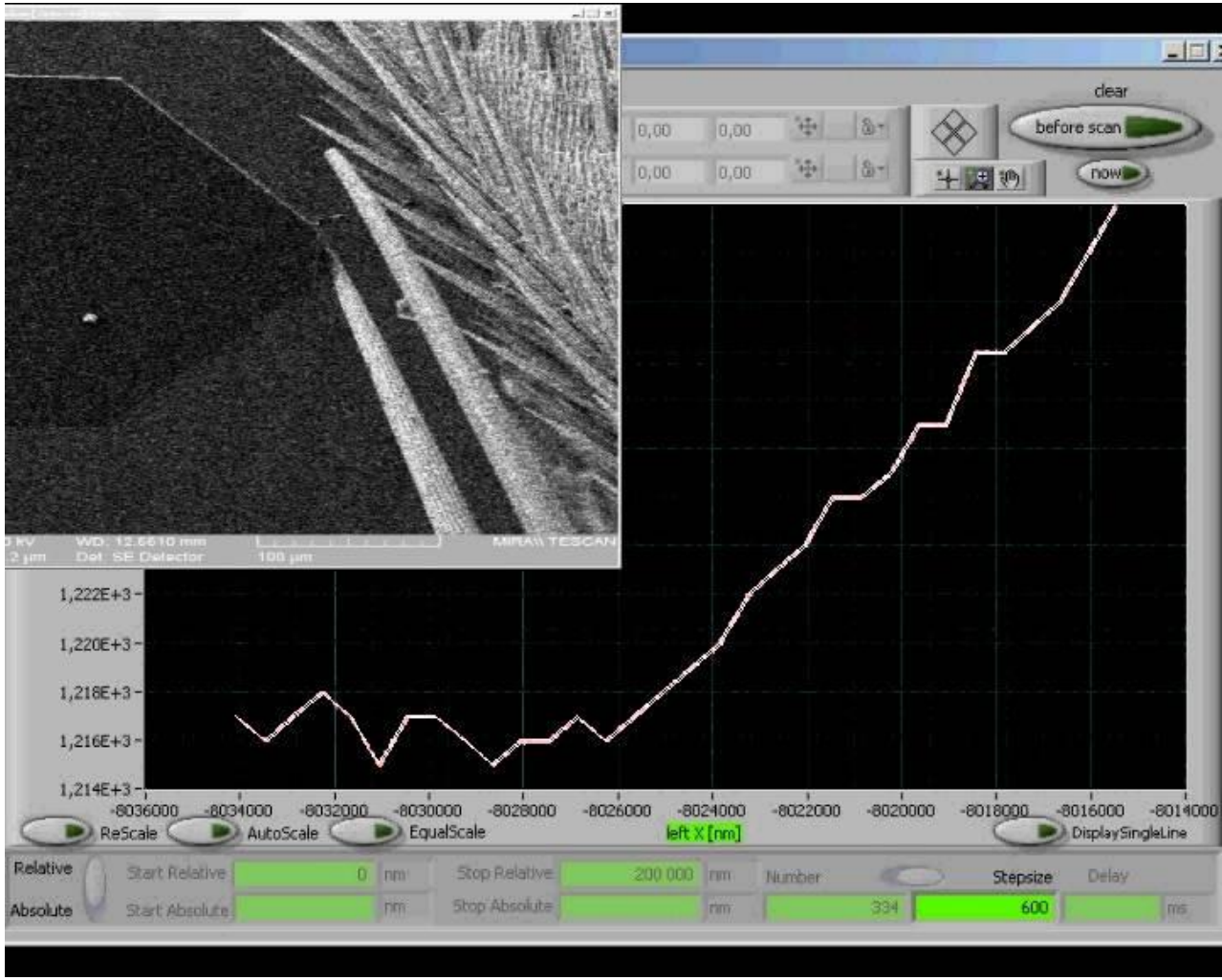
Force-Distance Measurements

Live Science Applications

SEM image and measurement:

- The force sensor moves against a hair at a leg of a fly

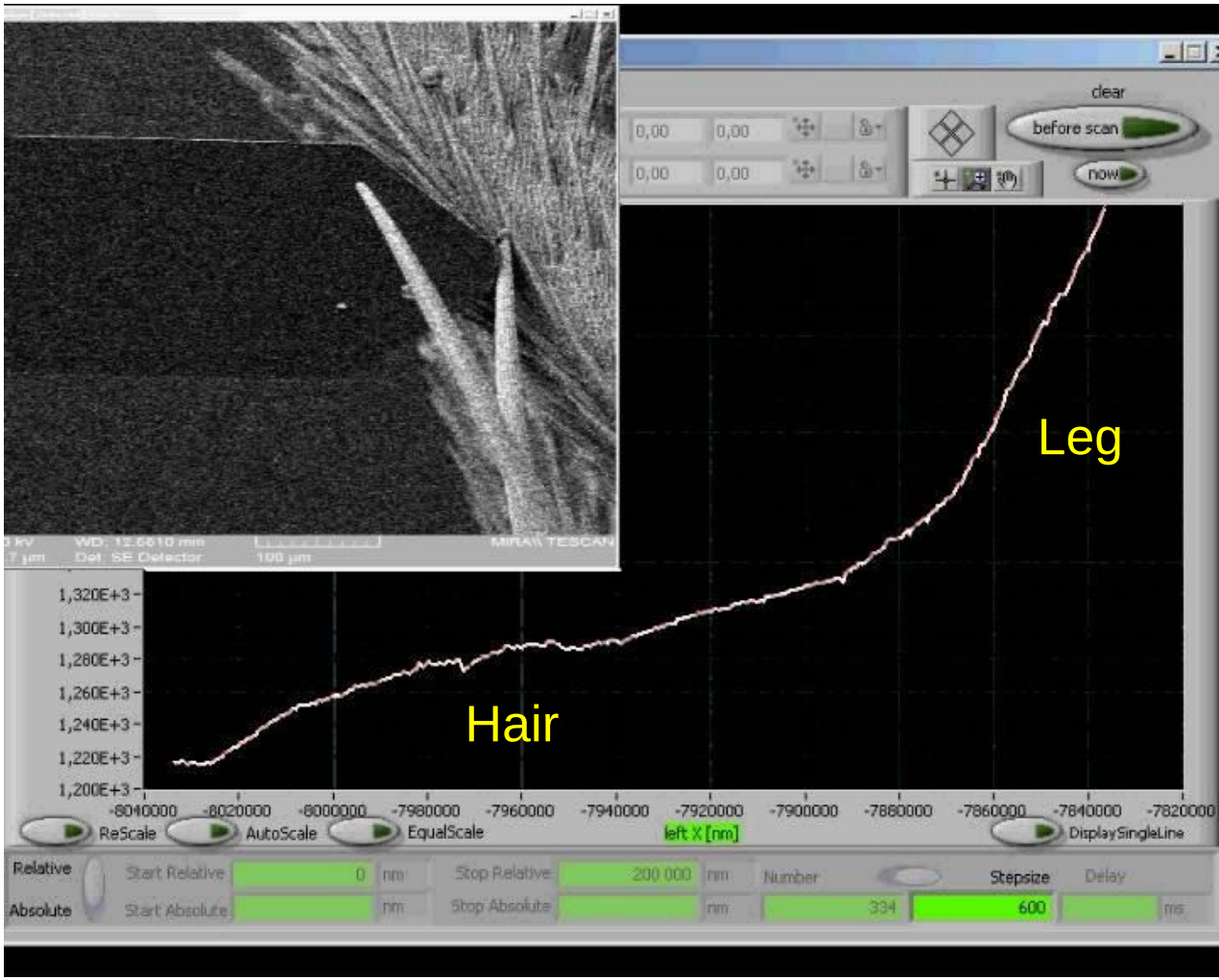
- SEM image and the growing force-distance graph are visible simultaneously



Force-Distance Measurements

Live Science Applications

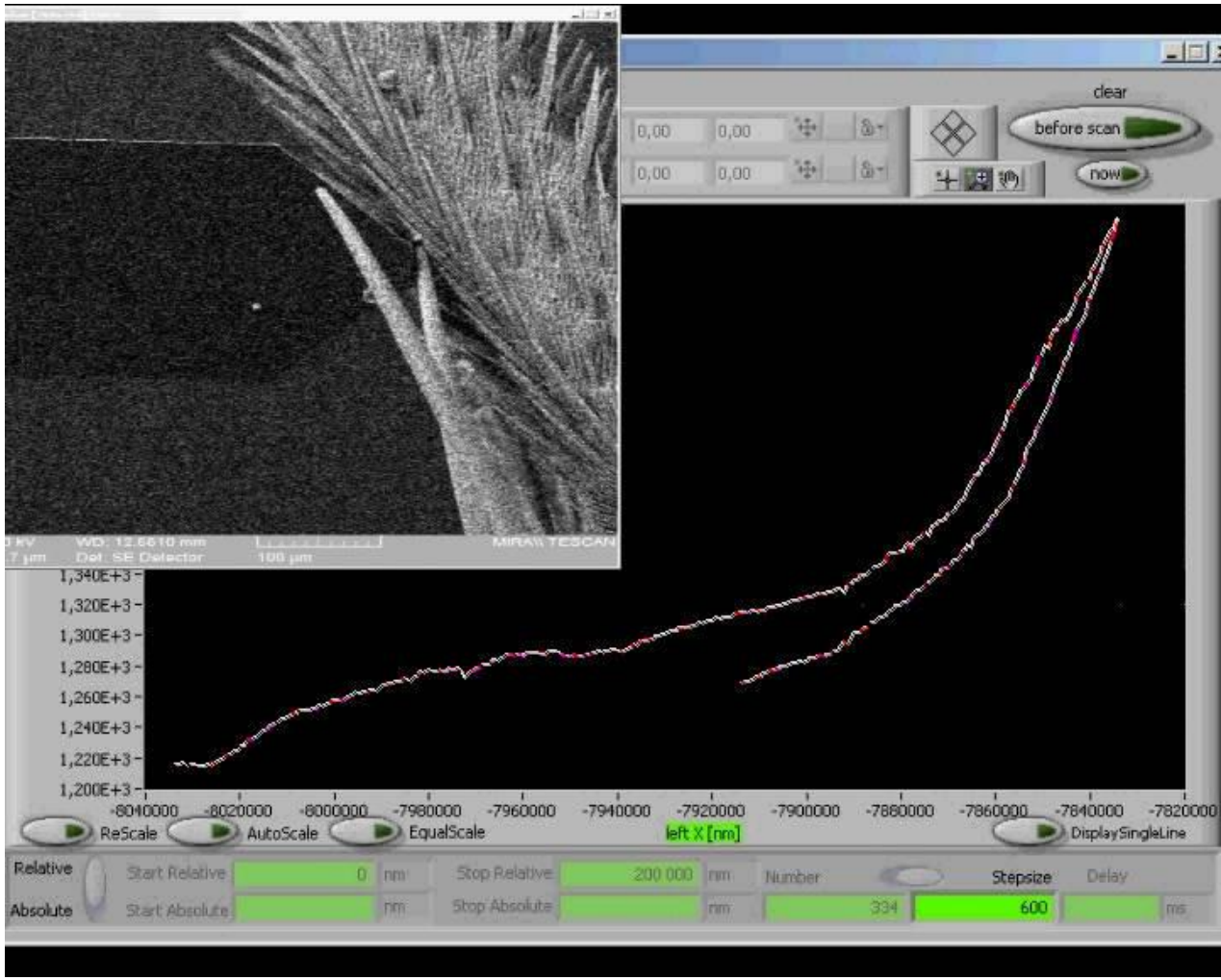
- The force sensor first deforms the hair and later the leg (top right)
- The force-distance graph increases its slope when the leg is also bent



Force-Distance Measurements

Live Science Applications

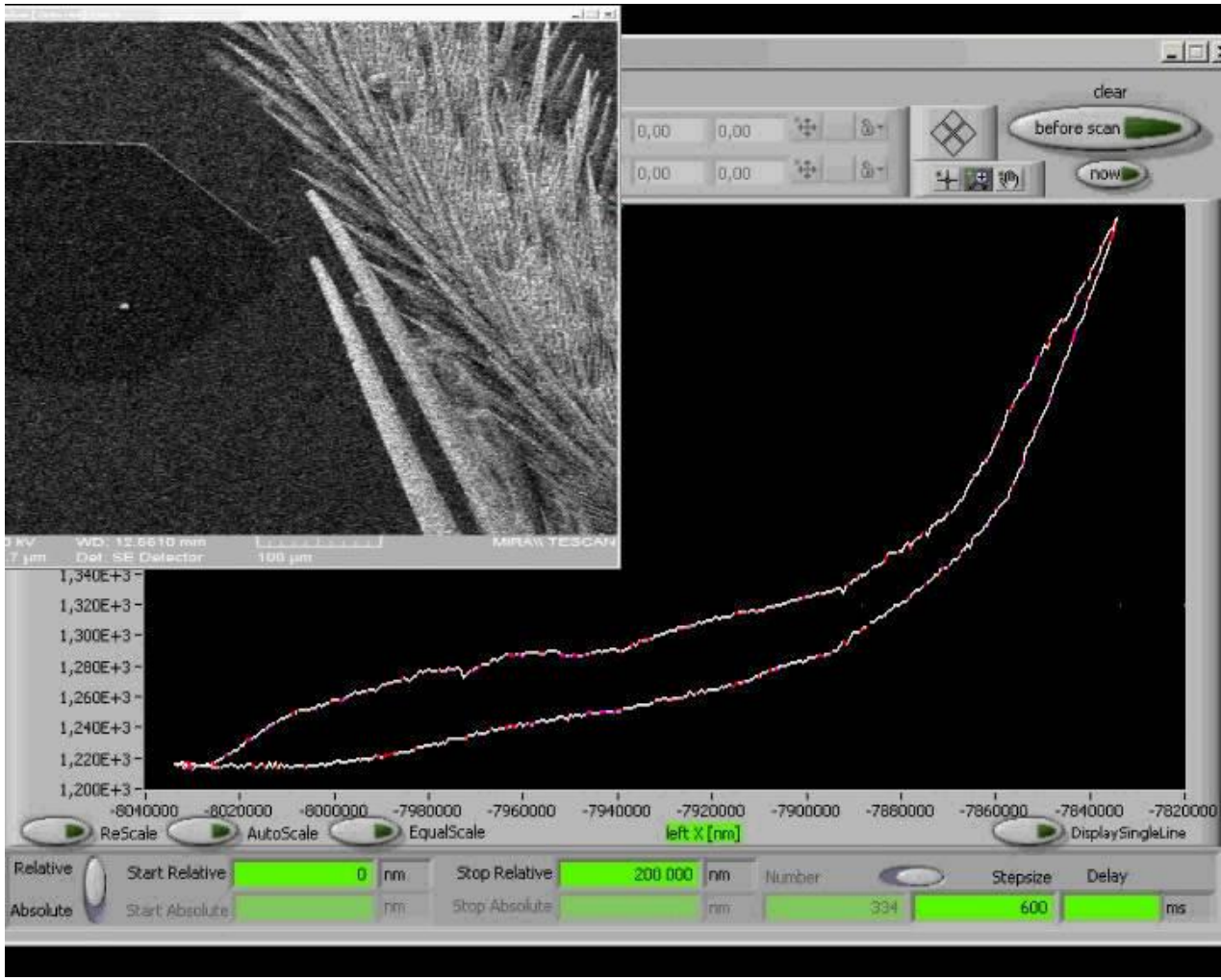
- The force sensor moves back (top left)
- The force-distance graph forms a hysteresis



Force-Distance Measurements

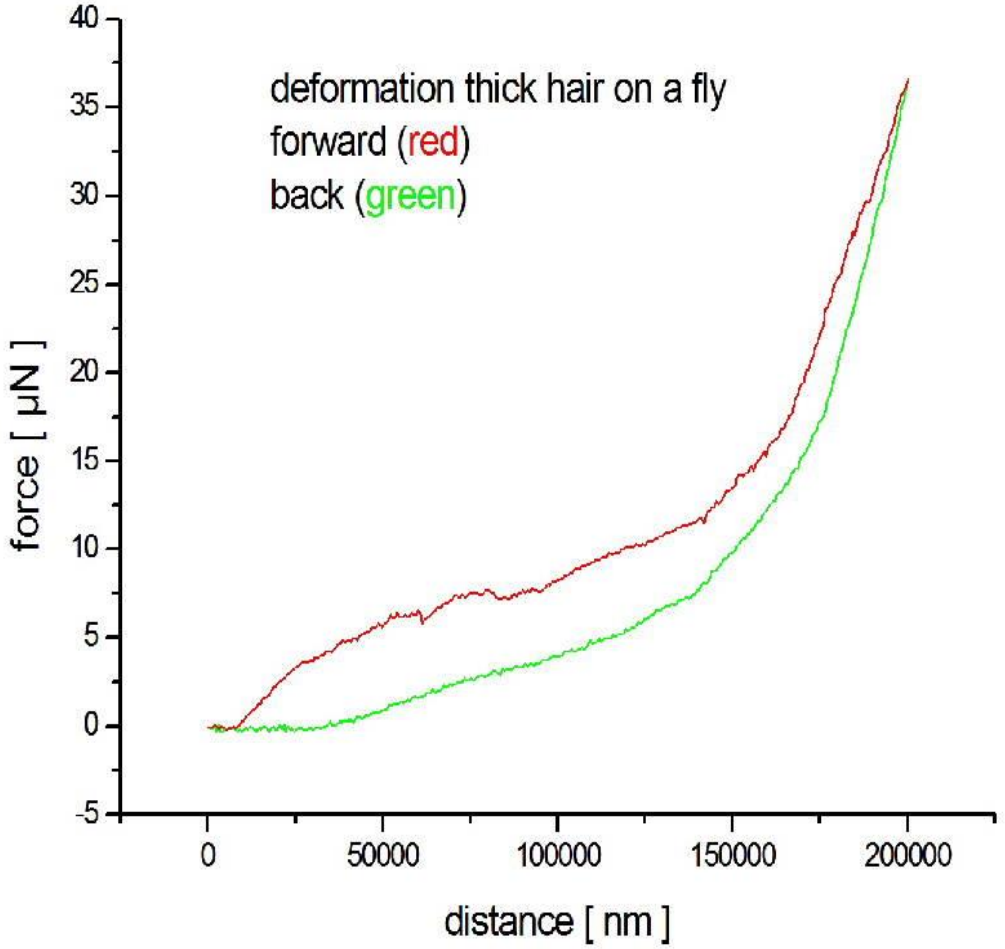
Live Science Applications

- Process completed.
- The slope of the lower hysteresis line corresponds to the elasticity of the leg.



Force-Distance Measurements

Live Science Applications



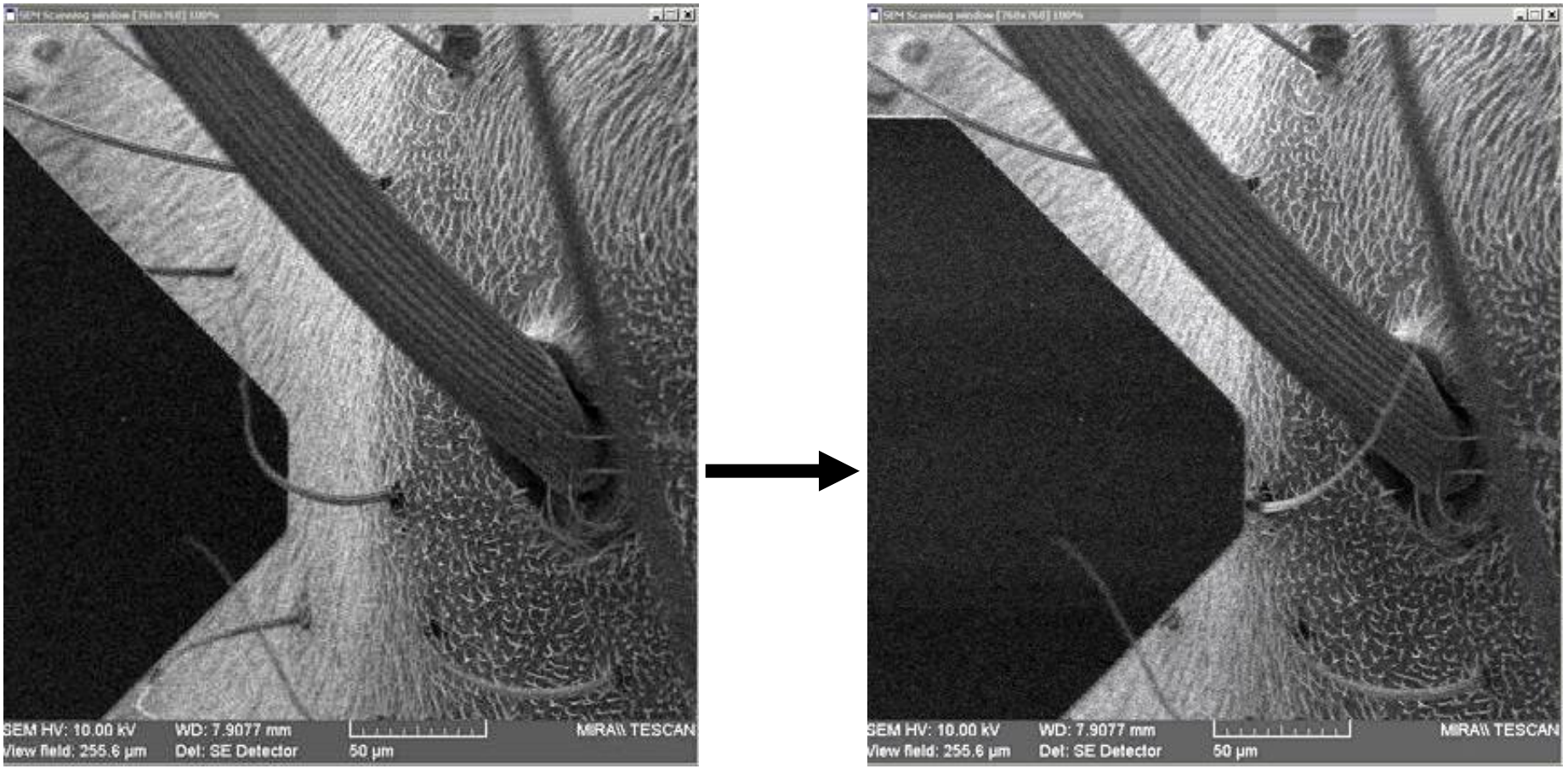
Force – Distance Diagram:

- Bending of a hair on a fly's leg and the leg itself
- Forward direction - red
- Back - green

Force-Distance Measurements

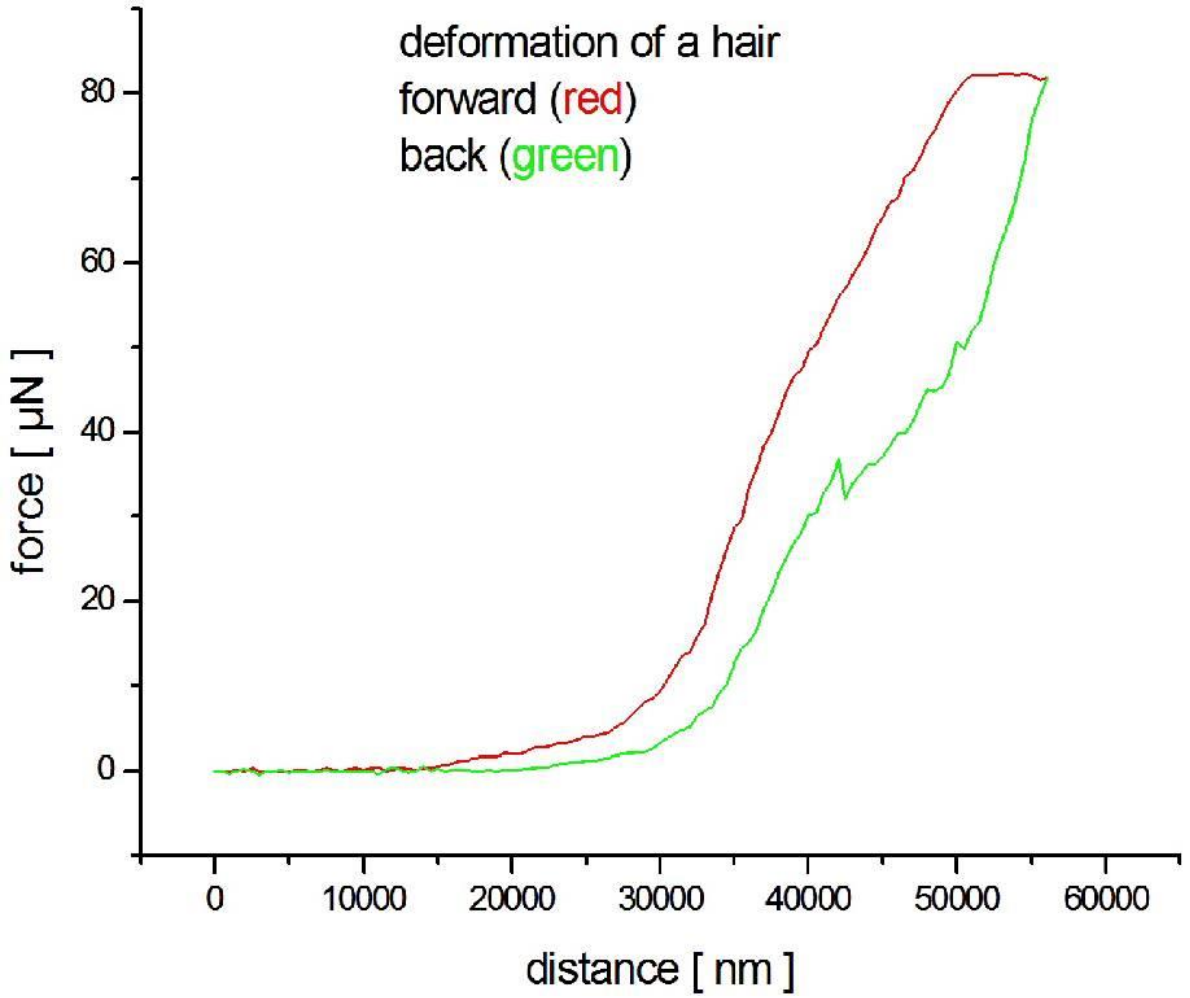
Live Science Applications

- The force sensor is moved from the left against a single thin hair of a fly:



Force-Distance Measurements

Live Science Applications



Force – Distance Diagram:

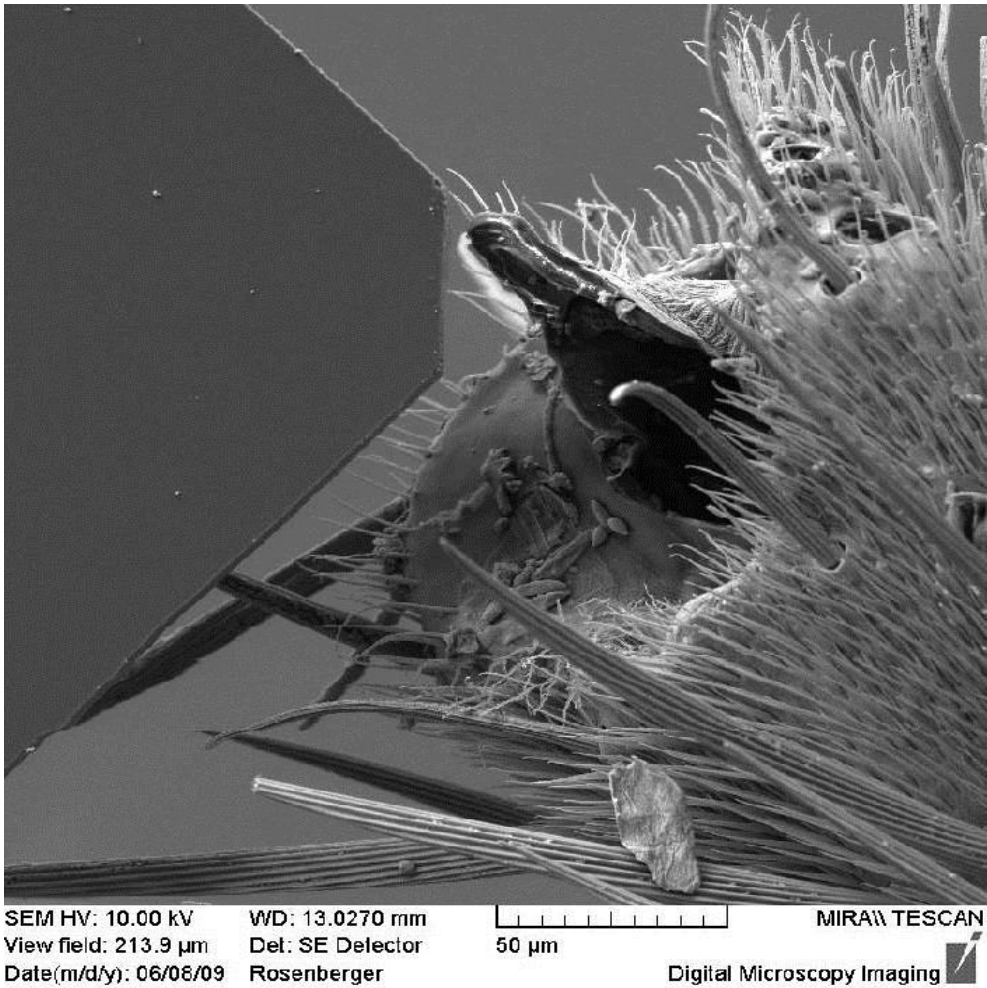
- Single nm resolution in displacement
- Force range depending on used sensor

Force-Distance Measurements

Live Science Applications

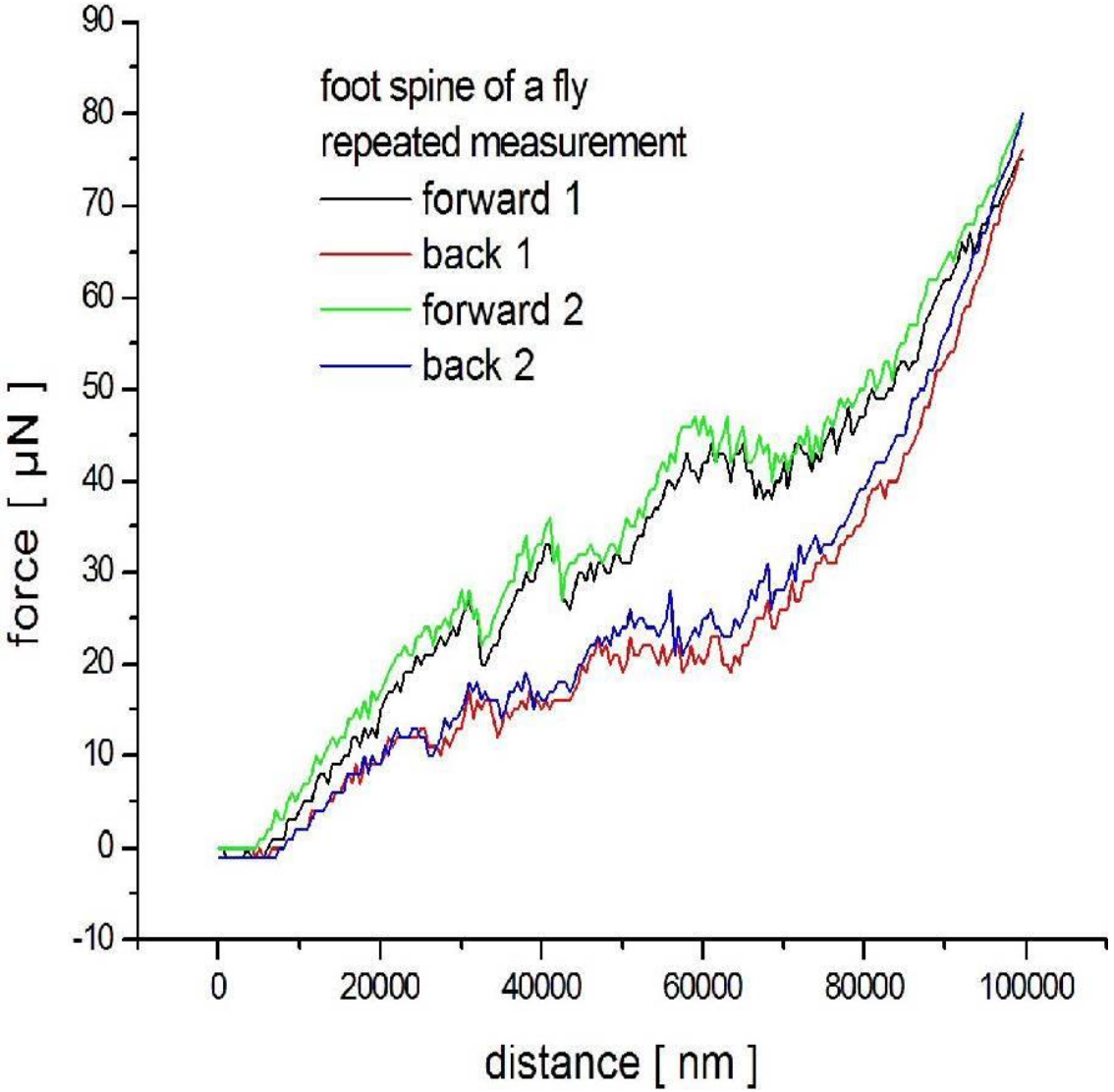
Force-distance diagram repeatability:

- A force sensor is moved against a foot of a fly and then bends the whole leg.
- Force and position information are recorded



Force-Distance Measurements

Live Science Applications



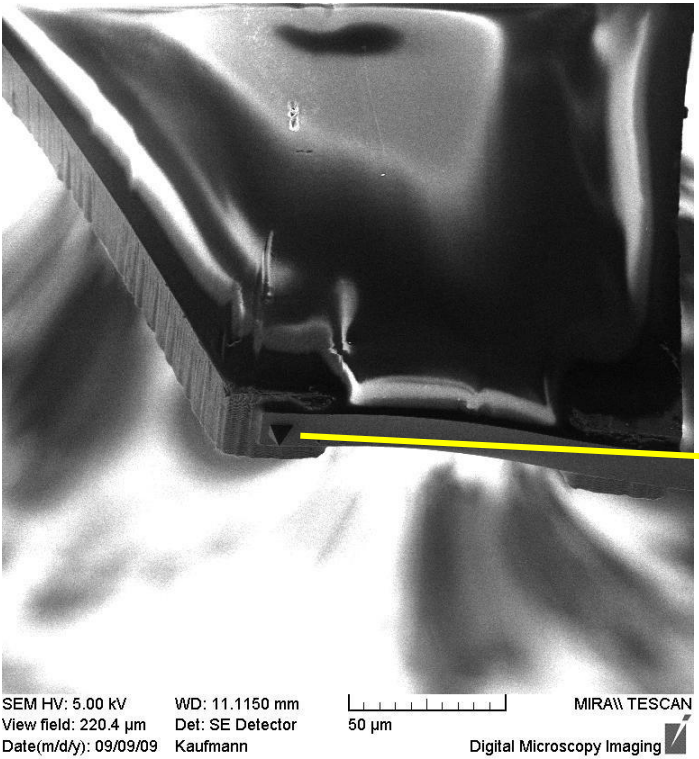
Force – Distance Diagram
Repeatability:

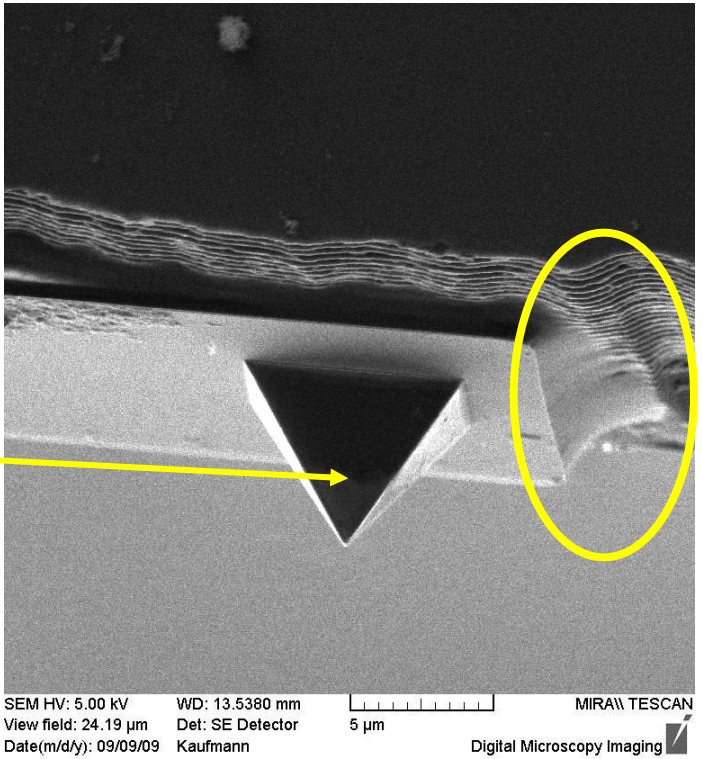
- Bending of a fly leg
- Measured two times:
- The second measurement shows the good repeatability
- First measurement
  forward direction – black
  back – red
- Second measurement
  forward direction – green
  back - blue

Force-Distance Measurements

High Stiffness Sensors

Klocke Nanotechnik developed special high stiffness force sensors for harder samples:





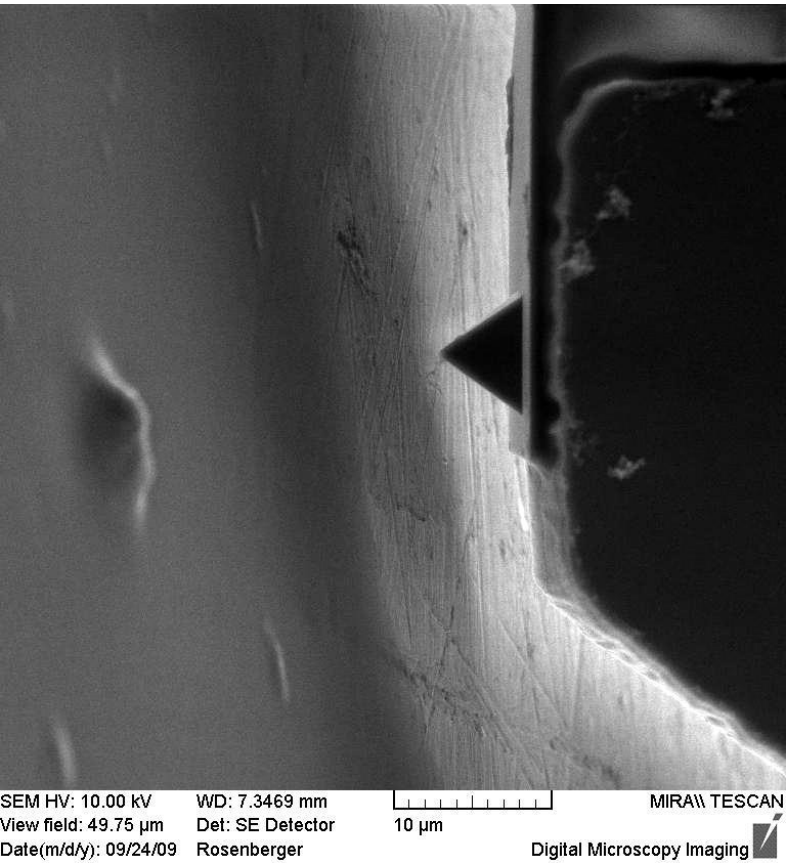
Option:

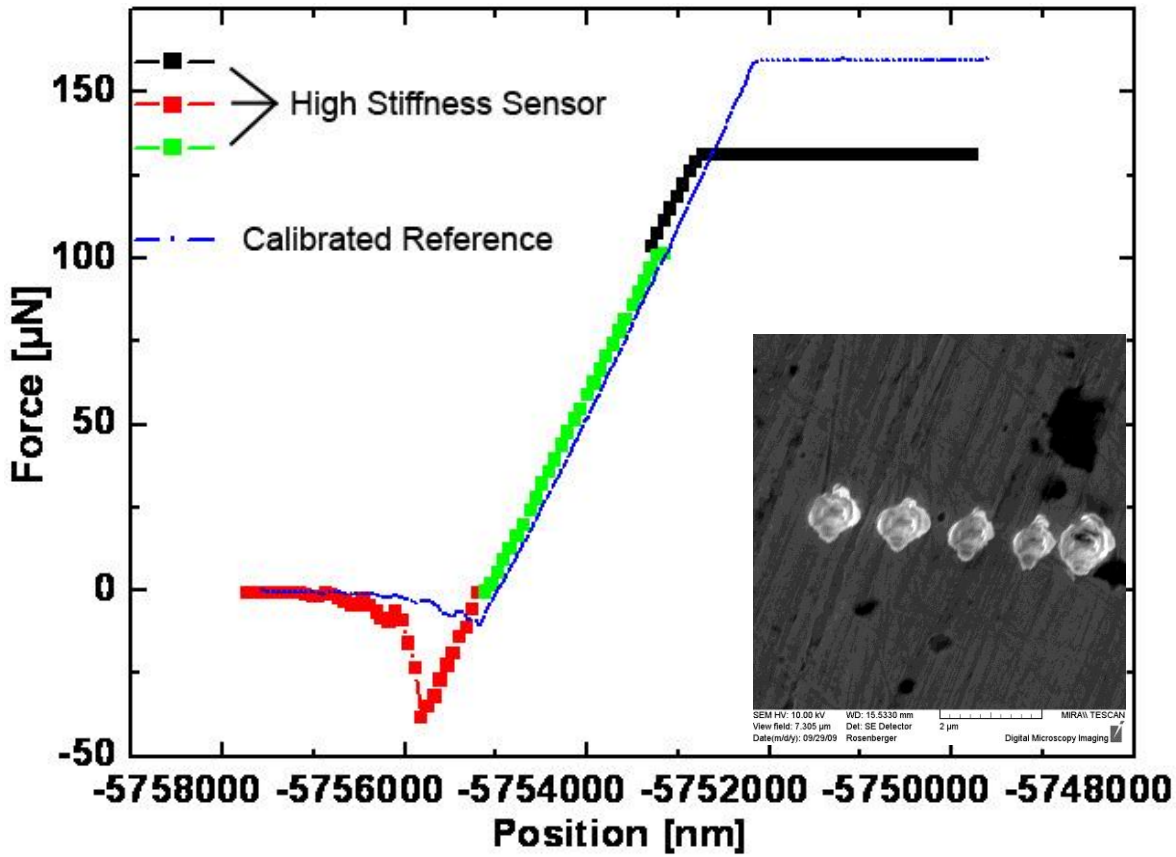
- Different probe tips with inelastic fixture at the force sensor

Force-Distance Measurements

High Stiffness Sensors

High stiffness force sensor calibration:



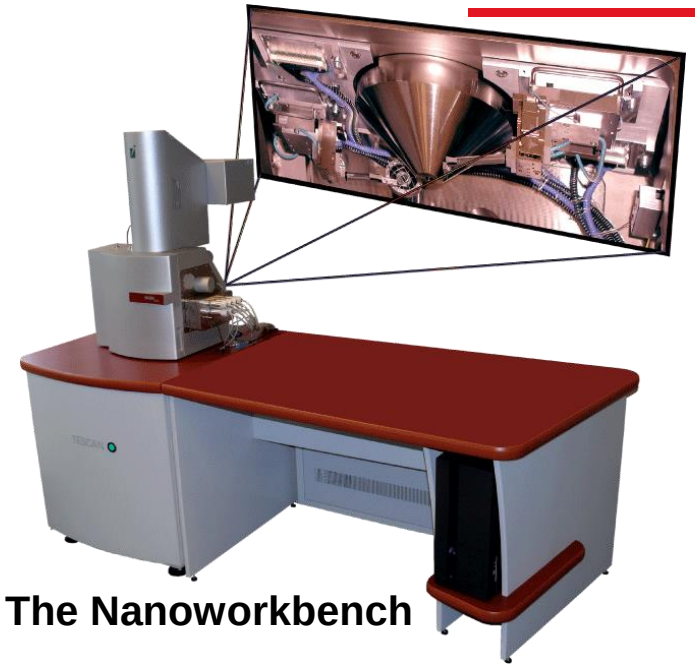


Summary

- Force-Distance measurements in SEM/FIB systems is one of the Nanoworkbench Standard Application Packages from Klocke Nanotechnik.
- The Live Image Positioning module allows to direct the sensor in XY to the target area just by mouse-click into the SEM image.
- Different force sensors are available that can be equipped with probe tips in different shape
- Automation modules allow to program e.g. repeated measurements or measurements at arrays of sample positions.

The Nanoworkbench

and its Application Packages



The Nanoworkbench

Force-Distance Measurement …

is one out of several "Standard Application Packages"

of our Nanoworkbench.

The Nanoworkbench enables the **hand-eye coordination**

as used at Light Microscopes now in any SEM/FIB,

together with automation of the SEM/FIB **(@ZEISS, FEI, TESCAN)**





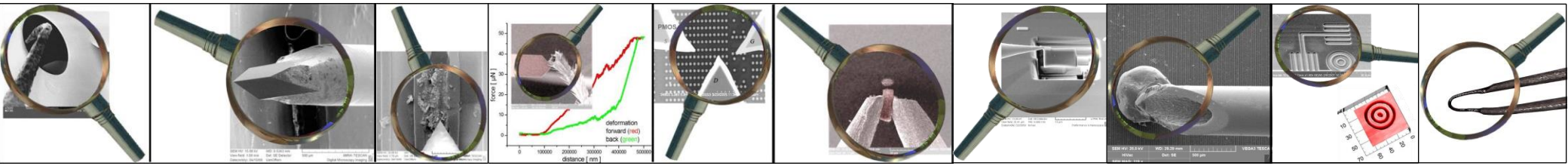
At Light Microscopes it is natural for everybody to use tool sets like tweezers, knives, hooks, probes and several different measurement tools, so it is with the Nanoworkbench.

The Nanoworkbench

One Product for all applications

The Nanoworkbench Standard Packet includes:

- The basic application package “Nanomanipulation” and
- one additional “Application Package” out of:

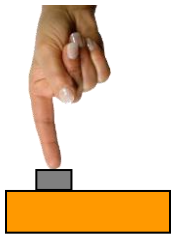


Manipulation, NanoCleaning, NanoProbing, TEM-Lamella, 3D-Nanofinger
NanoCutting, Force-Distance, Particle sorting, NanoFriction Spot-Heating

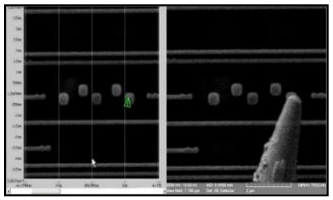
Each application package includes a standard tool, a standard sample and pre-defined processes as source-code and origin for own projects.

- **The following set of modules for easy usage an application control:**

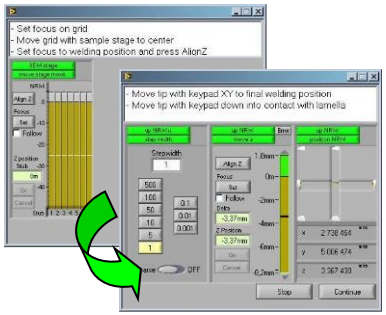
The Standard Packet



Nanofinger® as Scout, guiding the Nanoworkbench Tools,



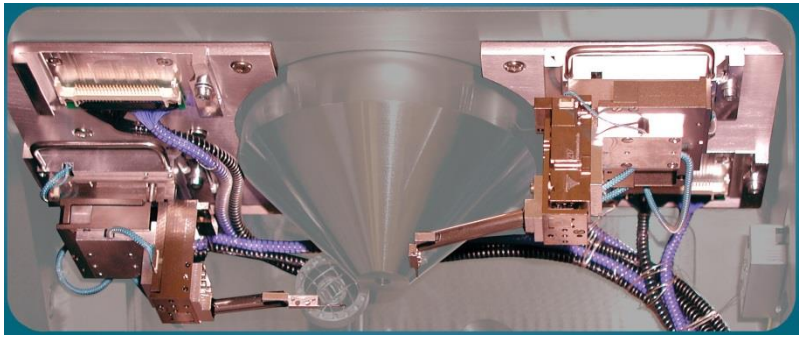
Live Image Positioning,



Assistants (Wizards),

Hand-eye coordination:

Sequencer for automation,
Macro Executor,
Remote Control,
…



2 Nanorobotics Manipulators with docking stations

More information?

Please ask for the leaflet "Nanoworkbench"