Instrumentations based on DVD Optical Pickup Unit (OPU)

Edwin Hwu

2014/06/04

Surface and Nano Science Lab
Institute of Physics, Academia Sinica, Taipei, Taiwan

Outline

- Astigmatic Detection Mechanism
- ADS based instrumentation
  - Scanning Probe Microscope
  - Laser Vibrometer
  - High Throughput Bio-sensing System
- Conclusions

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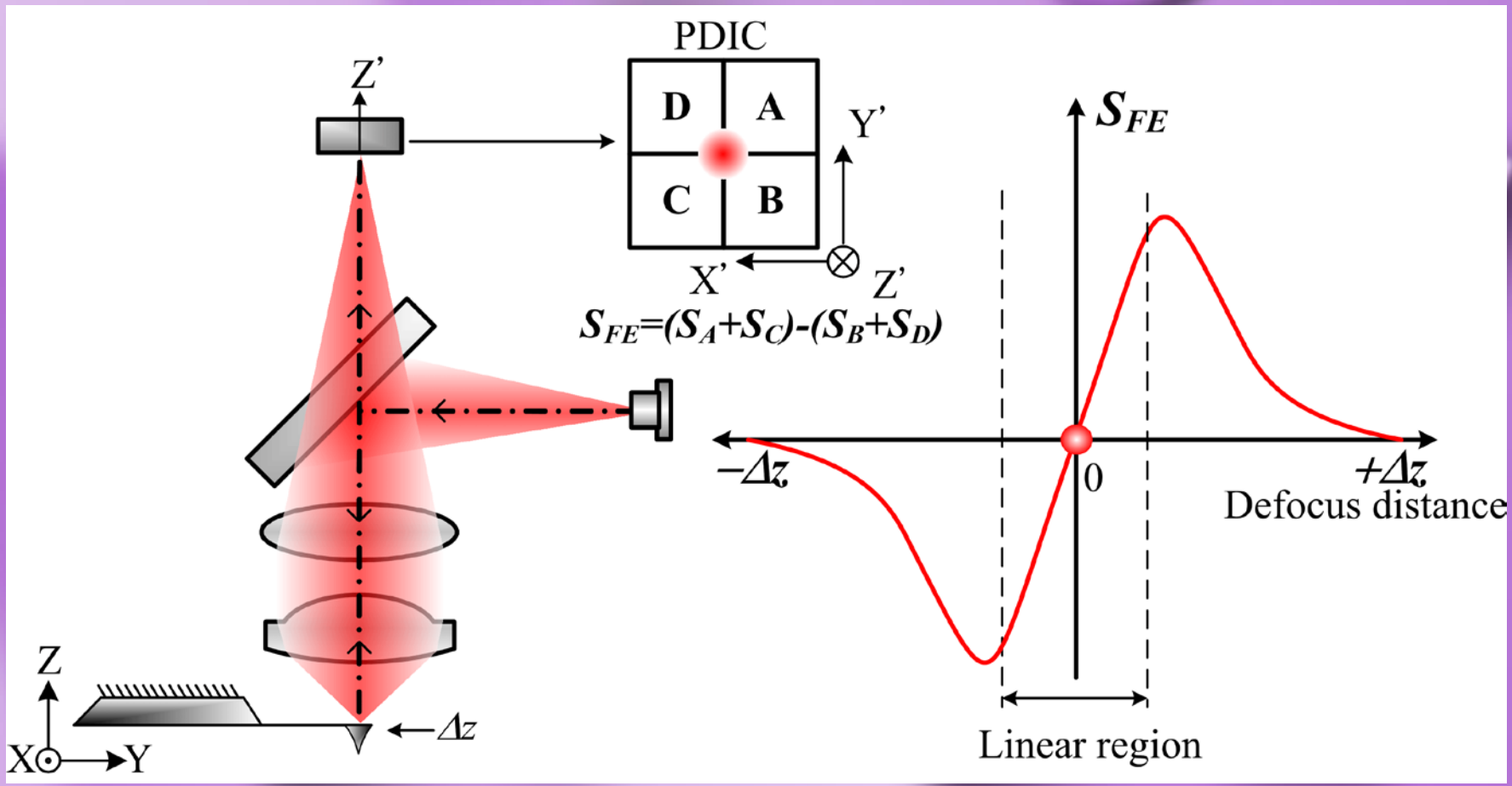
Astigmatic detection mechanism inside the OPU



Applied Physics Letters, Vol. 91, No. 221908. (2007)

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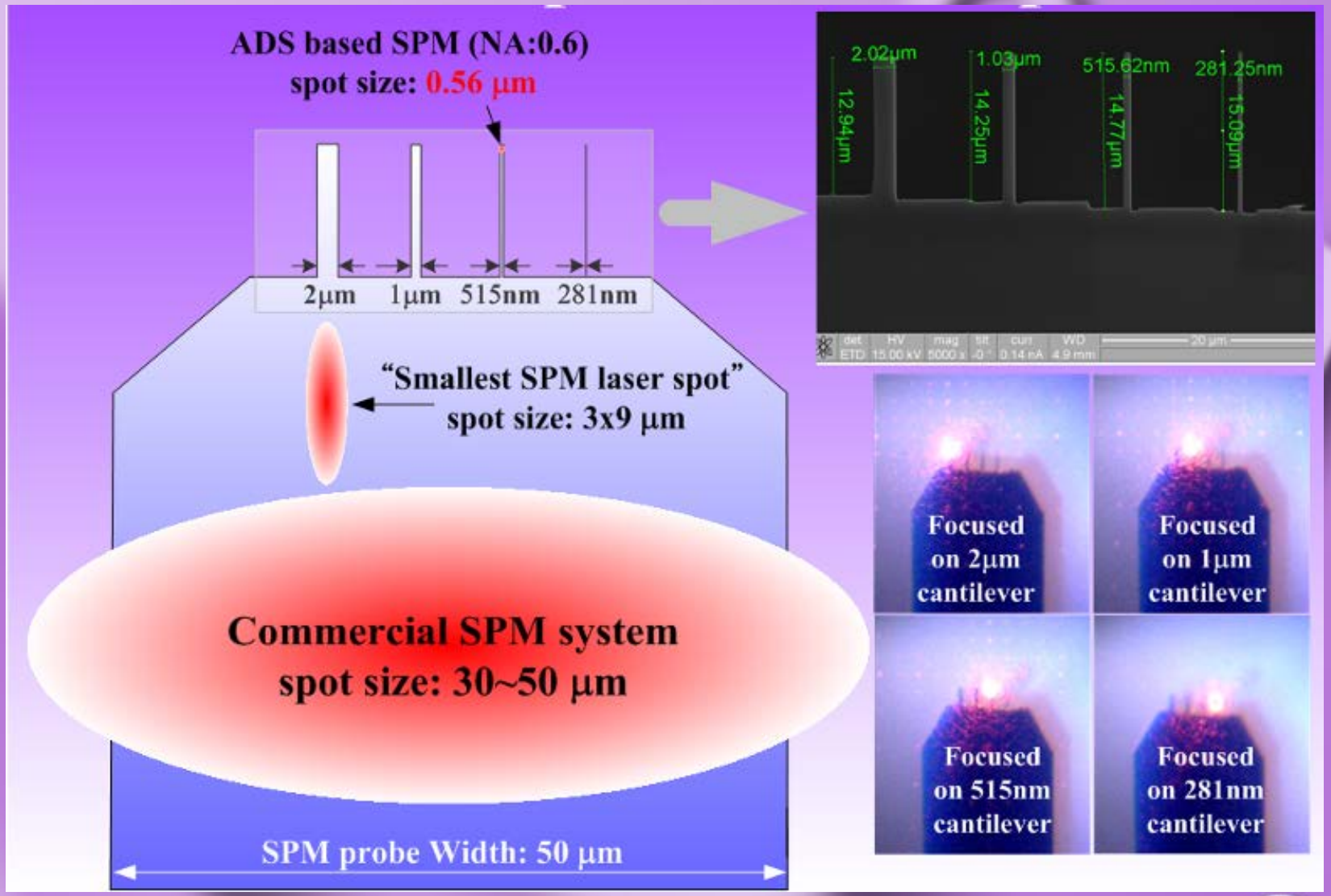
Comparison of Detection Mechanism

	Beam deflection method	Astigmatic method (DVD optical pickup unit)
Size comparison		
Mechanism	Beam deflection	Astigmatism
Laser spot size	30~50μm	0.5μm
Production cost	USD 5,000	USD 10
Z Resolution	0.01 nm	0.01 nm
Detection bandwidth	~ 5 MHz	80~100 MHz
Volume	250 cm^3	9 cm^3
Weight	~ 500 g	~20 g

Comparison of Laser Spot Size



The OPU can be a very precise transducer called

Astigmatic detection System (ADS)

for nano-scale applications

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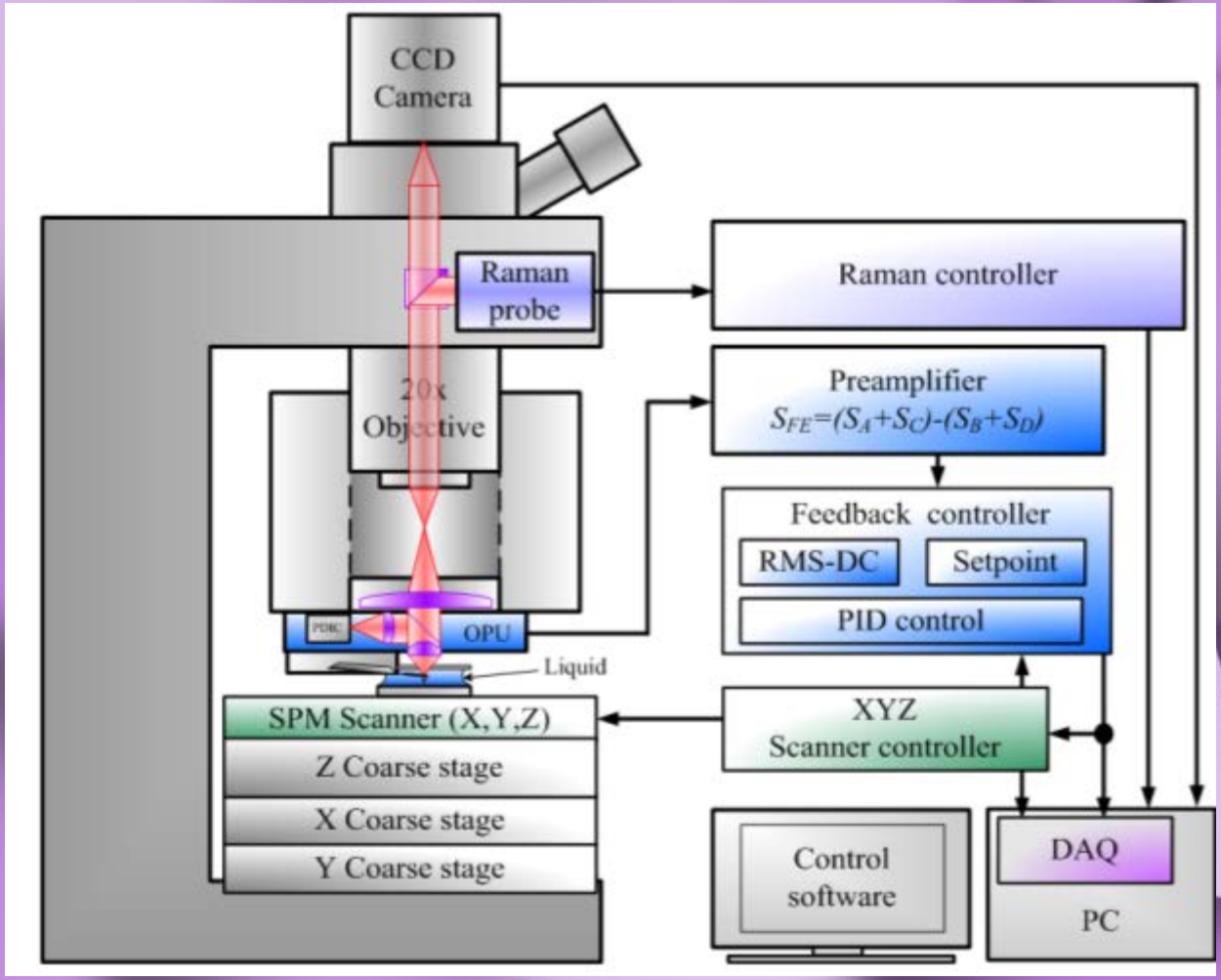
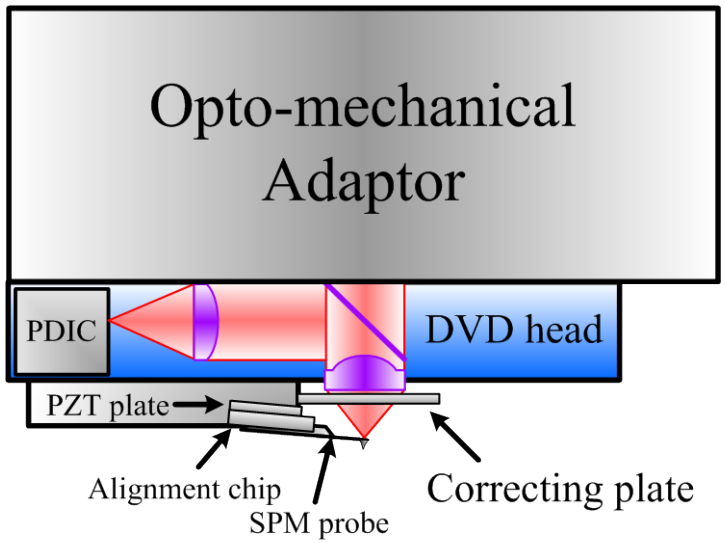
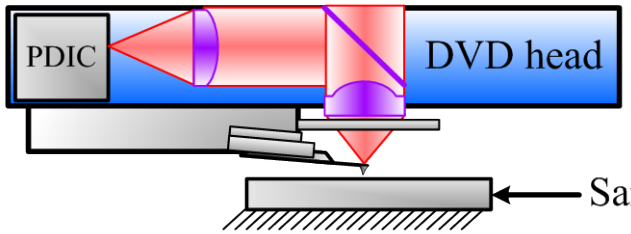
ADS Based SPM Combined with Commercial Optical Microscope



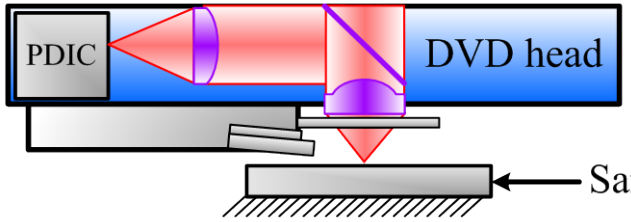
ADS Based Hybrid SPM Head



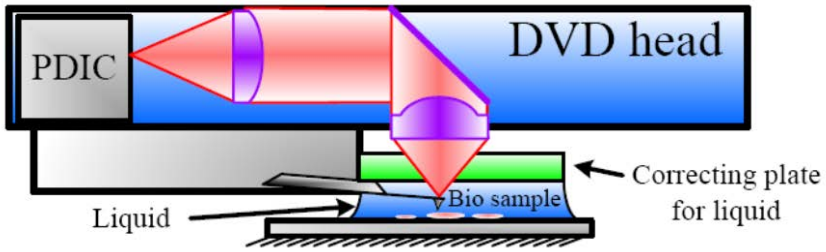
(a) SPM module



(b)SPM mode

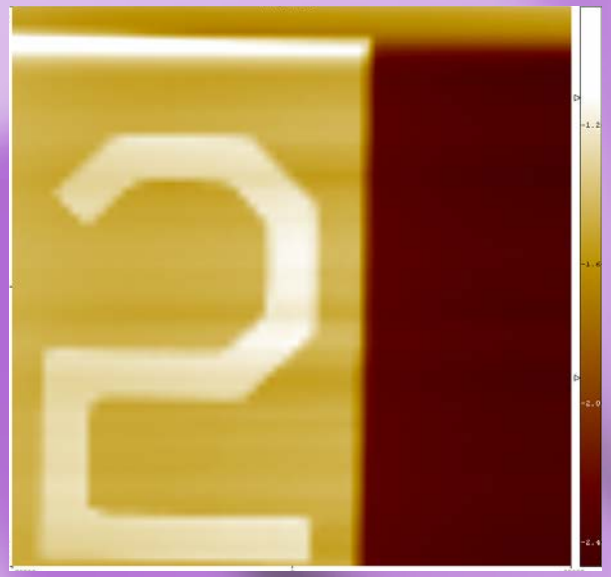


(c) Optical profiler mode

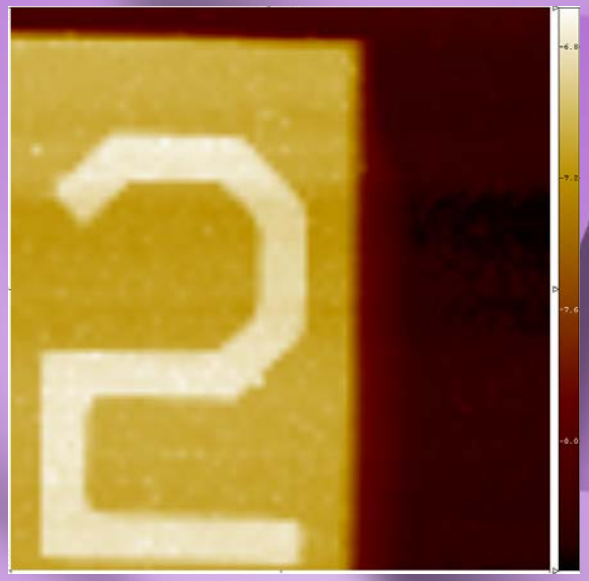


SPM Module Multi-mode Measurement

800nm Height standard measurement (Topography area: 100x100 μm)



SPM contact mode



SPM Tapping mode

Optical profiler mode

2007-2009@Physikalisch-Technische Bundesanstalt (PTB)

Measurement Science and Technology,20 (2009)084005

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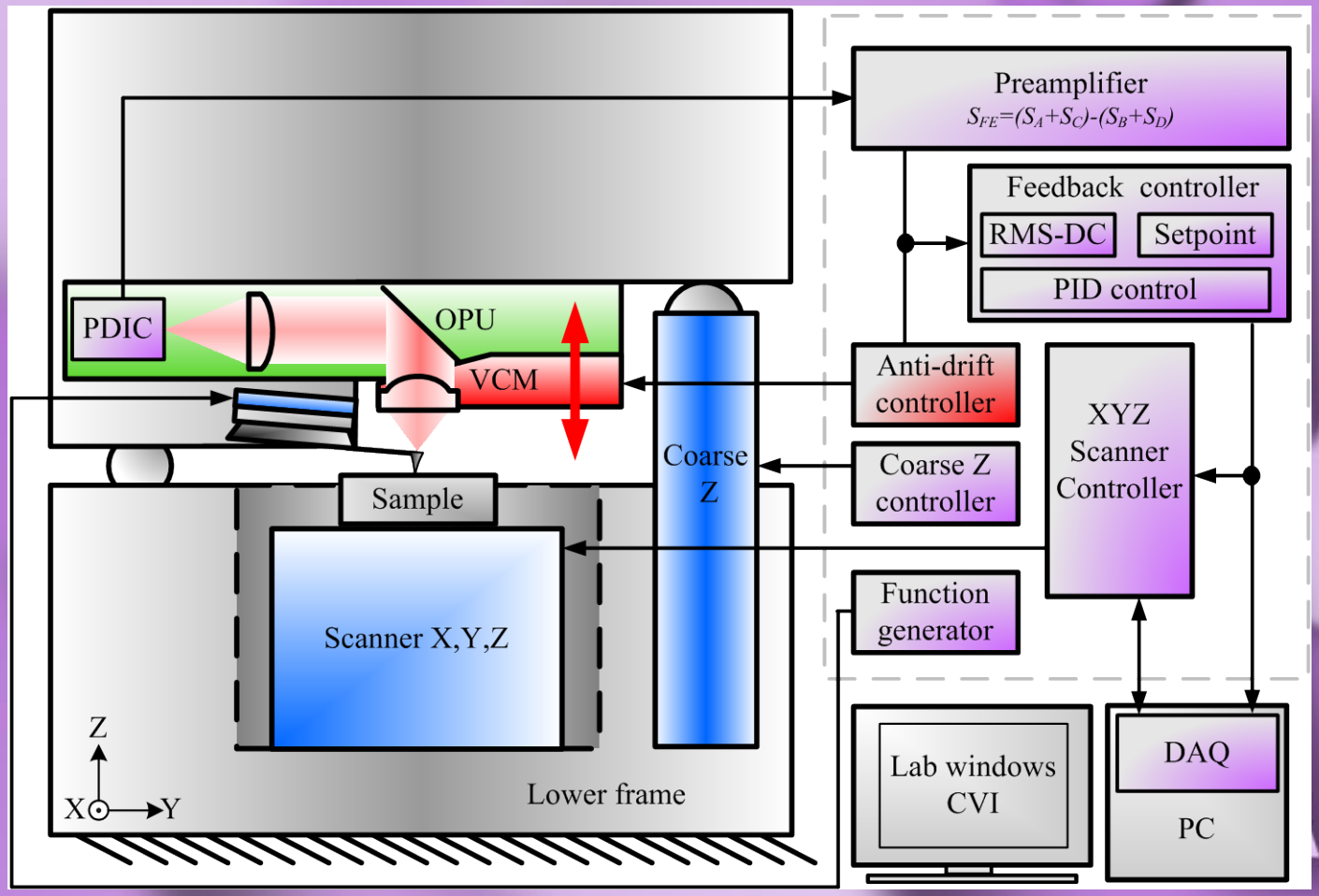
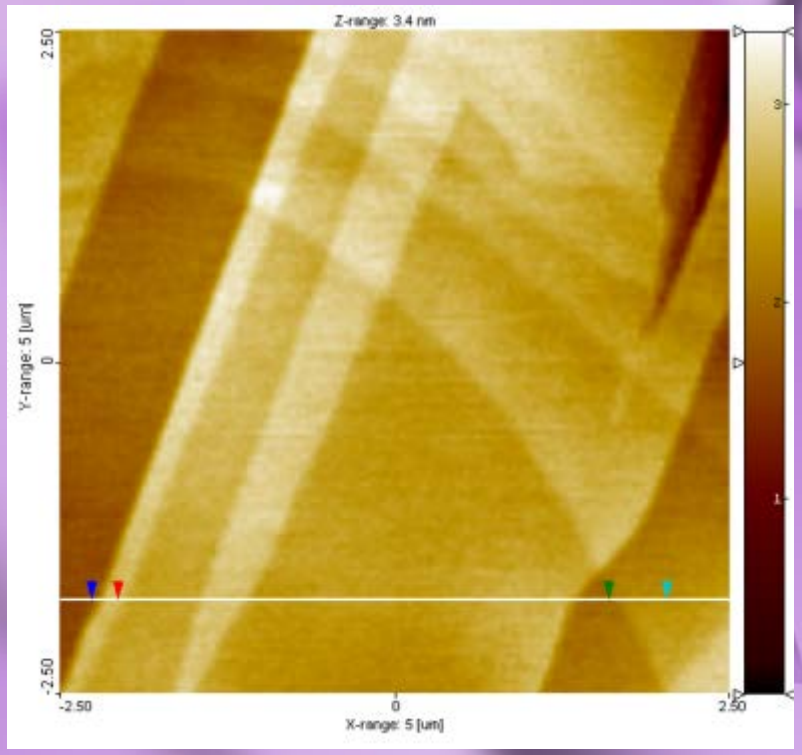
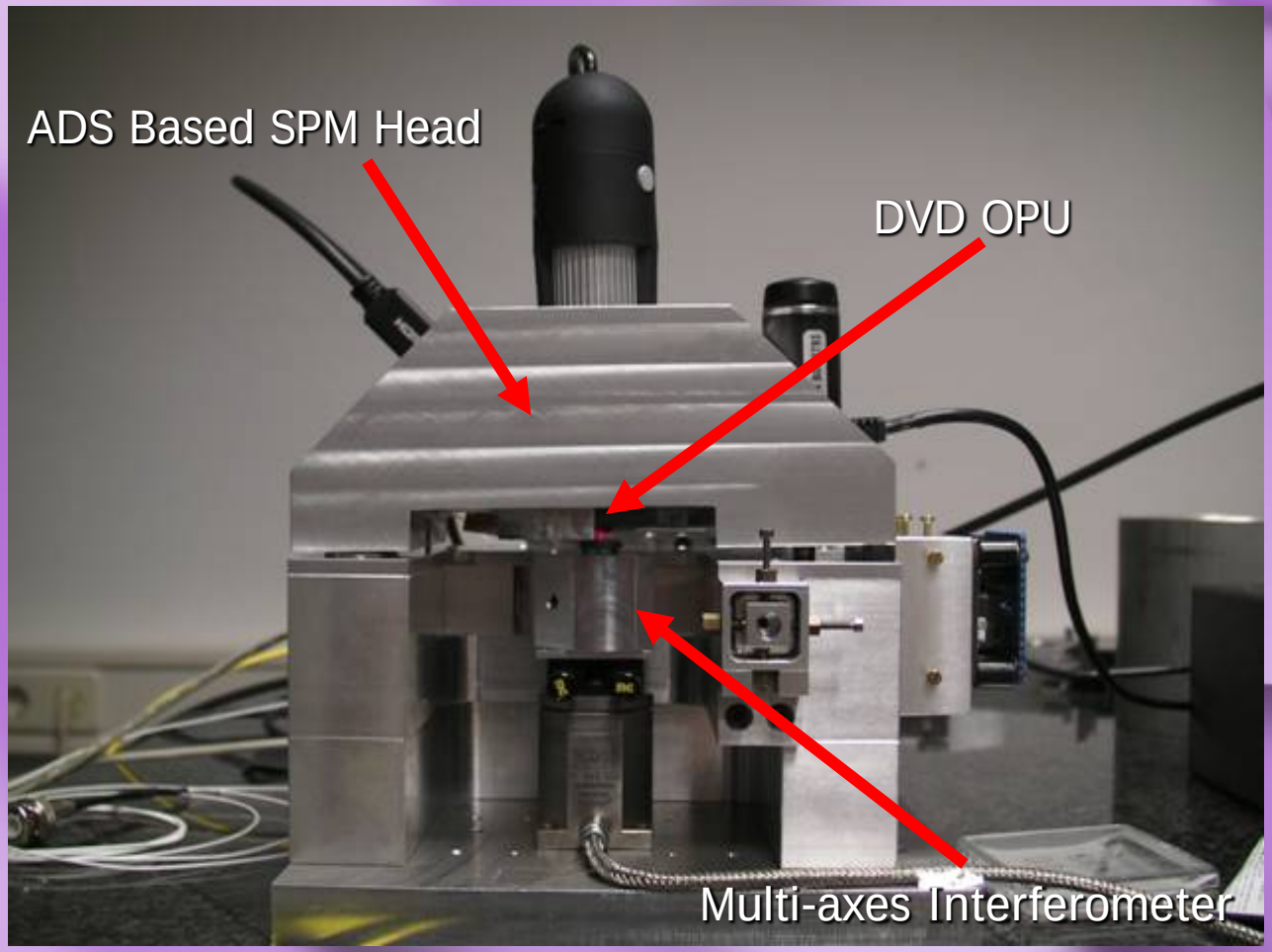
ADS Based AFM for Atomic Scale Measurement

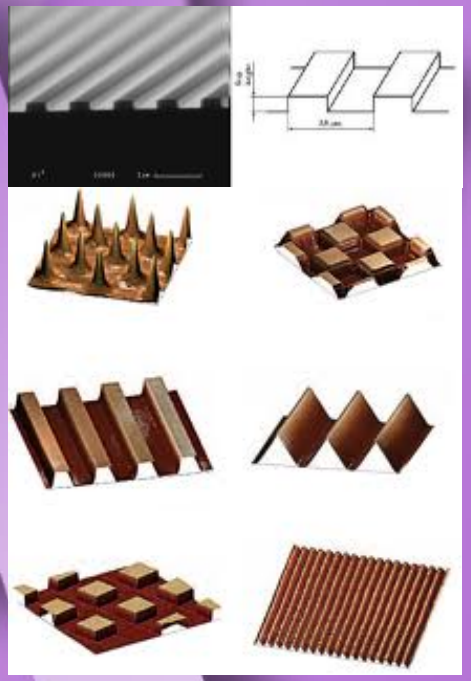


HOPG single atomic layers



Pico-meter Scale Quantitative Scanning Probe Metrology System





To “Calibrate”
the Calibration Samples

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Physikalisch Technische Bundesanstalt (德國國家量測中心)

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Low Voltage Piezoelectric Scanner

Traditional tube scanner:

PC → DA converter → ±10V 16bit → High voltage amplifier → ±200V 16bit?

USD 2,000

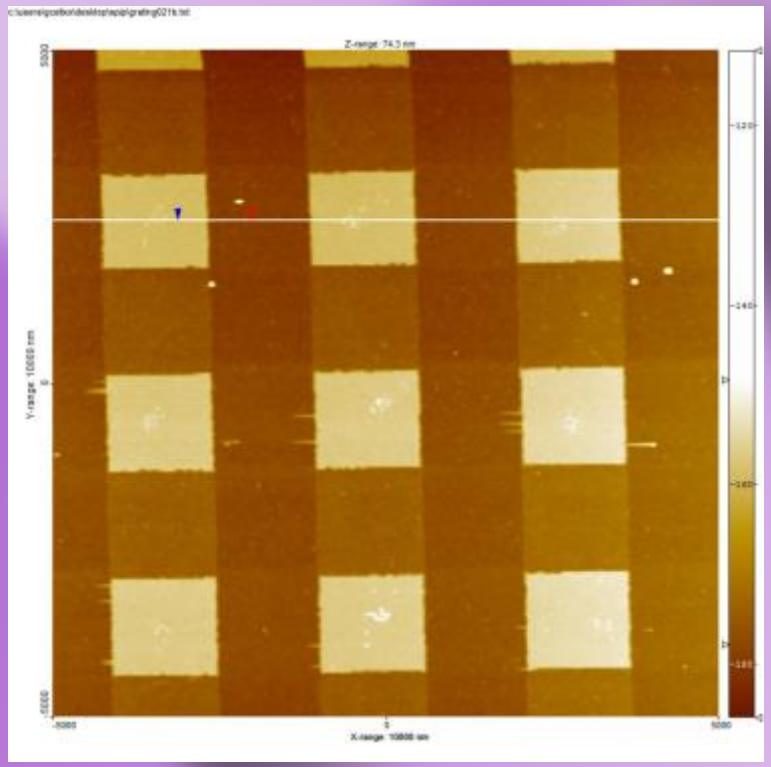
USD 1,000

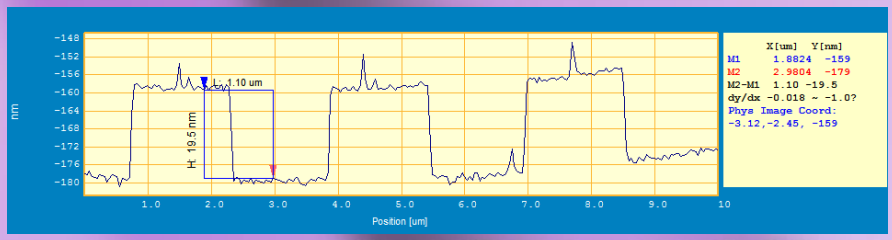
New developed low voltage scanner:

PC → DA converter → ±10V 16bit

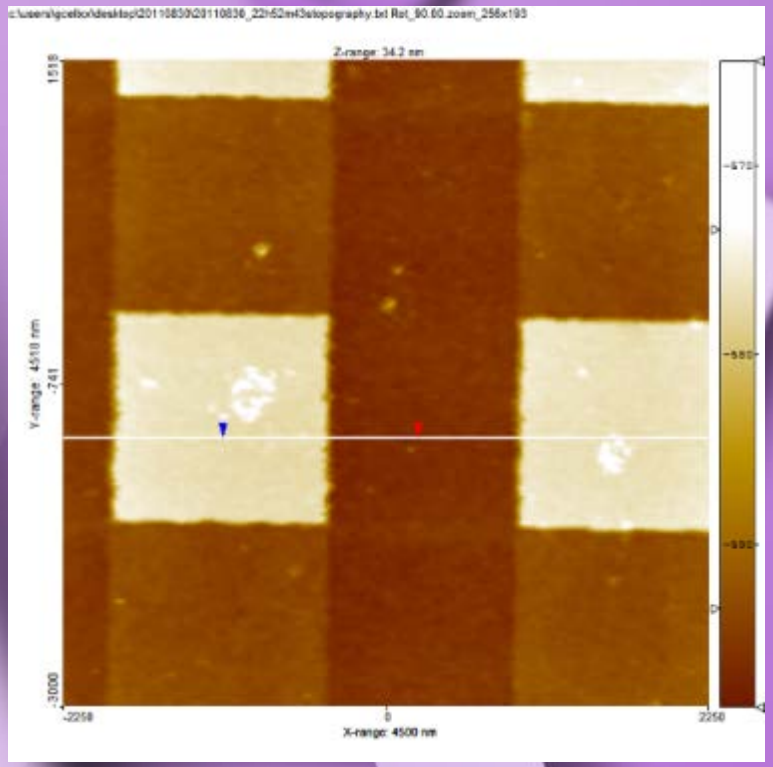
Comparison of measurement result

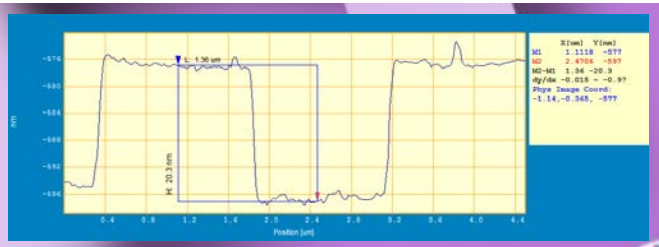
Traditional tube scanner:





Low voltage scanner:





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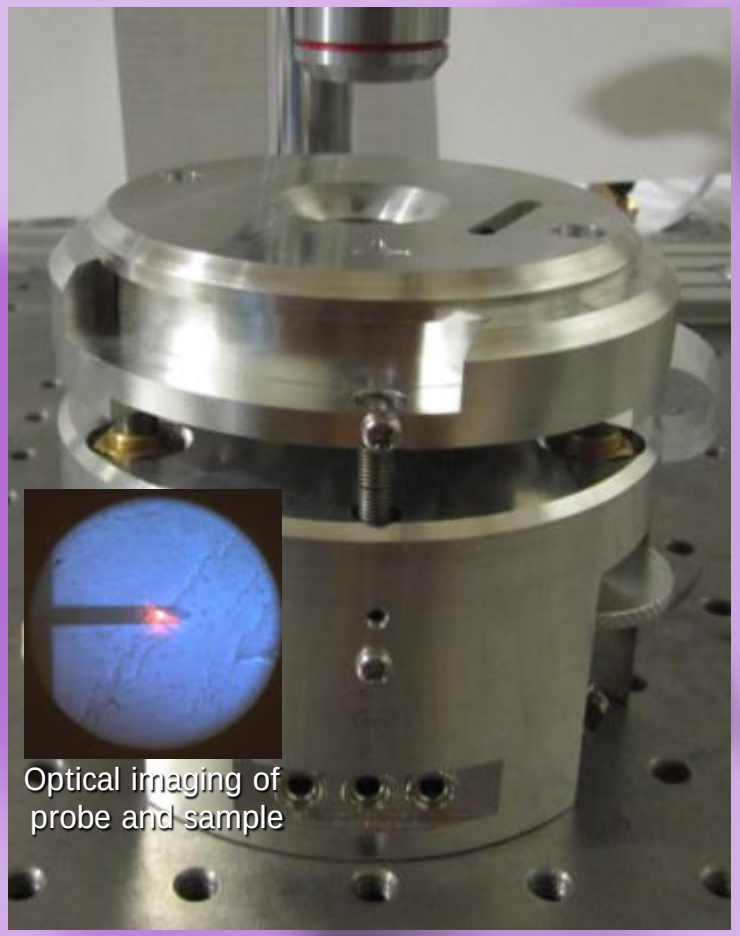
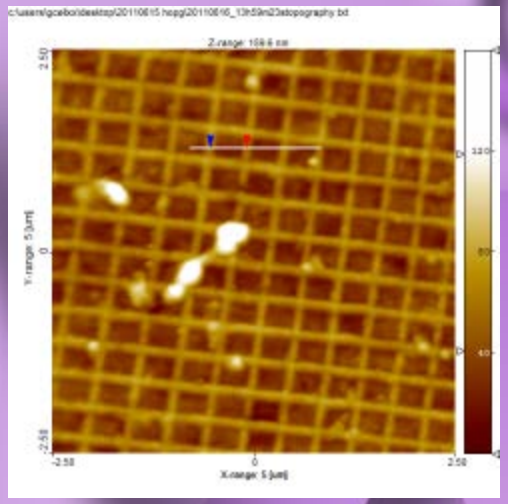
Measurement Results of ADS based AFM with Low Voltage Piezoelectric Scanner

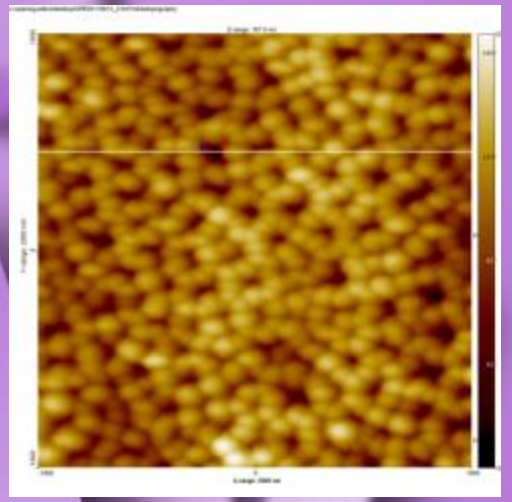


Optical imaging of probe and sample

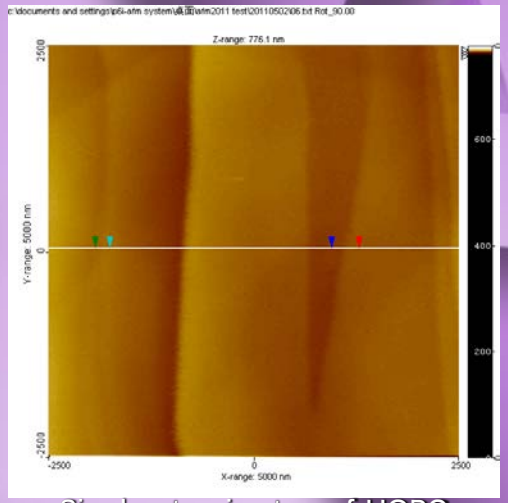
Mechanical part of the Educational AFM with low voltage piezoelectric scanner



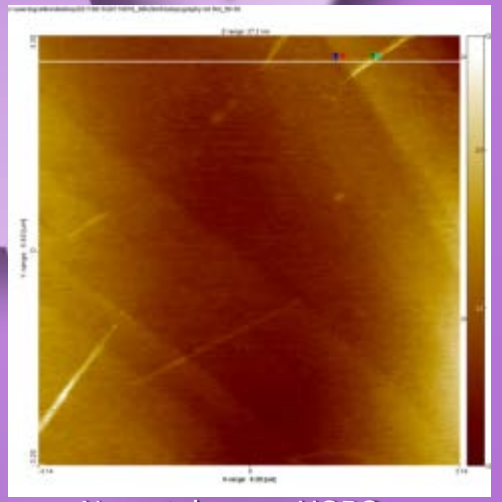
30nm height calibration sample



AAO sample surface



Single atomic step of HOPG



Nano tubes on HOPG

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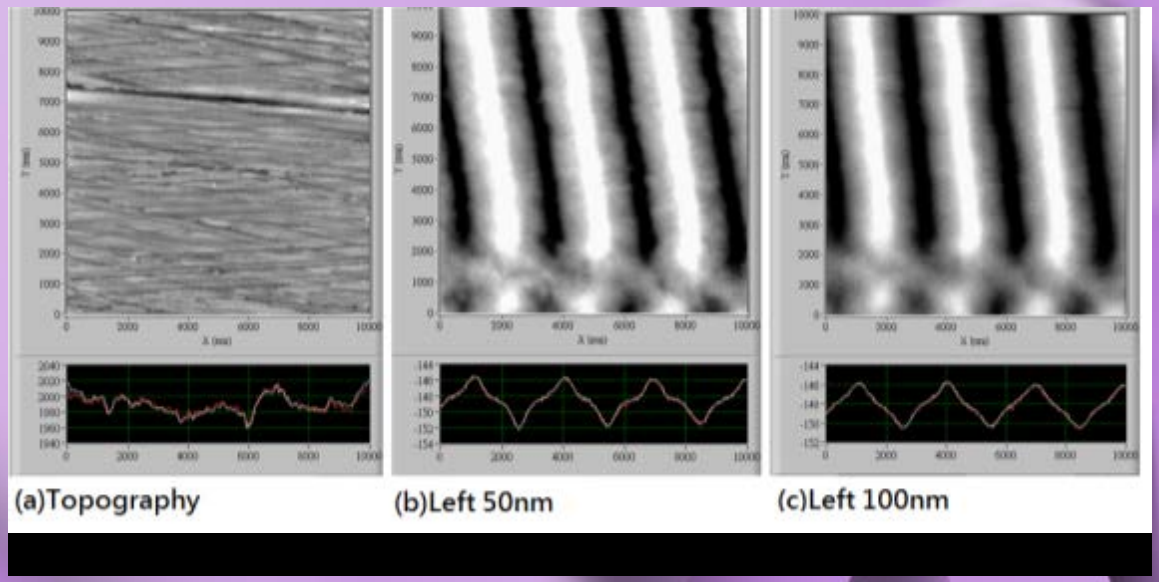
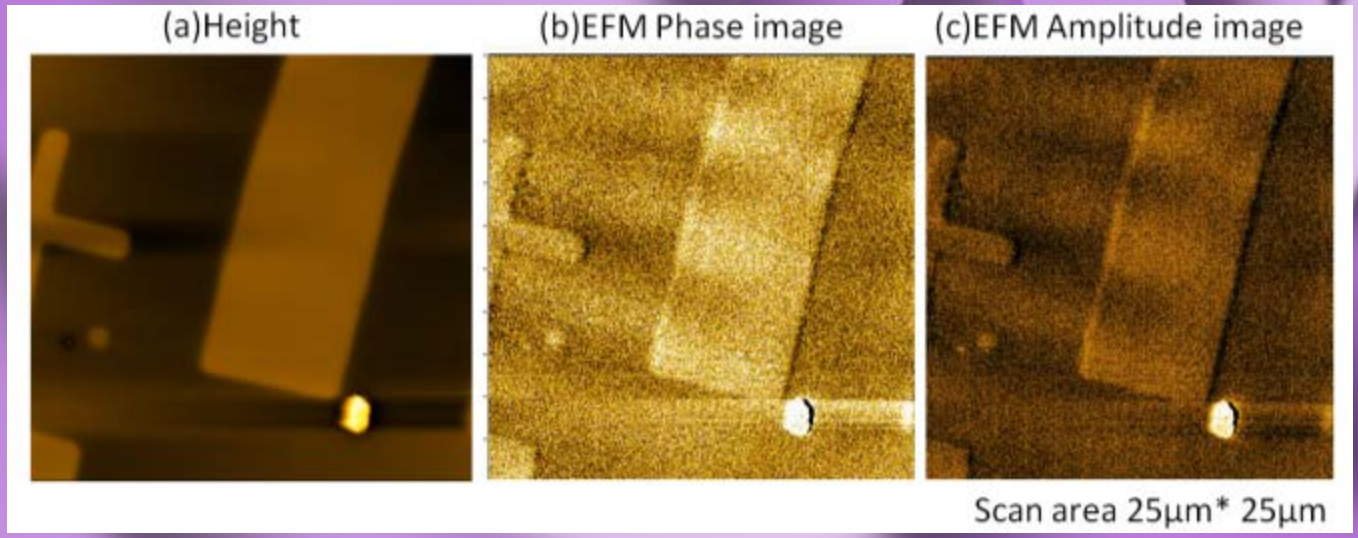
MFM & EFM images





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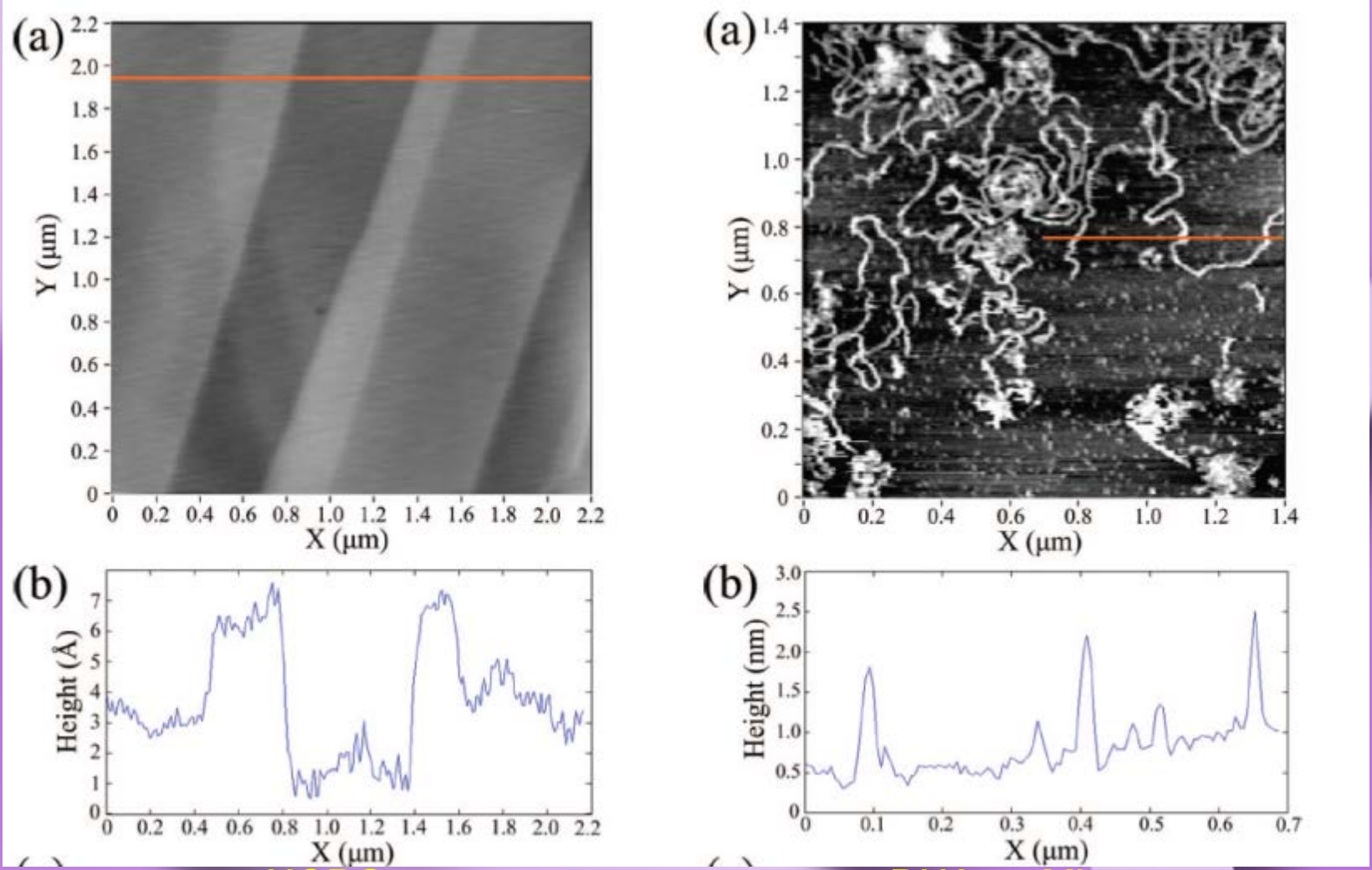
Measurements in liquid environment



HOPG

DNA on Mica

HS Liao, KY Huang, IS Hwang, TJ Chang, WW Hsiao, HH Lin, ET Hwu, CS Chang, Review of Scientific Instruments 84 (10), 103709-103709-7 (2013)

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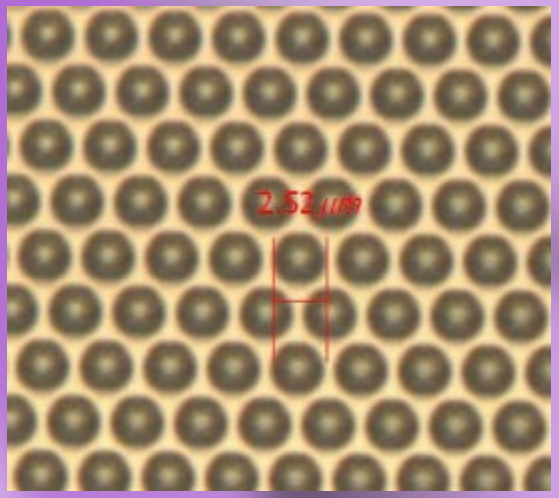
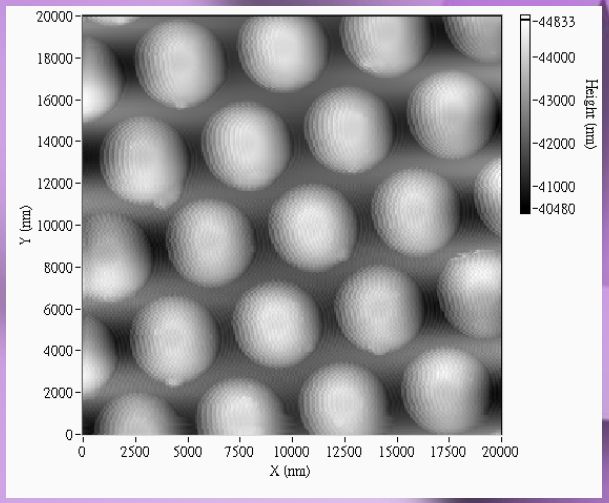
Patterned Sapphire Substrate (PSS)

Measured by IPAS ADS based AFM AFM mode and profiler mode

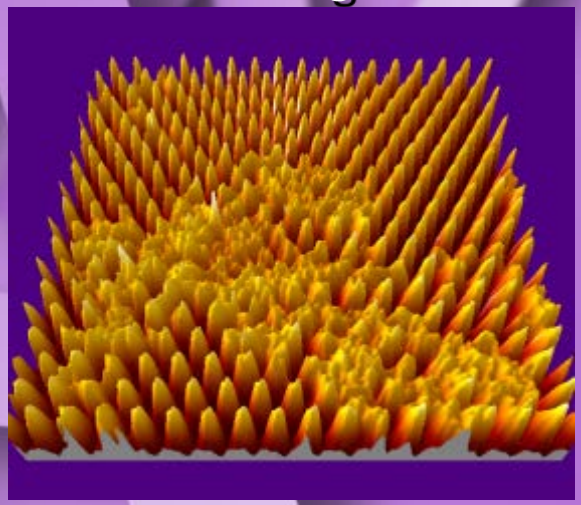
Optical Microscope
Optical Image



AFM Mode
Topography



Profiler Mode
FES Image



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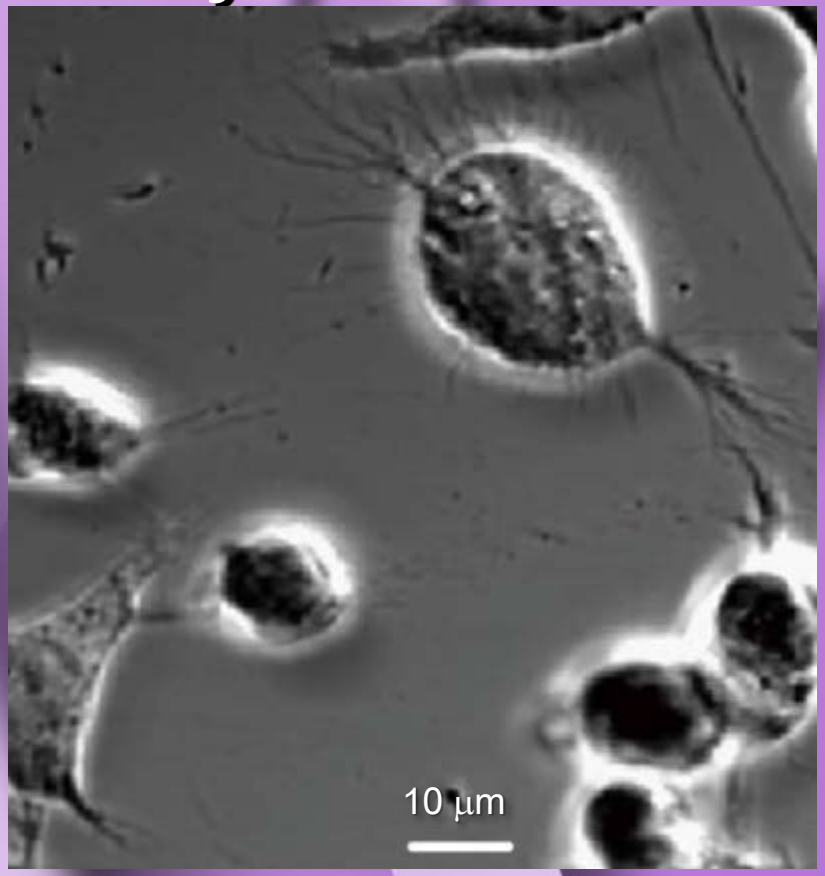
Application of the ADS optical profiler mode Imaging of astrocytes

1000X OM phase contract image with Oil lens (Contrast: 0.143)



ADS profiler mode (Contrast: 0.224)

Wesley W. HSIAO,Hsien-Shun LIAO,Hsing-Hung LIN, Yueh-Lun LEE, Chia-Kwung FAN, Chien-Wei LIAO, Po-Yen LIN, En-Te HWU, and Chia-Seng CHANG , Analytical Sciences, 29(9), 885 (2013)

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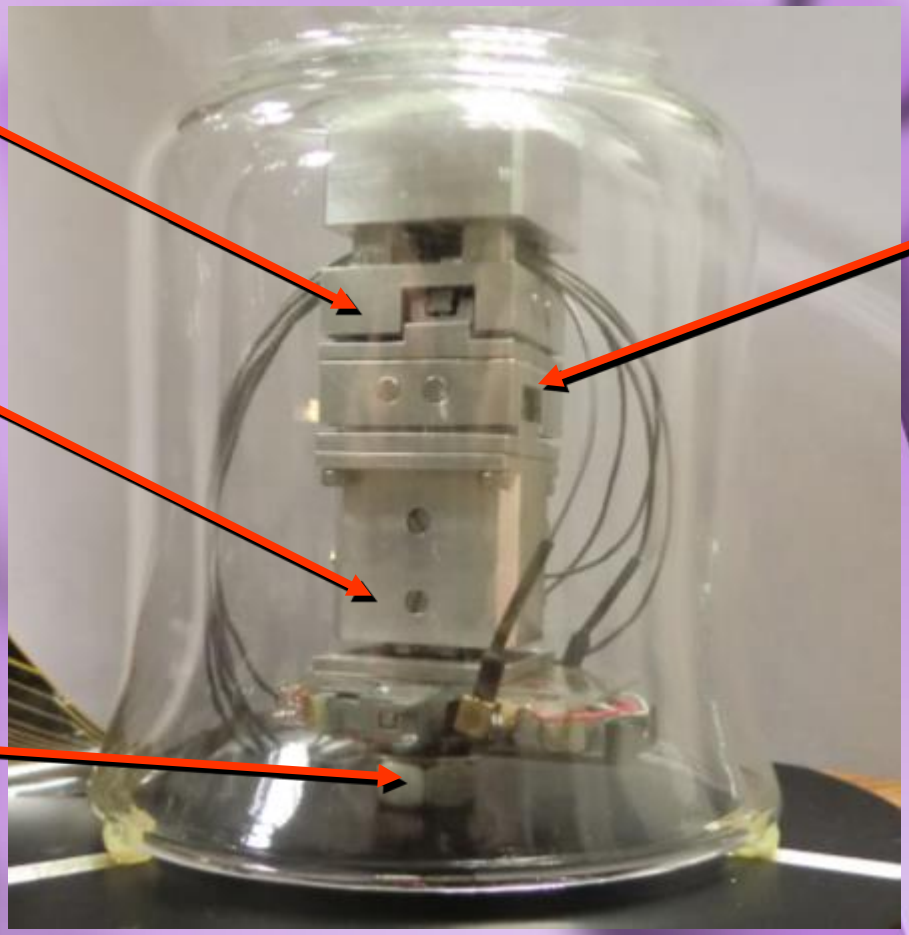
XYZ Actuator for AFM System



X axis for 12 mm stepping and 10 μm scanning
Y axis for 12 mm stepping and 10 μm scanning
Z axis for 6 mm stepping and 1.8 μm scanning

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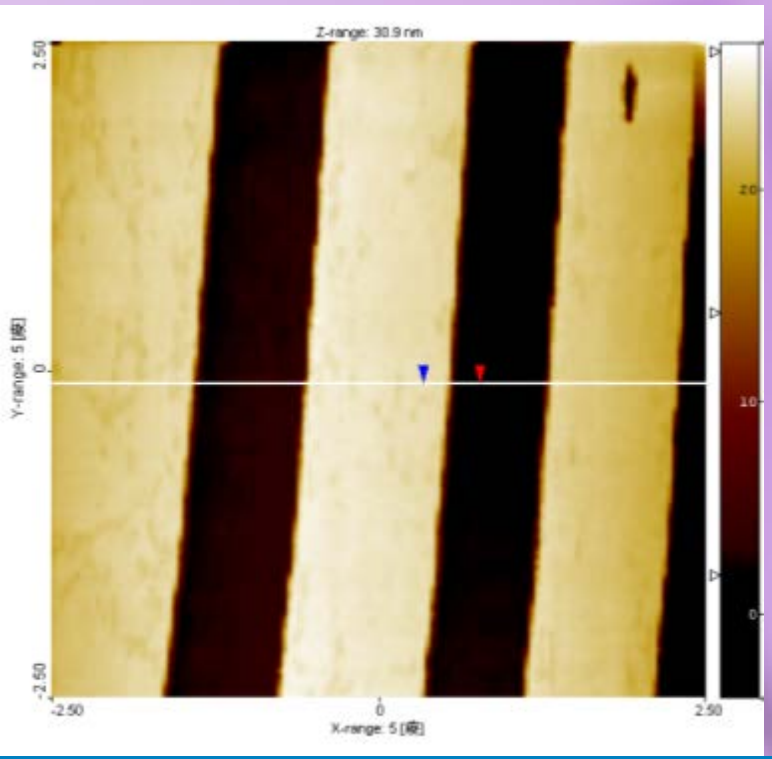
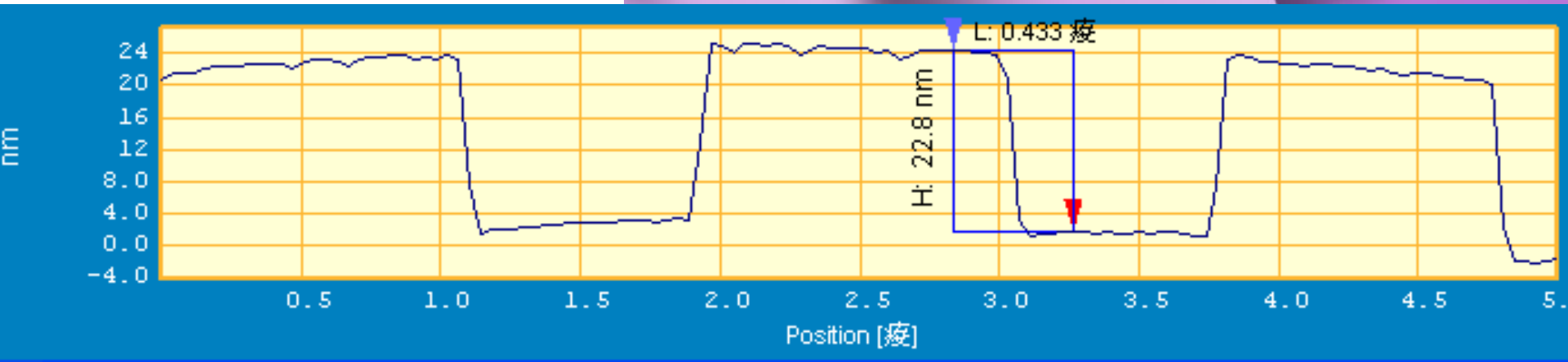
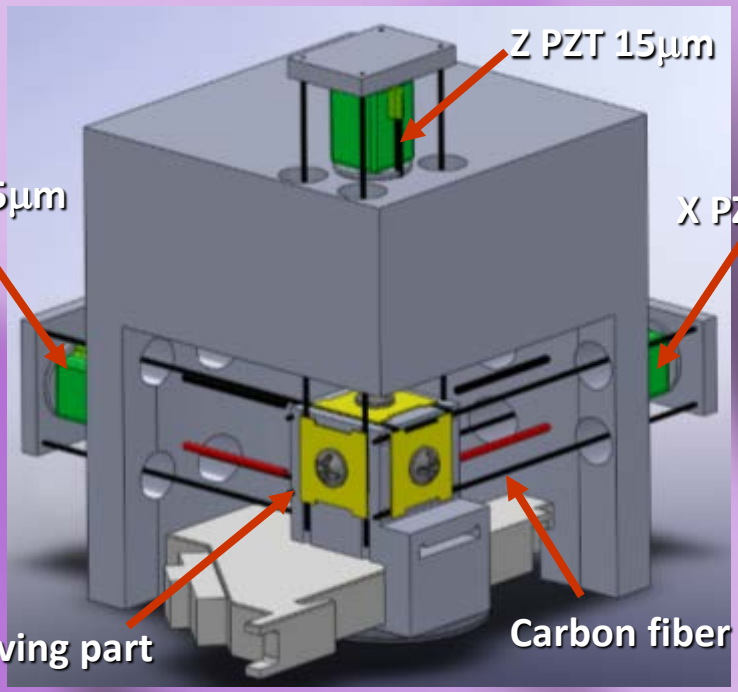
Z calibration data & System parameters

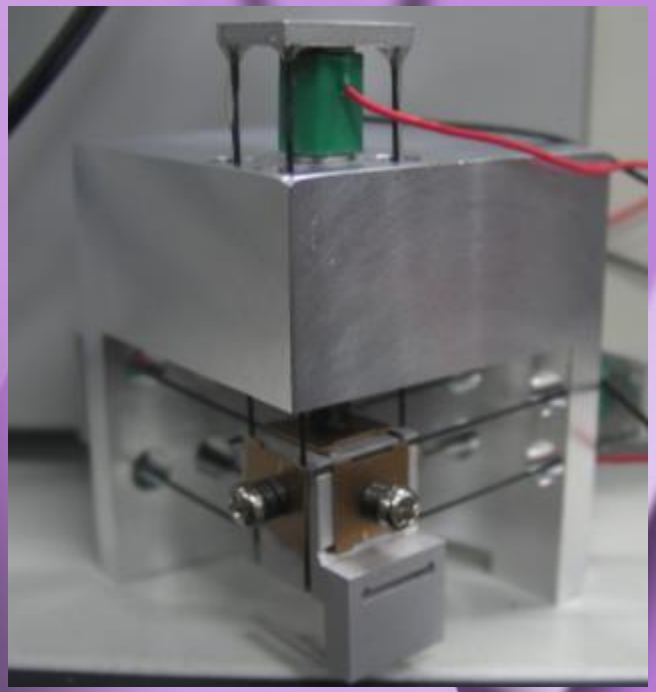


- Probe: Tapping mode
- Frequency: 263.9 kHz
- Scanning range:~8 mm
- Z sensitivity: 42 nm/V
- Noise level: 0.03 nm (RMS)



High stiffness XYZ Actuator for AFM System





X,Y,Z Coarse adjustment

Range: >4mm (driven by saw tooth wave @ 50V)

Resolution: < 100nm (need evaluation)

X,Y,Z Fine scan range:

Range: 15mm (driven by triangular wave @ -30~150V)

Resolution: 0.2nm (15mm with 16 bit resolution)

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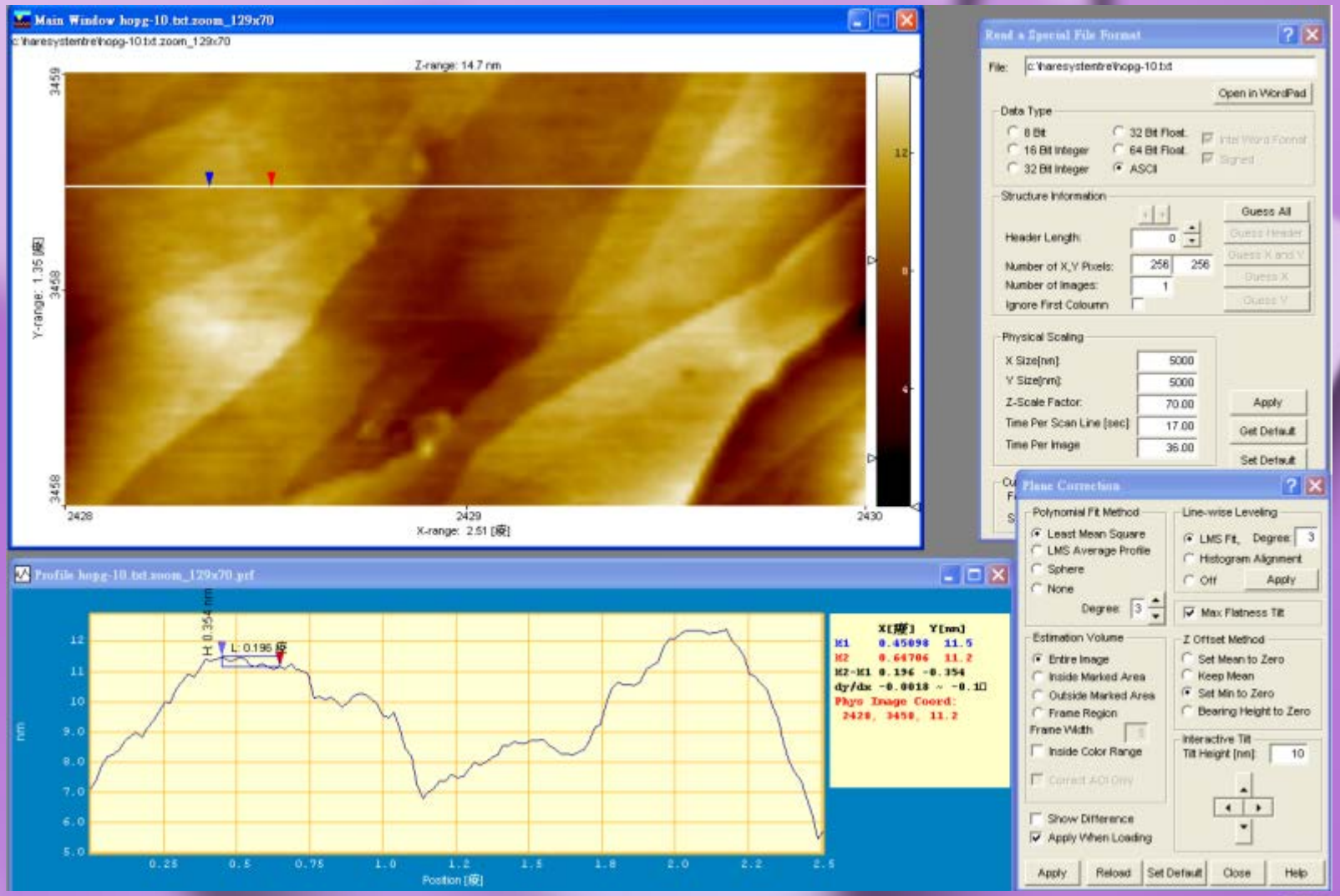
HOPG surface single atomic step



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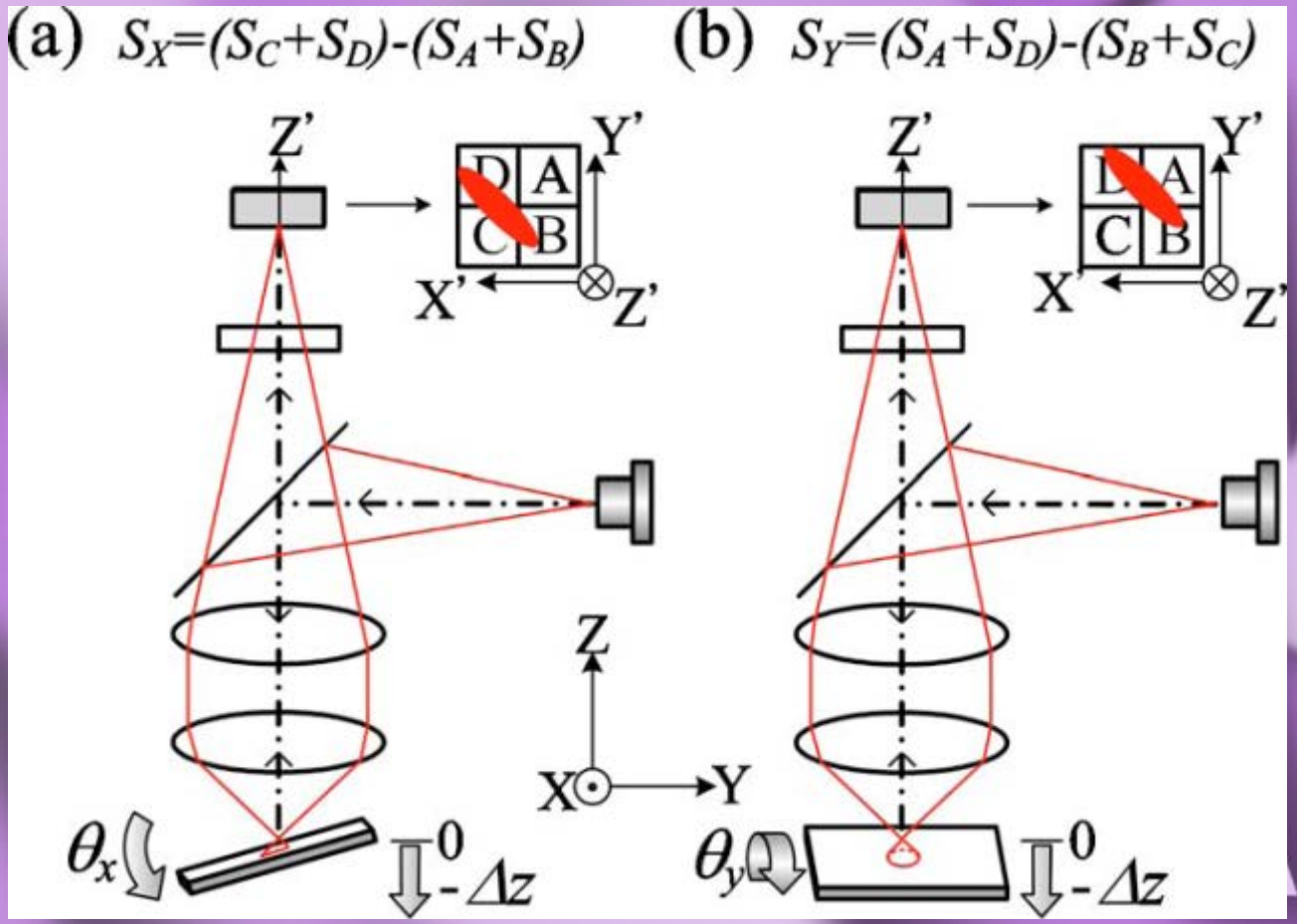
MSA-500 Micro System Analyzer

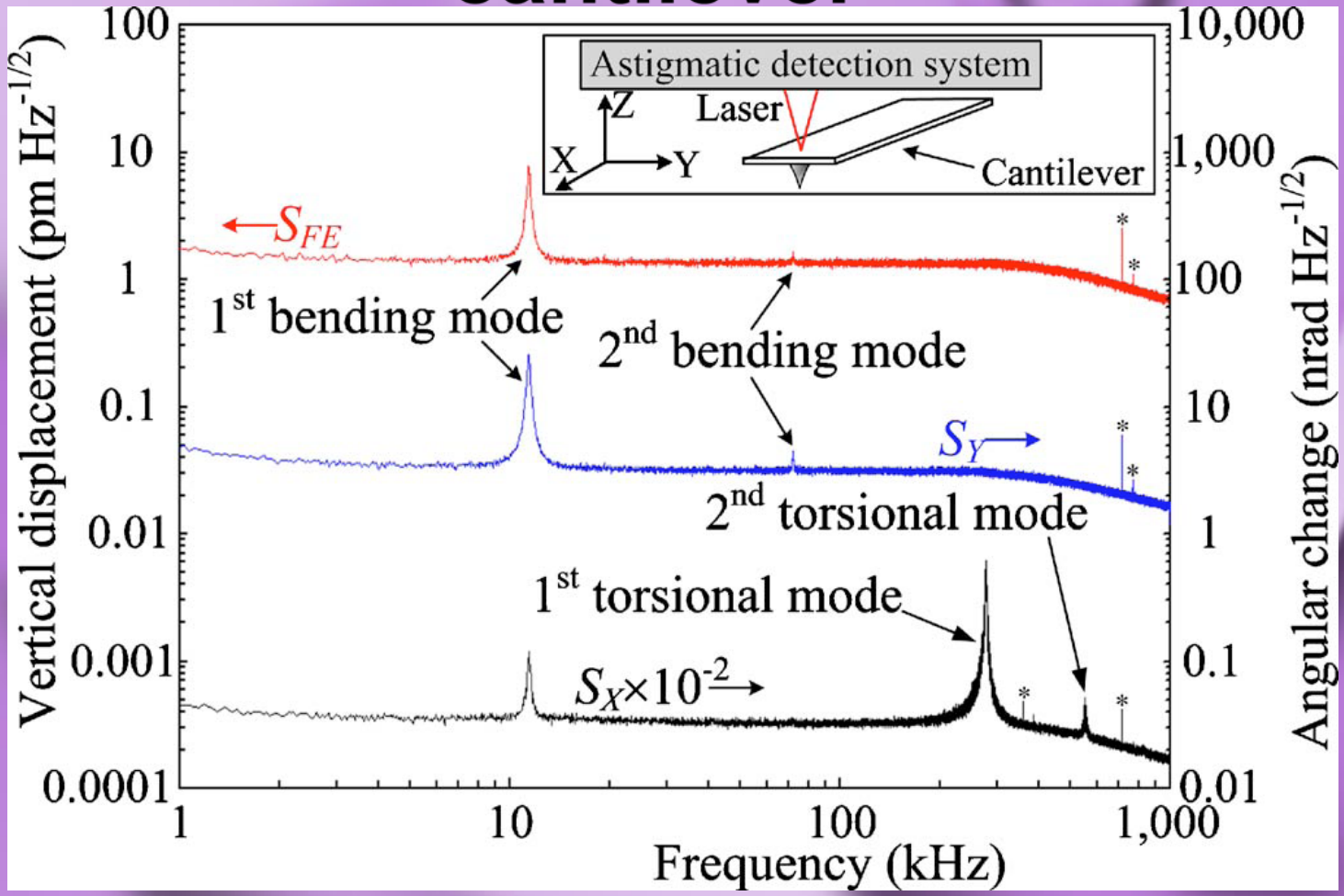
USD: 200,000

The Micro System Analyzer is the premier measurement tool for the analysis and visualization of structural vibrations and surface topography in micro structures such as MEMS. By fully integrating a microscope with scanning laser doppler vibrometry, stroboscopic video microscopy and scanning white light interferometry, the Micro System Analyzer is designed with an all-in-one combination of technologies that clarifies real microstructural response and topography.

Angular detection mechanism



Thermal noise spectra of an AFM cantilever

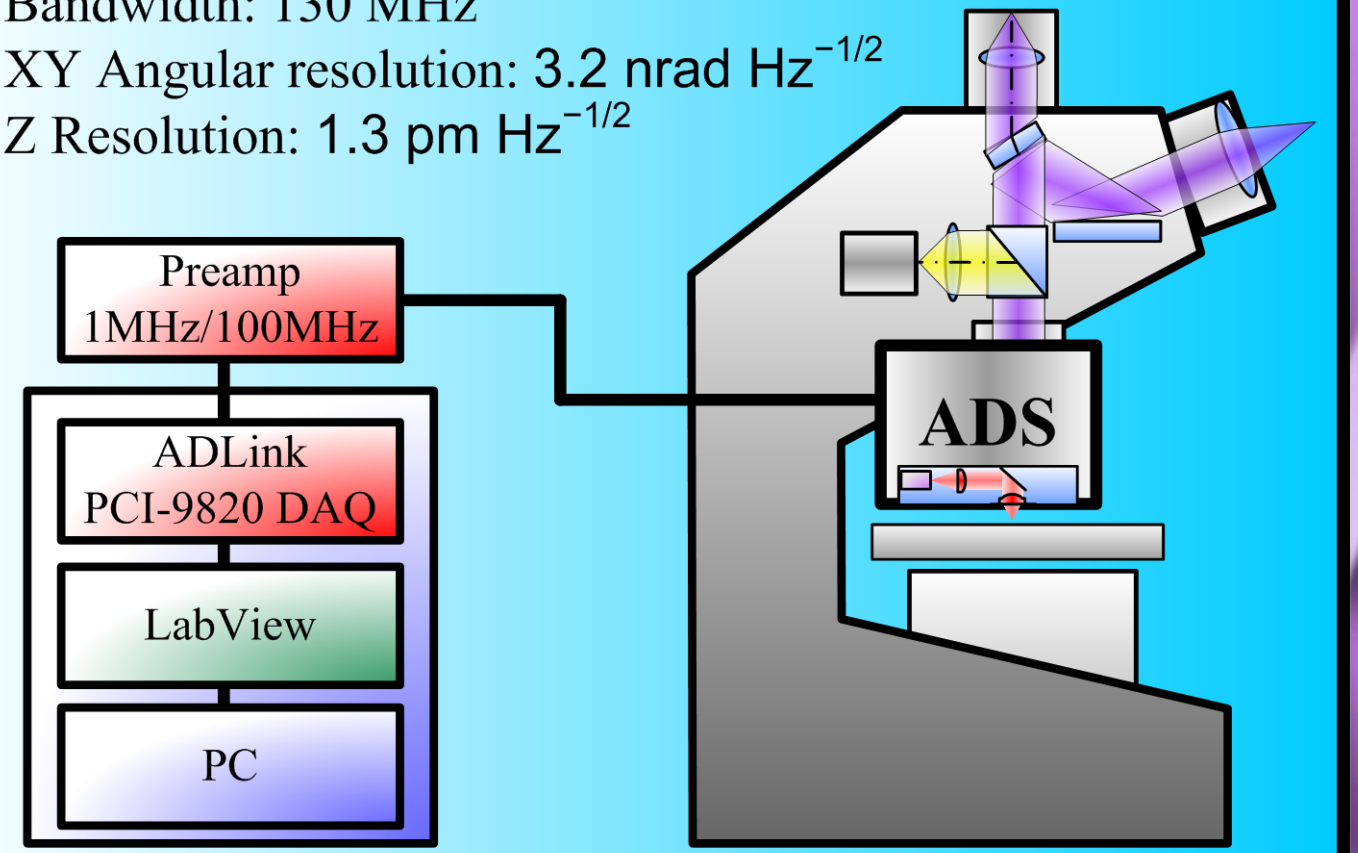


Nanotechnology 19 (2008) 115501

ADS Based Laser Vibrometer

For MEMS characterization

- Spot size: 560 nm (FWHM)
- Bandwidth: 130 MHz
- XY Angular resolution: 3.2 nrad $Hz^{-1/2}$
- Z Resolution: 1.3 pm $Hz^{-1/2}$



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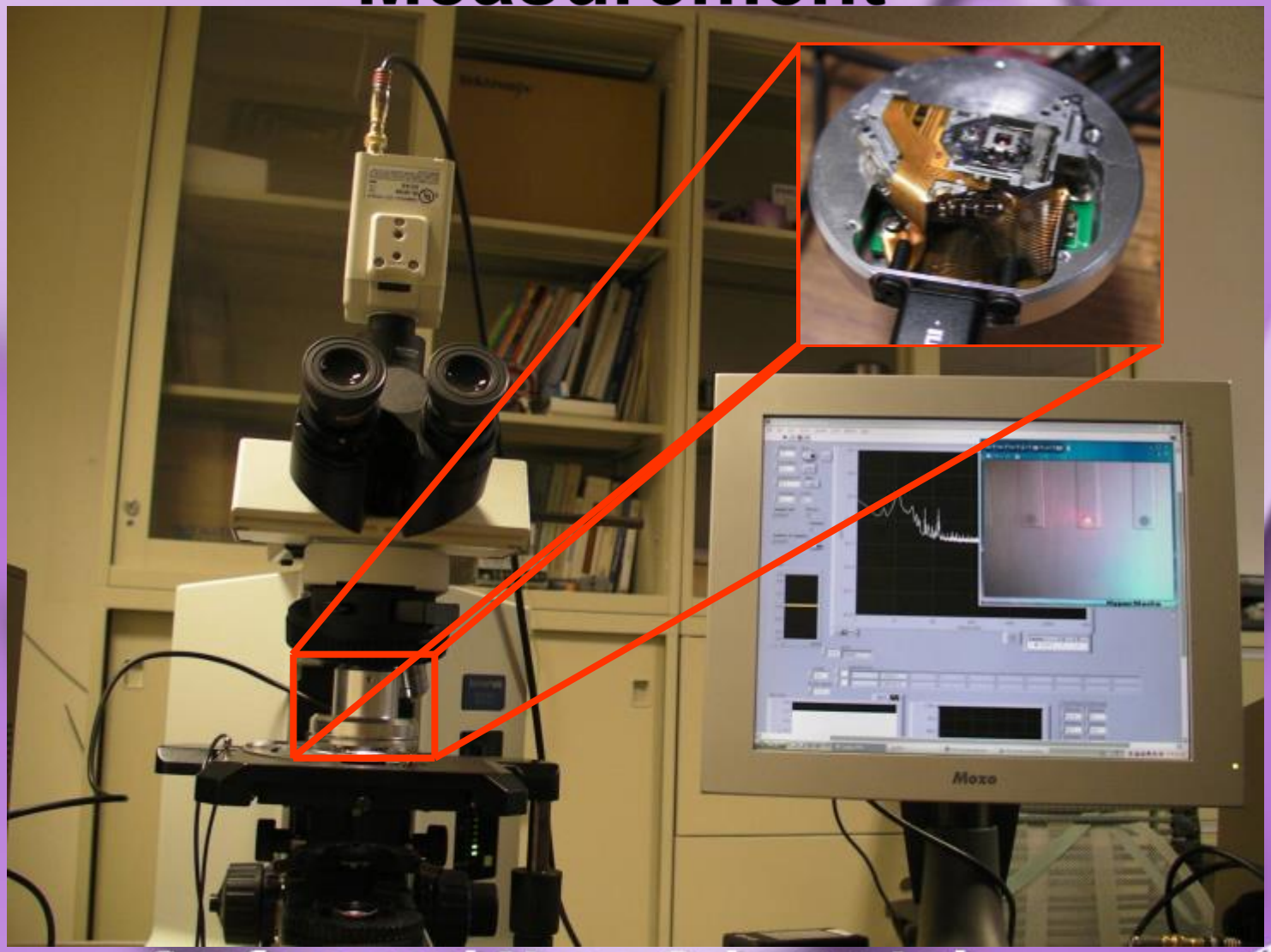
ADS Combined with OM for MEMS Measurement



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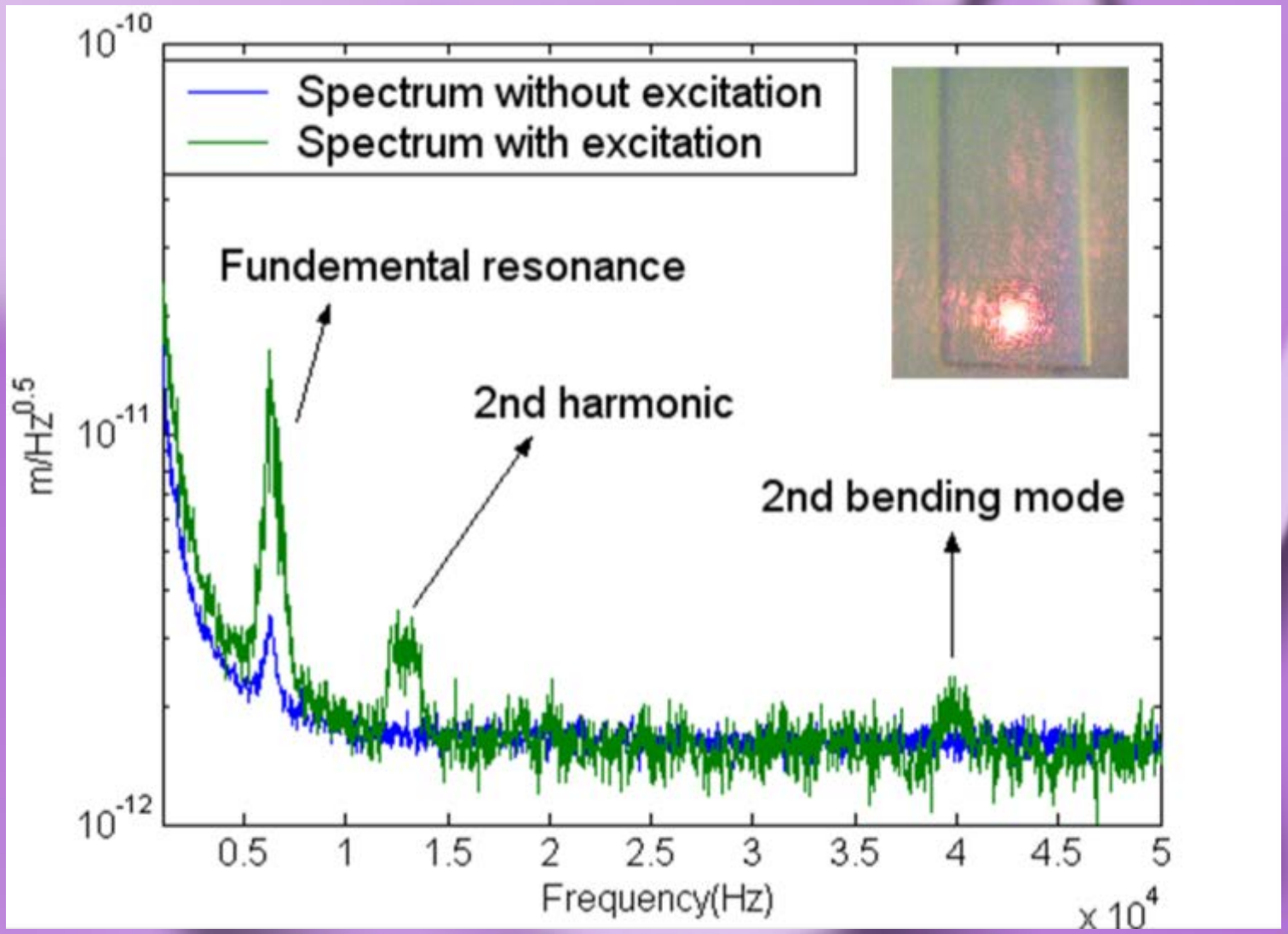
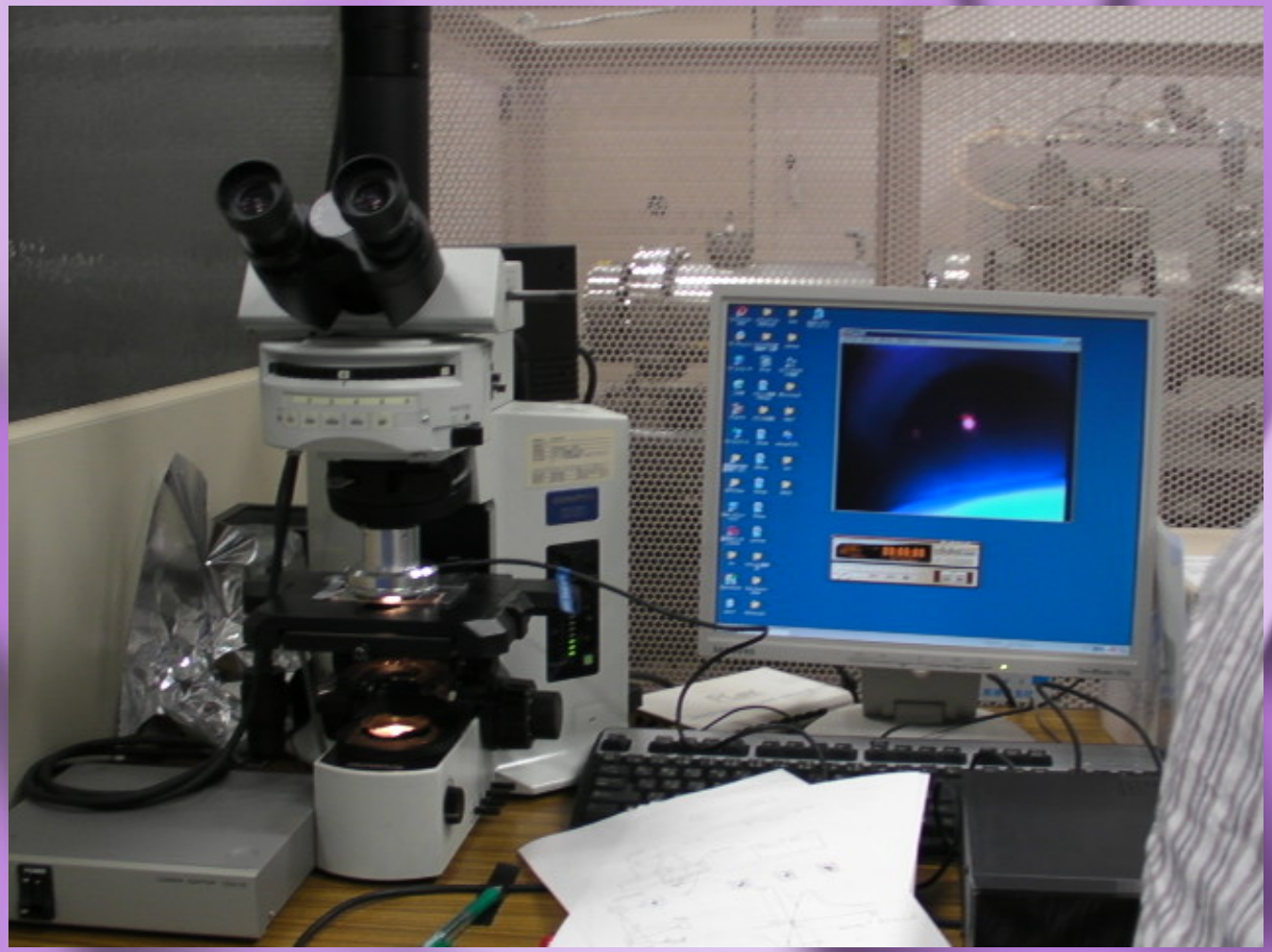
MEMS characterization



One Setup in Tokyo University



Department of Mechanical Engineering, University of Tokyo

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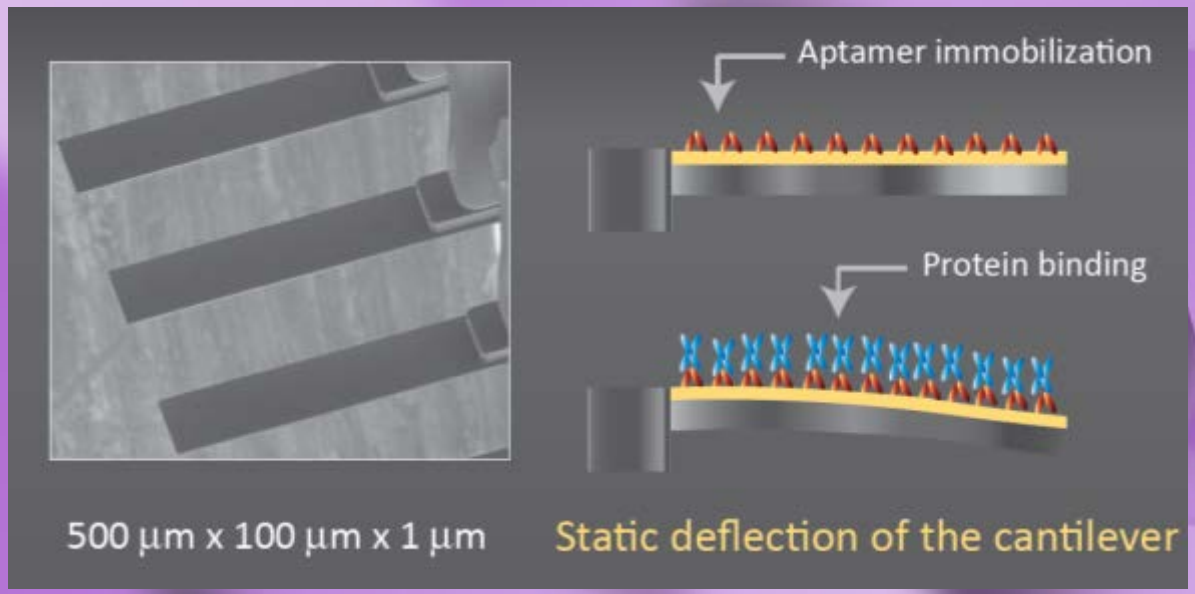
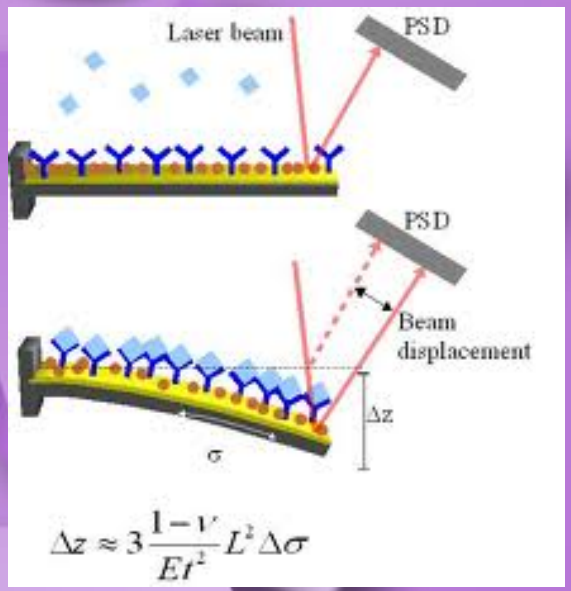
Micro Cantilever Based Label-free Biochemical Detection



Label-free biochemical detection mechanism



Traditional read out

Traditional read out: 1 min for 1 cantilever

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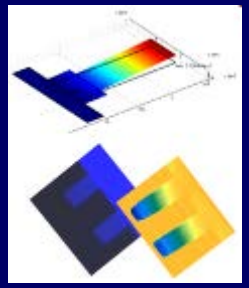
Exsisting technologies

mecwins
Innovation in nanomechanics for biotechnology

Optical readout



the displacement of the read-out laser beam provides a fast acquisition and the capability to detect of the full 3D profile of cantilever arrays of any size, shape and number of elements.

cantion

Piezoresistive readout

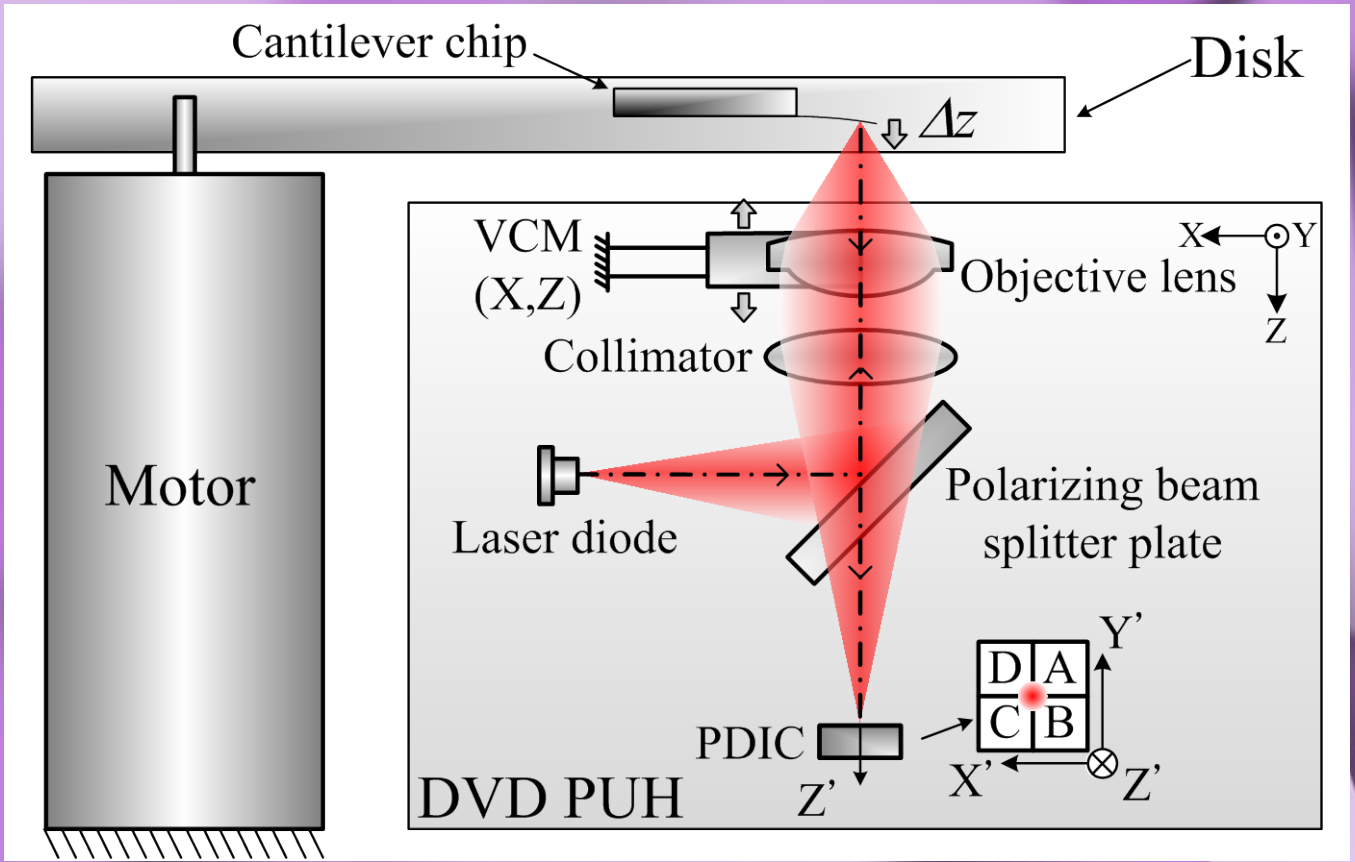
Easy replacement of the chip. Possibility of working in liquid and gas flow.

Concentrís
...smart analytical solutions

Optical readout

Integrated temperature control. Automated sample handling system. Possibility of working in liquid and gas

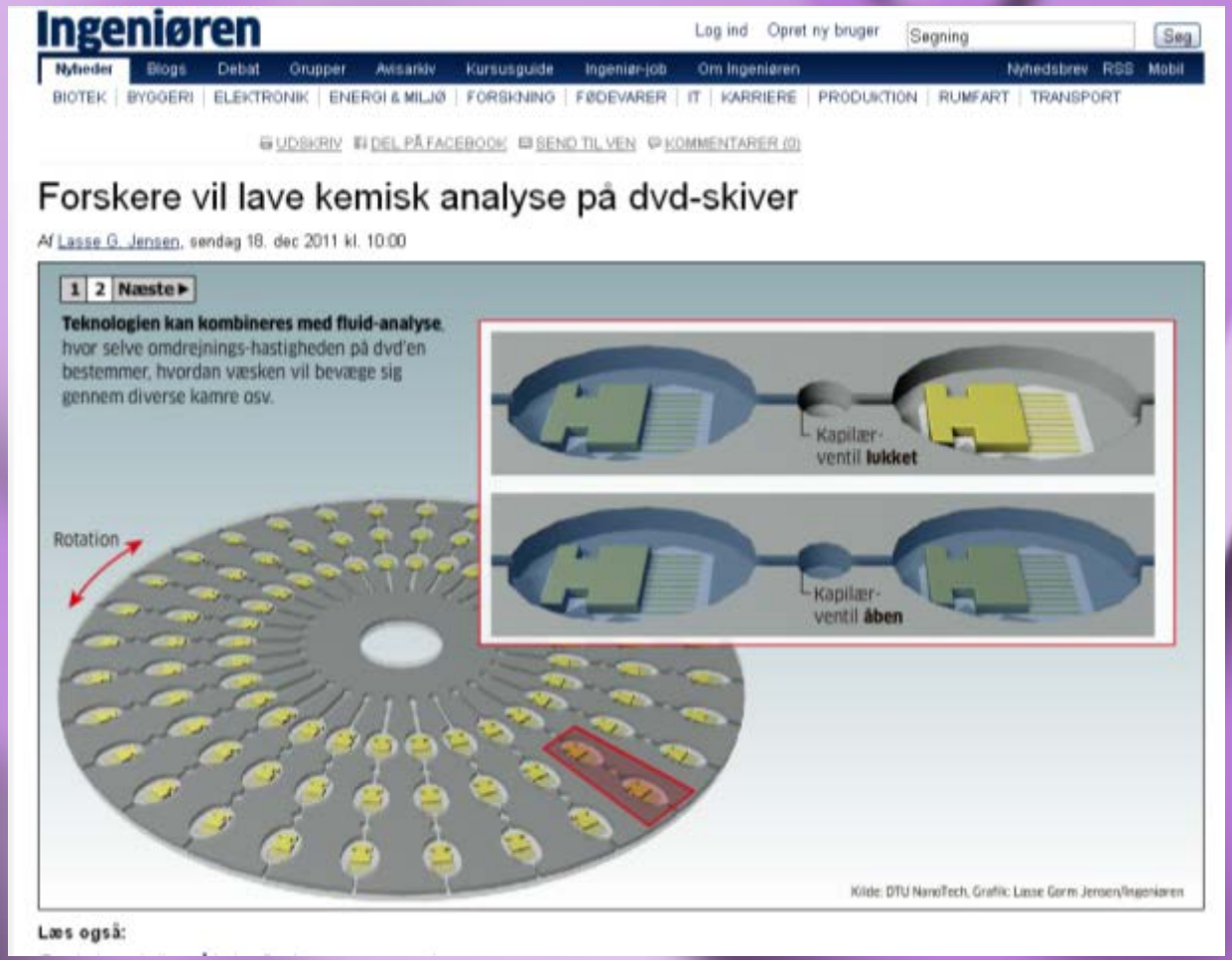
ADS Based Bio-sensing Read-out Setup



ADS Based read out: 500 cantilever per second

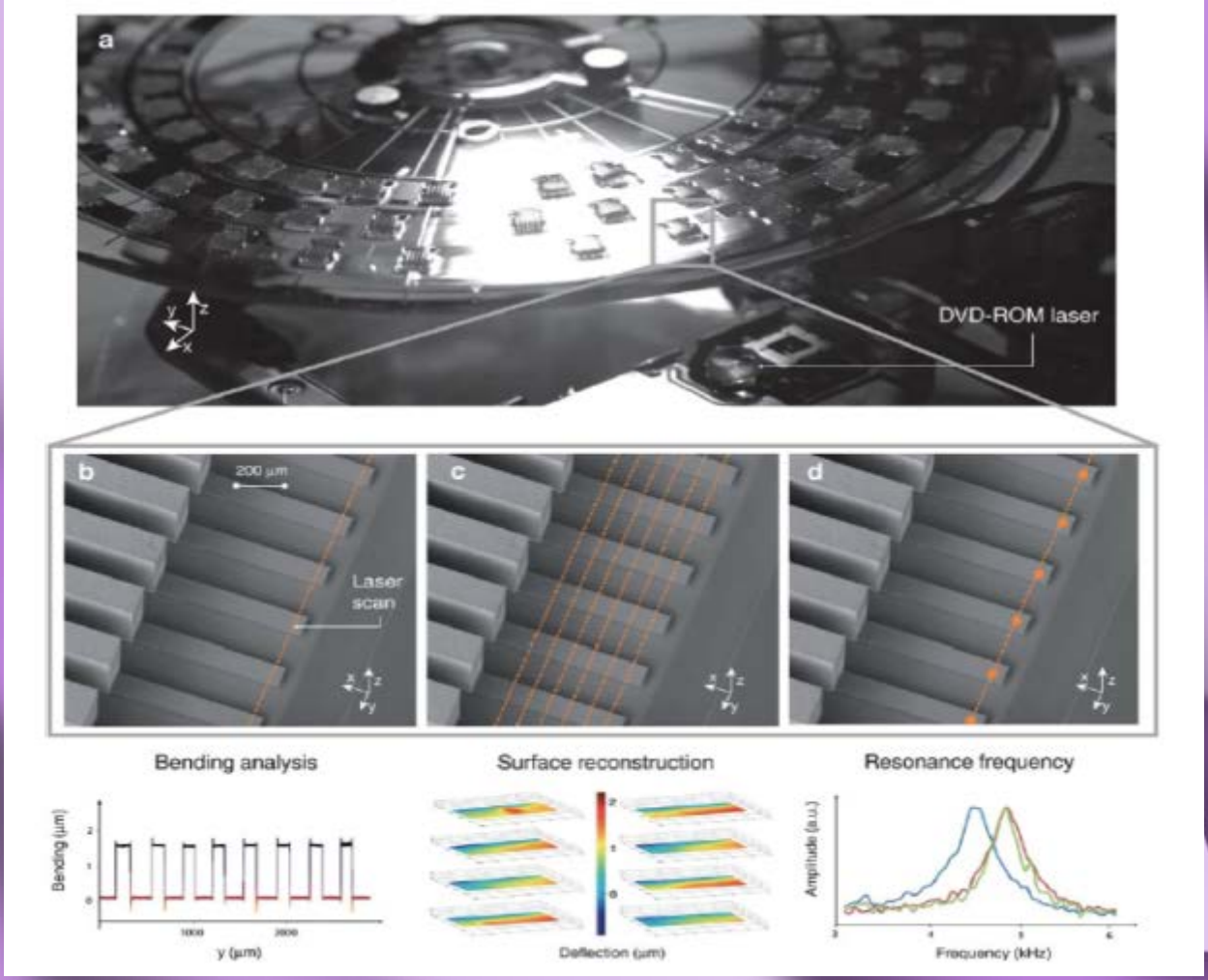
Danish Government to Invest 17 million kr. on this System

Lab on a CD
Sample preparation



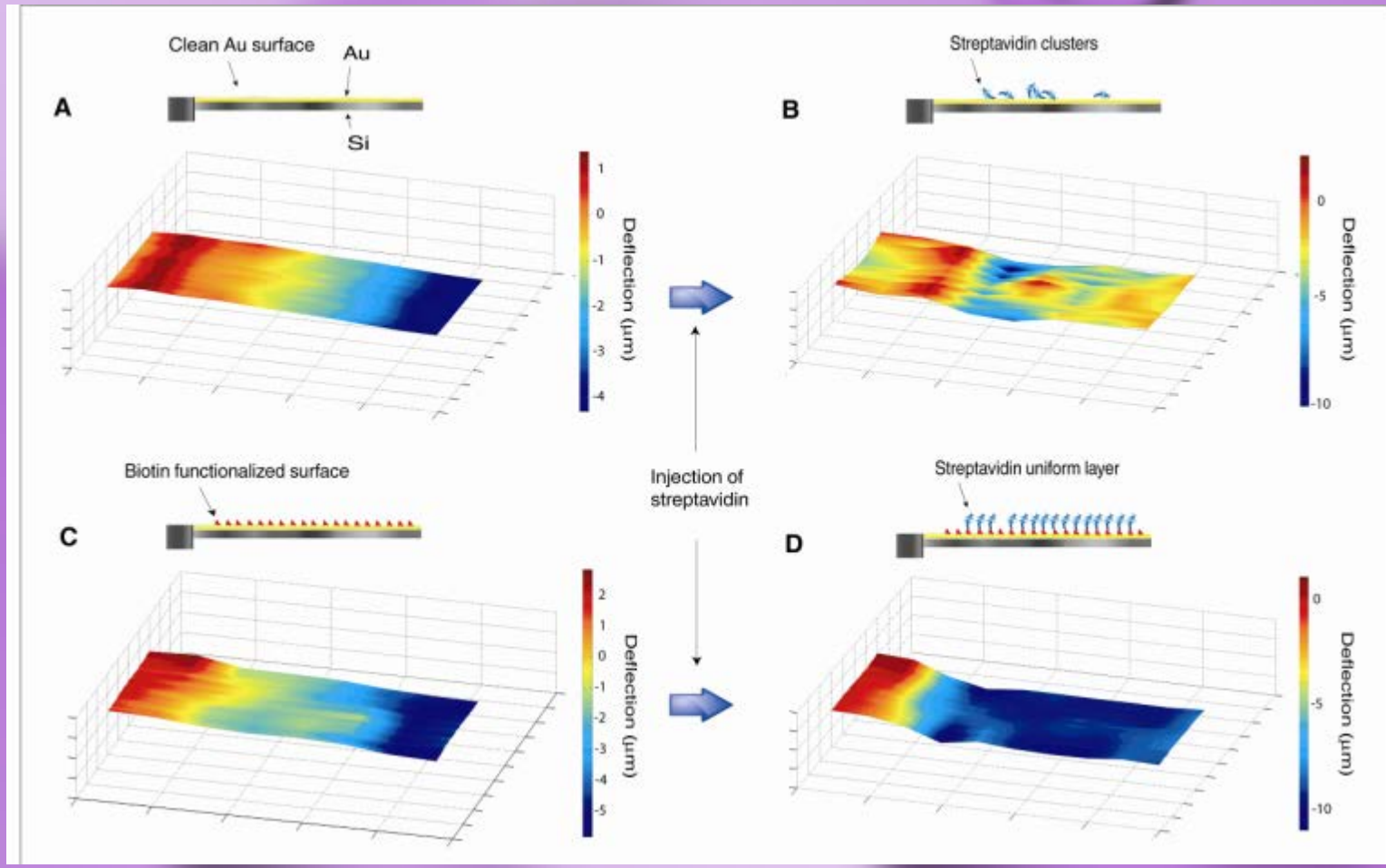
http://ing.dk/artikel/125118-bombejaeger-vil-ogsaa-lede-efter-hormoner-og-sygdomme

Static Bending, 3D Surface Reconstruction and Resonant Frequency Characterization

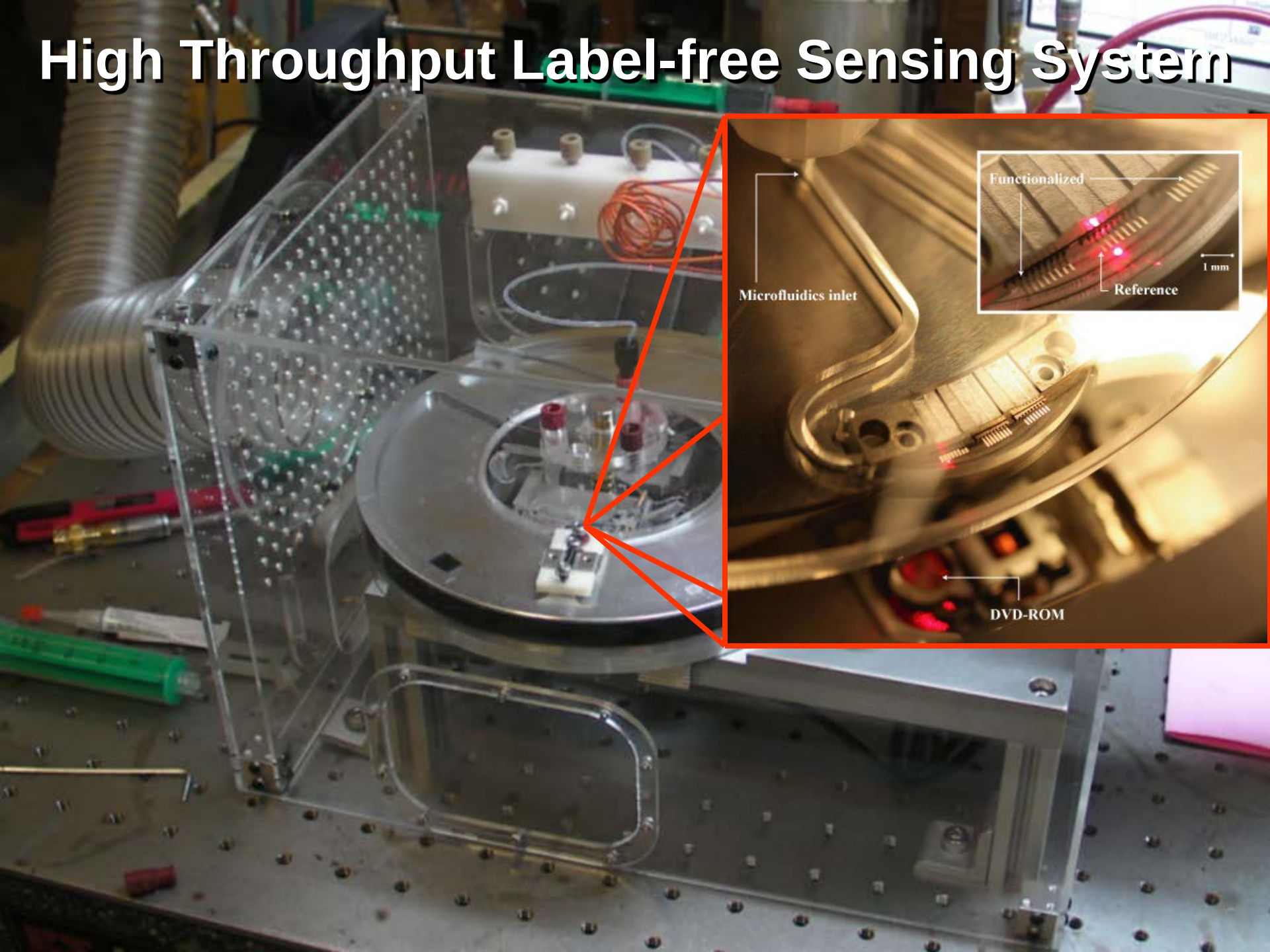


F. G. Bosco, E.-T. Hwu, C.-H. Chen, S. Keller, M. Bache, M. H. Jakobsen, I.-S. Hwang and A. Boisen, "High throughput label-free platform for statistical bio-molecular sensing," (2011) Lab on a Chip (SCI) Vol. 11. pp. 2411-2416. (IF:6.306)

Measurement Results



High Throughput Label-free Sensing System



Xsense

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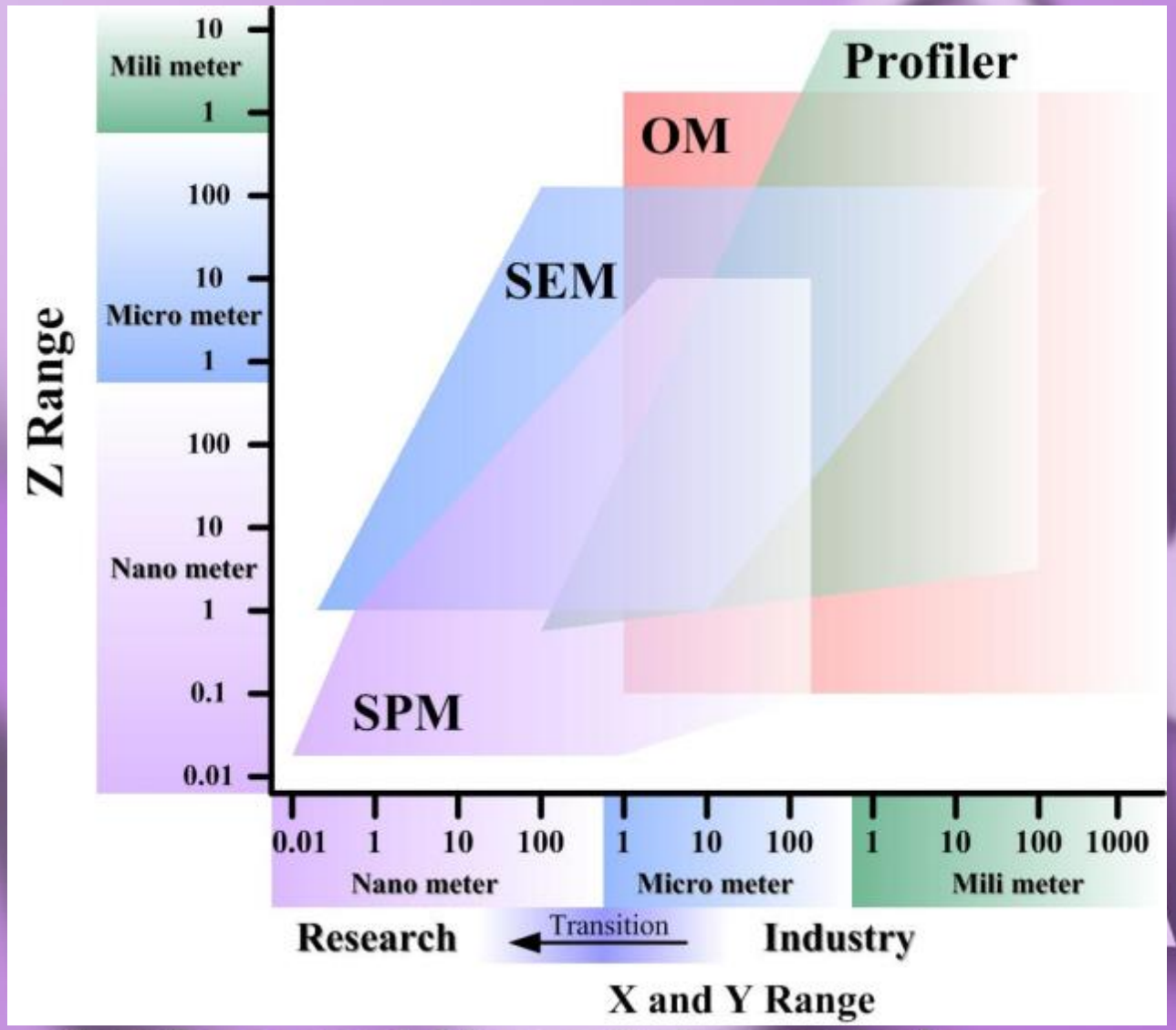
Outline

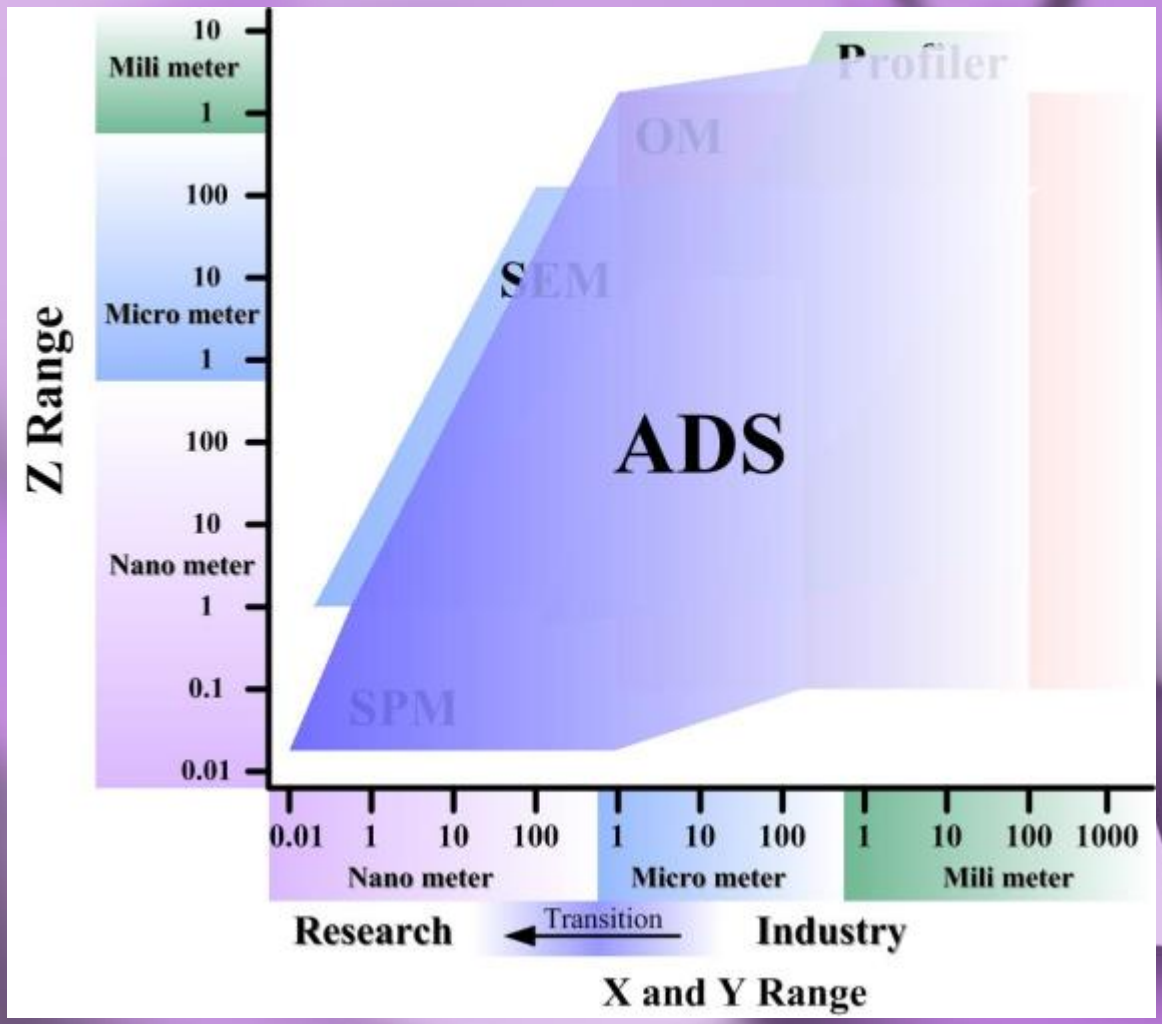
- Astigmatic Detection Mechanism
- ADS based instrumentation
  - Scanning Probe Microscope
  - Laser Vibrometer
  - High Throughput Bio-sensing System
- Conclusions

Comparison of Different Techniques



Conclusions:

Millimeter-Micrometer-Nanometer



Thank you !!

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