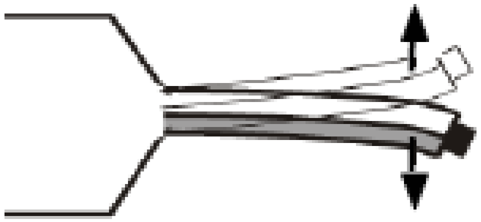
Cantilever based Sensors

bi-metallic

Heat Source

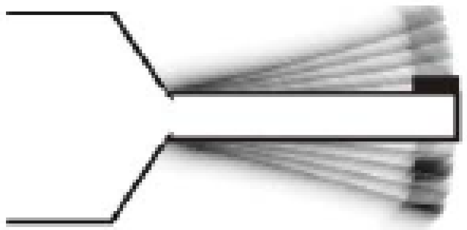


Heat Drain

Calorimeter
Pico-Joule

dynamic

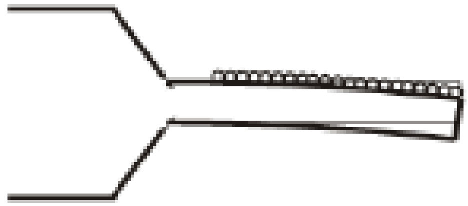
Resonance frequency-shift



Microscale
Pico-Gramm

static

Cantilever Bending

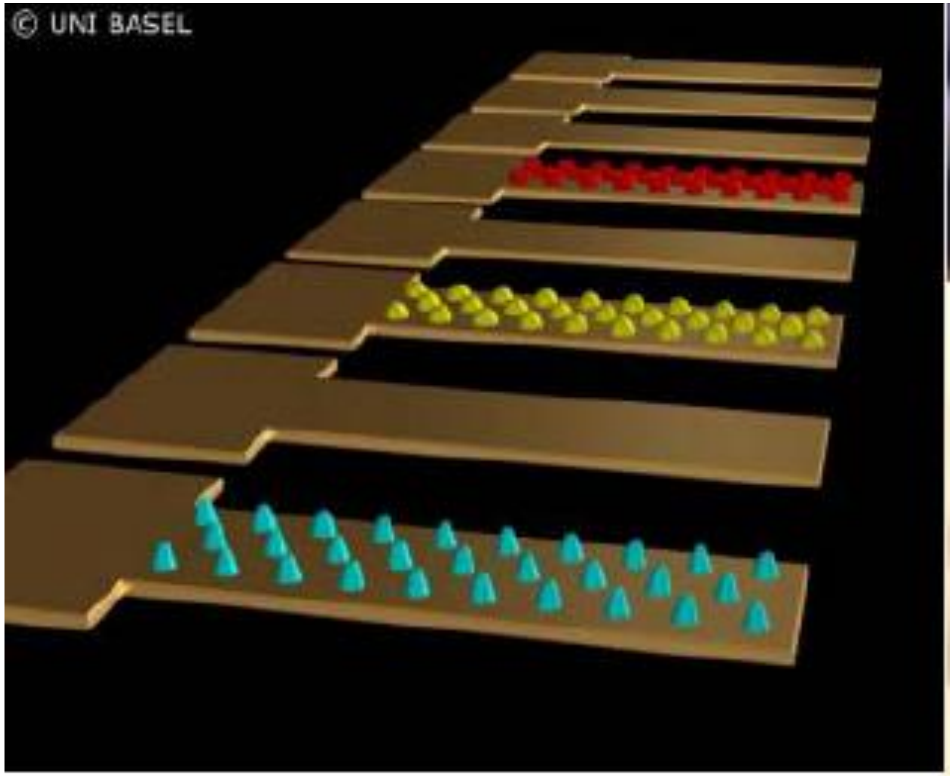


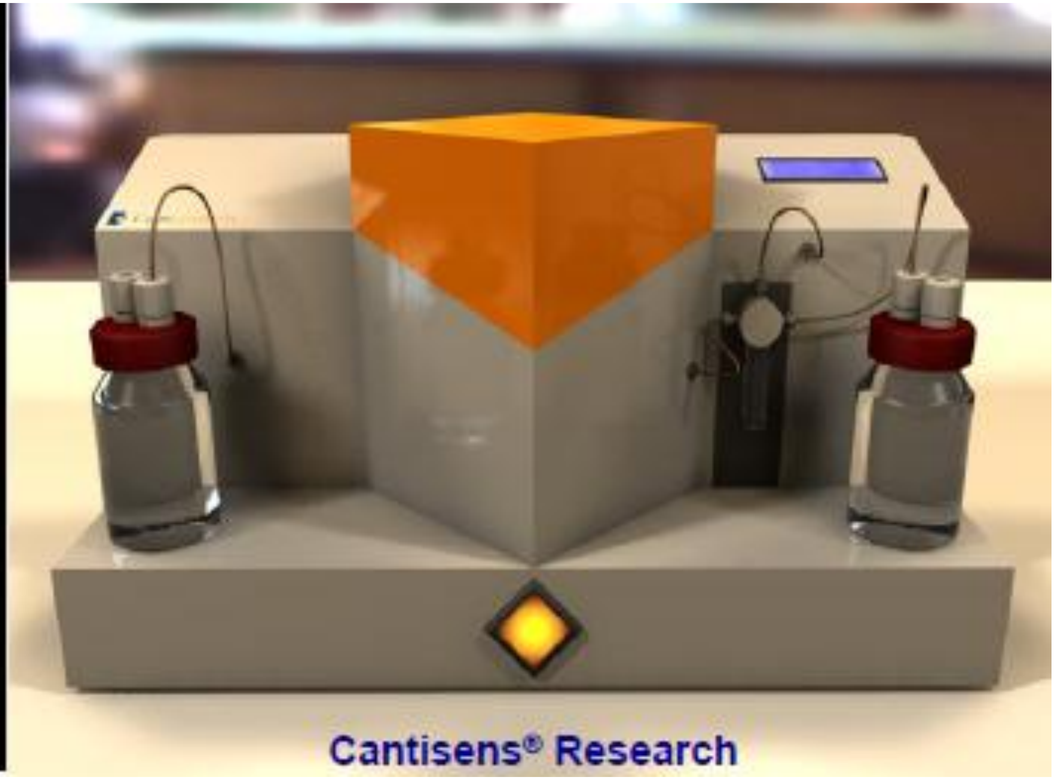
Surface Tension
Atto-Mol

Important: Functionalization of Cantilever Surface.

Cantilever Sensor Principle

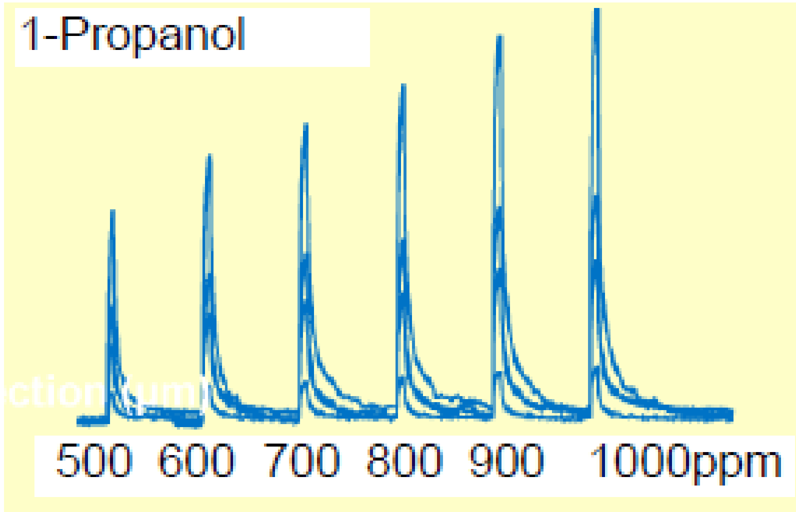
Detection of Molecular Interactions using Cantilever Array



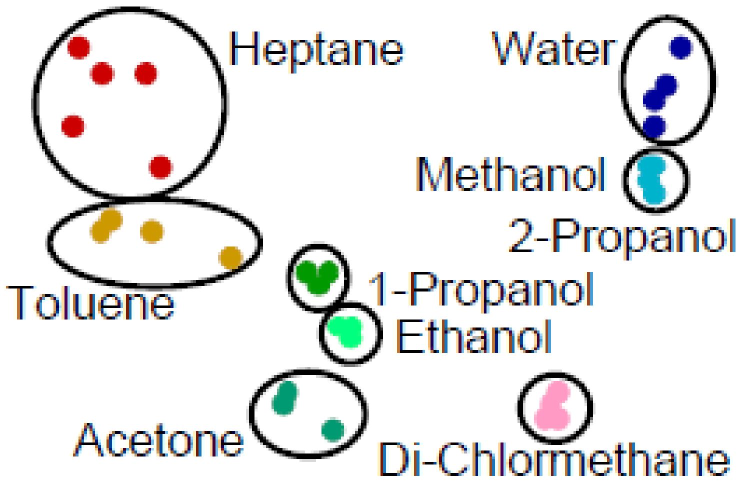


Cantilever based chemical Nose

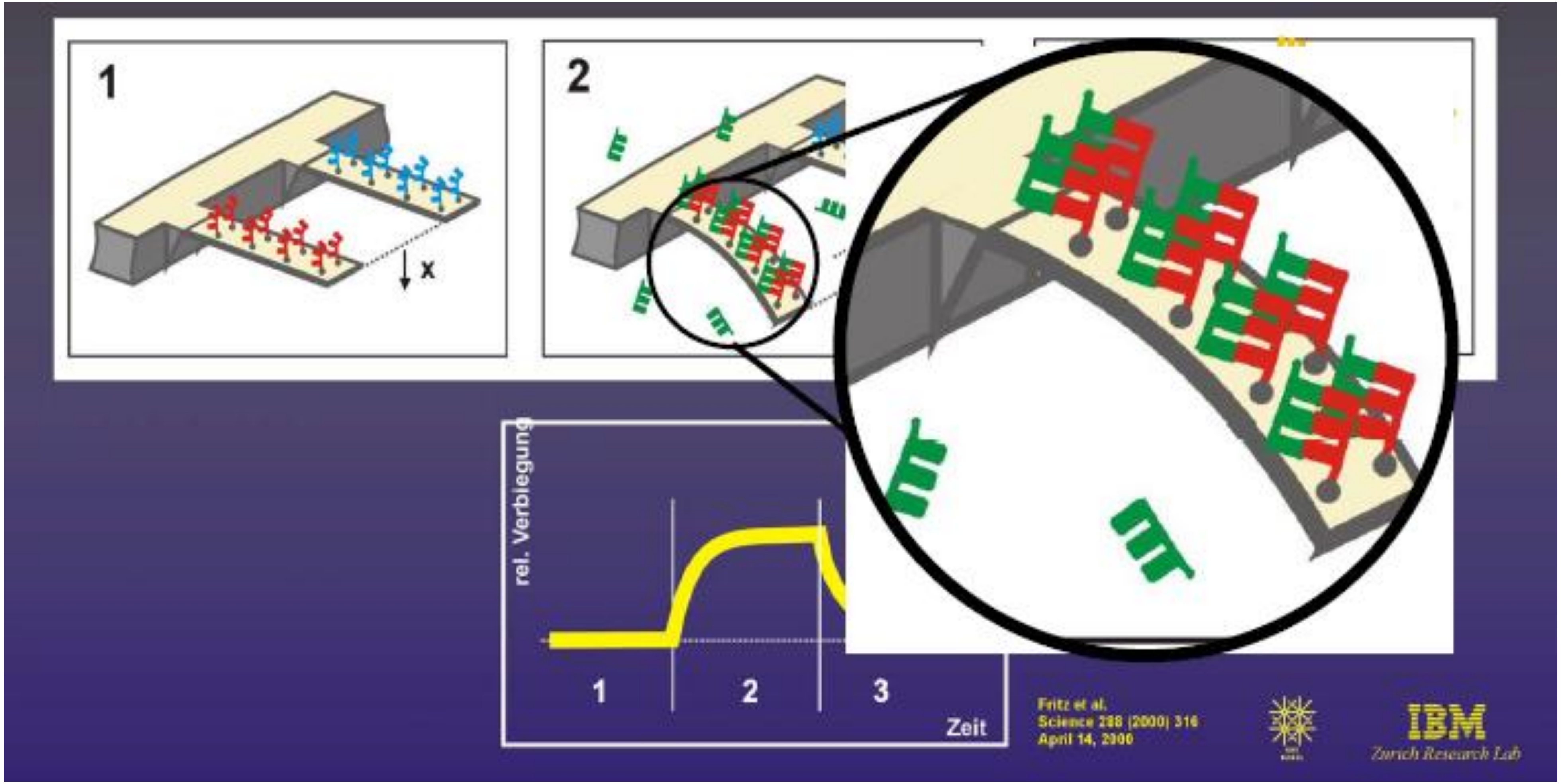
Quantitative Analysis



Neuronal Network Analysis



DNA Sensor


1
2
x
rel. Verbiegung
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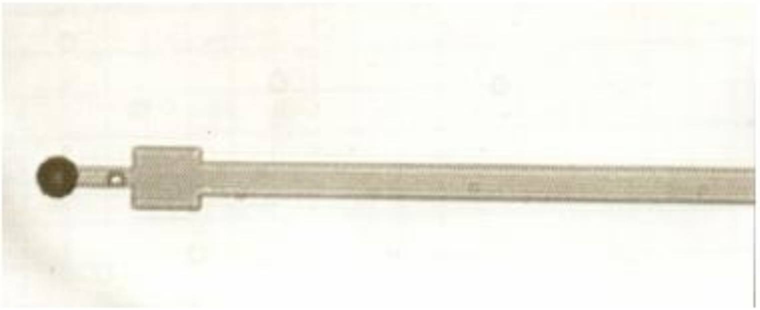
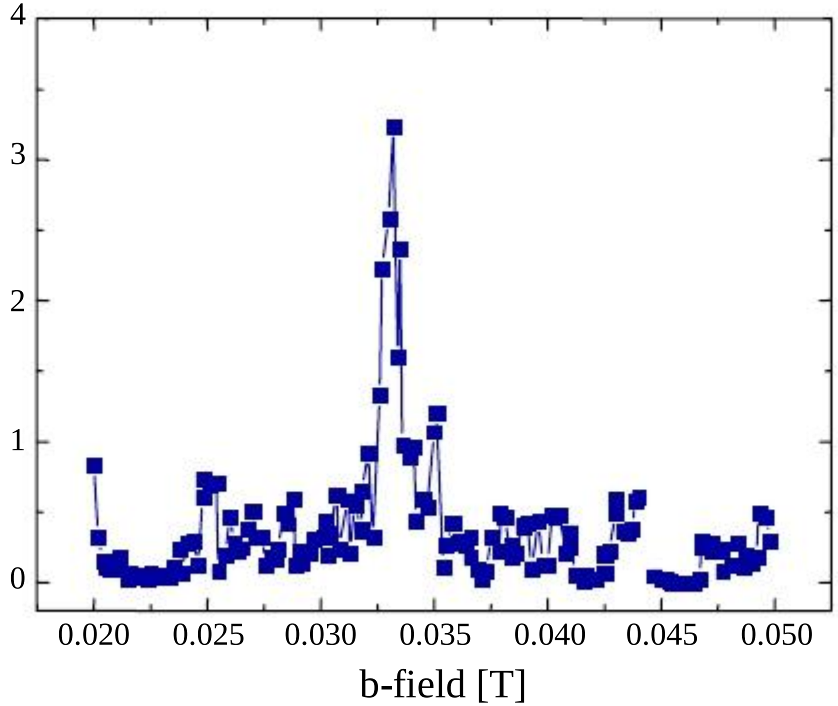
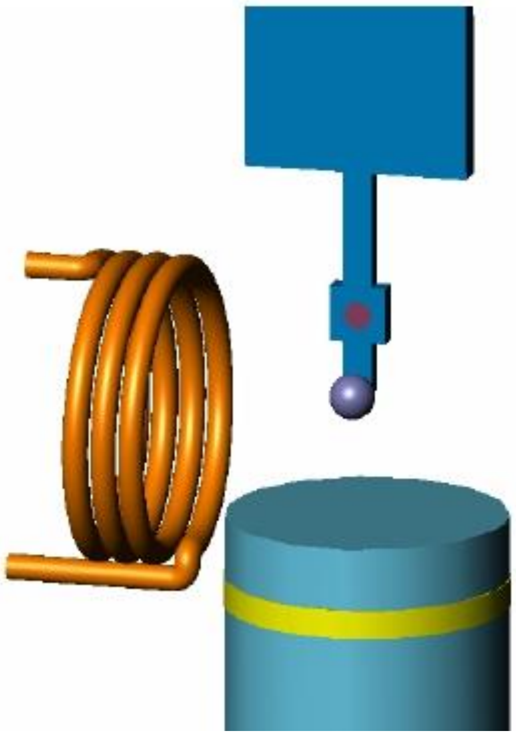
3
Zeit
Fritz et al.
Science 288 (2000) 316
April 14, 2000
IBM
Zurich Research Lab

Magnetic Resonance Force Microscopy: Towards Detection of Single Spins







Why SFM with ultrasmall cantilevers?

The ideal SFM or AFM would simultaneously and directly map the:

- vertical or force gradients
- lateral forces or force gradients
- loss of energy due to vertical mode of oscillation
- loss of energy due to torsional mode of oscillation
- tunneling current (as good as an STM)

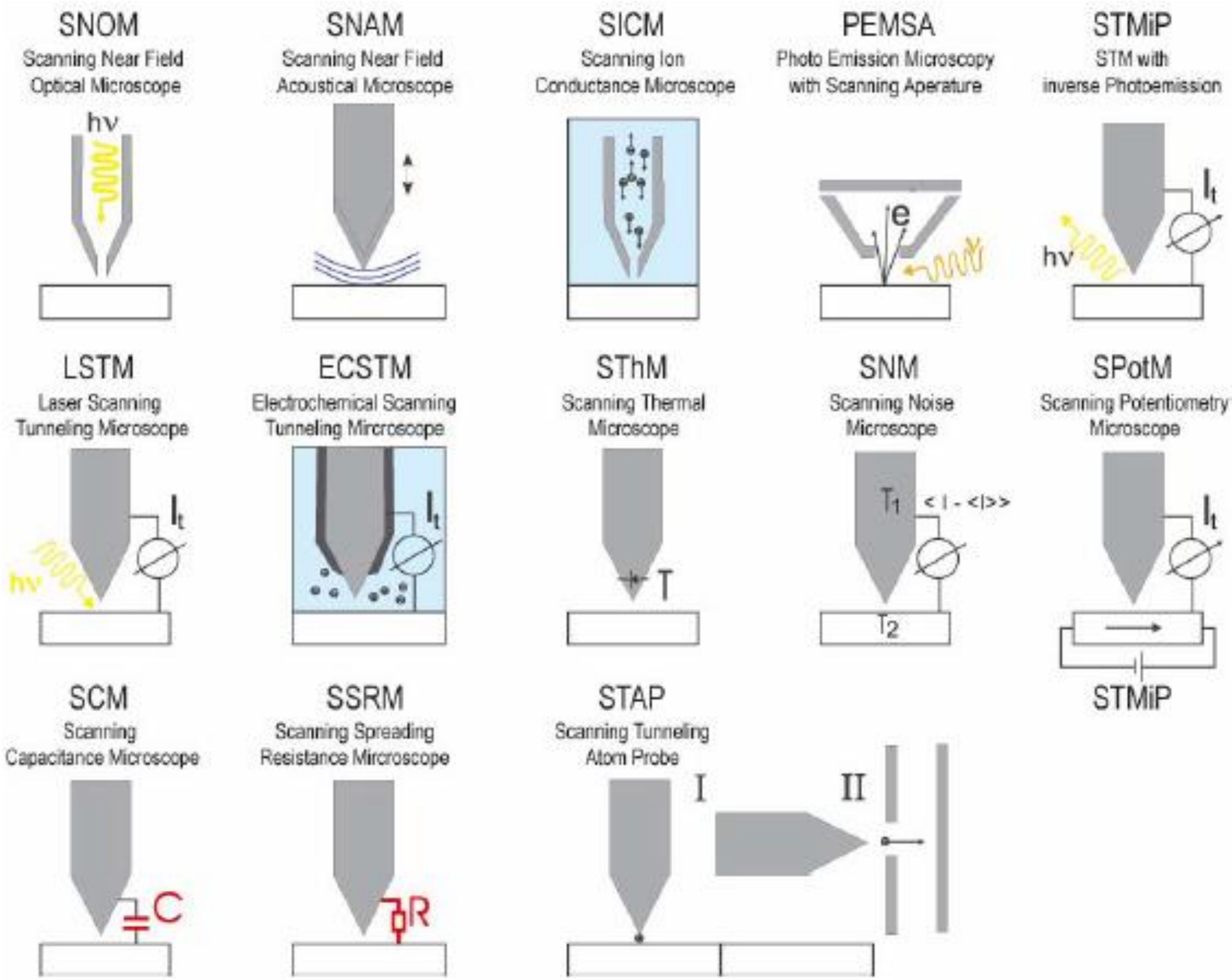
And

- have an extremely high force sensitivity << 0.1pN
- allow measurements at a high bandwith
- be able to position AND keep the tip at an arbitrarily small distance, i.e. have a tip with a controllable compliance

Our approach:

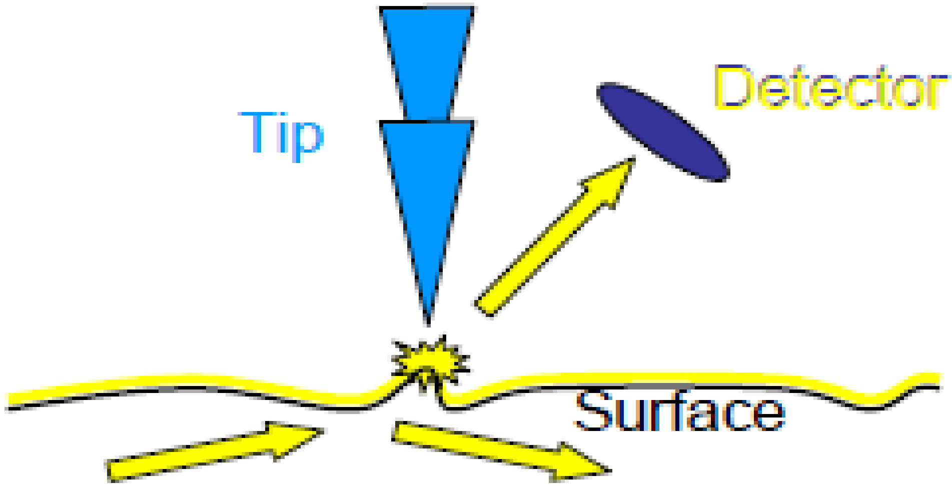
use sufficiently stiff (>200N/m)
operate them at small oscillation amplitudes (< 0.1 A)
make them sufficiently small (10-20um) to get the required sensitivity at high bandwiths.

Other Members of the SPM Family

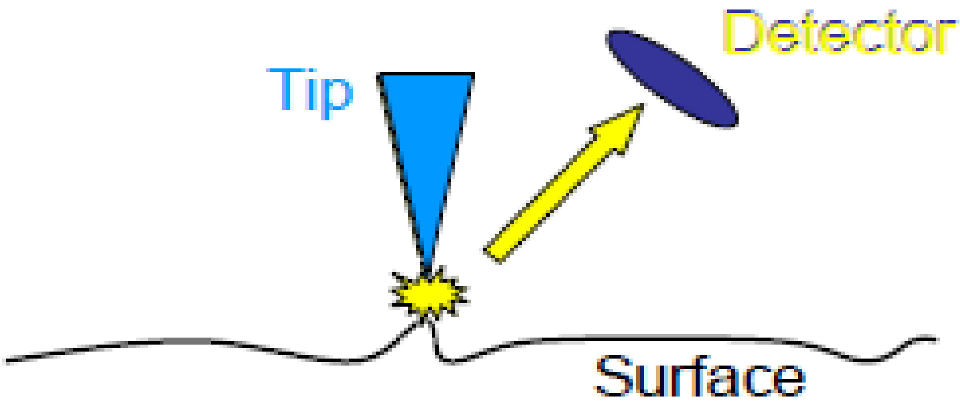


1- Scanning Near Field Optical Microscopy (SNOM)

Peak in the vicinity (a few nm) of a evanescent field surface can into a propagating field convert: apertureless SNOM



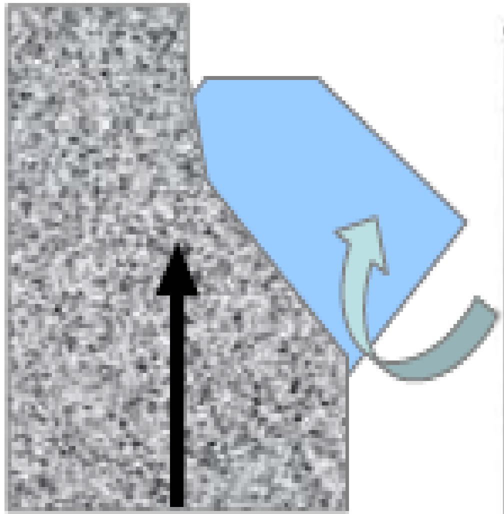
Reciprocity: A localized (evanescent) in the near field source near a surface leads to generate a propagating field: aperture SNOM



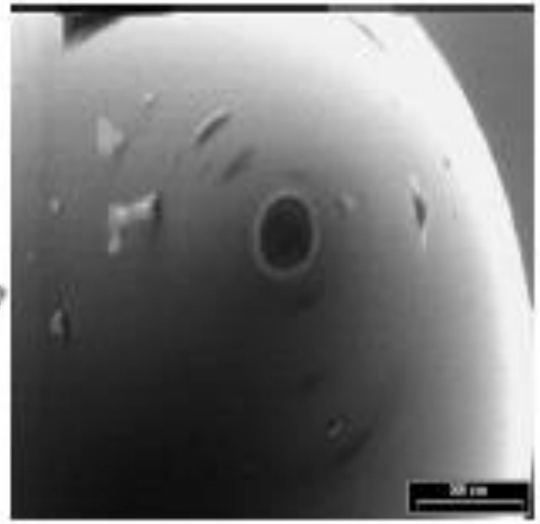
- *Fabrication of the aperture*

Metal deposition and shadow effect:

- Poor reproducibility
- Aperture of ~ 70 nm
- Parallel production of the acute

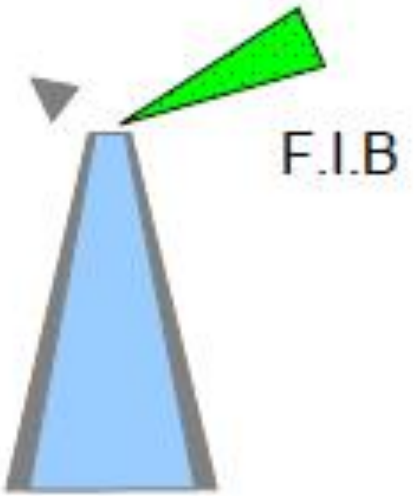


metallization



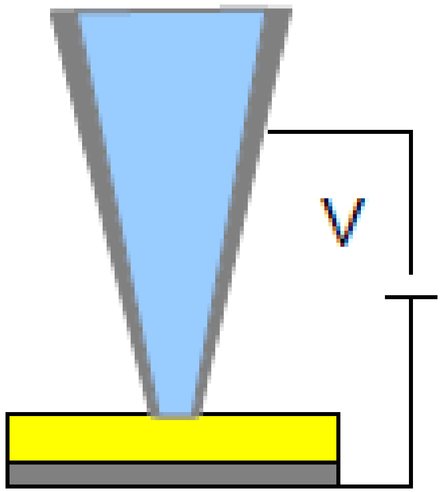
Focussed Ion Beam:

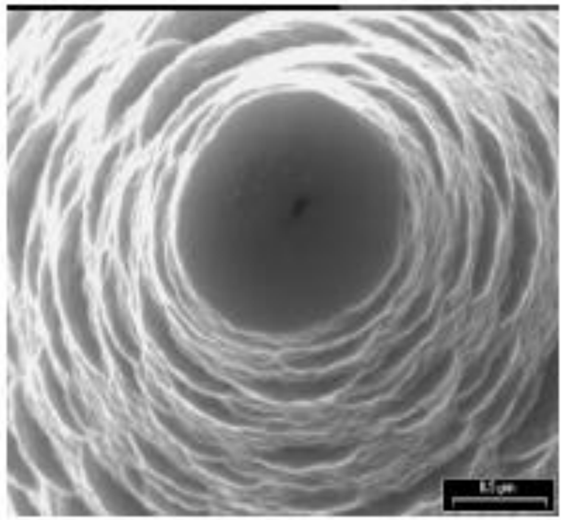
- Good reproducibility
- Aperture of ~ 20 nm
- Single peak process
- Expensive



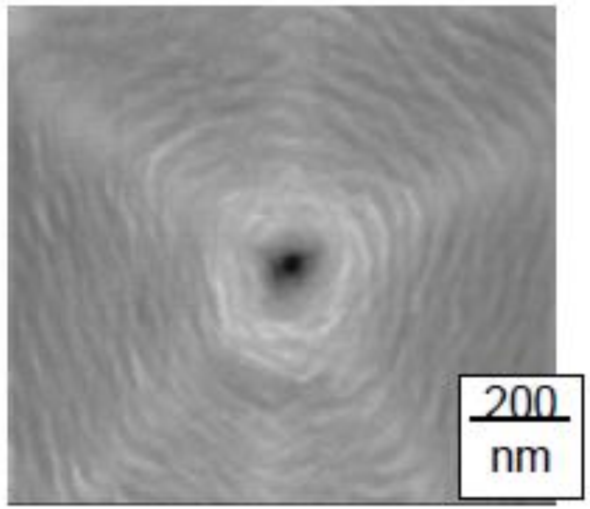
- Fabrication of the aperture

Solid electrolyte
- good reproducibility
- aperture of <40 nm
- cheap
- metal-dependent
- single peak process



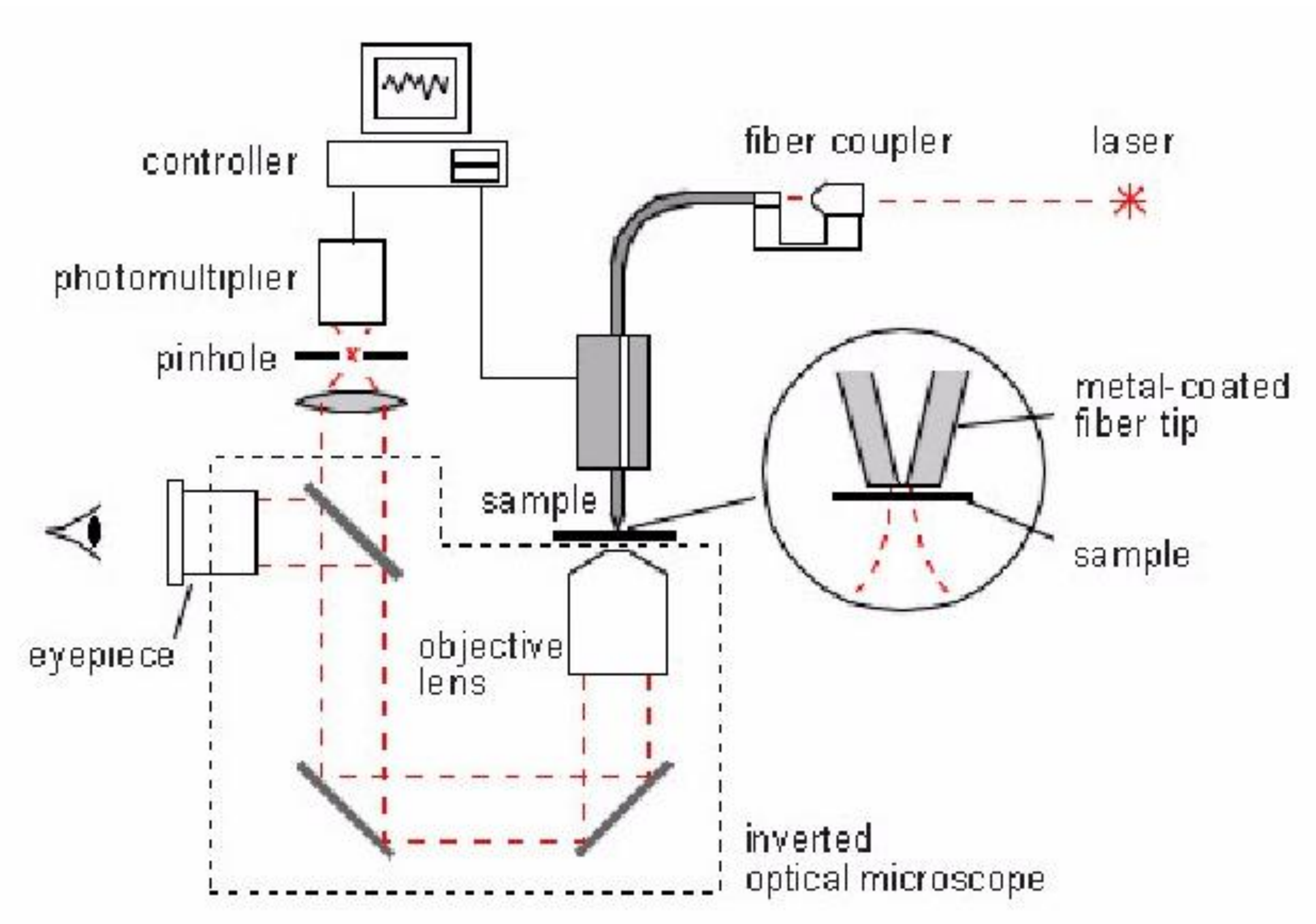


cantilever tips
- AFM imaging is possible
- aperture of <40 nm
- microfabriacation
- cheap

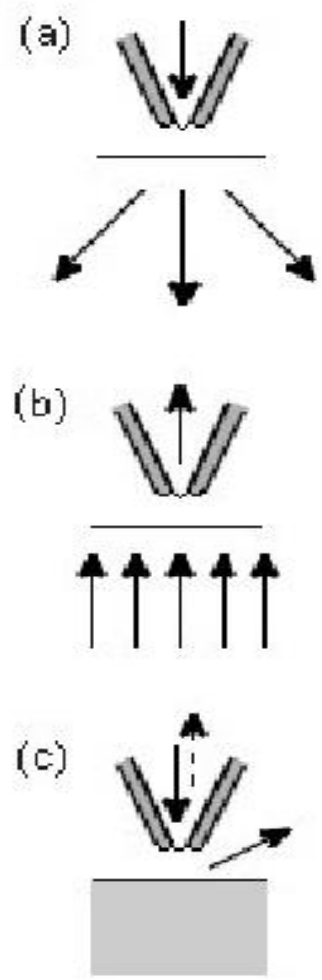


- *Principle of SNOM and modes*

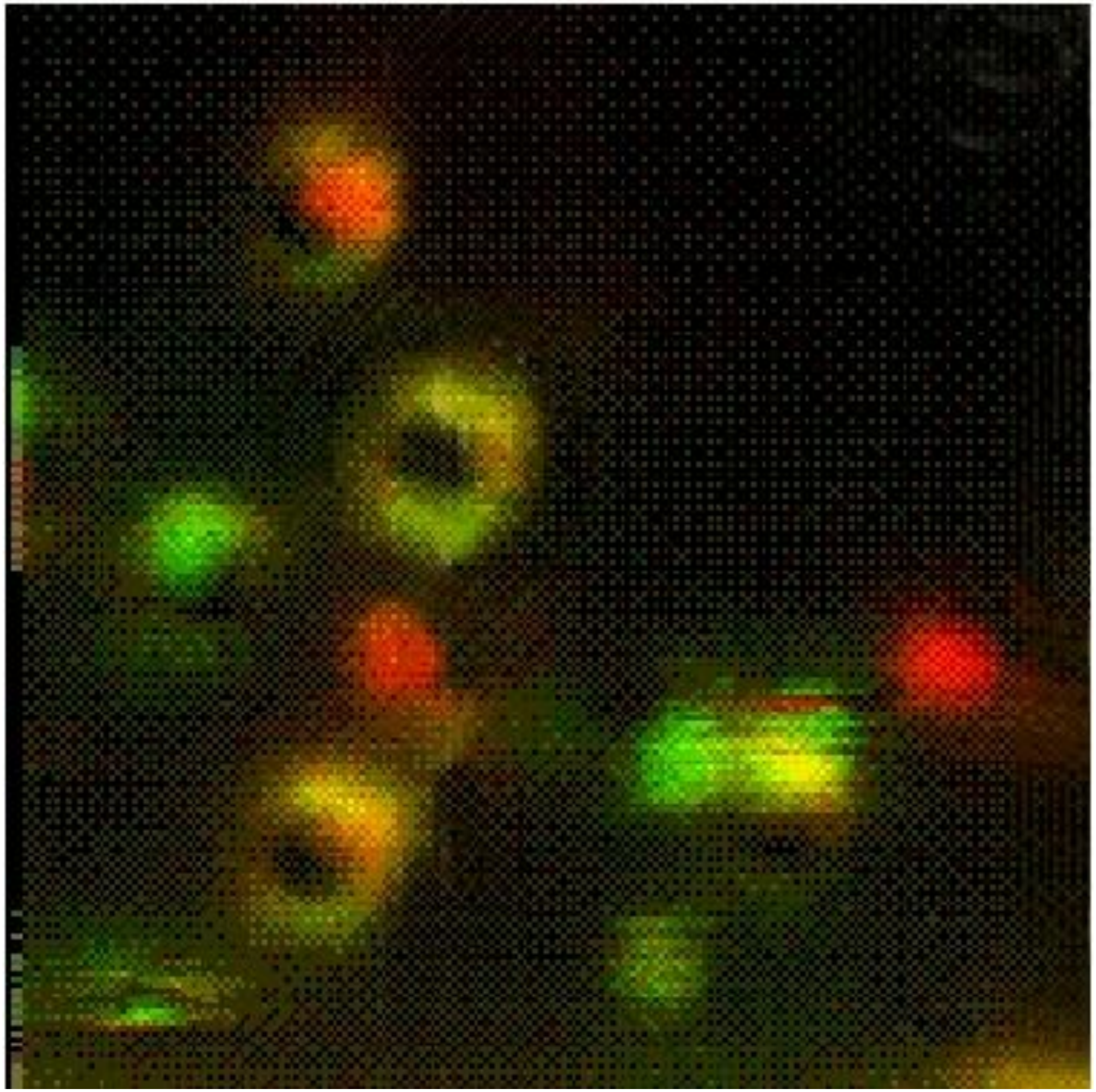
Scheme



Modes



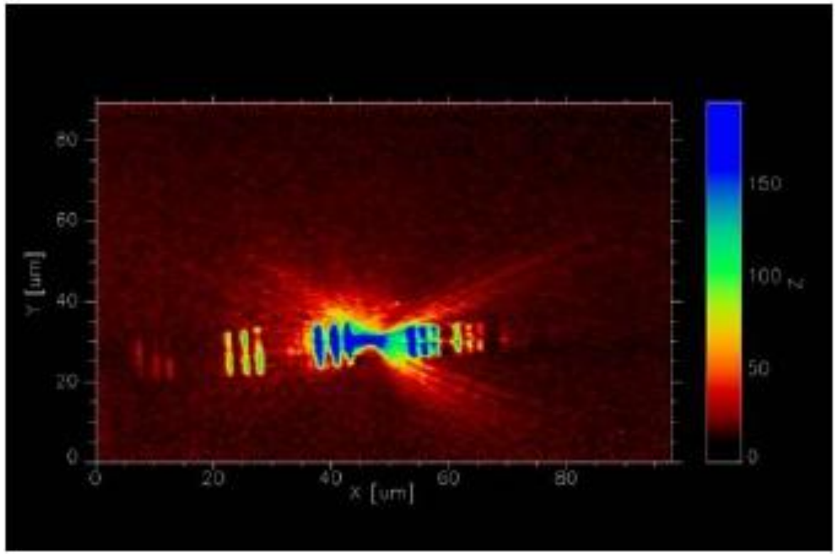
SNOM single fluorescent molecules

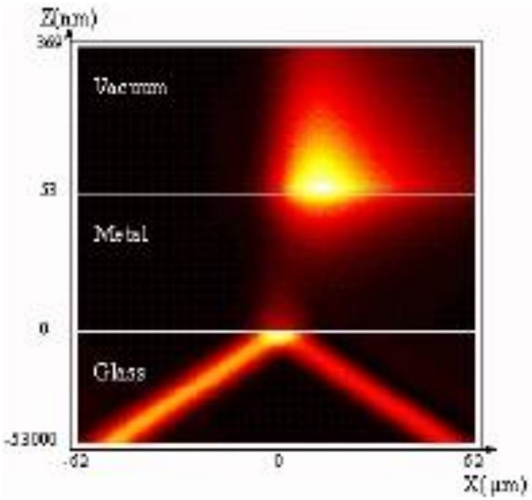


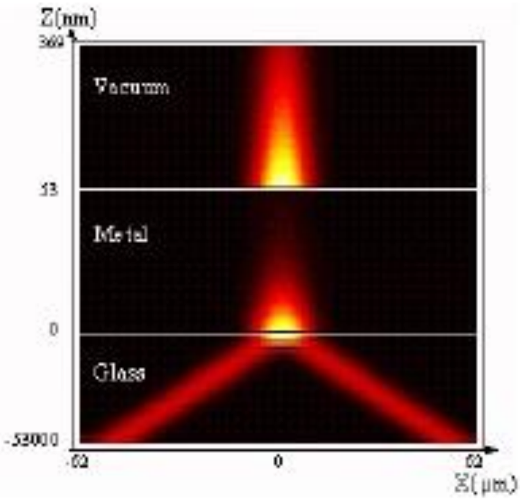
SNOM fluorescence image of individual Molecules. Each molecule is a point source and produces according to its orientation of different images tip e.g. bright dots, rings, bright double points.

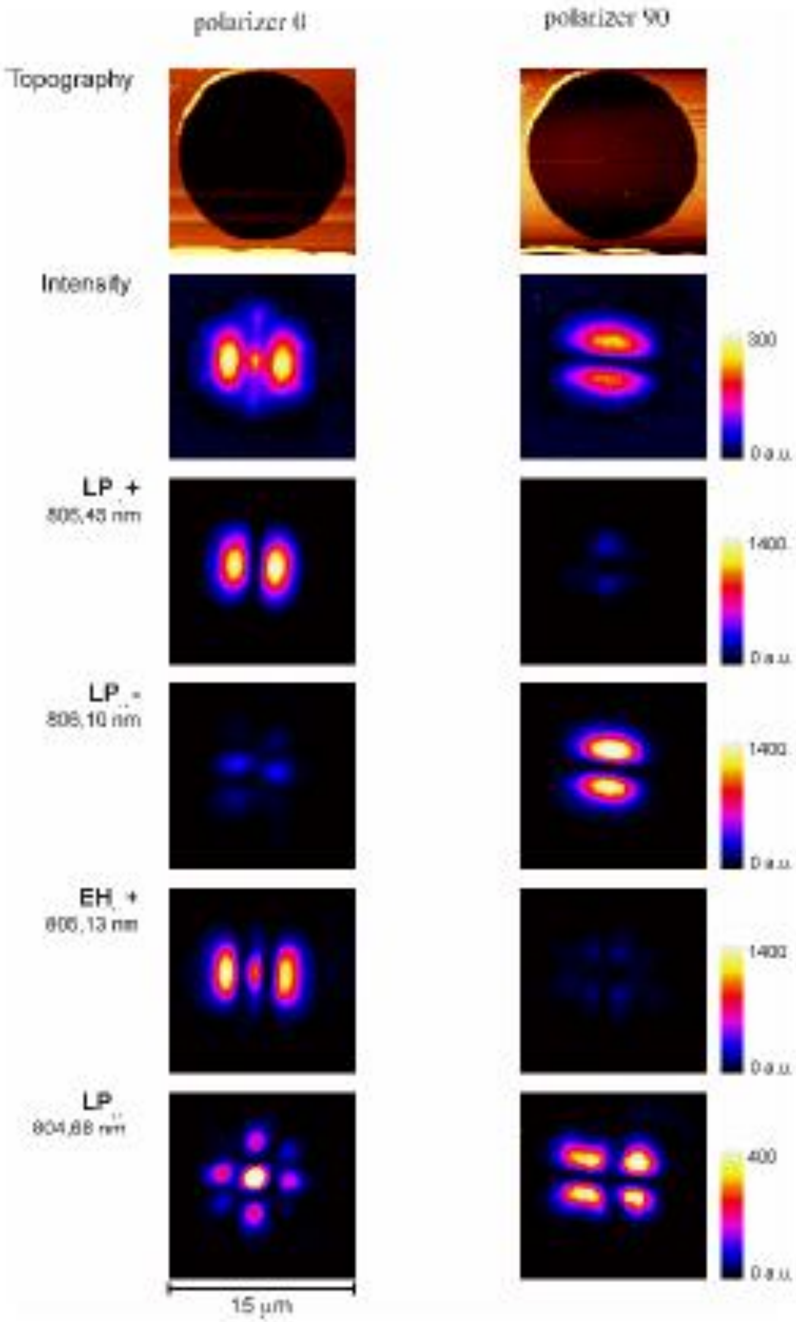
Material science:

- Surface plasmon & field enhancement
- Semiconductors



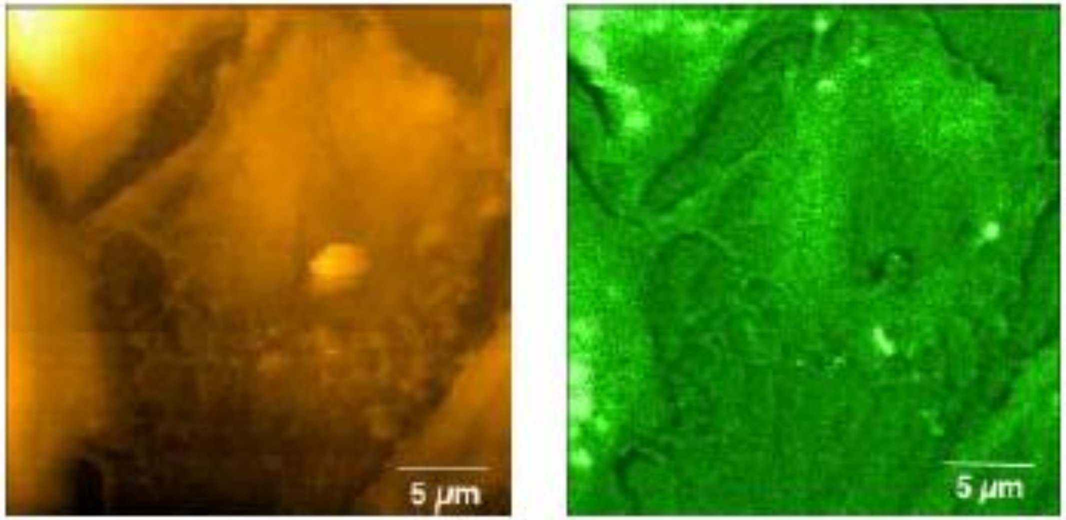




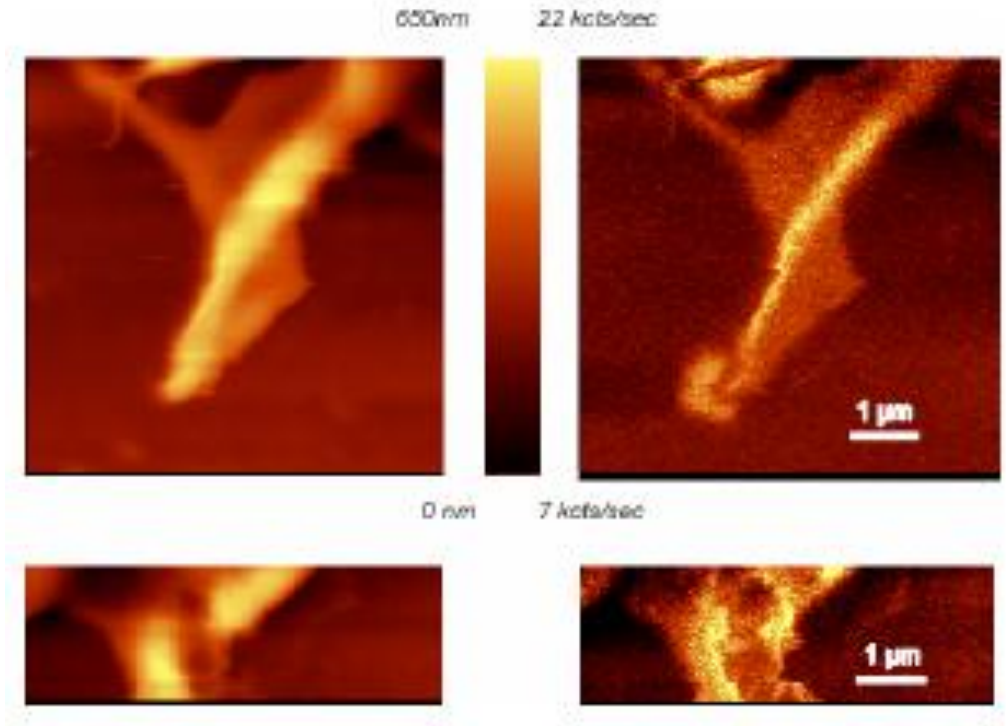


Biology:

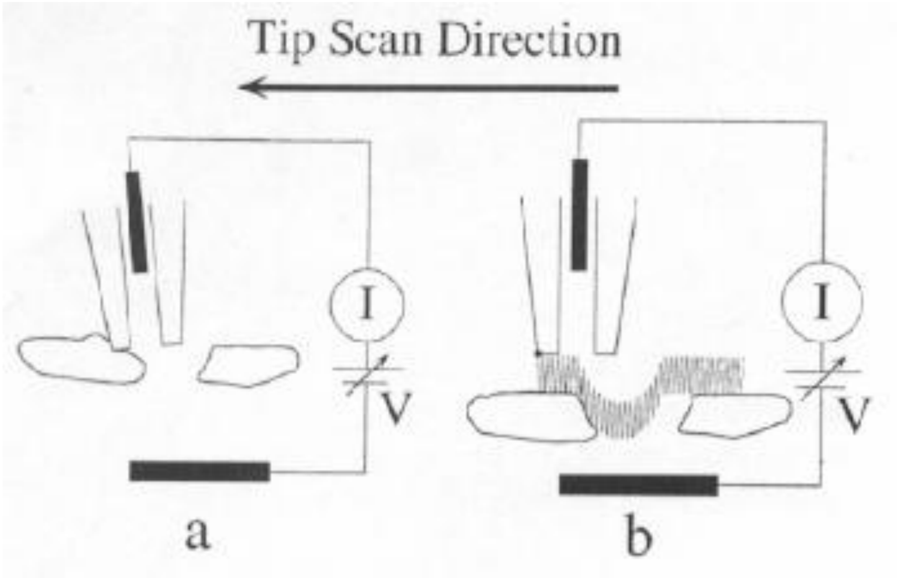
Shear-force topography and near-field fluorescence from GFP-labeled fibroblast cells.



Topography and florescence images of a growth cone of nerve cells of the hippocampus of a rat. The samples are fluorescence labeled with DIC18.



2- Scanning Ion Conductance Microscope (SICM)



The SICM uses a micropipette which approaches the surface of a sample immersed in an electrolyte. The ion conductance between the electrode in the solution and the electrode in the pipette is measured As the pipette approaches the sample surface, the cross-section of the ion path from one electrode to the other is reduced and the conductance decreases. The resolution is essentially given by the size of the aperture. Compared to glass pipette tips, microfabricated probes have the advantage of smaller aperture size and higher stability. Structures of the order of 100 nm can be resolved. The distance is controlled by the ionic current. Alternatively, a combination of SICM and SFM can be used. In this case, the pipettes were made of pulled quartz glass tubes, where the front-end portion is bent. The deflection of the pipette can be measured with conventional laser beam deflection method. The microscope can either be operated in contact mode or in tapping mode. In both cases, the ionic current is measured during imaging. However, the resolution in tapping mode on the pores is found to be improved. The main application of SICM is to measure the distribution of ionic currents through the pores in a porous surface.

3- Photoemission Microscopy with Scanning Aperture (PEMSA)

In PEMSA the photoemission of electrons escaping a surface and passing through a small aperture is measured. Using polarized light the circular polarization dependence of this photoemission current can be measured. McClelland and Rettner introduced this method and achieved a resolution of 30 nm . Magnetic domains of a Co/Pt film were imaged by the polarization Dependent PEMSA. The magnetic contrast of PEMSA is related to scanning Kerr microscopy. The photons which contribute to the signal must be absorbed very close to the surface. The created photoelectrons have low energies (some electron volts) which limits the mean free path to some nanometers. The apertures used by McClelland et al. were 30-45 nm in diameter. The sample was first biased at +1V to suppress photoemission and was approached towards the tip until the tunneling current raised. Then the sample was retracted 30nm and the bias switched to -10 V to detect photoemission. With 2 mW of light, 100 nÅ photocurrent is generated and 1pÅ is passed through the 30 nm aperture. The photoemission is recorded as the light polarization is alternated. Then the sample is moved to the next position and the cycle is repeated. Since the resolution is approximately given by the mean free path of the photoelectrons and the aperture size, McClelland et al. suggest that the resolution will surpass the SNOM resolution. The potential of PEMSA is not yet fully explored. The energy analysis may provide useful information about the local band structure. Experiments in analogy to ultraviolet photoemission spectroscopy (UPS) or x-ray photoemission spectroscopy (XPS) may be performed, where the local chemistry could be determined with superblateral resolution.