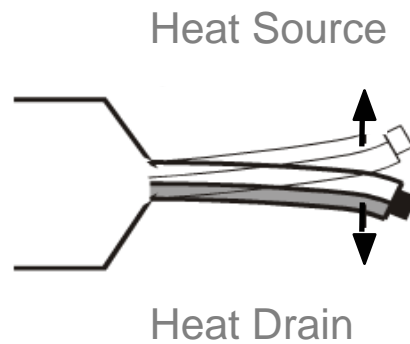


4.

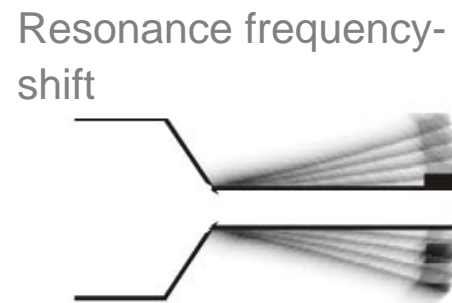
Cantilever Based Sensors

bi-metallic



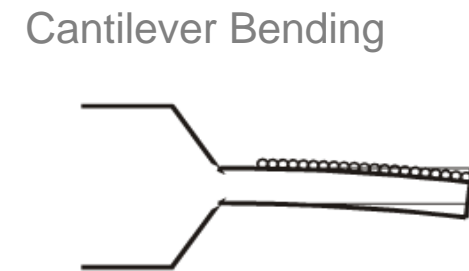
Calorimeter
Pico-Joule

dynamic



Microscale
Pico-Gramm

static

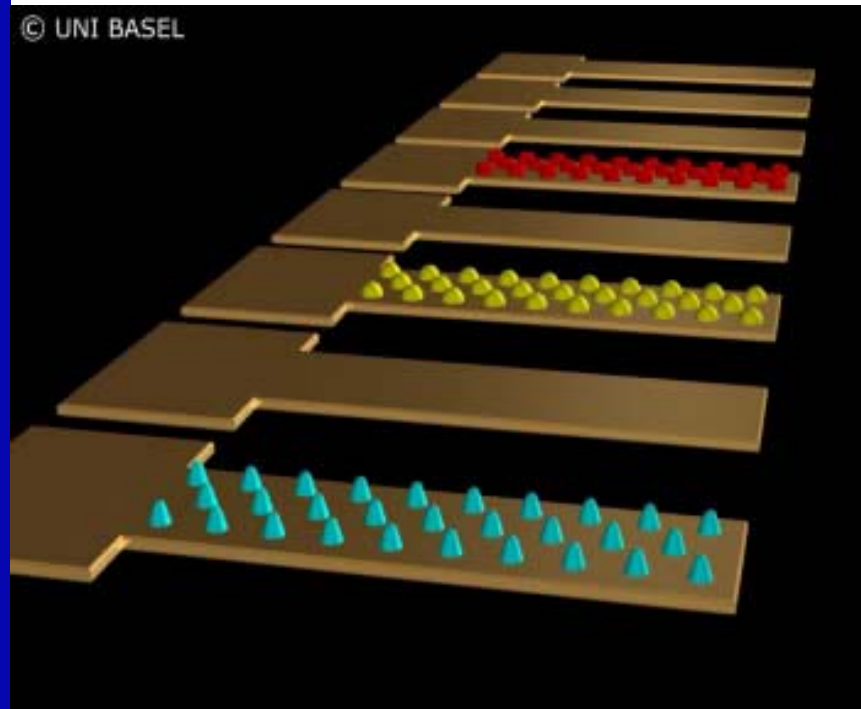


Surface Tension
Atto-Mol

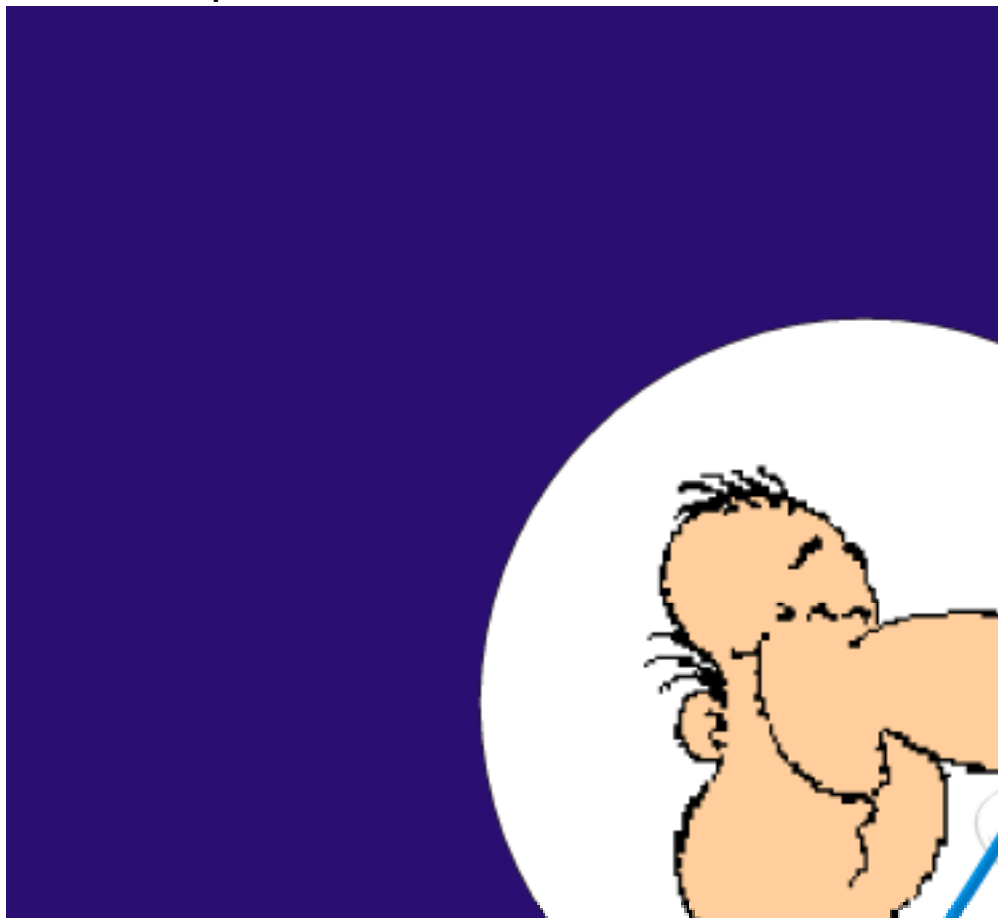
Important: Functionalization of Cantilever Surface.

Cantilever Sensor Principle

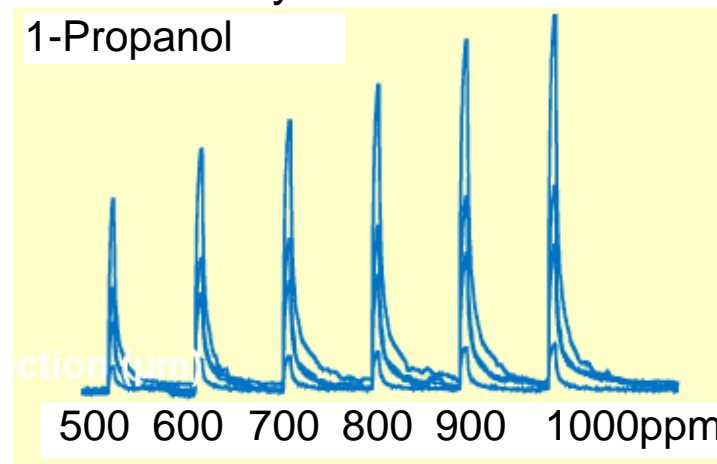
Detection of Molecular Interactions using Cantilever Arrays



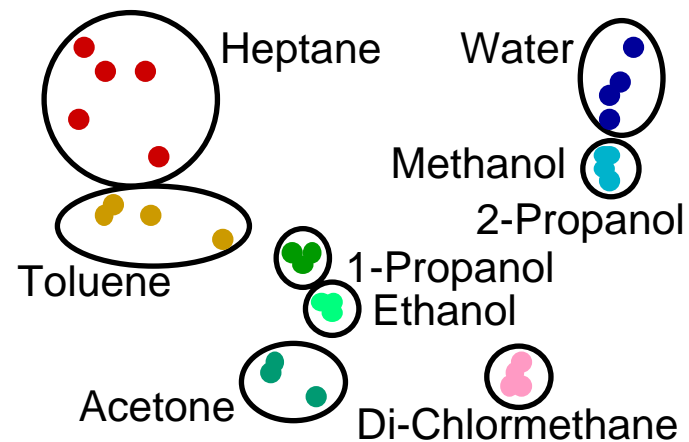
Principle



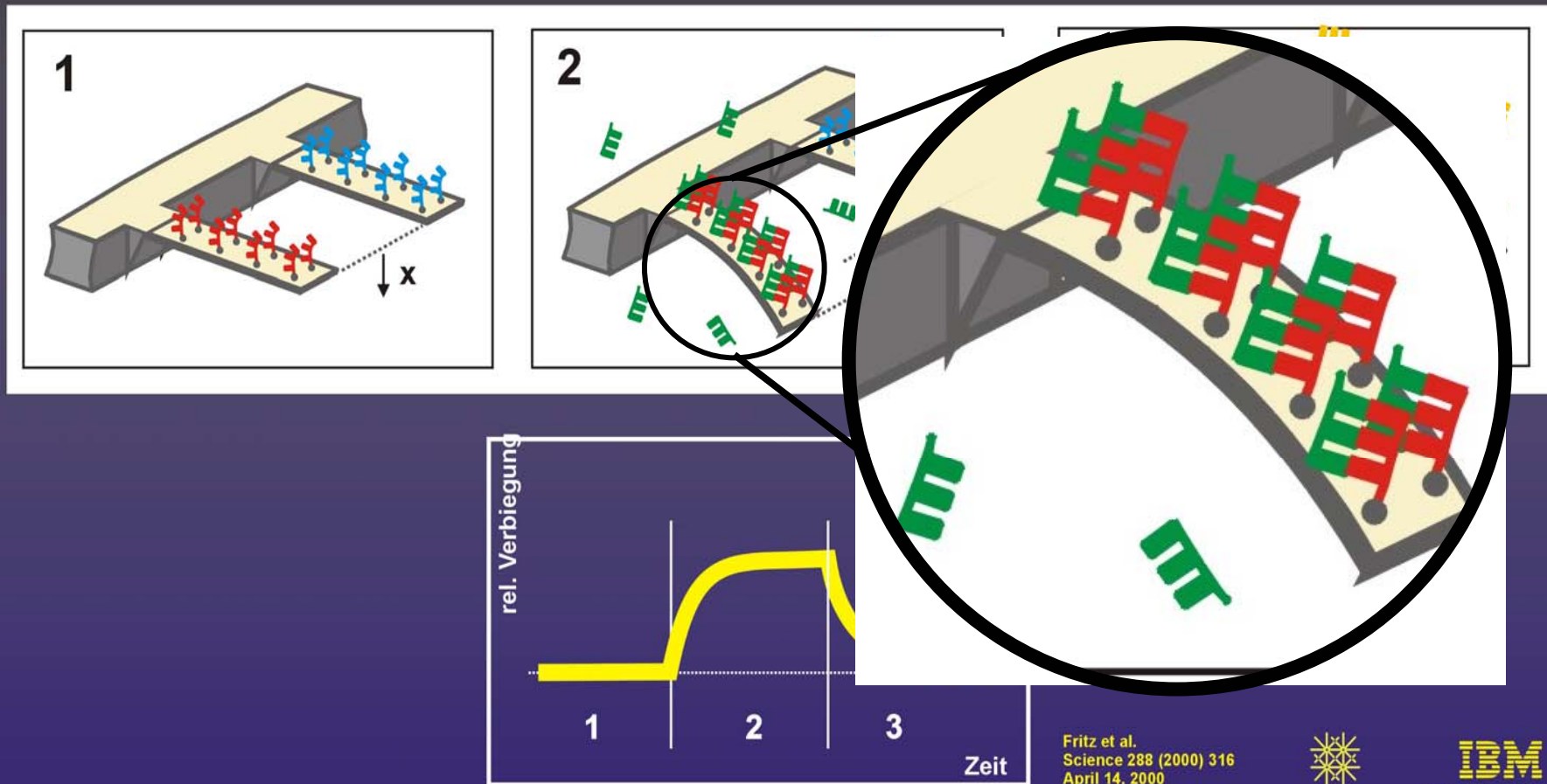
Quantitative Analysis



Neuronal Network Analysis



DNA Sensor

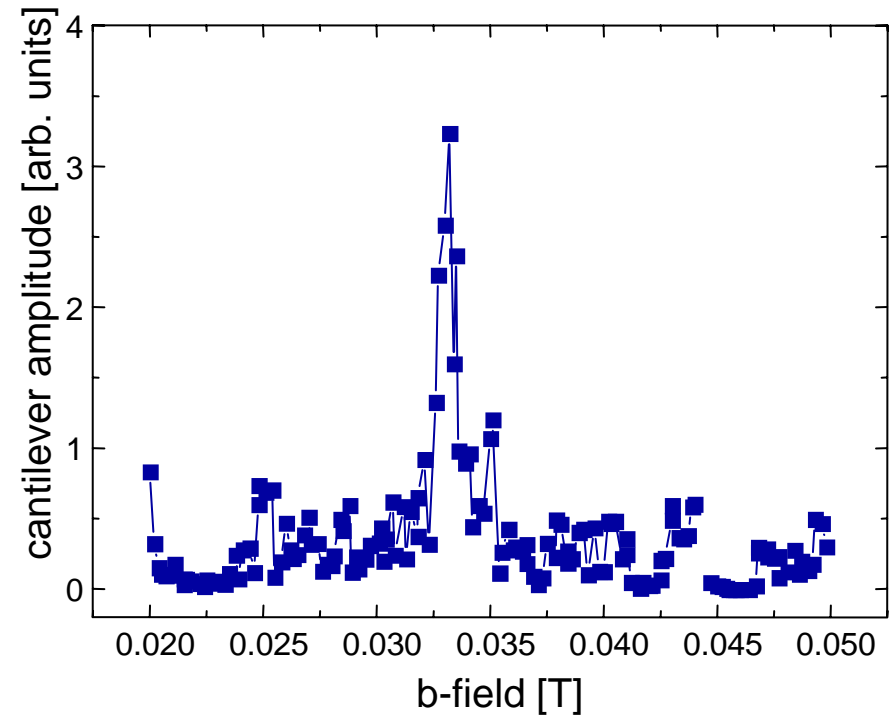
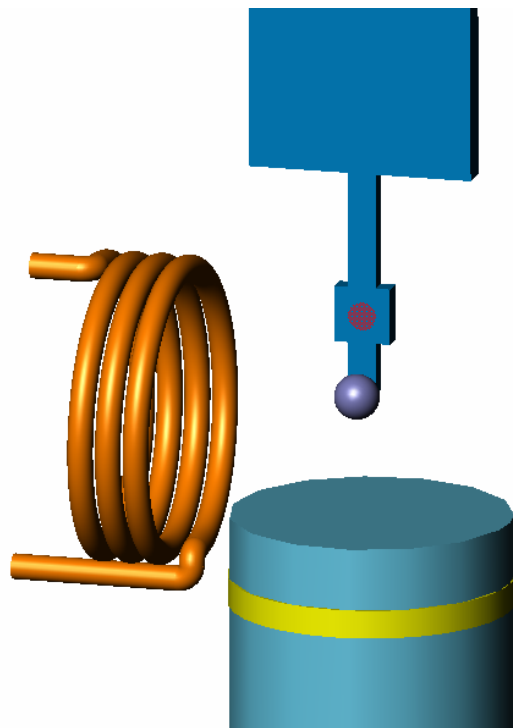
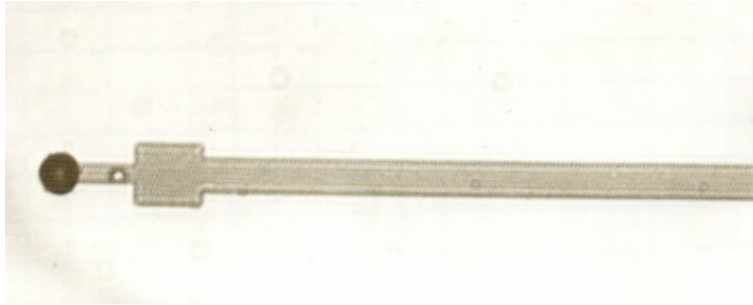


Fritz et al.
Science 288 (2000) 316
April 14, 2000



IBM
Zurich Research Lab

Magnetic Resonance Force Microscopy: Towards Detection of Single Spins



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

1. vertical or force gradients
2. lateral forces or force gradients
3. loss of energy due to vertical mode of oscillation
4. loss of energy due to torsional mode of oscillation
5. tunneling current (as good as an STM)

And

1. have an extremely high force sensitivity $\ll 0.1$ pN
2. allow measurements at a high bandwidth
3. be able to position AND keep the tip at an arbitrarily small distance, i.e. have a tip with a controllable compliance

Our approach:

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

6.

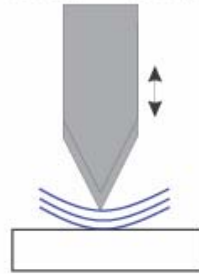
Other Members of the SPM Family

Other Members of the SPM Family

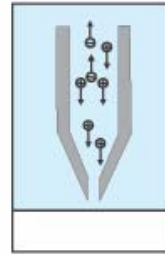
SNOM
Scanning Near Field
Optical Microscope



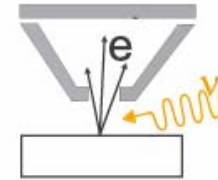
SNAM
Scanning Near Field
Acoustical Microscope



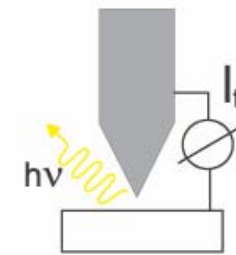
SICM
Scanning Ion
Conductance Microscope



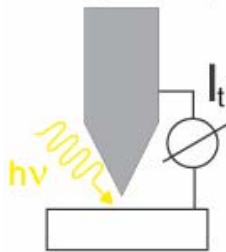
PEMSA
Photo Emission
Microscopy
with Scanning Aperture



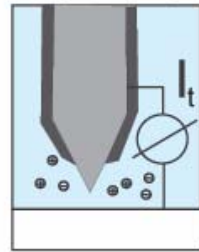
STMiP
STM with
inverse Photoemission



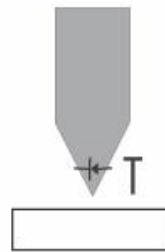
LSTM
Laser Scanning
Tunneling Microscope



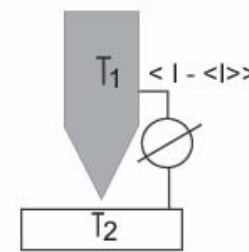
ECSTM
Electrochemical Scanning
Tunneling Microscope



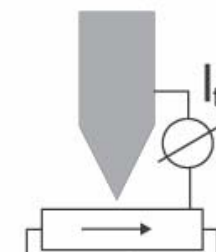
SThM
Scanning Thermal
Microscope



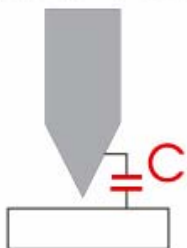
SNM
Scanning Noise
Microscope



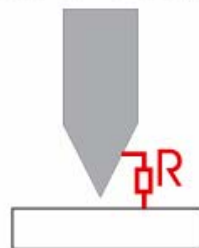
SPotM
Scanning Potentiometry
Microscope



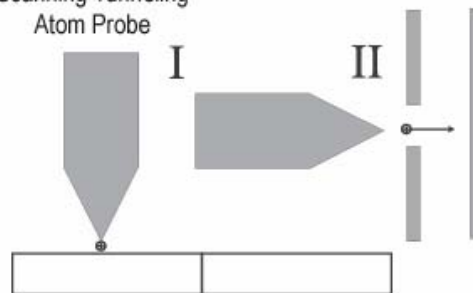
SCM
Scanning
Capacitance Microscope



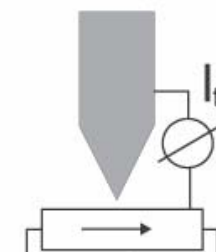
SSRM
Scanning Spreading
Resistance Microscope



STAP
Scanning Tunneling
Atom Probe



STMiP

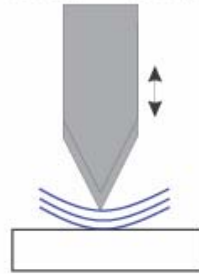


Other Members of the SPM Family

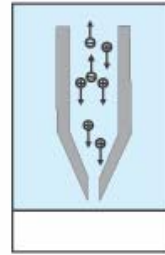
SNOM
Scanning Near Field
Optical Microscope



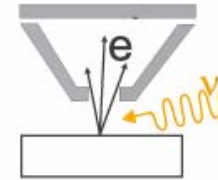
SNAM
Scanning Near Field
Acoustical Microscope



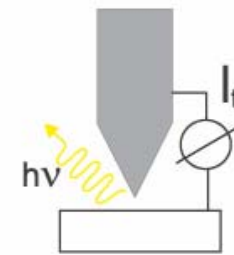
SICM
Scanning Ion
Conductance Microscope



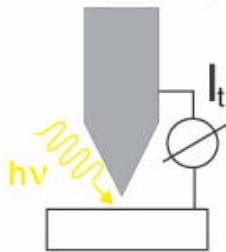
PEMSA
Photo Emission
Microscopy
with Scanning Aperture



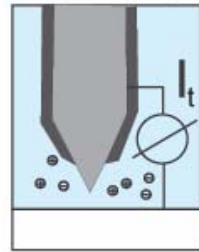
STMiP
STM with
inverse Photoemission



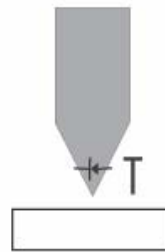
LSTM
Laser Scanning
Tunneling Microscope



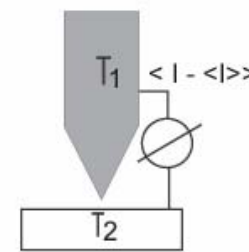
ECSTM
Electrochemical Scanning
Tunneling Microscope



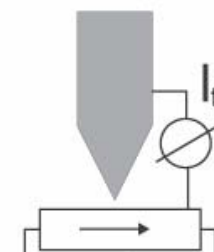
SThM
Scanning Thermal
Microscope



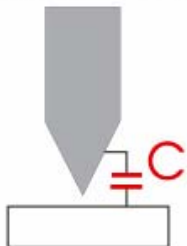
SNM
Scanning Noise
Microscope



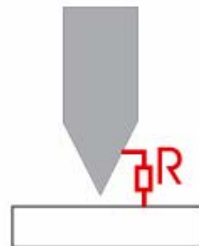
SPotM
Scanning Potentiometry
Microscope



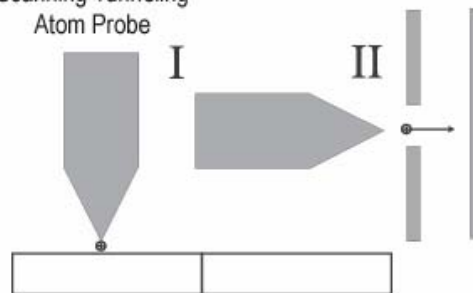
SCM
Scanning
Capacitance Microscope



SSRM
Scanning Spreading
Resistance Microscope



STAP
Scanning Tunneling
Atom Probe



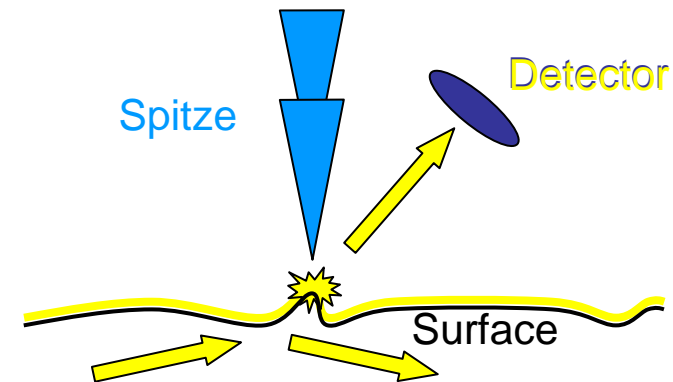
STMiP

5.1. Scanning Near Field Optical Microscopy (SNOM)

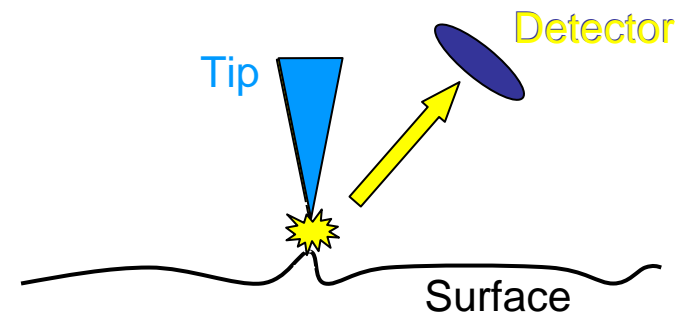
5.1.1. Introduction

Das Nahfeldoptische Mikroskop Scanning Near Field Optical Microscope (SNOM, NSOM)

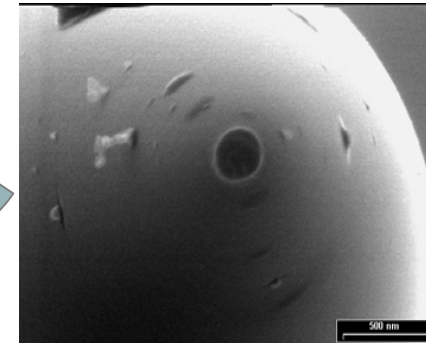
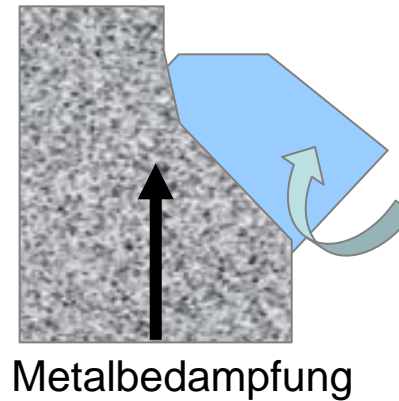
- Spitze in der Nähe (einige nm) einer Oberfläche kann evaneszentes Feld in ein propagierendes Feld umwandeln: **apertureless SNOM**



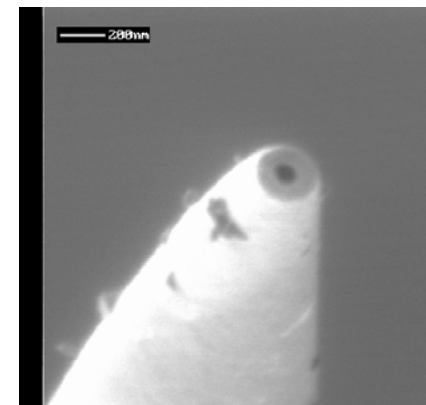
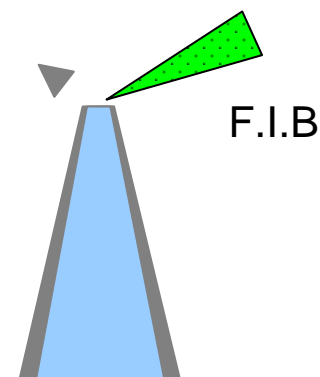
- Reziprozität: Eine lokalisierte (evaneszente) Nahfeldquelle in der Nähe einer Oberfläche führt zur Erzeugung eines propagierenden Feldes: **aperture SNOM**



- Metal Bedampfung und Schatten Effekt:
 - Schlechte Reproduzierbarkeit
 - Apertur ~ 70 nm
 - Parallele Produktion der Spitzen

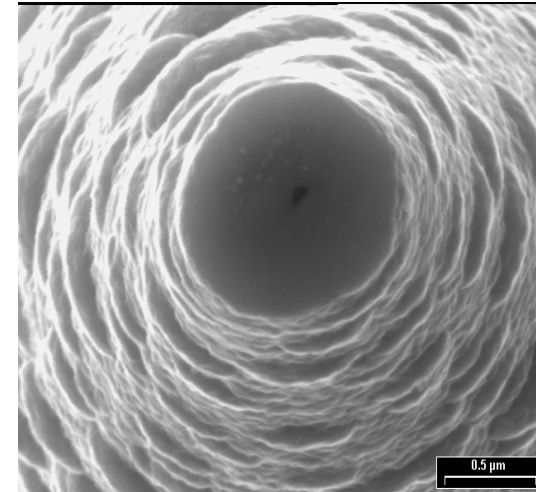
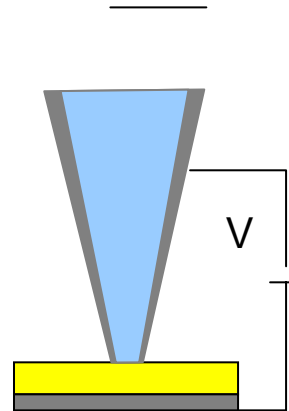


- Focussed Ion Beam:
 - Gute Reproduzierbarkeit
 - Apertur ~20 nm
 - Einzelspitzen Prozess
 - Teuer



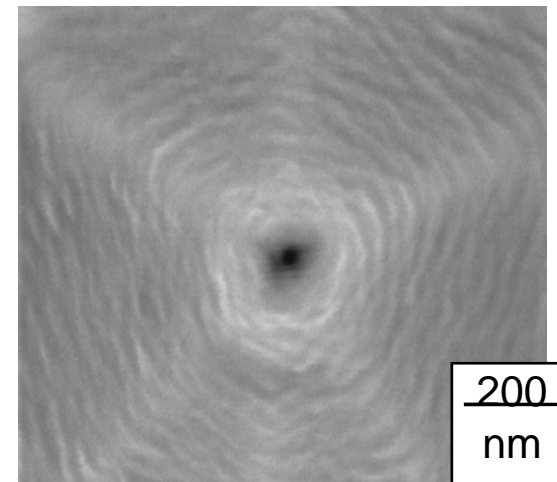
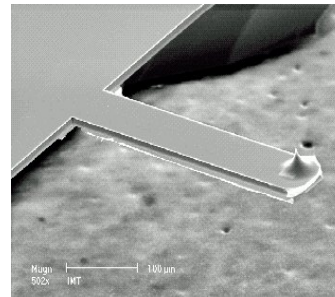
Th. Huser, Uni Basel

- Festkörper Elektrolyt
 - Gute Reproduzierbarkeit
 - Apertur < 40 nm
 - Billig
 - Metal abhängig
 - Einzelspitzen Prozess



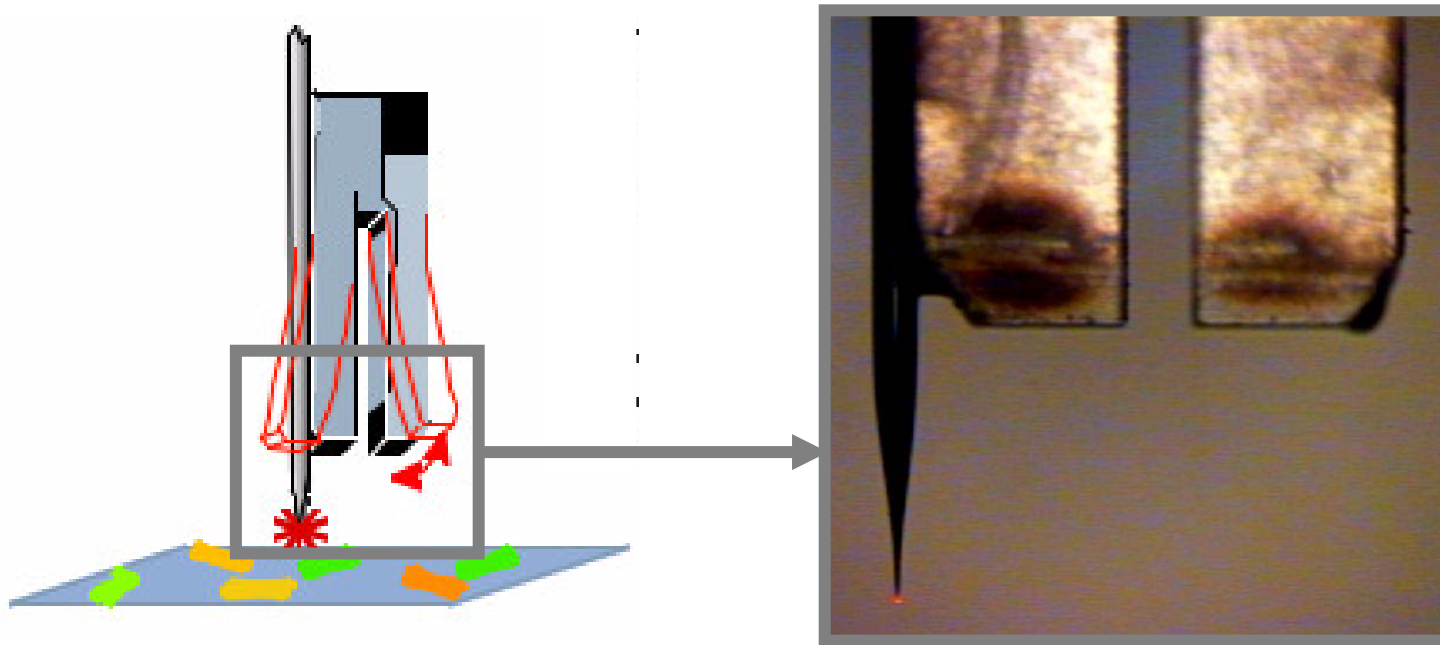
A. Bouhelier, Uni Basel

- Cantilever Spitzen
 - AFM Abbilden möglich
 - Apertur < 40 nm
 - Mikrofabriktion
 - Billig



Courtesy IMT & CSEM

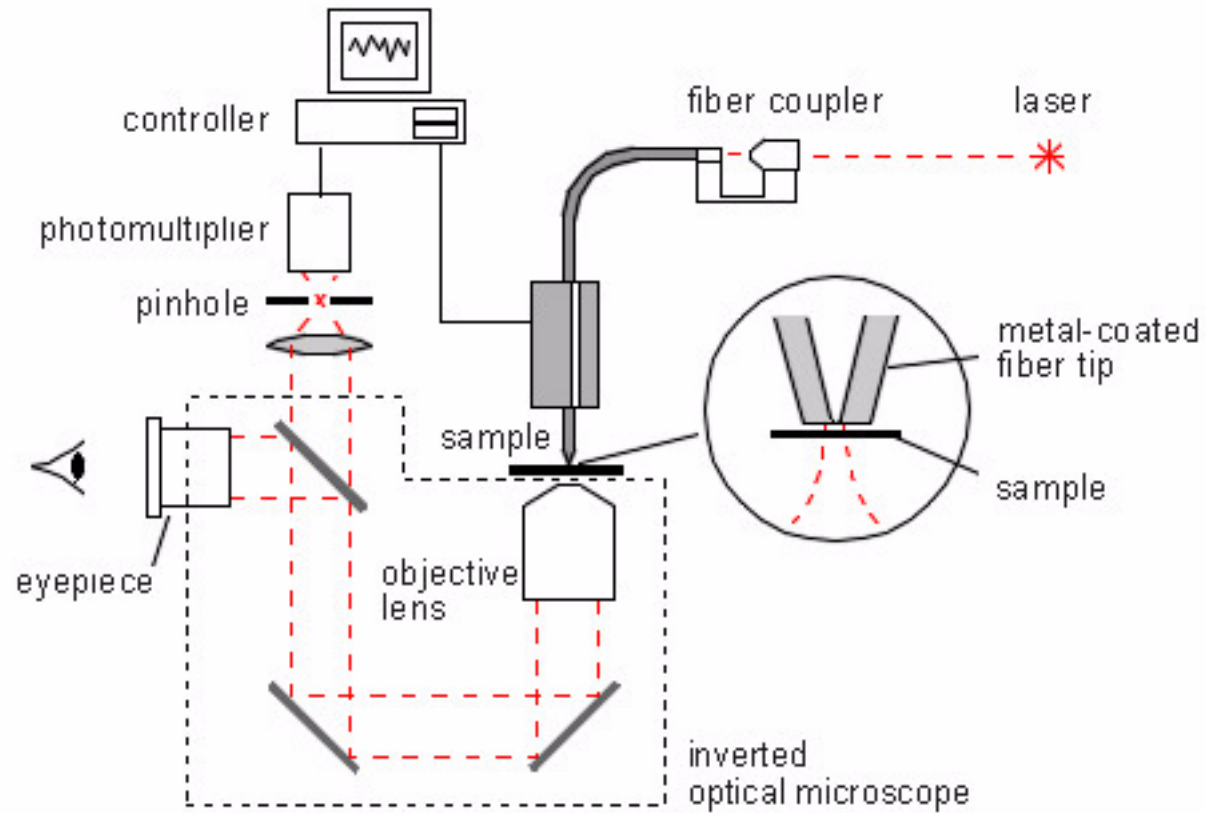
Shear Force Detection



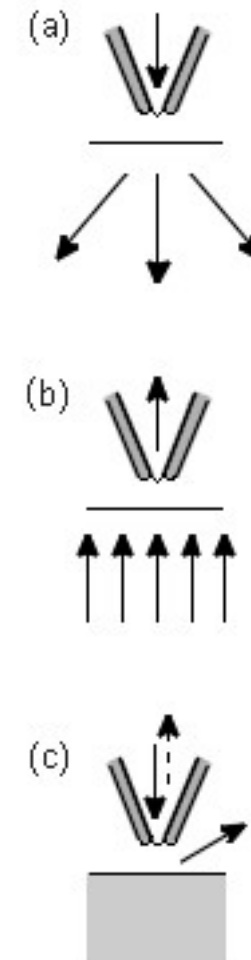
Typische Betriebsparameter

- Resonanzfrequenz: 33000 Hz
- Q-Wert: 500
- Schwingungsamplitude: 1 nm

Schema

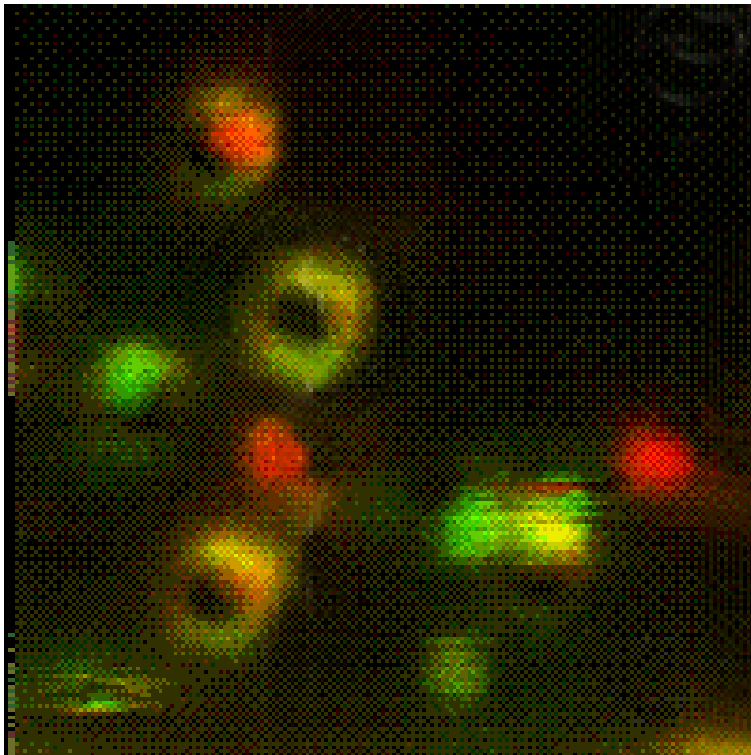


Betriebsarten



5.1.2. Imaging a few Examples

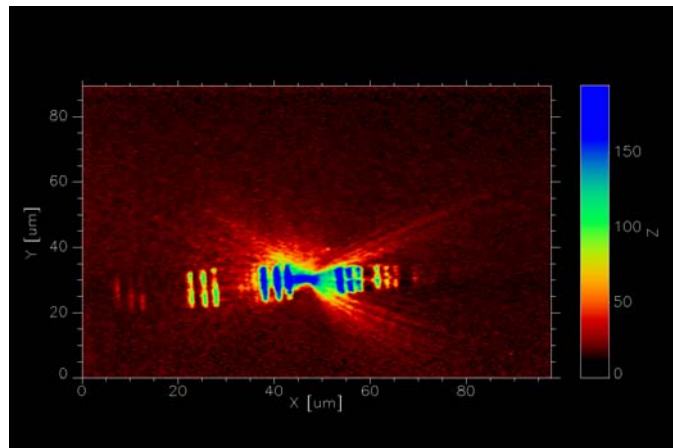
SNOM einzelner fluoreszierender Moleküle



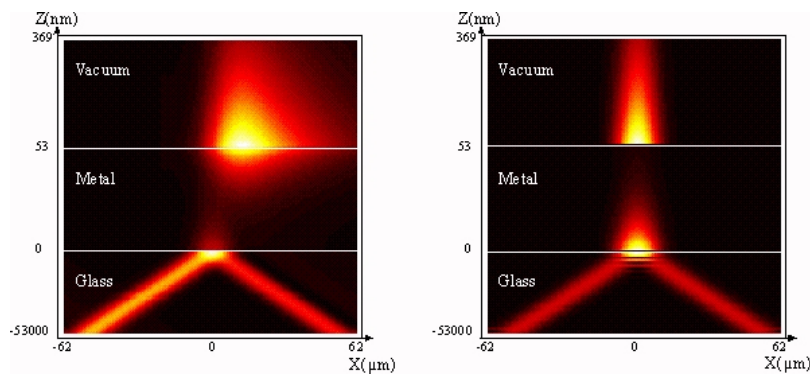
SNOM Fluoreszenz Bild einzelner Moleküle. Jedes Molekül ist eine Punktquelle und erzeugt je nach seiner Orientierung unterschiedliche Bilder der Spitze, z.B. helle Punkte, Ringe, helle Doppelpunkte.

N. Van Hulst, Uni Twente

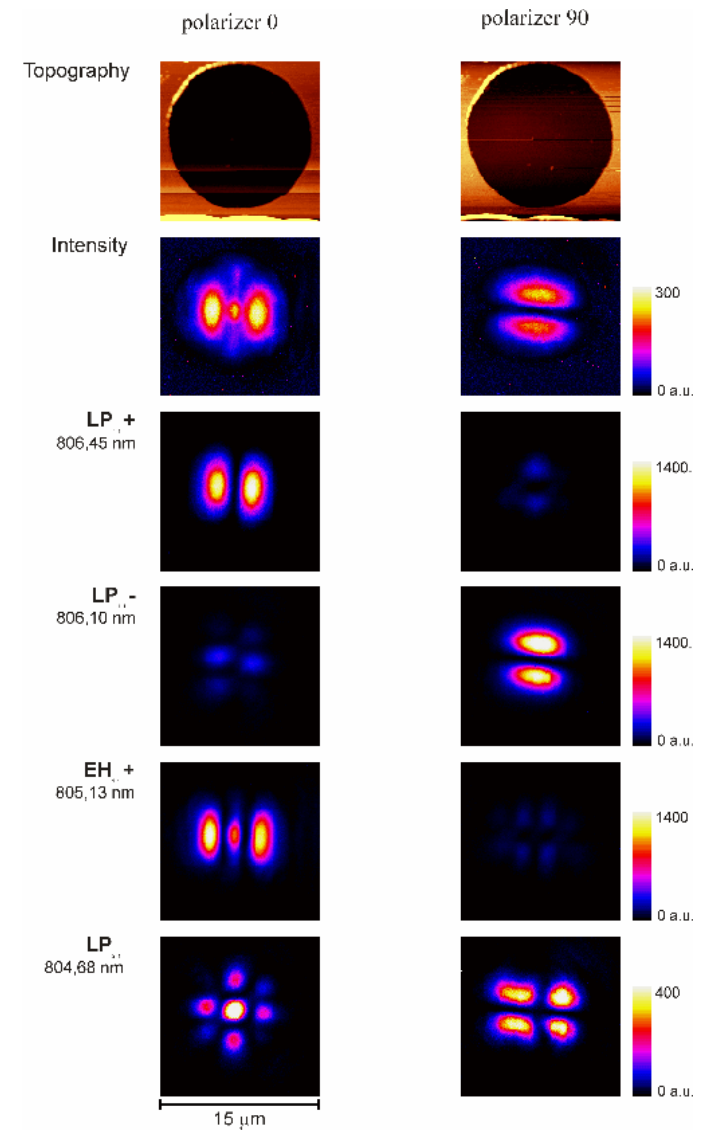
- Material science:
 - Surface plasmon & field enhancement
 - Semiconductors



A. Bouhelier, Uni Basel



F. Baida, Uni Besancon

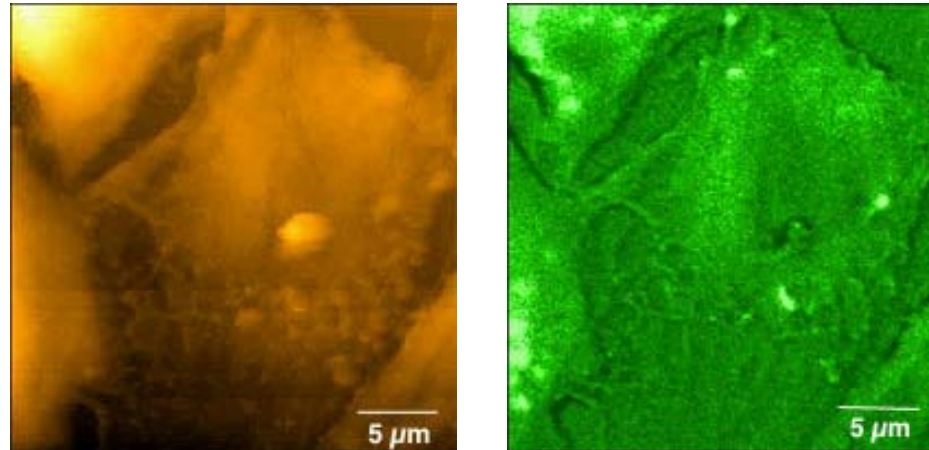


VCSELs.
O. Marti, Uni Ulm

- **Biology:**

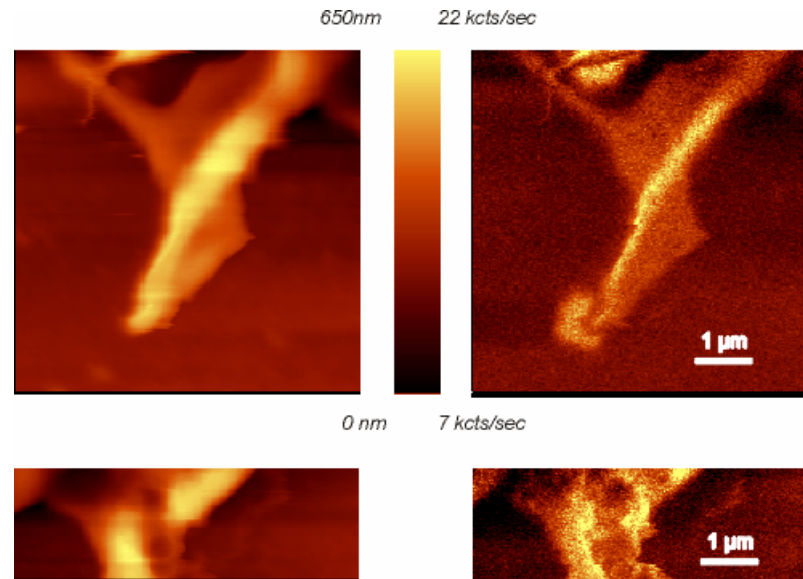
Shear-force topography and near-field fluorescence from GFP-labeled fibroblast cells.

R. Zenobi, ETHZ



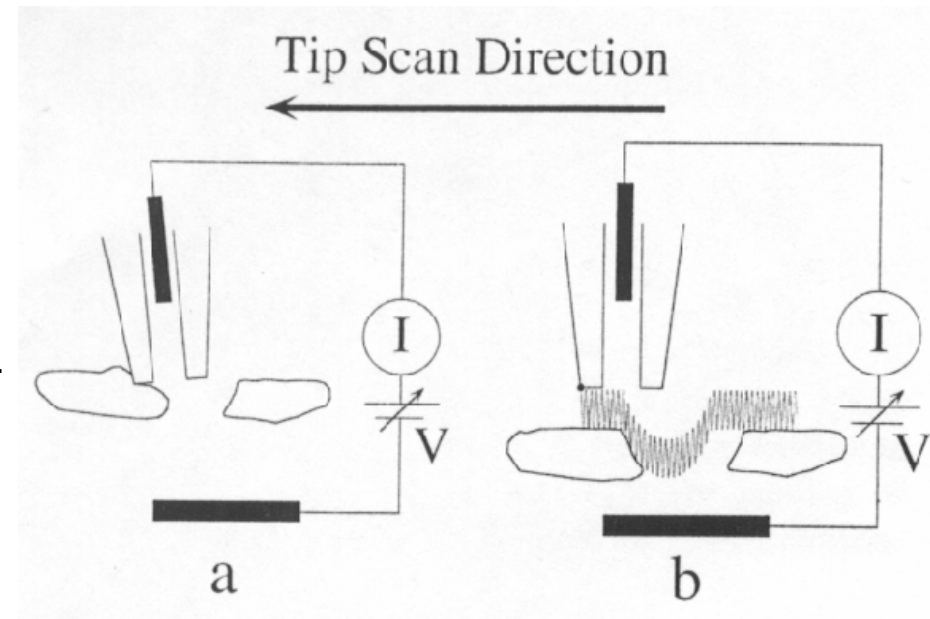
Topography and fluorescence images of a growth cone of nerve cells of the hippocampus of a rat. The samples are fluorescence labeled with DIC18

O. Marti, Uni Ulm



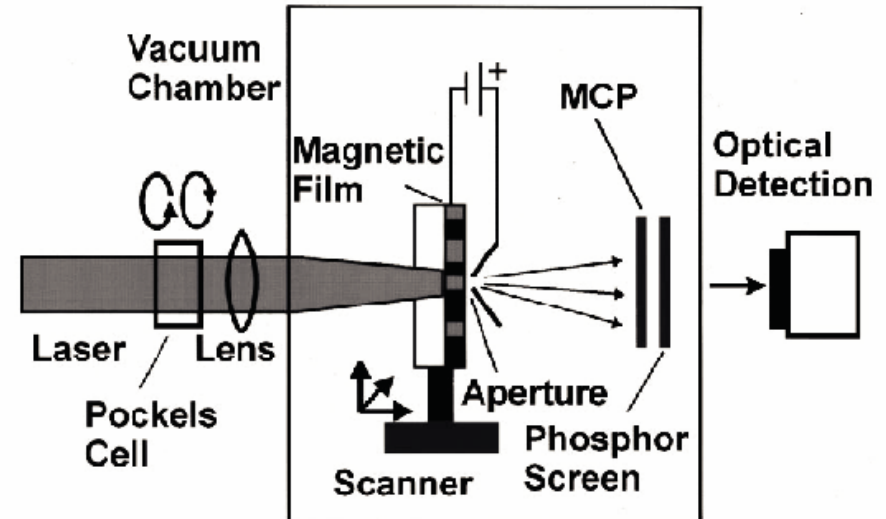
5.3. Scanning Ion Conductance Microscopy (SICM)

The *scanning ion conductance microscope* (SICM) uses a micropipette which approaches the surface of a sample immersed in an electrolyte [1]. 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 [2] have the advantage of smaller aperture size and higher stability. Structures of the order of 100nm can be resolved. The distance is controlled by the ionic current. Alternatively, a combination of SICM and SFM can be used [3]. 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 [4]. The main application of SICM is to measure the distribution of ionic currents through the pores in a porous surface.



5.4. Photoemission Microscopy with Scanning Aperature (PEMSA)

In *photoemission microscopy with a scanning aperture* (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 30nm [1]. Magnetic domains of a Co/Pt film were imaged by the polarization Dependent PEMS. The magnetic contrast of PEMS 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 30-45nm 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 -10V to detect photoemission. With 2mW of light, 100nA photocurrent is generated and 1pA is passed through the 30nm 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 PEMS 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.



5.5. STM with inverse Photoemission (STMiP)

In *photoemission microscopy with a scanning aperture* (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 30nm [1]. Magnetic domains of a Co/Pt film were imaged by the polarization Dependent PEMS. The magnetic contrast of PEMS 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 30-45nm 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 -10V to detect photoemission. With 2mW of light, 100nA photocurrent is generated and 1pA is passed through the 30nm 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 PEMS 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.

