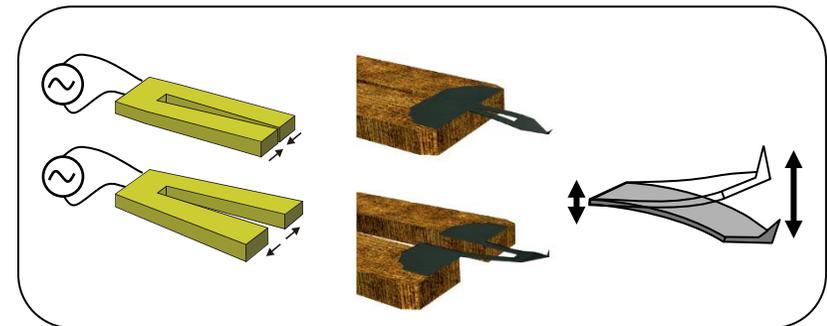
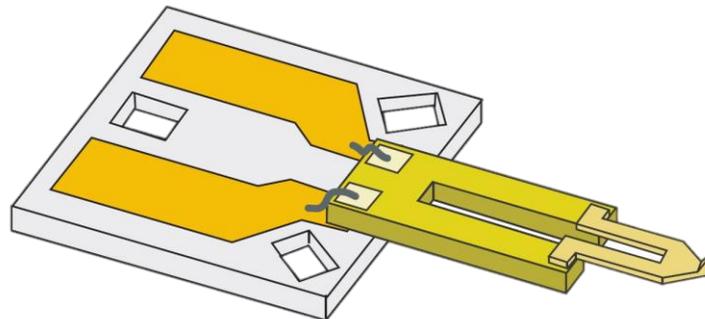
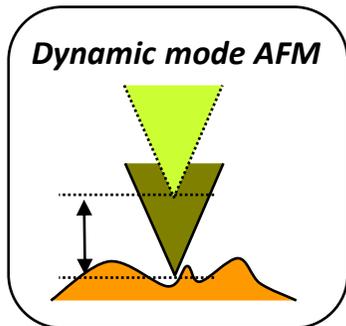




# *Akiyama-Probe (A-Probe) guide*

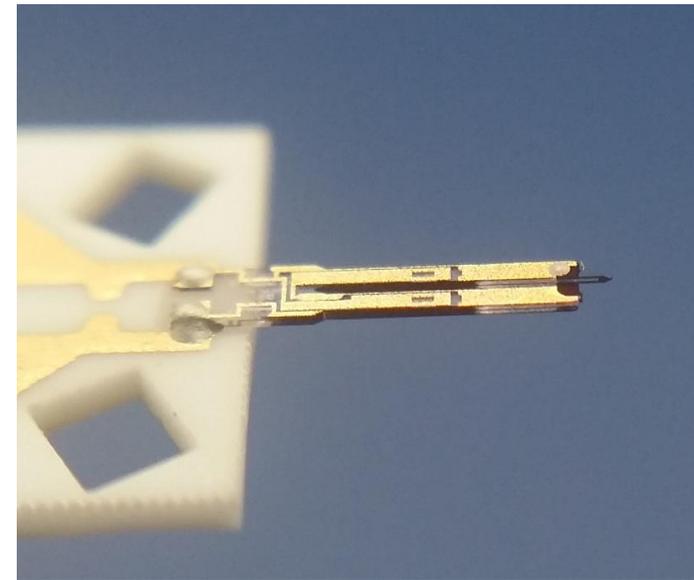
***This guide presents:  
what is Akiyama-Probe, how it works, and what you can do***



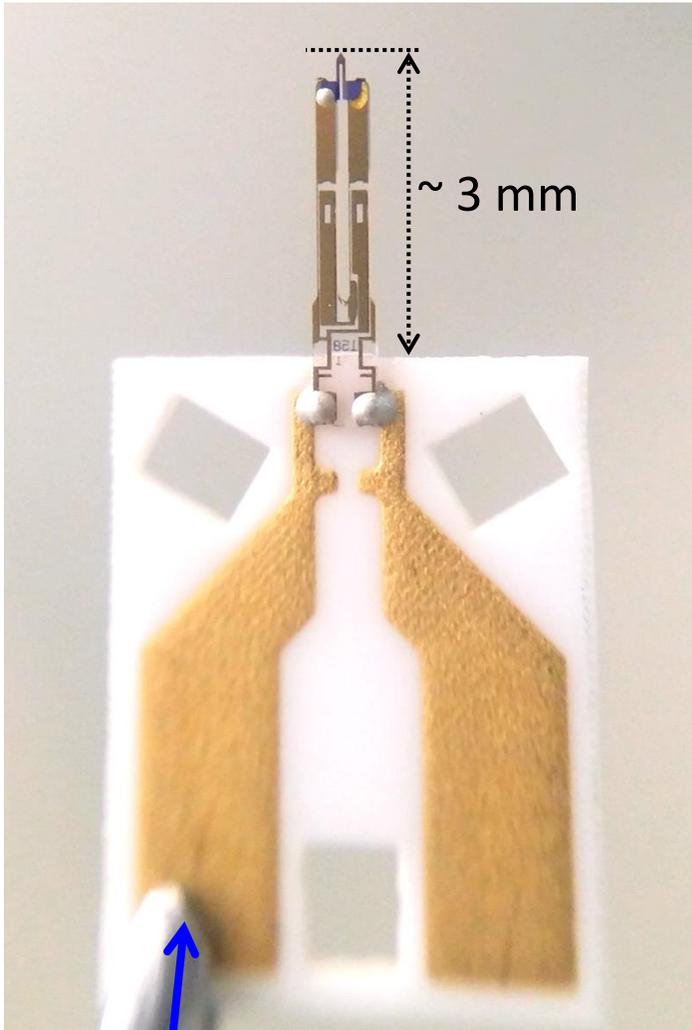


- ❑ NANOSENSORS™ Akiyama-Probe (A-Probe) is a self-sensing and self-actuating (-exciting) probe based on a quartz tuning fork combined with a micromachined cantilever for dynamic mode AFM.
- ❑ The great advantage of this probe is that one can benefit from both the tuning fork's extremely stable oscillation and the silicon cantilever's reasonable spring constant with one probe. Akiyama-Probe is equipped with a high-end sharp silicon tip and has an excellent imaging capability on various samples with different properties, which is as high as a conventional optical lever system.
- ❑ Akiyama-Probe requires neither optical detection, nor external shaker. Akiyama-Probe occupies only a small space above the sample.
- ❑ Since it was introduced in 2006 these features have contributed to the creation of new generation SPMs.

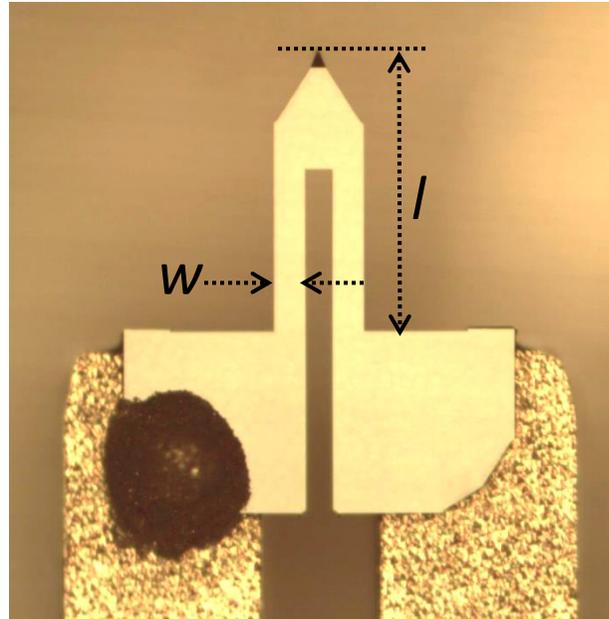
## *Akiyama-Probe Since 2006*



*Akiyama-Probe is a patented technology.*



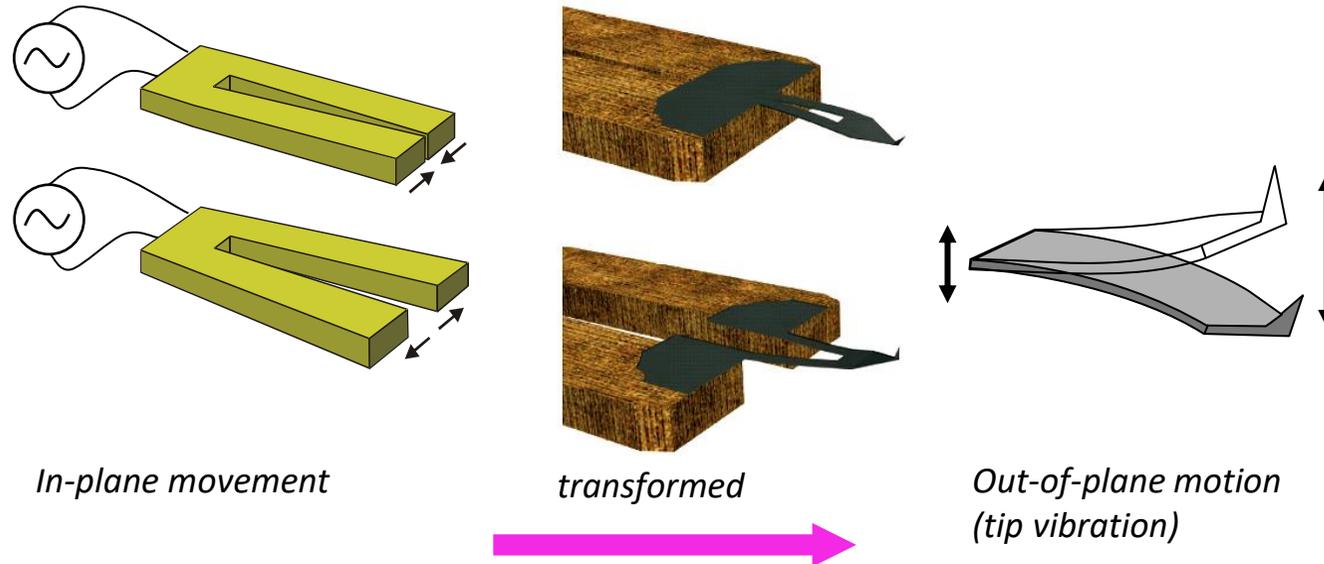
This side is electrically connected to the cantilever.



## Specifications (typical values)

Cantilever	length: 310 $\mu\text{m}$ , thickness: 3.7 $\mu\text{m}$ , width: 30 $\mu\text{m}$ each material: n <sup>+</sup> silicon (0.01 - 0.025 Ohm•cm)
Tip	AdvancedTEC™-like tip radius <15 nm, tip height 28 $\mu\text{m}$
Force constant	5 N/m (Si cantilever)
Resonance frequency	45 kHz (33 – 60 kHz)
Ceramic plate	approximately 6.5 mm x 5.1 mm x 0.4 mm

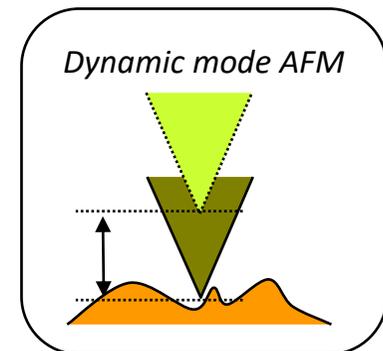
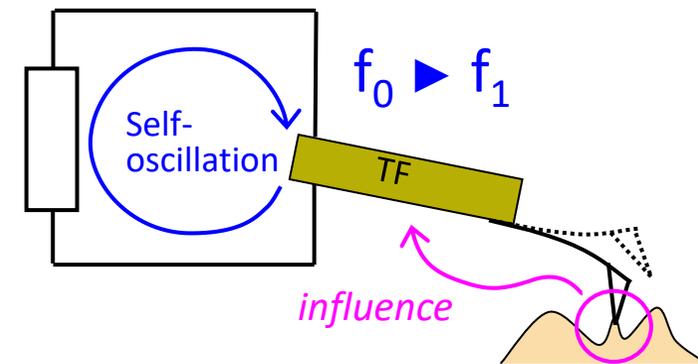
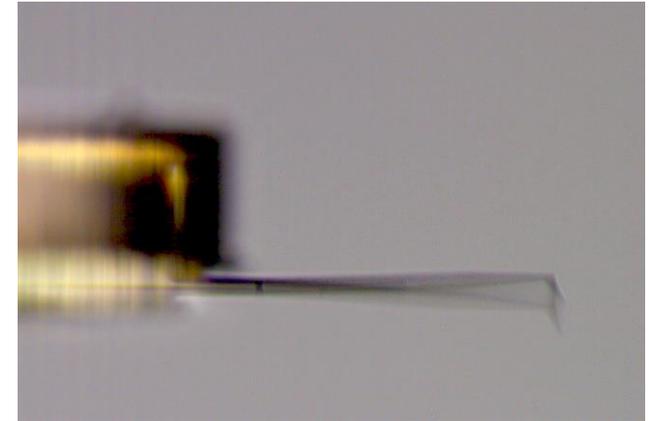
All values are subject to change without notice.

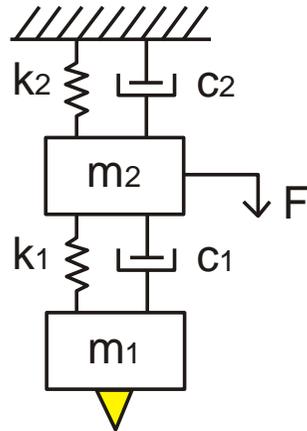


- ❑ In operation, the electrical driving signal is directly applied to the electrodes of the tuning fork (TF) to excite it at its lowest resonance. In this mode, the ends of the two prongs are moving in-plane and have opposite phases, meaning that they approach and withdraw from each other.
- ❑ The vibration amplitude is typically in the order of tens of nm. This motion applies a small vibration at the glued ends of the cantilever, which always contains a component in z-direction (*i.e.*, the axis of the tip) due to the twisting motion of the prongs (*i.e.*, the cantilever disturbs a symmetry of the TF).
- ❑ The cantilever amplifies the vibration according to its mechanical property and a large out-of-plane motion of the tip is obtained.



- ❑ The TF is used as an oscillatory force sensor similar to a quartz microbalance. Its frequency and amplitude are influenced by those of the tip motion. Consequently, the tip-sample interaction can be electrically detected with the TF.
- ❑ The recommended operation mode for Akiyama-Probe is dynamic mode with the frequency modulation (FM) detection, where the TF is self-excited (oscillating) at its first resonance frequency.
- ❑ During sample imaging, the resonance frequency is tracked by a phase locked loop (PLL) and kept at a set value by adjusting the tip-sample distance with a feedback loop.
- ❑ The amplitude modulation (AM) detection (fixed driving frequency) is also feasible, if one would accept a slower scan speed and compromise on spatial resolution.
- ❑ Akiyama-Probe is designed for operation in ambient conditions. It may work in other conditions, like vacuum, UHV, or low temperatures, etc.





Resonance of TF before  
cantilever was glued

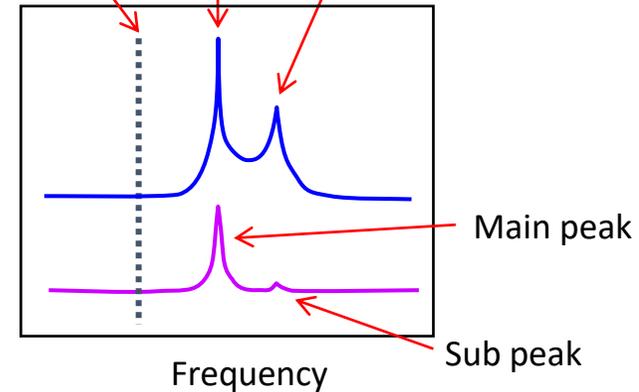
32.768 kHz

1st resonance

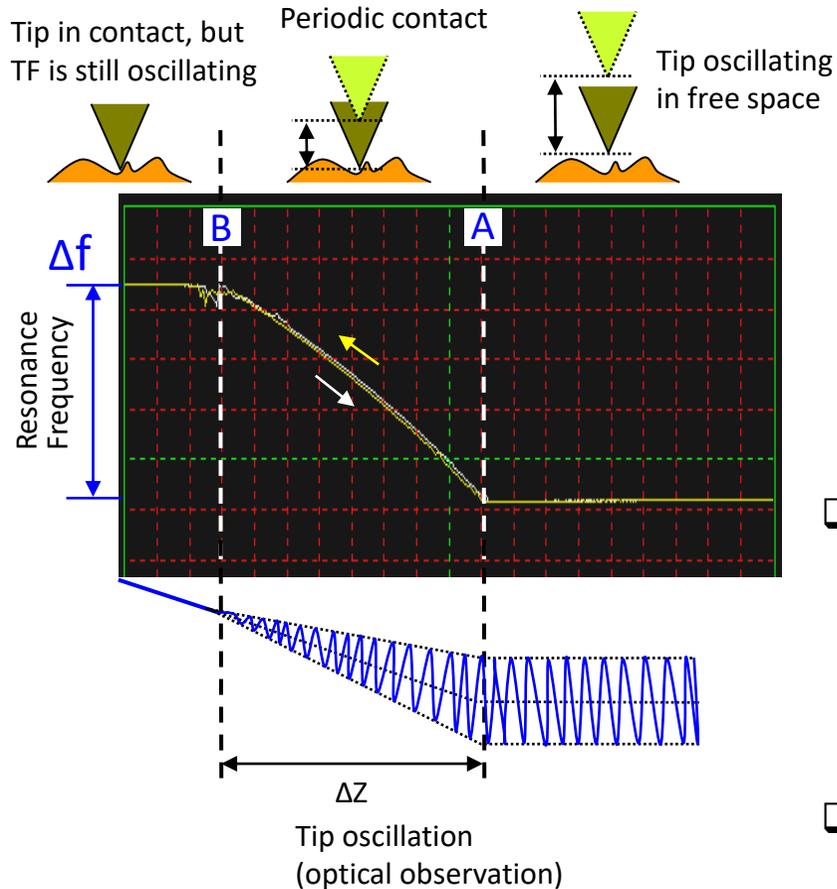
2nd resonance

Optical detection  
of tip vibration

Electrical signal  
from TF



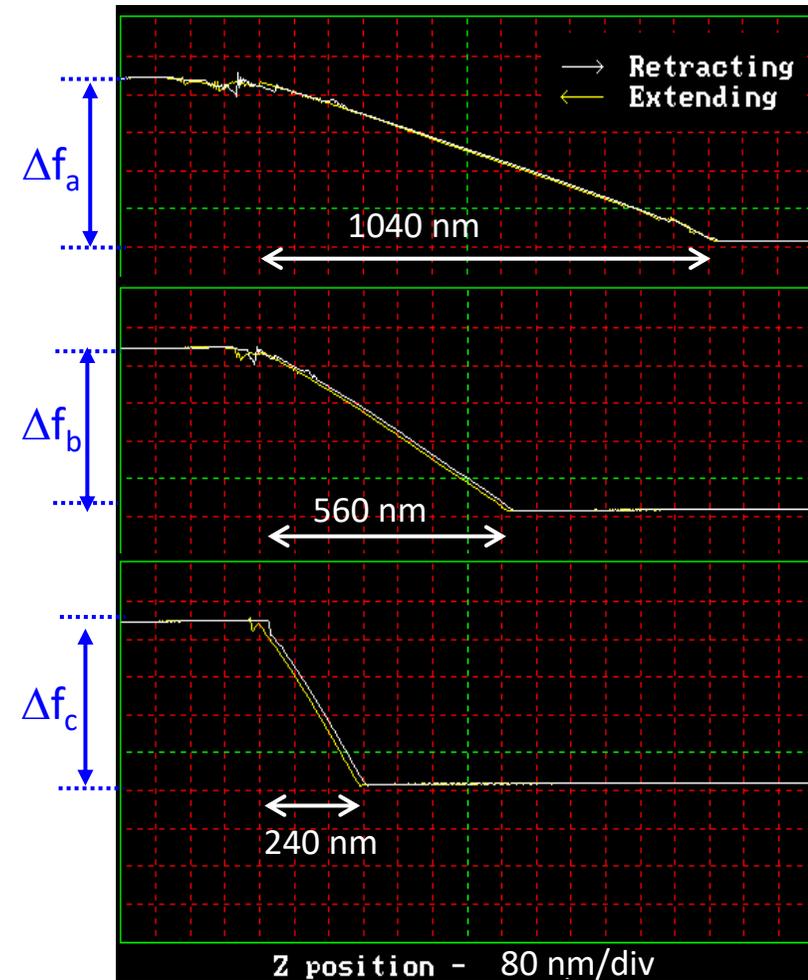
- ❑ Akiyama-Probe is a system with two coupled resonators that are moderately matched in terms of resonance frequency. The left figure illustrates a simplified model of Akiyama-Probe, where the cantilever corresponds to Resonator 1 ( $m_1$ ,  $k_1$ ,  $c_1$ ) and the TF to Resonator 2 ( $m_2$ ,  $k_2$ ,  $c_2$ ).  $F$  is the driving force created by the piezoelectric effect of the TF.
- ❑ Like with other similar systems, one obtains two typical resonances: in-phase (1st) and anti-phase (2nd) peaks. By sweeping the driving frequency, the two large vibration peaks can be observed at the tip by optical means. In the electrical signal from the TF, one observes a large peak at the 1st resonance and a small, or almost none, peak at the 2nd resonance. The large peak at the 1st resonance is the operation frequency of Akiyama-Probe.

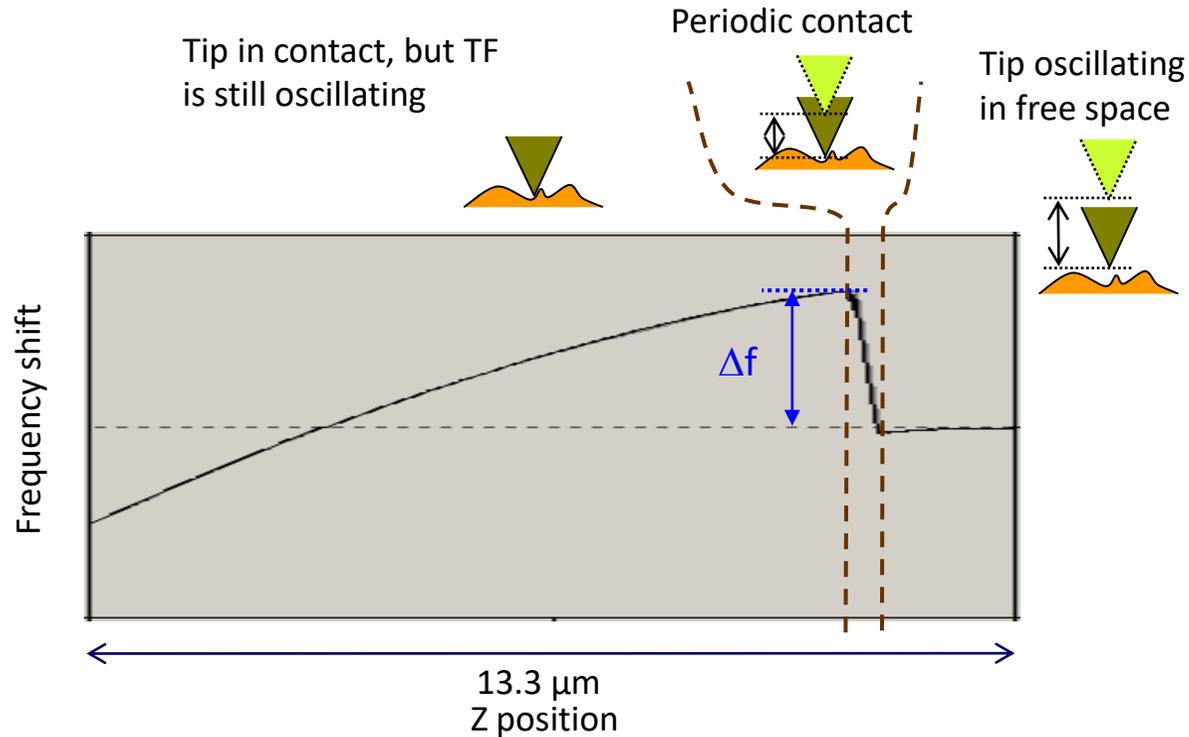


- The figure shows a typical approach curve of Akiyama-Probe. The dashed line “A” indicates the critical point where the tip starts periodic contact on the sample surface. Beyond this point, the resonance frequency increases almost linearly as the tip is moved closer to the sample surface in the periodic contact region. Oscillation amplitude of the tip decreases linearly and the center of the vibration is shifted in this region (*i.e.*, illustration at the bottom of the figure).
- The end of the periodic contact region is indicated by the dashed line “B”. Beyond this point, the probe works in a “quasi” contact mode, *i.e.*, the tip remains in contact with the surface during the full oscillation cycle, whereas the cantilever is still vibrated by the TF.
- The maximum frequency shift obtained in the periodic contact region (denoted as  $\Delta f$ ) is a specific and constant value for each probe. The distance  $\Delta Z$  is about a half of the peak-to-peak amplitude of the tip oscillation in free space.

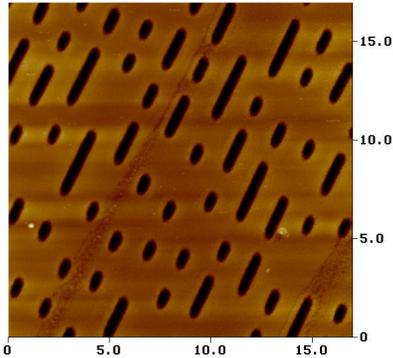


- ❑ One of the important features of Akiyama-Probe is that the maximum frequency shift  $\Delta f$  does not depend on the tip vibration amplitude. The figure shows three approach curves with different amplitude settings. It demonstrates  $\Delta f_a = \Delta f_b = \Delta f_c$ .
- ❑ The sensitivity defined as the maximum frequency shift divided by the amount of tip displacement in the periodic contact region differs for each setting of the tip vibration amplitude. The sensitivity is increased as the tip vibration amplitude is decreased.
- ❑ The range of  $\Delta f$  is approximately 30 Hz ~ 400 Hz. This is not guaranteed and subject to change without notice.  $\Delta f$  varies depending on temperature and humidity.

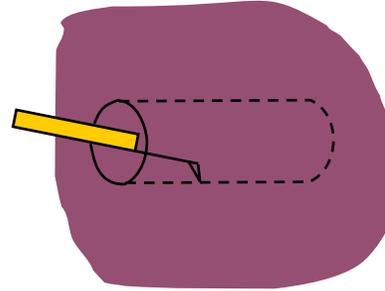




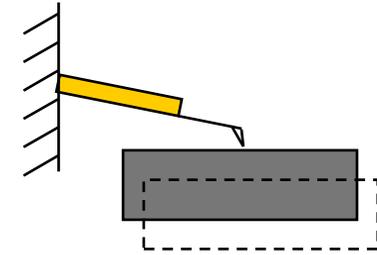
- ❑ The figure shows a long range approach curve. The resonance frequency of the TF decreases gradually in the region of the “quasi” static mode. This region lies over a couple of tens  $\mu\text{m}$  in z-direction. Although Akiyama-Probe operated in this mode could be used for *e.g.* measuring displacement, the tip is strongly pushed onto the sample surface and, hence, operation in this mode is not recommended for AFM imaging.



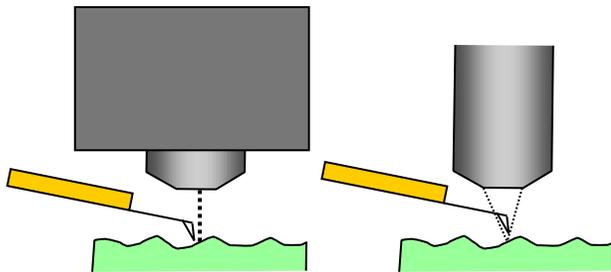
AFM imaging  
(topography, roughness)



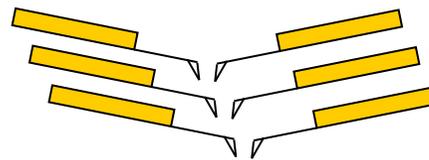
Measurement inside  
of channel



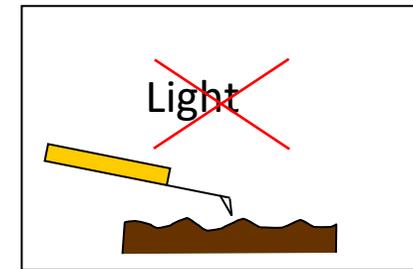
Displacement  
measurement



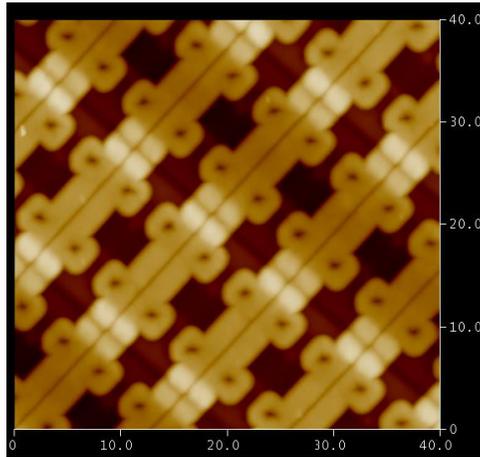
Combination with SEM/ optical  
microscope



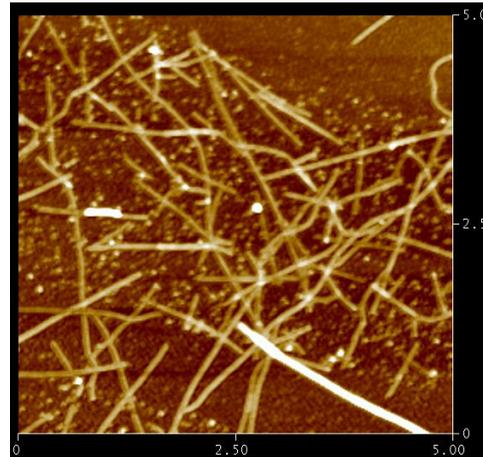
Multi-probe



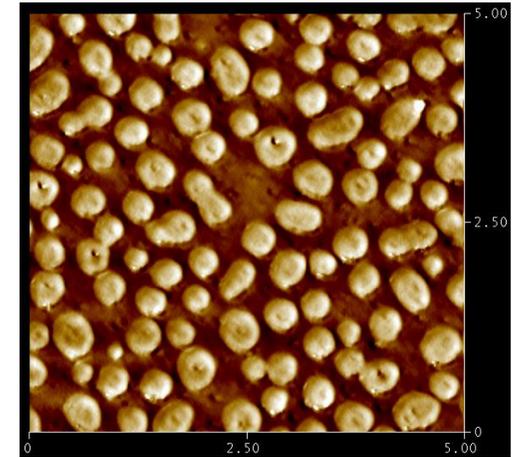
AFM imaging of light  
sensitive samples



IC chip (40  $\mu\text{m}$  x 40  $\mu\text{m}$ )



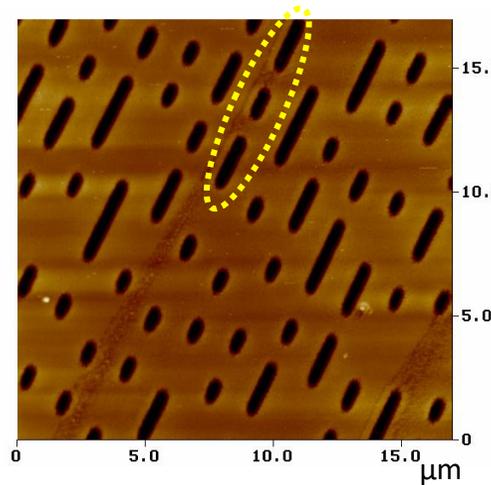
Carbon nanotube (5  $\mu\text{m}$  x 5  $\mu\text{m}$ )



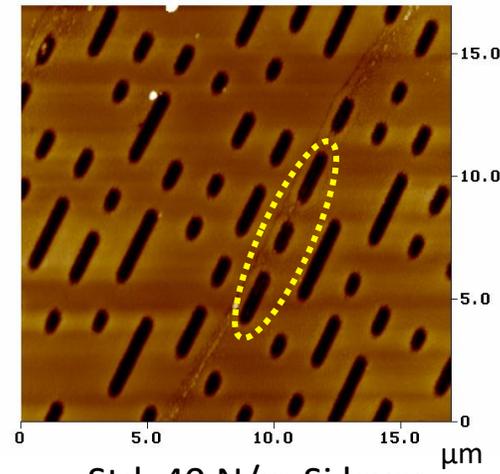
PS/PMMA film (5  $\mu\text{m}$  x 5  $\mu\text{m}$ )

Samples from Nanosurf AG

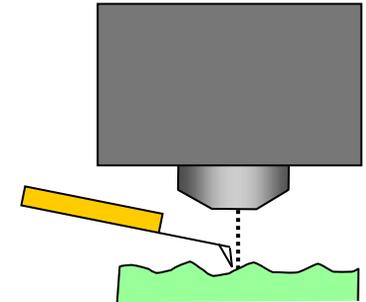
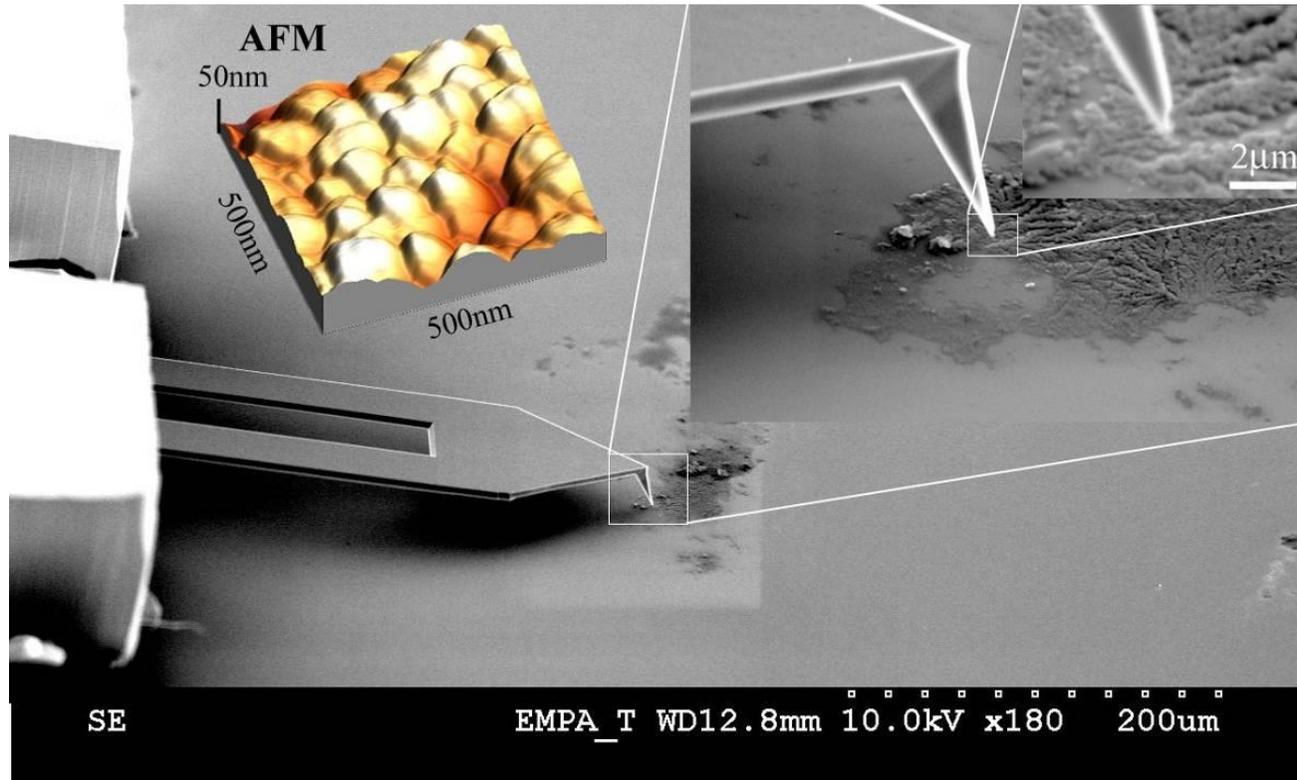
*Akiyama-Probe vs.  
Optical lever*



Akiyama-Probe

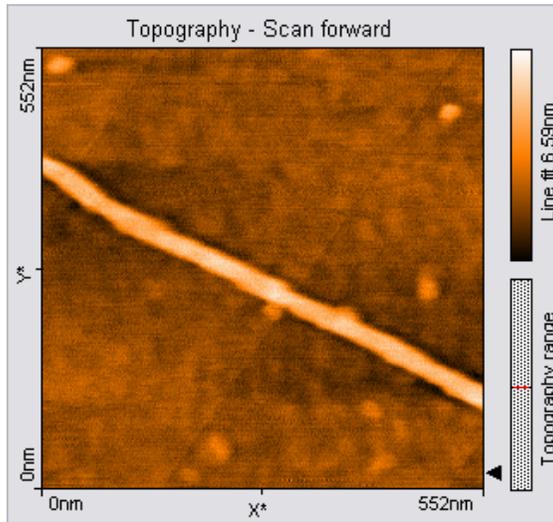


Std. 40 N/m Si lever  
Tapping mode

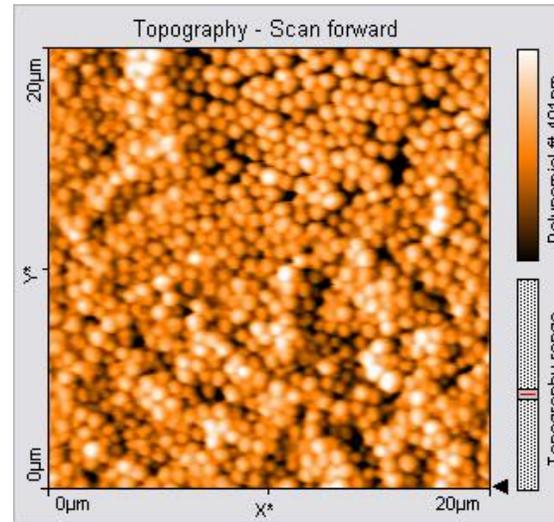


EMPA Switzerland

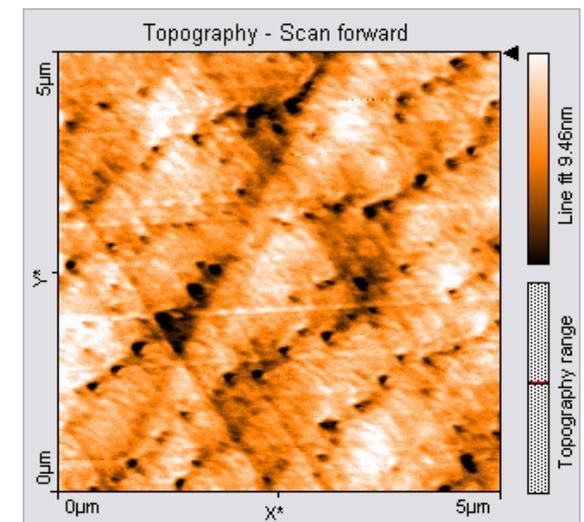
Dr. Vinzenz Friedli, "Focused electron- and ion-beam induced processes : in situ monitoring, analysis and modeling," dissertation EPFL, no 4036 (2008).



Carbon nanotube



Staphylococcus aureus bacteria

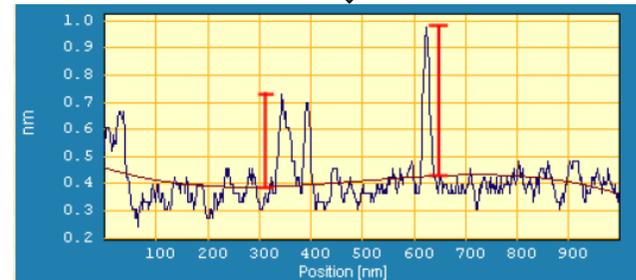
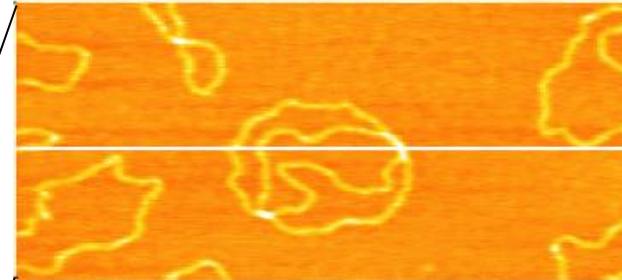
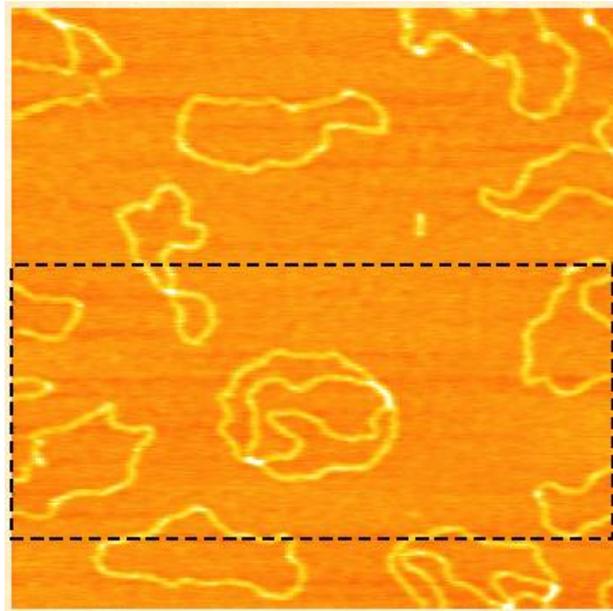


Atomic steps on PbSnSe  
etch pits

Topographic images taken under ambient conditions in intermittent contact mode using Akiyama-Probe with *Nanosurf Nanite A100 A-Probe AFM*



Plasmid-DNA (2,686 bp)

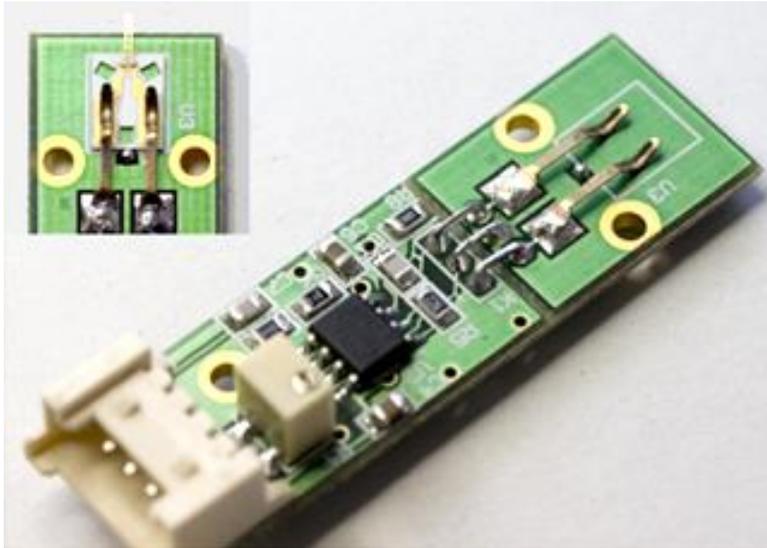


Scan Size : 1x1  $\mu\text{m}$

Topographic images taken under ambient conditions in intermittent contact mode using Akiyama-Probe with : *SXM Standard* (*Research Institute of Biomolecule Metrology Co., Ltd., Japan*)



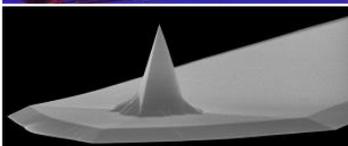
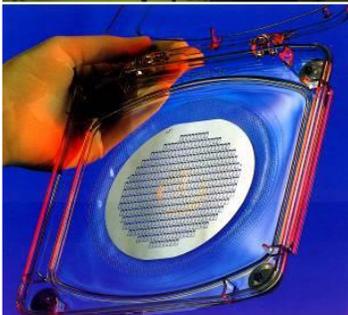
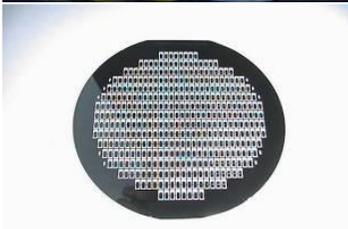
## Tuning Fork Sensor Controller (Commercialized by NanoAndMore)



 **NANOANDMORE GMBH**  
The World of Scanning Probes and More



THANK YOU FOR  
YOUR INTEREST



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