20 Years of success

NT-MDT
Molecular Devices and Tools for NanoTechnology

Piezoresponse Force Microscopy

PFM Tutorial Workshop. August, 26

NT-MDT: History and Background

- The oldest AFM manufacturer in the world
- Two-time R&D100 AWARD winner.
- The second position of global AFM manufacturers
- 250 experts in HQ offices

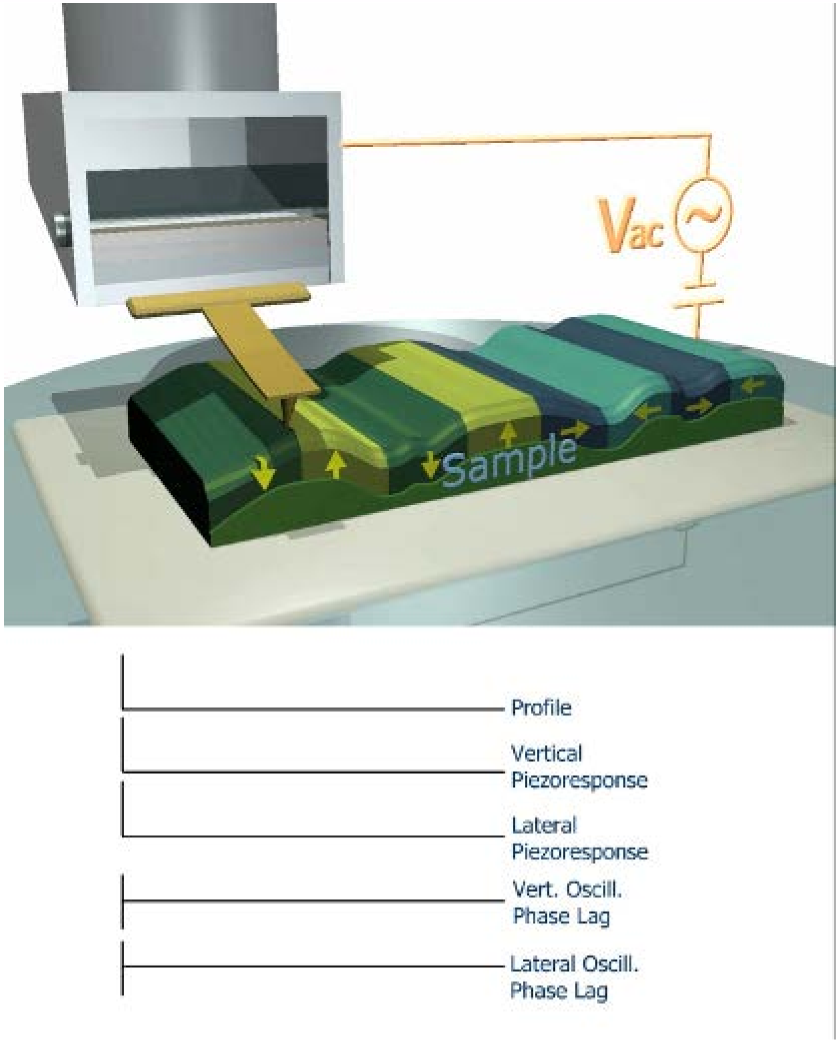
NT-MDT: Experience + Innovations

NT-MDT has achieved high results in **Piezoresponse Force Microscopy** technique development due to careful attention to the trends in the world of scientific research.

The Basic Idea of Piezoresponse Force Microscopy (PFM)

Step 1 Polarize the piezoelectric sample locally applying the electric potential

Step 2 Analyze the response

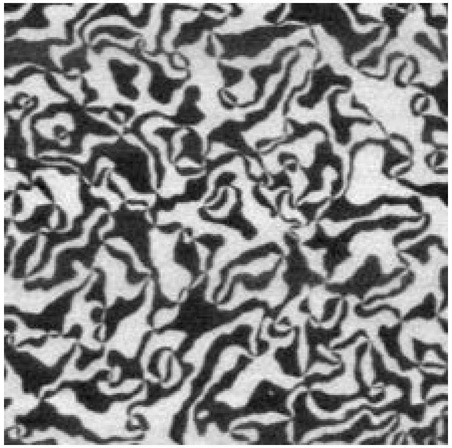


PFM is a Perspective Mode

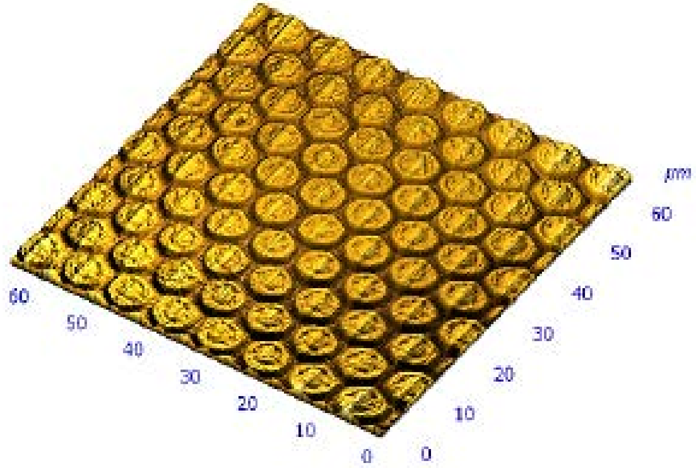
PFM since its inception and first implementation has steadily attracted more and more interest.

It can be applied in various fields:

- Ferroelectrics
- Semiconductors
- Biology



PFM image of a z-cut ferroelectric single crystal



Hexagonal domain structure of Lithium Niobate

Sample courtesy by C. Gawith, Optoelectronics Research Centre University of Southampton.
Image courtesy of T. Jungk, A. Hoffmann, E. Soergel, University of Bonn.

PFM is a Standard Mode of NT-MDT Equipment

PFM mode is implemented in each product of:

NTEGRA Platform

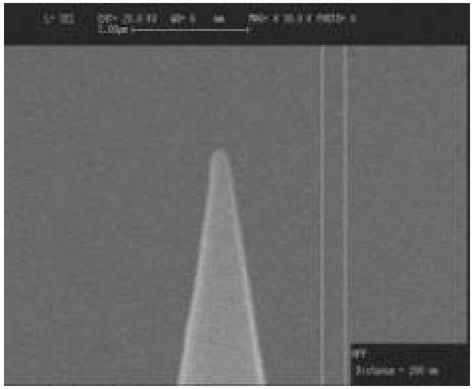
SOLVER Platform

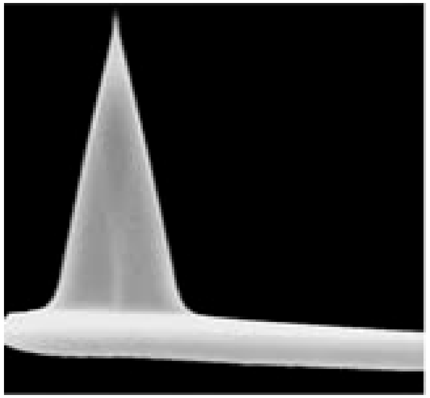
By Default!

NT-MDT meets the wishes of PFM researchers

Probes

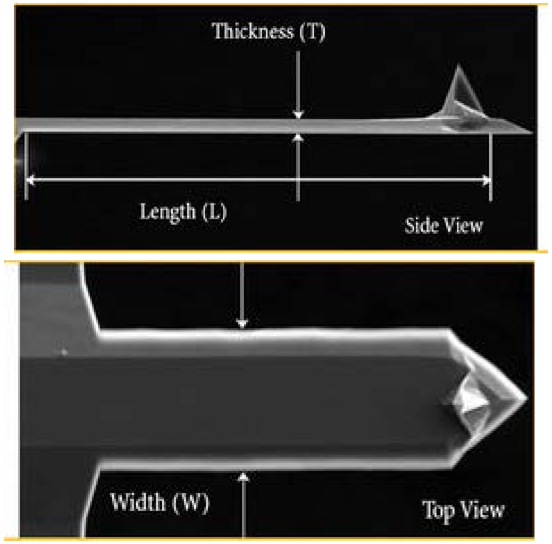
DCP11





Tip with diamond-like extra-stable coating

CSG01/Pt



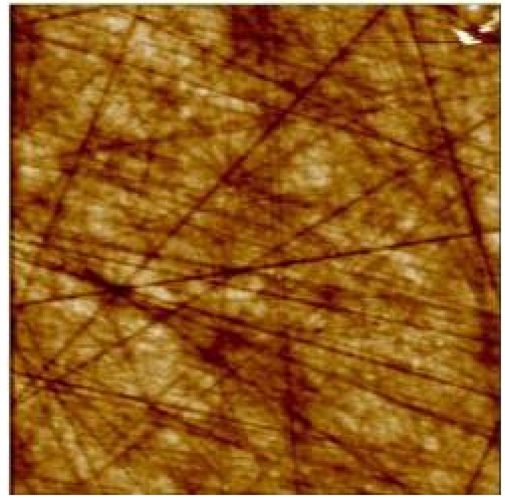
High Resolution CONTACT "GOLDEN" Silicon Cantilevers CSG01 series with PtIr conductive coating

PFM Capabilities

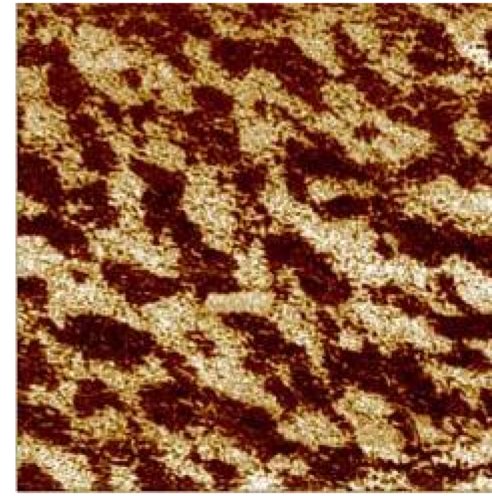
Domain imaging

Switching spectroscopy mapping

Domain lithography



Topography image

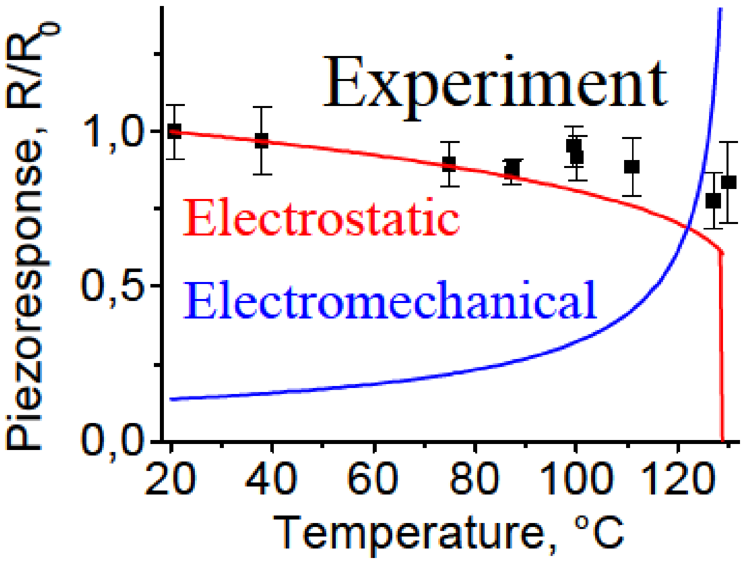


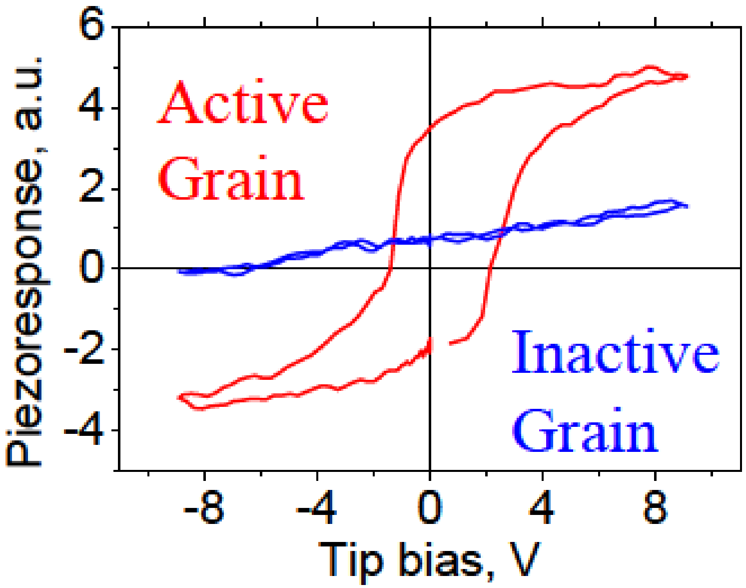
Piezoresponse image

Ferroelectric properties of the P(VDF-TrFE) nanostructures*

*<u>Source</u>: Regular arrays of highly ordered ferroelectric polymer nanostructures for non-volatile low-voltage memories.
Zhijun Hu1,2, Mingwen Tian3, Bernard Nysten1,2 and Alain M. Jonas1,2*

PFM capabilities





Temperature dynamics and phase transitions

Spectroscopy

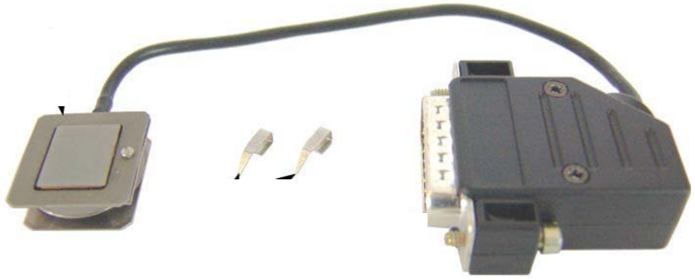
Thermal Control

Operation temperature range: from -20 °C to +300 °C

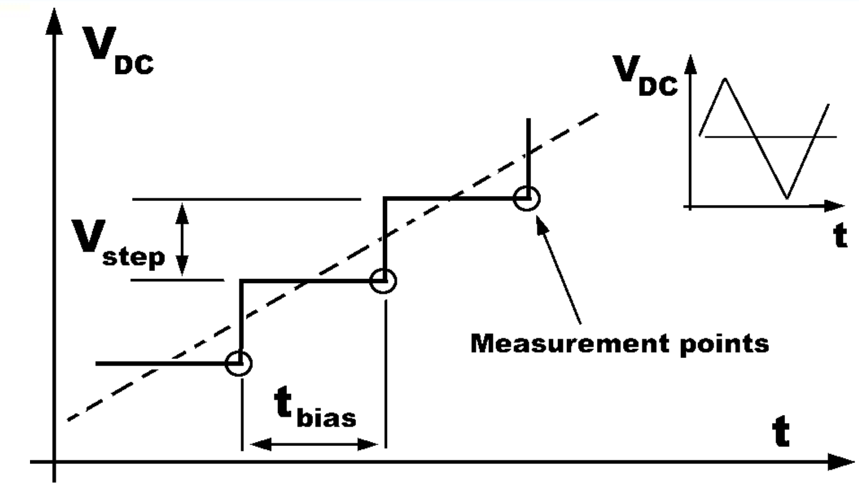
Peltier

300 °C heating stage

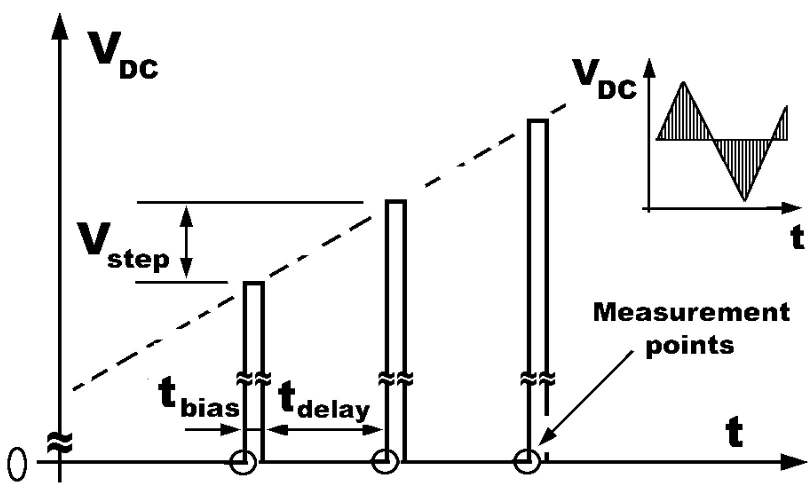
150 °C heating stage



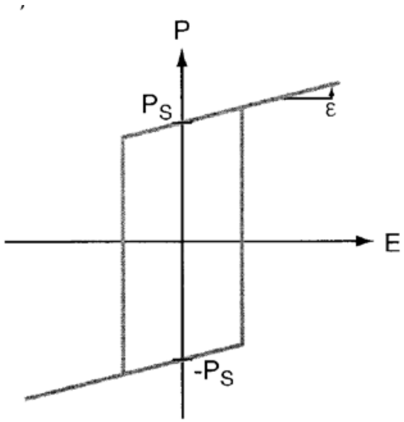
Piezo Hysteresis Spectroscopy



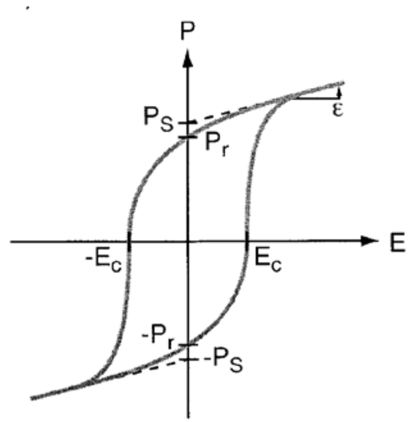
Measurements by steps



Measurements by peaks



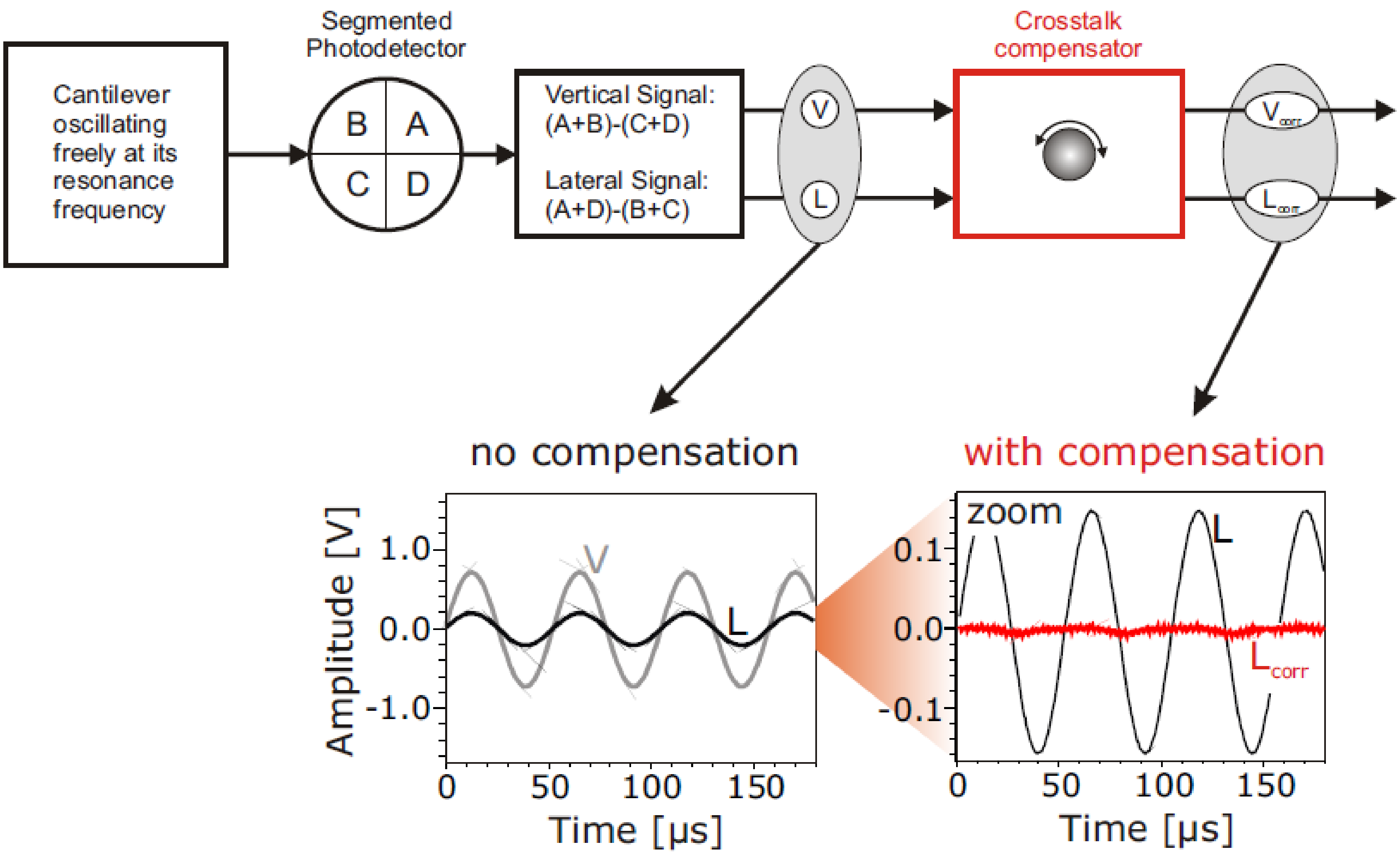
Hysteresis loop on a microscopic scale (within a single domain)



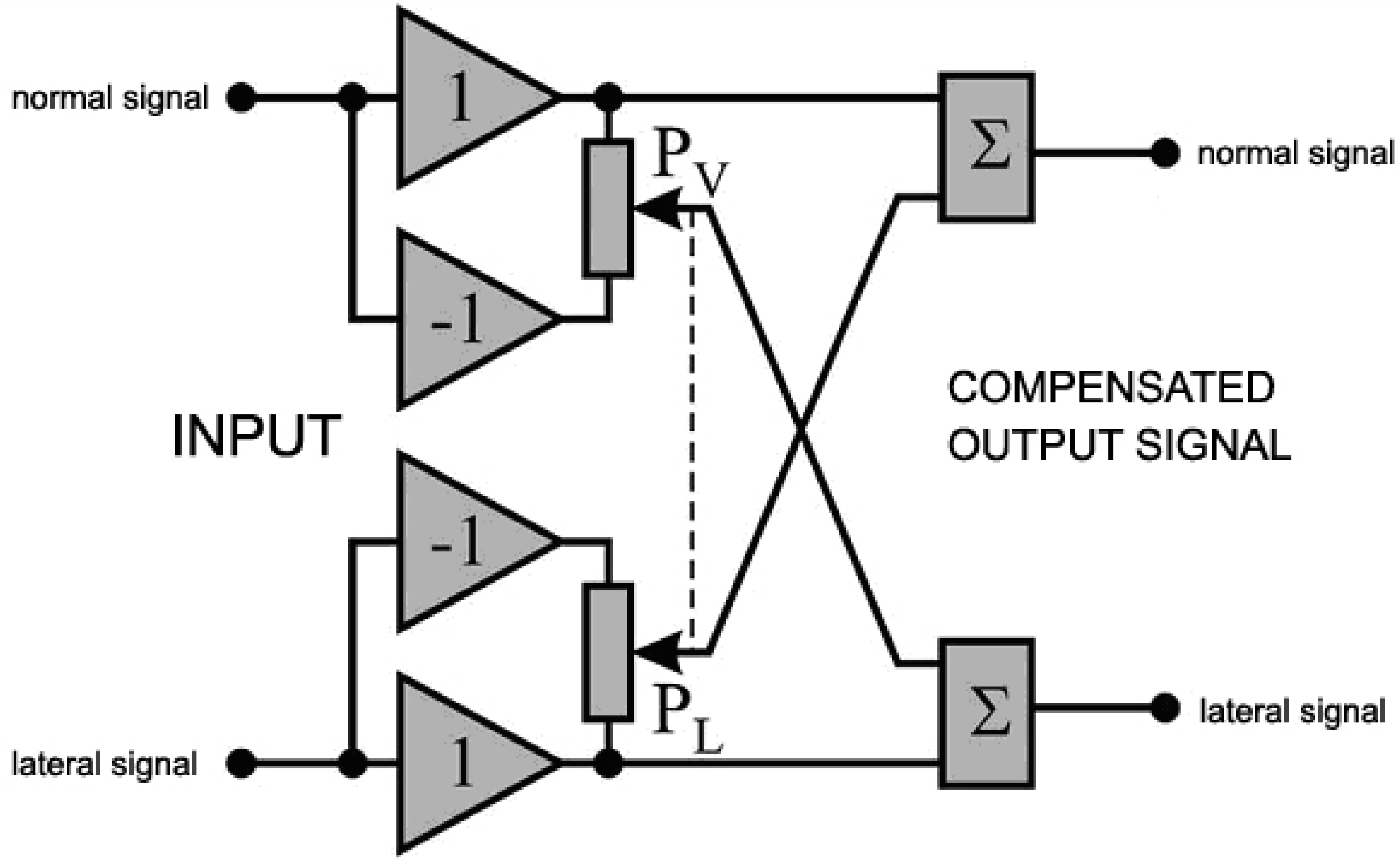
Hysteresis loop on a macroscopic scale

<u>Note:</u> the definitions of the spontaneous polarisation Ps, the remanent polarization Pr, and the coercive field Ec

Principle of Crosstalk Compensator



Basic Diagram for Crosstalk Compensator

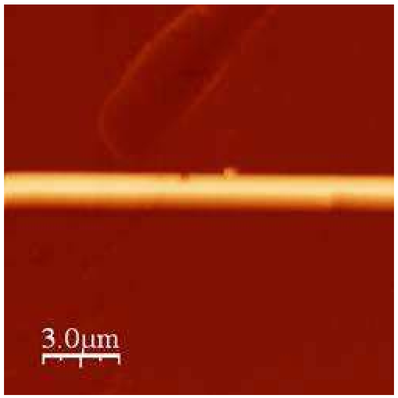


P_L , P_V - potential dividers, Σ - adder

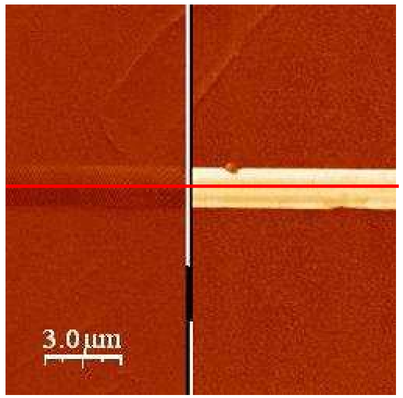
Compensated signals: $$\begin{bmatrix} V_c \\ L_c \end{bmatrix} = \begin{bmatrix} 1 & -x \\ x & 1 \end{bmatrix} \begin{bmatrix} V_m \\ L_m \end{bmatrix} = \frac{1}{\cos a} \begin{bmatrix} V \\ L \end{bmatrix}, \quad x = tga$$

Crosstalk Compensator Operation

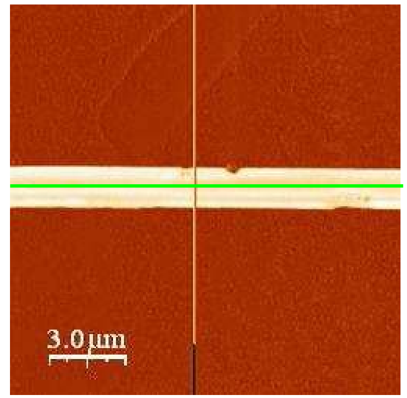
Experiment with peptide nanotubes (high in-plain signal):



Topology



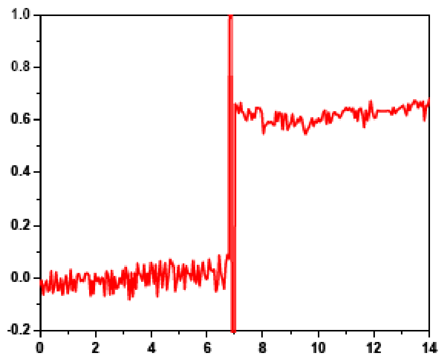
Amplitude
(vertical)



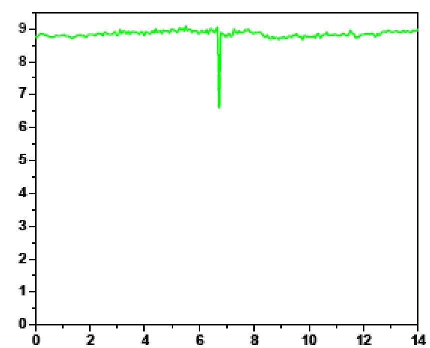
Amplitude
(lateral)

Left part of images: with compensator

Right part of images: without compensator



section



section

frequency 125 kHz,
amplitude 10 V

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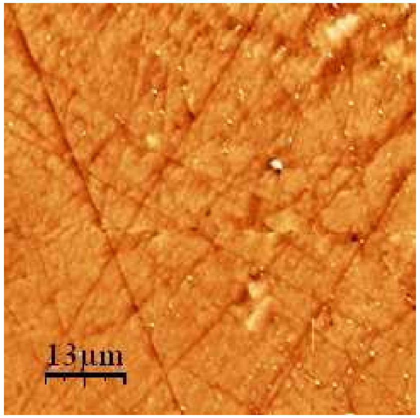
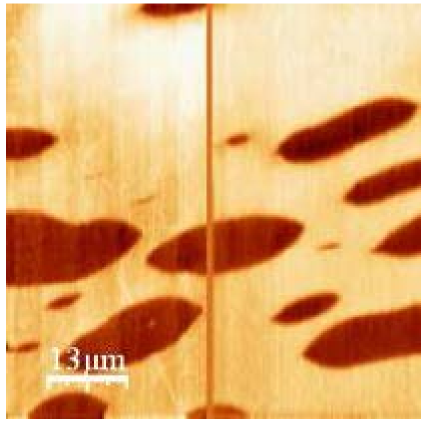
Crosstalk Compensator Operation

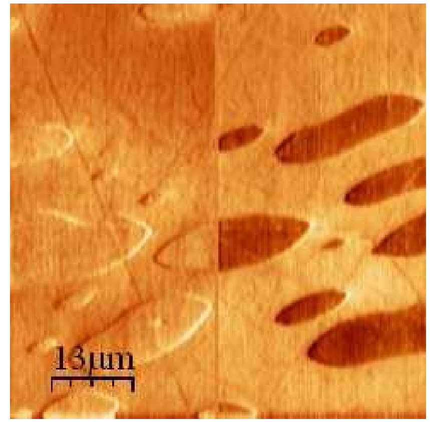
Experiment with TGS crystals (high out-of-plane signal):



Topology



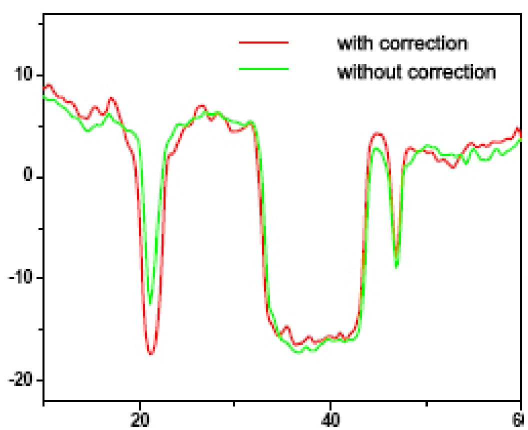
Amplitude
(vertical)

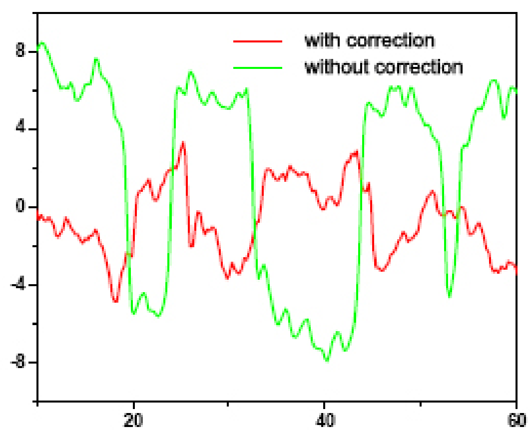


Amplitude
(lateral)

Left part of images:
with compensator

Right part of images:
without compensator





frequency 30 kHz,
amplitude 5 V
T=45 C^o (after 60 C^o)

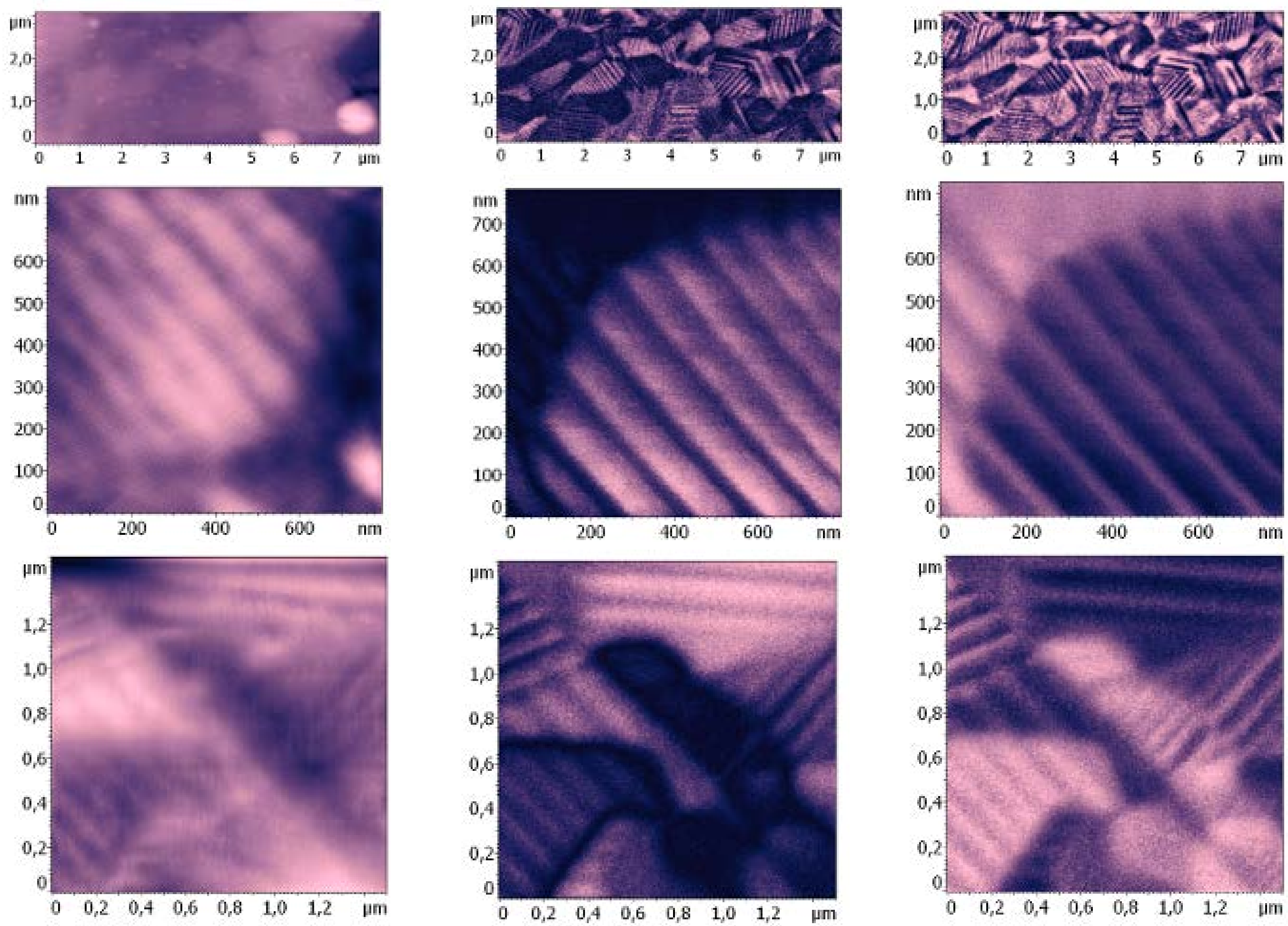
Crosstalk Compensator

The Compensator eliminates the crosstalk effect

NT-MDT Crosstalk Compensator

Measurement Results

PFM : PZT High Resolution



Topography PFM Amplitude PFM Phase

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Thank You!

NT-MDT
INTEGRATED SOLUTIONS FOR NANOTECHNOLOGY

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