Contract NMP2-CT-2005-515739

PRONANO

Technology for the Production of Massively Parallel Intelligent
Cantilever - Probe Platforms for Nanoscale Analysis and Synthesis

Instrument: Integrated Project
Thematic Priority: NMP

Month 24 Periodic Activity Report
Publishable executive summary

Period covered:	from 01-04-2006 to 31-03-2007	Date of preparation:	16-05-2007
Start date of project:	01-04-2005	Duration:	5 years

Project coordinator: Thomas Sulzbach
Project coordinator organisation: Nanoworld Services GmbH
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Publishable executive summary

During the reporting period the activities focused on the integration of the realised parallel cantilever arrays with addressable cantilevers into a test set-up for demonstrating parallel surface imaging on the nanoscale. After the realisation of the first demonstrators of probes within the prior period the combination with the dedicated control and data acquisition electronics as well as the integration into the scanning system have been the major issues. Most remarkable result of these efforts was the demonstration of surface imaging with the integrated cantilever actuation and integrated sensing at calibrated nano-patterns.

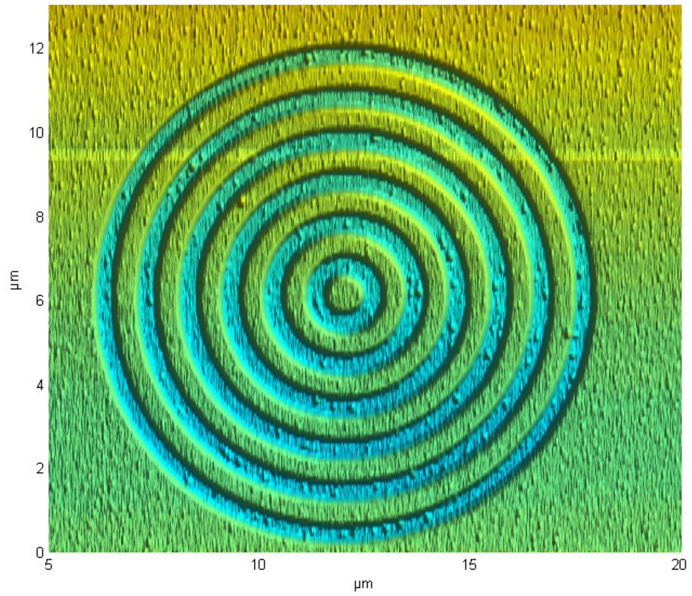

Figure 0.1 Circular grating scans made by PRONANO cantilever on the test bench

The set-up of a demonstrator for parallel scanning surface imaging was accomplished in work package 1 by several runs of probe fabrication with iterative improvement of probe quality and yield. The layout as well as implantation techniques were improved for enhancement of read-out sensitivity and increasing the actuator efficiency. Parallel to that, the integration of sharp tips and the fabrication of 1-dimensional cantilever probe arrays at an industrial fabrication site were established. Polymer based cantilever techniques for highly efficient actuation were driven forward.

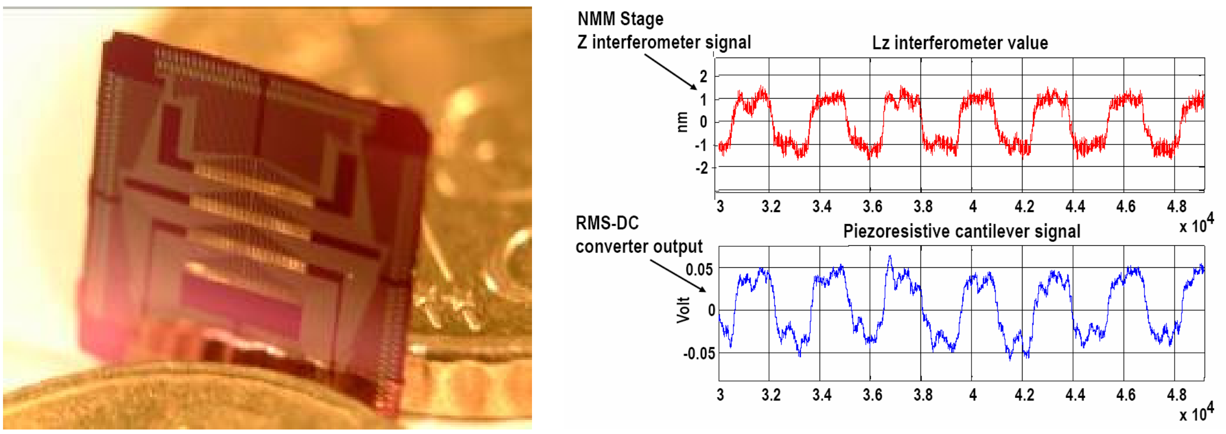

Figure 0.2 PRONANO-Chip with 128 self-actuated piezoresistive cantilevers and obtained sub-nm z resolution sensitivity measured with the Nano-Measurement-Machine.

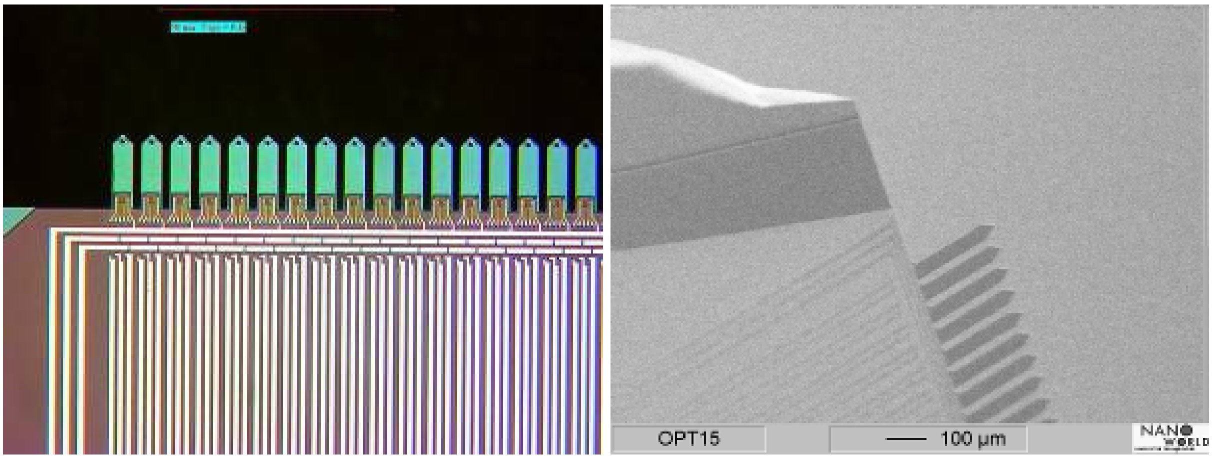

Figure 0.3 Realised functional cantilever arrays of 1x32 cantilevers (left: microscope image, right: SEM image)

The development of probes with addressable cantilever arrays was continued by the preparation of the next generation of probe arrays with higher integration density. Basis technologies for this new generation of probes as the vertical through wafer interconnections, controlled cantilever pre-deflection and reduction of cross-talk were addressed. Although not all results of the technology development were satisfying a precise fabrication scheme for the second generation of probes with up to 8x64 addressable cantilevers was developed.

In work package 2 is the design, development and test of precise, wide band and low noise control and measurement electronics for the application and characterization of the fabricated intelligent single cantilever as well as 1D and 2D sensor arrays was addressed. The resonance cantilever vibrations shall be excited by using the thermal heater (actuator) integrated into the spring beam. Simultaneously the cantilever oscillation is detected by monitoring the output signal of the cantilever piezoresistor. The change of the cantilever vibration which occurs under the influence of the force acting at the microcantilever tip is a measure of distance between the nano-tip and the surface.

Figure 0.4. PRONANO experimental cantilever control and data acquisition system

During the reporting period a discrete electronics for the single cantilever systems and up to 32 beam 1D sensor arrays was developed enabling the detection of the cantilever vibration and control the resonance and static beam deflection. Based on experiments with this electronics and the fabricated probe arrays a dedicated ASIC system for the 2D sensor arrays was designed and will be fabricated, tested and applied. The hybrid and ASIC measurement and control systems include selective preamplifier stage, detector of the cantilever oscillation amplitude, tip-surface distance controller and high resolution system for the excitation of the cantilever vibration. The performance of the discrete cantilever control electronics was demonstrated by nanoscale surface imaging experiments performed with single cantilever probes. The electronics system for parallel scanning of several cantilevers is currently assembled and tested, and will be applied at the beginning of the next period.

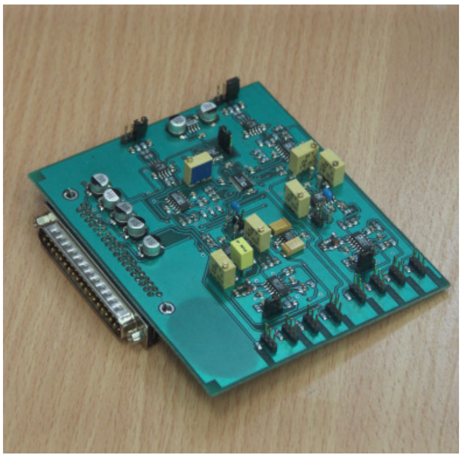


Figure 0.5 PID controller module (left) and DSP data acquisition system with digital-analogue and analogue-digital-converters (right)

The development of an ASIC based electronics was driven forward by the realization and testing of first pre-amplification, filtering and actuator supply ASICS for parallel operation of up to 8 cantilevers. These ASICS will be integrated into the discrete cantilever control electronics replacing commercially available components with inferior performance. Additionally, the analogue-digital converter block was designed during reporting period and will be available within the next period.

Parallel to the development of an electronics system based on RMS-conversion the development of a control system enabling the operation of the PRONANO cantilevers in the self oscillation mode and the detection of the resonance frequency of the spring beam is addressed. These activities will be merged with the “classic” approach in subsequent project period for optimum performance of the scanning probe based measurement system.

Of particular importance for the use of massively integrated cantilever array systems is the development of dedicated data transfer concepts handling the enormous data flow. The work on this task is tightly linked with the development software module for the ASIC based electronics and, therefore, it was carried in close cooperation between all partners involved into the electronics development. Main achievement in the reporting period was the establishment of a test set-up for the data transfer system and the successful demonstration of feasibility.

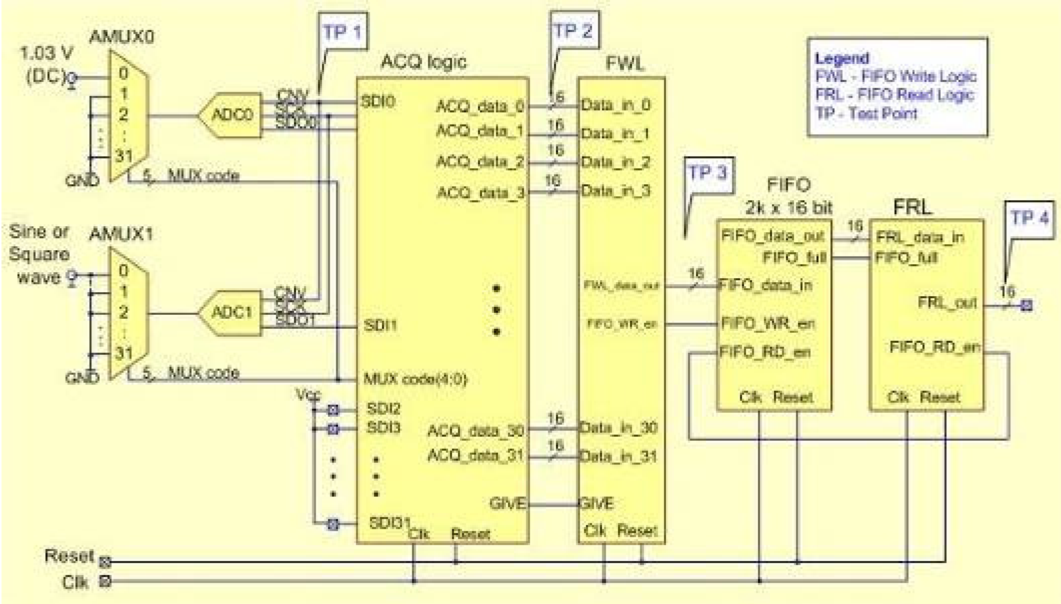

Figure 0.6 Data Transfer System hardware implementation – block diagram. (TPx indicates a test point).

Beside the completion of single cantilever probe integration and demonstration of feasibility in work package 3 the nano-measurement machine was adopted to the integration of 1-dimensional and 2-dimensional cantilever arrays. For that, a precise motorized probe fixture was developed enabling the 2-axis compensation of any tilt between probe and measurement sample.

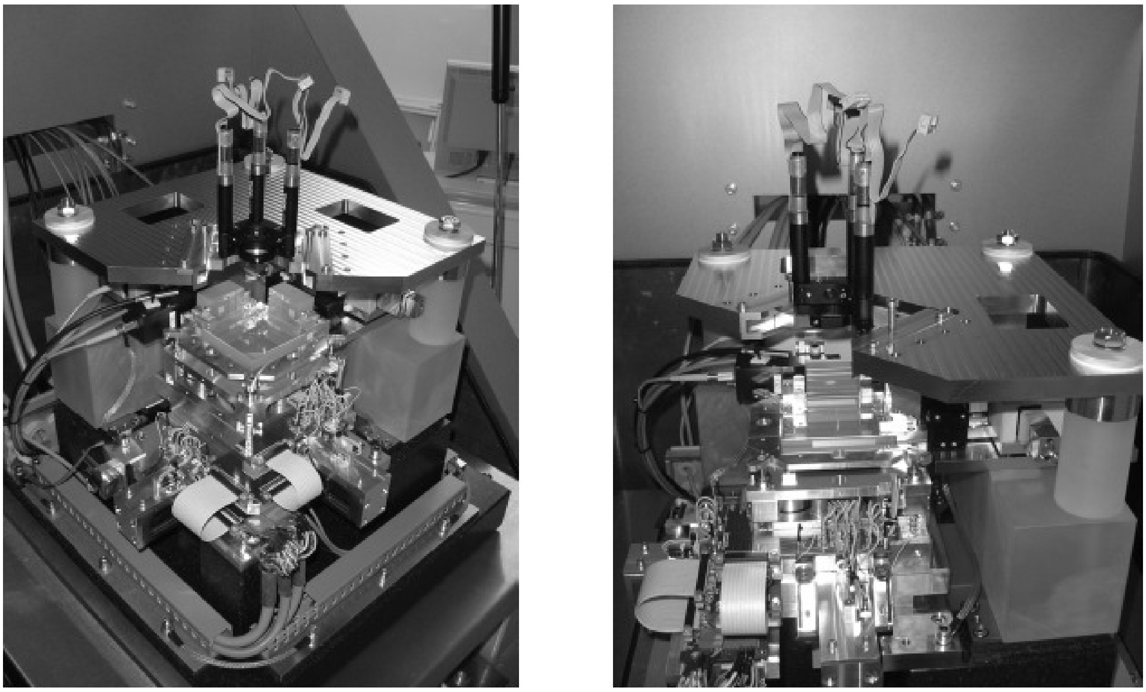

Figure 0.7 Alignment tool for 1x32 and 2x32 arrays, integrated on the NMM

Additionally to the system integration activities, a second centre of gravity for the work was the testing of realised probe iterations to provide feedback to the probe manufacturing partners. Although, the central test bench for final characterization and performance tests is the nano-measurement machine additional test set-ups were installed by different partners either for pre-characterization or for special purposes. The probe manufacturer installed set-ups for the determination of sensor and actuator resistances as well as the determination of cantilever resonance frequencies, test set-ups for the optimization of the interaction between probes and cantilever control electronics were assembled by the electronics development partners and a test-set-up for the determination of the actuation efficiency was installed by the main system integration partner. This equipment allows a complete characterization of probe prior to the application tests which will be performed systematically at the beginning of the next project period.

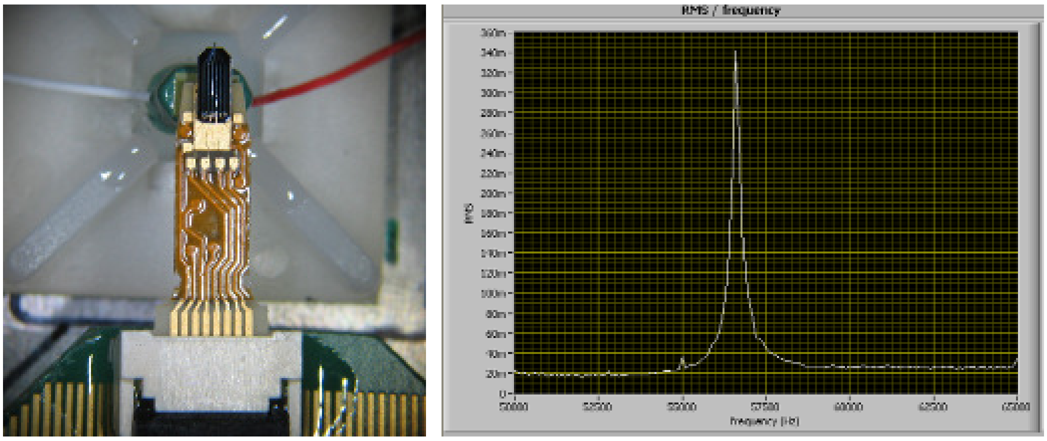

Figure 0.8 Test set-up for the pre-characterization of single cantilever probes with mounted packaged probe (left) and determined resonance curve of the internal actuation measured by the internal cantilever beam deflection sensor (right)

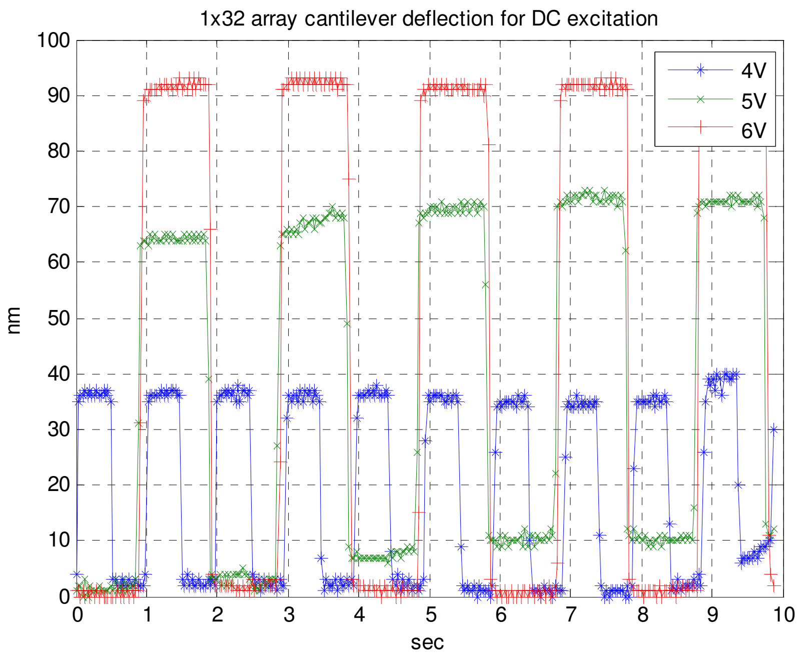

Figure 0.9 Absolute DC deflection of one cantilever of a 1x32 array for different excitation voltages measured by an optical interferometer system (vibrometer)

For raising the public awareness of PRONANO several publications in scientific journals and presentations at conferences were organized in the frame of work package 4. The public website (http://www.pronano.org) provides short introduction to the project goals including a News section and presents the project partners with their contact details. The progress of the project is visible by updated links to publications and provision of public reports.

Different **workshops** were realized which were also open to an public audience. During the reporting period, two workshops have been organized:

- April 24, 2006 at Technical University of Ilmenau. Topic: *Scanning Probe Arrays*

- October 18^{th}, 2006 in Abingdon, UK. Topics: *Design and working principles of AFM; Analog electronics for sensor readout and actuator control; PPL; Test and characterization of cantilevers*.

Currently scheduled workshops and courses are published on the Pronano Website (http://www.pronano.org).

Under the overall course title "Micro Cantilevers - an enabling platform for Nanotechnology" a first e-learning module "**Introduction to Microcantilever Applications**" has been elaborated and is available since December 2006.

It is accessible via a personal password and allows the users to train themselves at their personal computer and thus avoid time consuming traveling to external course locations.

Learning time is about 1 h. All details on how to register are on the public Pronano public website.

<u>Objectives of the e-module:</u>

- to transfer knowledge available inside the Pronano project to a wider public.
- to show an overview of the possible applications of microcantilever technology as sensors and actuators in high growth markets (Biomedical, Security, Environmental) and other industries
- to provide the foundations for further reading into the field of microcantilevers

<u>Target group of the e-module:</u>

The first module is an introduction to the field of microcantilevers and thus targeted to non-specialists in the domain: students, researchers and engineers from university and industry interested in the fundamental background or/and exploitation of microcantilever technology. It also addresses those actively working in the filed of micro- and nano-technology but who are new in the filed of microcantilevers.

<u>Content of the e-module:</u>

- Introduction: Overview of Microtechnology
- Why Microcantilevers?
- Microcantilever Applications:
- Biomedical: Protein arrays, Viral detection, Micromanipulation, Biological Imaging
- Security: TNT sensor, Pathogenic Sensor, Biometrics, Infrared Imaging
- Chemical and Environmental: Calorimetry, Fluid Sensor, Vapour Detectors, Chemical Sensors
- Other Applications: Data storage, Optical scanners, Microrobotics, Metrology

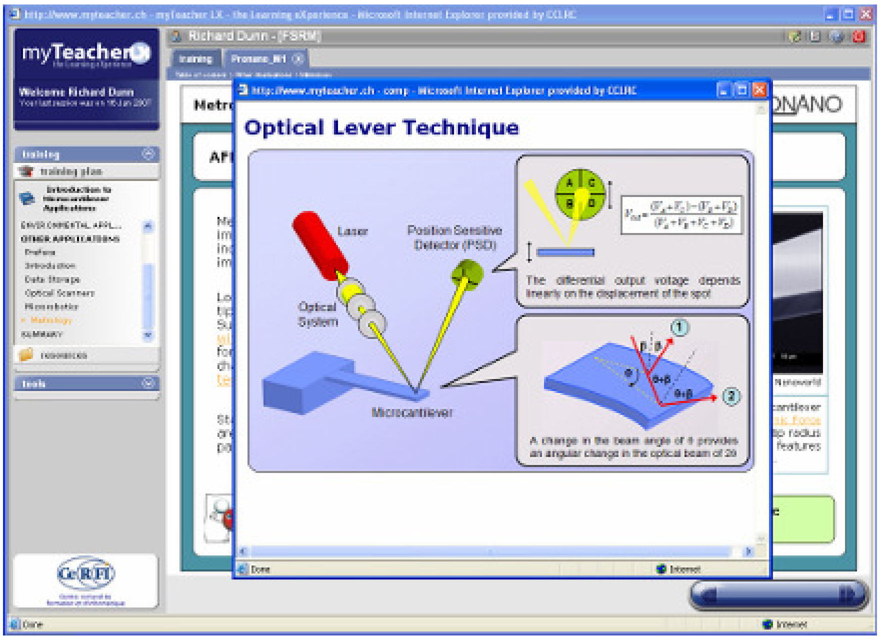

Figure 0.10 Example page of the first module of the web-based course "Microcantilevers - An Enabling Platform for Nanoscience"

Encouragement of **mobility of researchers and the appointment of PhD** students is also an activity of this Work Package.

In the end of the second year, 16 students and young researchers are participating in the activities of the project and numerous working visits and meetings between the project partners took place.

Among the **dissemination activities**, several articles in magazines and newsletters have been published by different partners. The aim is to inform a wider public about the activities of the network and to publish concrete results.