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High Speed Atomic Force Microscope

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Summary

Atomic Force Microscope (AFM) is now a common tool for material analysis in the academic and industrial areas because it enables non-destructive high-resolution images of nanometric objects. However, a main drawback is the slow scan rate that hinders many potential applications. Recently, breakthroughs have been achieved in AFM sensors based on MEMS technology, allowing to extend AFM operation in terms of measurement bandwidth and data acquisition. The present work focuses on developing an electronic controller for AFM featuring the wide bandwidth and the fast data processing rate required to enable the exploitation of the full potential of MEMS AFM sensors.

AFM probes in the present work were developed at IEMN-CNRS (Lille, FRANCE) and are now available from Vmicro SAS. A silicon ring holding a nanotip vibrates according to the elliptical resonance mode shape at about 13 MHz. Capacitive electromechanical transducers are integrated for driving and sensing the nanotip vibration. Typical measurement resolutions are 1.5 nm/√Hz in displacement and 0.5 pN/√Hz in force.

High frequency AFM probes (MEMS technology)

Contact and informations at:
https://www.laas.fr/projects/olympia

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Software architecture

PC – LabVIEW 2016, QMH project

UI@ 10 ms
- R/W network streams from RT
- Unbundle data
- Convert data to physical units (m,V)
- Averaging per pixel

UI@ 100 ms
- Display scaled data
- Display scan images
- UI management
- Save image files
- Control USB motor for approach

Real-time Controller – LabVIEW RT, QMH model

RT@ 5 ms non-deterministic
- R/W stream to UI
- Data 80 Mbit/s
- Messages

RT@ 1 ms deterministic
- Read data from FPGA
- FPGA – LabVIEW FPGA

Z control loop @1 µs pipelining
- Probe signal acquisition
- PID calculation with gain schedule
- Piezo Z command (20-bit word to external DAC)
- Scan control @10 µs or more
- Scan X, Y via Analog Outputs
- Read X, Y position sensors (Als)
- Watchdog @40 MHz

FPGA configuration

The controller of the AFM microscope is based on a 8-bit CompactRIO NI-9023.

2-screen wide User Interface

Images of graphite HOPG steps in AFM mode
(a) Image 2.5 × 2.5 µm (312 × 312 pixels) acquired in 60 s. (b) and (c) images forward and backward 200 × 200 nm (1.08 × 1.08 pixels) acquired in 5 s.

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