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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 focusses 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.

High frequency AFM probes (MEMS technology)

AFM probes used 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.

Software architecture

Real-Time Controller – LabVIEW RT, QMH model

- RT@ 5 ms non determinist
- RT@ 1 ms determinist
- Z control loop @1µs pipelining
- Scan control @10µs or more
- Watchdog @40MHz

FPGA – LabVIEW FPGA

- Probe signal acquisition
- PID calculation with gain schedule
- Piezo Z command (20-bit word to external DAC)
- Scan X, Y via Analog Outputs
- Read X, Y position sensors (AIs)

Software performance

- Scan duration: 0.02 s (50 images/s)  60 s
- Binary file size: 47 KB  140 MB

Hardware architecture

PC – LabVIEW 2016, QMH project

- UI@ 10 ms
- Display scaled data
- UI management
- Data 80 Mbit/s

NI CompactRIO configuration

The controller of the AFM microscope is based on a 6-slot CompactRIO NI-9056.

Piezo Z control Loop Timing

- DAC command 20-bit word
- Data –> FIFO

0.2 μs + ~ 0.8 μs + 1 μs

FPGA: microscope Z feedback operations take about 4 μs to complete. It executes every 1 μs with pipelining method.

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