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To cite this version:

HAL Id: hal-01529673
https://hal.laas.fr/hal-01529673
Submitted on 31 May 2017

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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 nano-metric 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.

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

PC – LabVIEW 2016, QMH project

UI@ 10 ms
R/W network streams from RT
Unbundle datas
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 determin.
R/W stream to UI

RT@ 1 ms deterministic
Read data from FPGA

FPGA – LabVIEW FPGA

Z control loop @1µs pipelining
Probe signal acquisition
PID calculation with gain schedule
Piezo Z command (20-bit word to external DAC)

Scan control @10µs or more
Scan X, Y via Analog Outputs
Read X, Y position sensors (Als)
Watchdog @40MHz

Piezo Z control Loop timing

Probe voltage acquisition
16 bits
PID calculation
32 bits
DAC command
20-bit word

Data -> FIFO to RTos
2.2 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.

Software performance

Small image
1k pixels

Biggest image
3M pixels

Scan duration
0.02s
(50 images/s)
60s

Binary file size
47 KB
140 MB

Contact and informations at:
https://www.laas.fr/projects/olympia
This work is supported by the projects:
ANR OLYMPIA ANR-14-CE26-0001
-CNRS DYNAMIC