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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.

**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 c**ontrol 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 (AIs)
  - Watchdog @40MHz

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

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**Images of graphite HOPG:**
- (a) Image 2.5 × 2.5 µm² (312 × 312 pixels) acquired in 60 s.
- (b) and (c) Images forward and backward 200 × 200 µm (312 × 312 pixels) acquired in 3 s. The topographic contrast is due to elasticity contrast of copolymers strips.

**Images of graphite HOPG steps in AFM-mode:**
- (a) Image 2.5 × 2.5 µm² (312 × 312 pixels) acquired in 60 s.
- (b) Image 1 × 1 µm (200 × 200 pixels) acquired in 40 s.
- (c) Image 1 × 1 µm (200 × 200 pixels) acquired in 20 s.