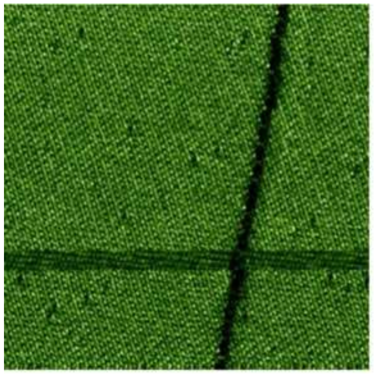
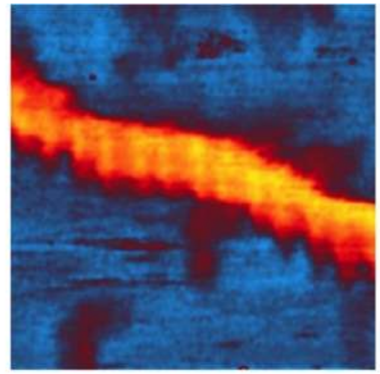
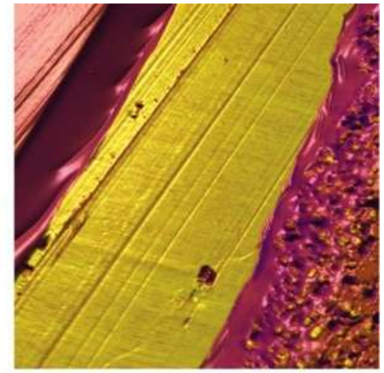
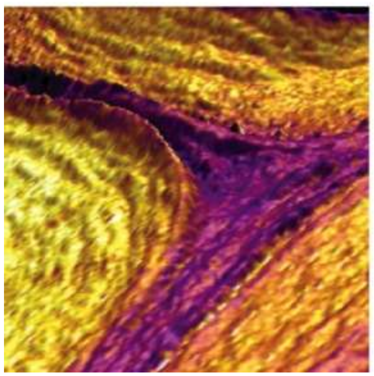
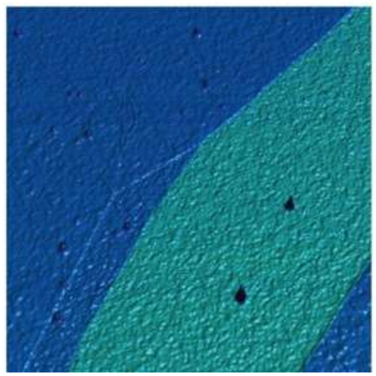
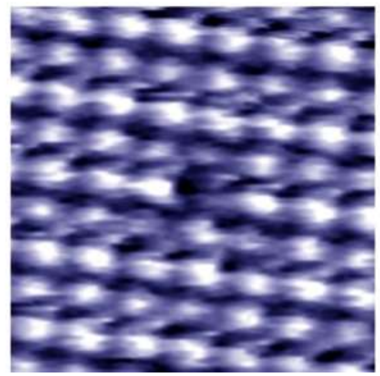
Recent Developments in Tapping Mode Imaging



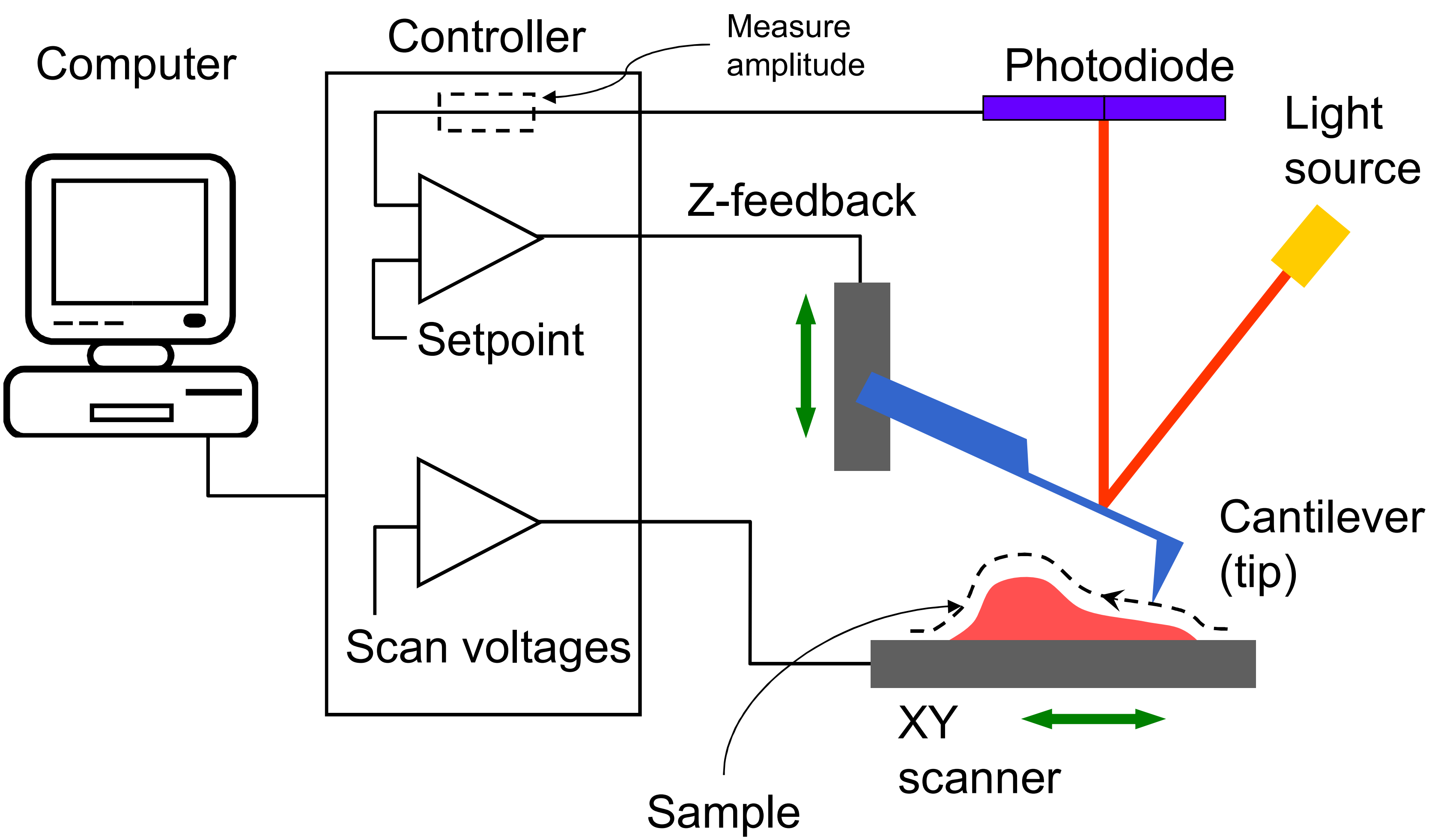

Rob Cain

rob.cain@oxinst.com

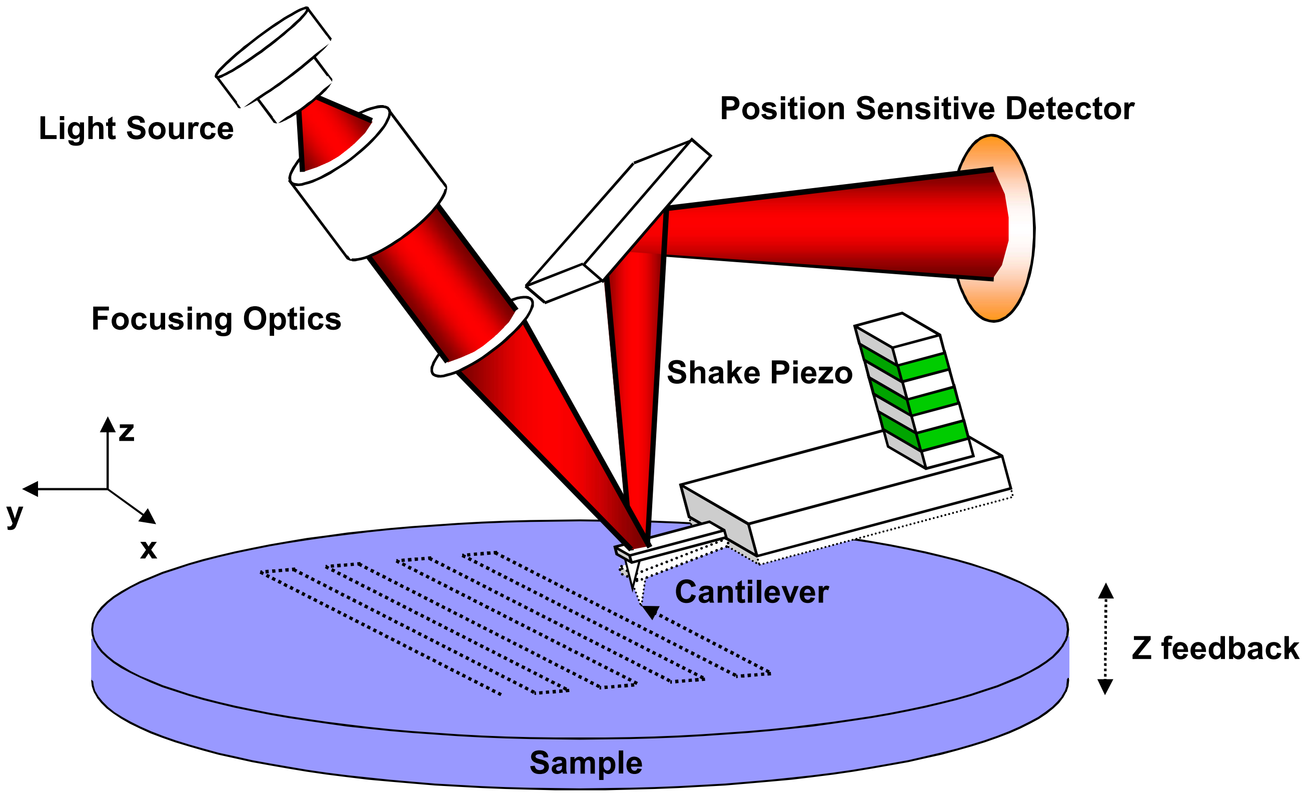
Outline

- AFM Basics
- Introduction to Tapping Mode
- Automated Imaging
- Improvements in Resolution and Speed
- Quantitative Nanomechanics

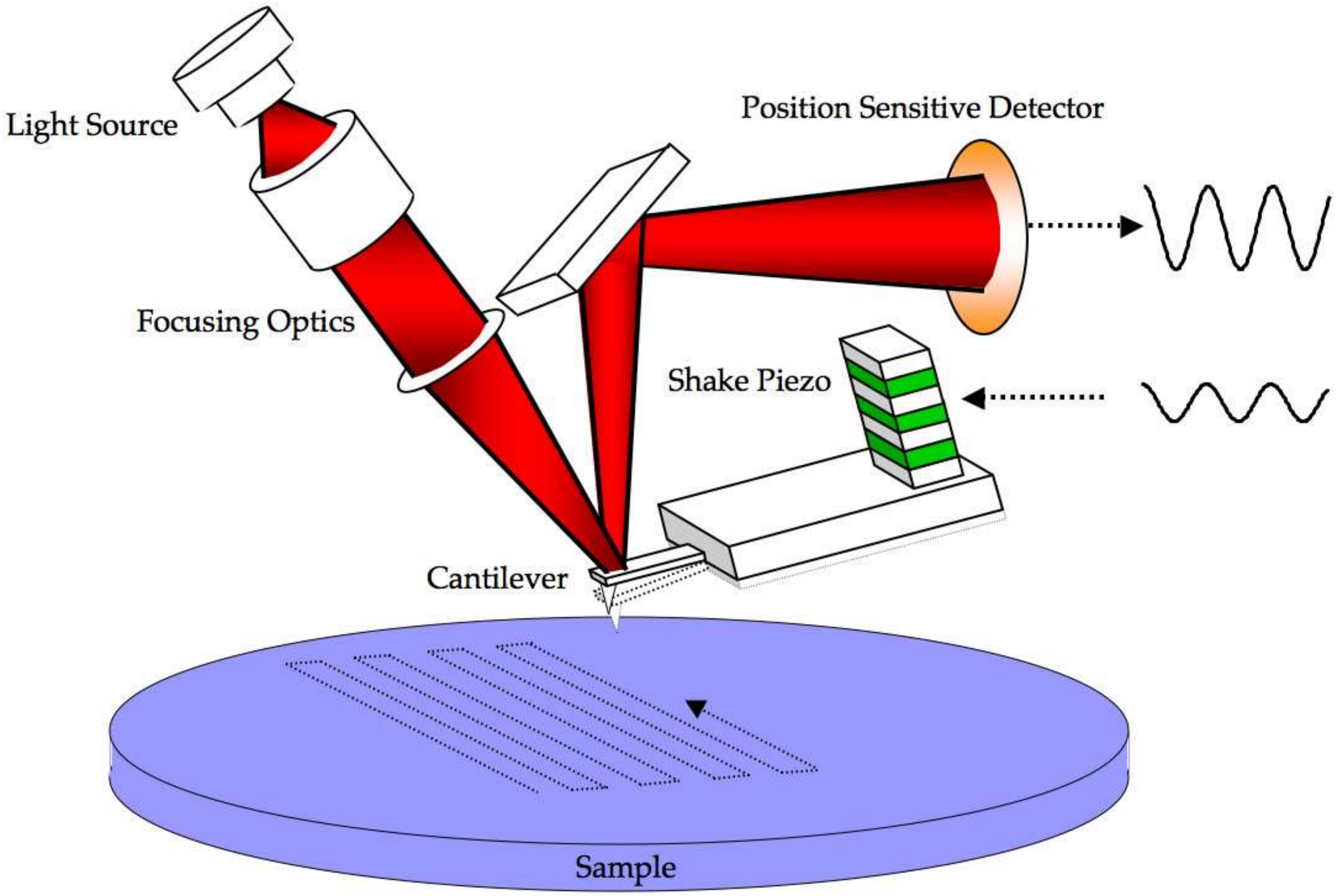
Principles of AFM



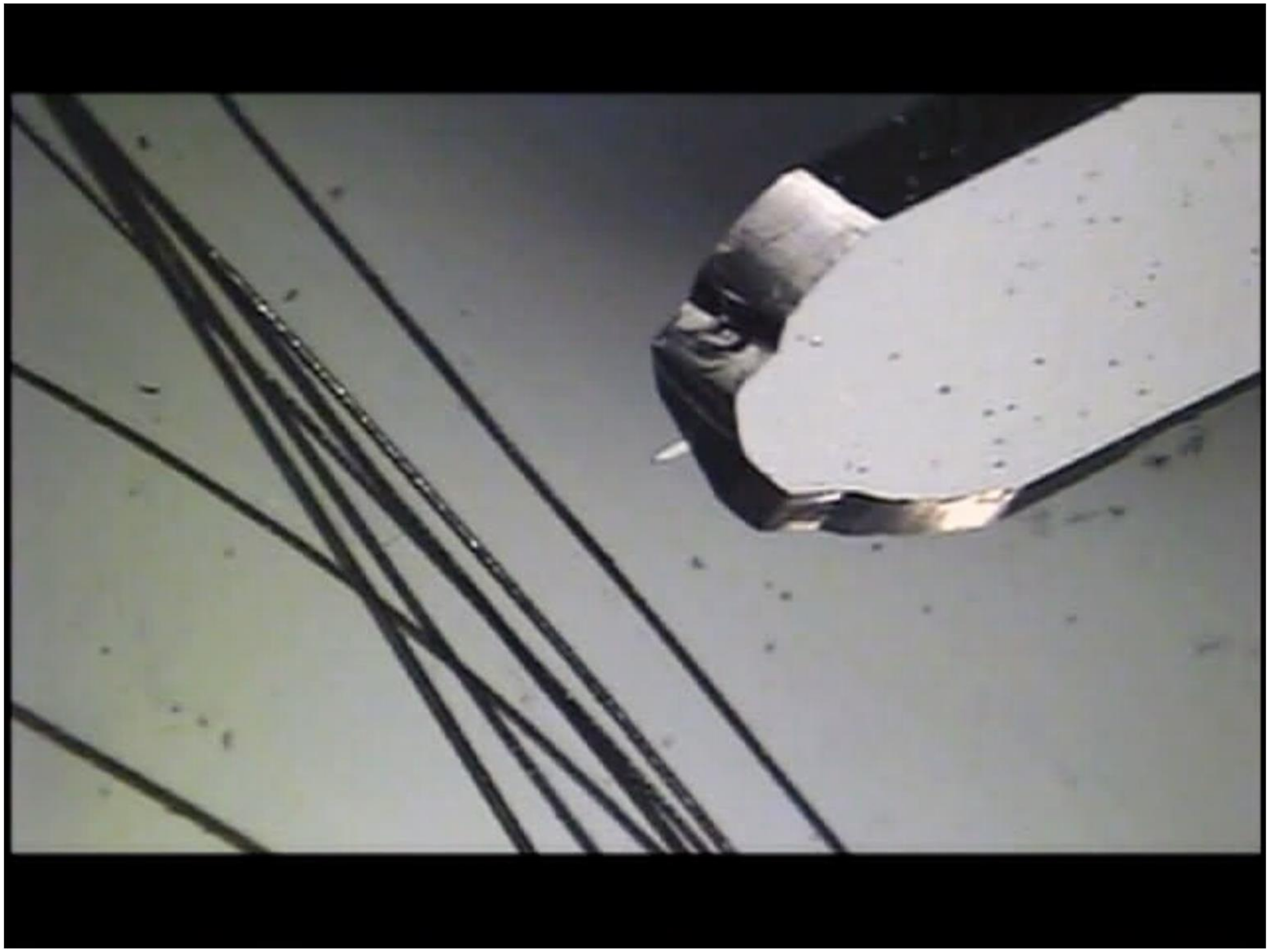
Contact Mode Imaging



Tapping Mode Imaging



Cantilevers

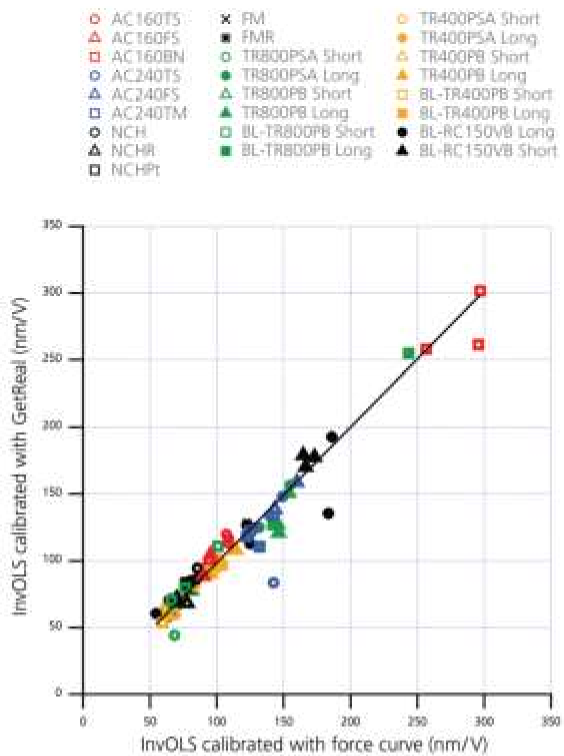


GetReal™ – Automated Probe Calibration

Because some things shouldn't be measured in volts

ASYLUM RESEARCH an Oxford Instruments company

One click starts the calibration → The thermal noise spectrum is measured automatically → The Sader method calibrates the spring constant, k → The thermal noise method calibrates the inverse optical lever sensitivity, InvOLS → Fully calibrated probe is ready to use!



Simple − pick, click, get InvOLS and k

Safe − protects tip sharpness

Accurate − fully calibrated cantilever deflection

Free − for new and existing Asylum AFMs

https://www.AsylumResearch.com/GetReal

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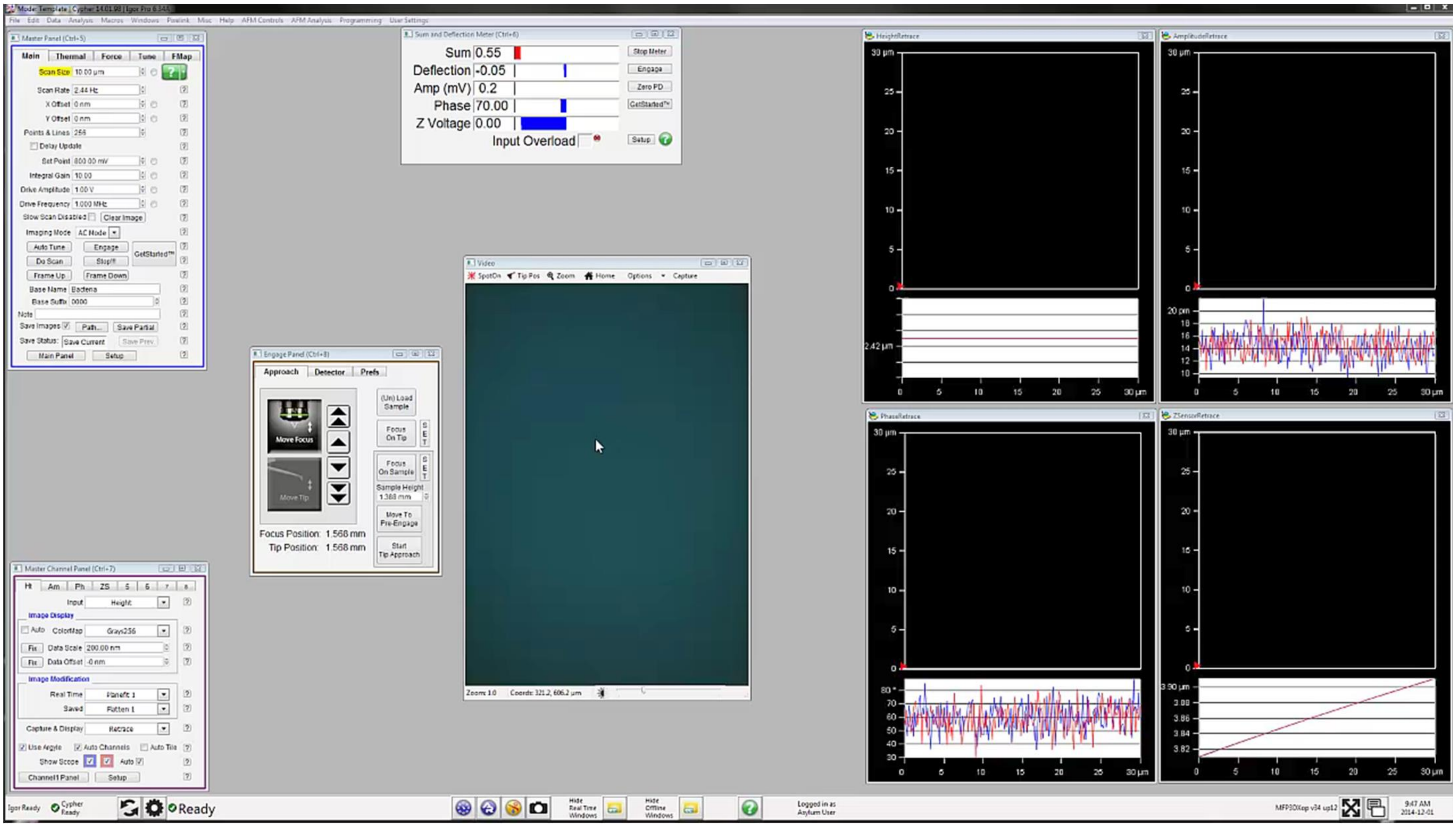
GetStarted™: Automated tapping mode image optimization for Cypher and the Infinity

Simple automated tapping mode imaging for high quality data from the first scan line

What is GetStarted?

- The Idea:
  - Gains for Feedback loops depend on the sensitivity of the inputs
  - We already know the sensitivities of the piezo actuators, the closed loop sensors, …
  - The cantilever is the last piece of the puzzle.
  - GetReal gives us the cantilever sensitivity!


Sum 0.55
Deflection -0.05
Amp (mV) 0.2
Phase 70.00
Z Voltage 0.00
Input Overload
Stop Meter
Engage
Zero PD
Setup
Master Panel (Ctrl+5)
Main
Thermal
Force
Tune
FMap
Scan Size
Scan Rate
Points & Lines
Set Point
Integral Gain
Drive Amplitude
Drive Frequency
Imaging Mode
Auto Tune
Do Scan
Frame Up
Frame Down
Engage Panel (Ctrl+8)
Approach
Detector
Prefs
Move Focus
Move Tip
Focus Position: 1.568 mm
Tip Position: 1.568 mm
Video
Master Channel Panel (Ctrl+7)
Ready

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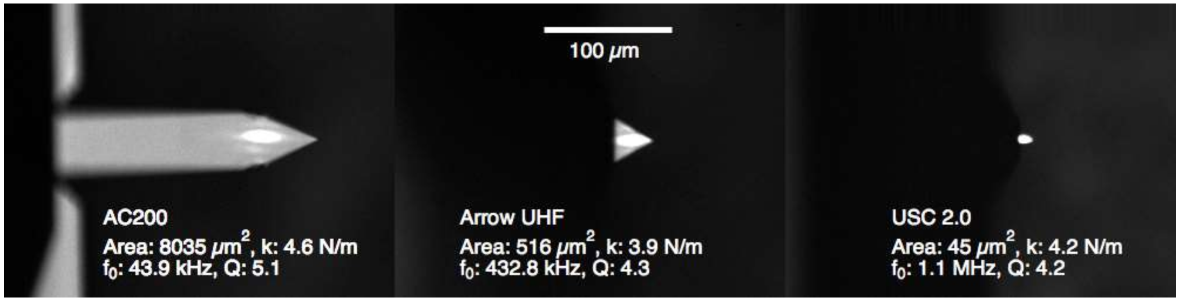
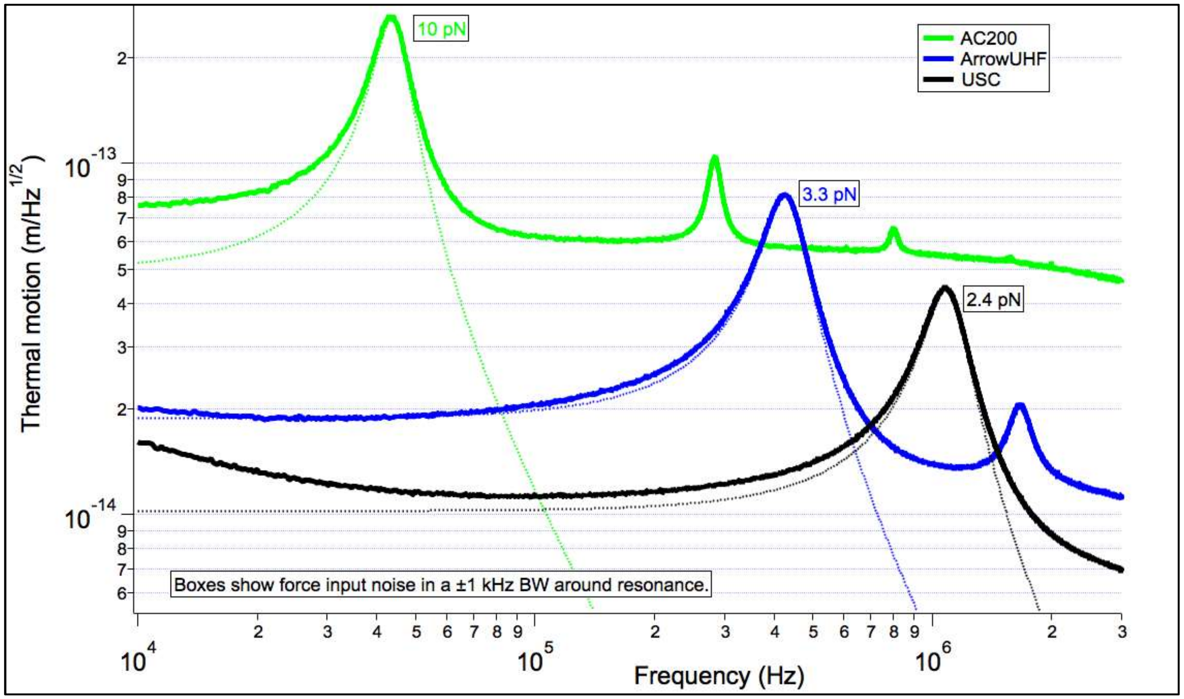
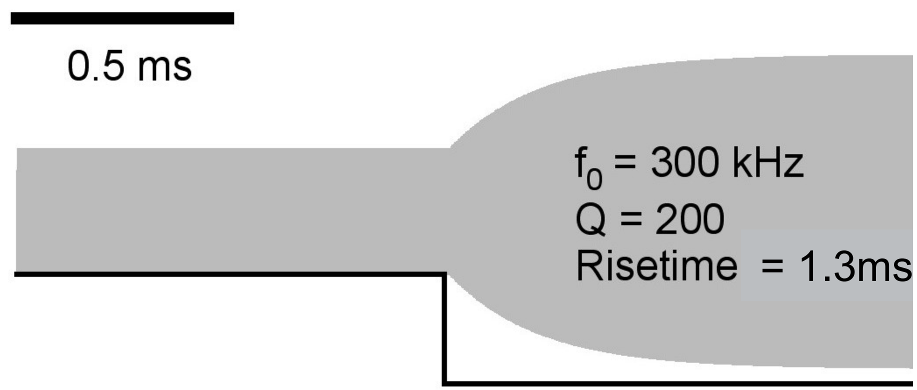
As the cantilevers get smaller…
… higher speed





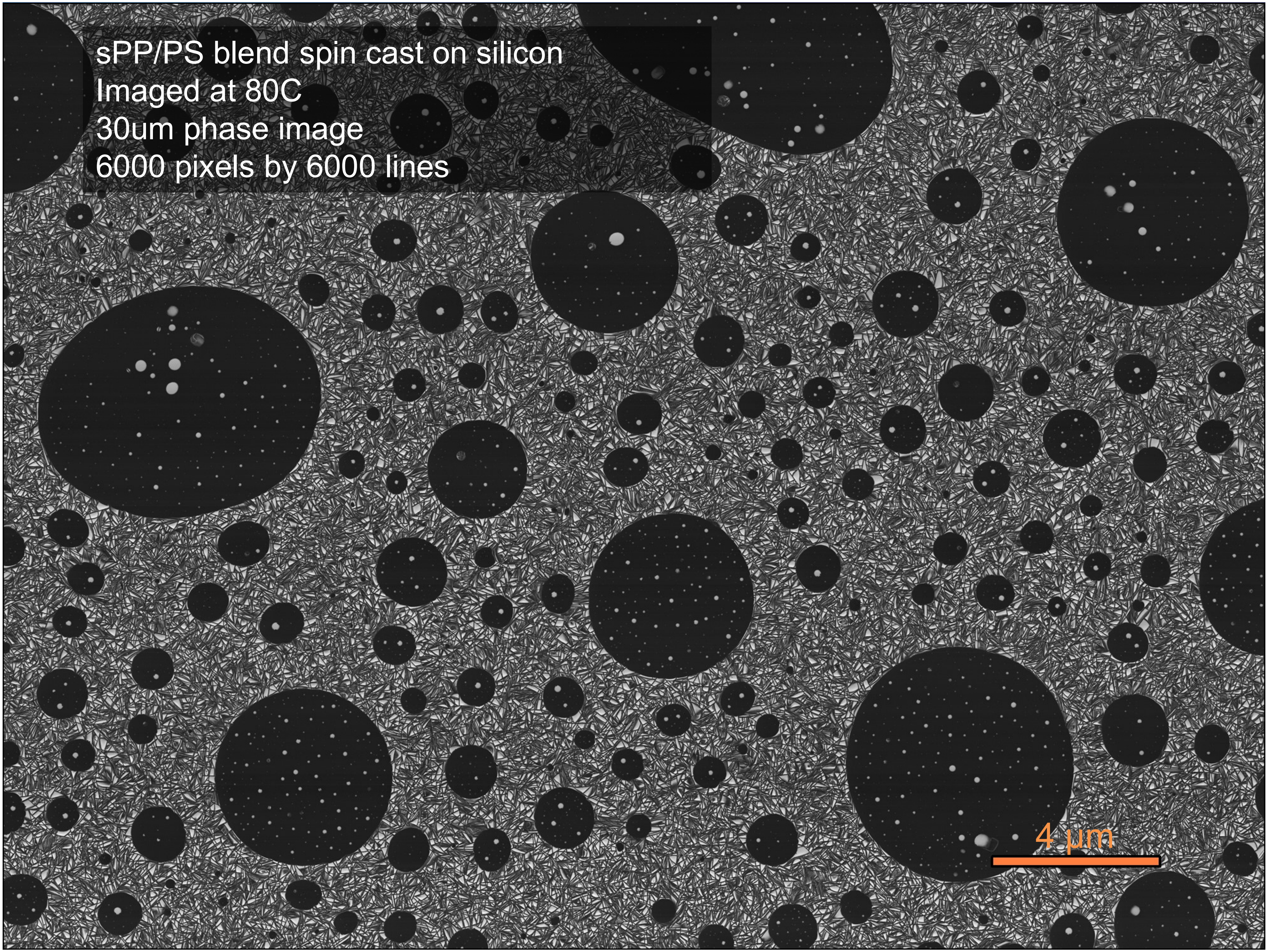
Cantilever Mechanical Bandwidth

- Conventional AC mode levers have resonant frequencies from 50 to 400 kHz. Fast right?

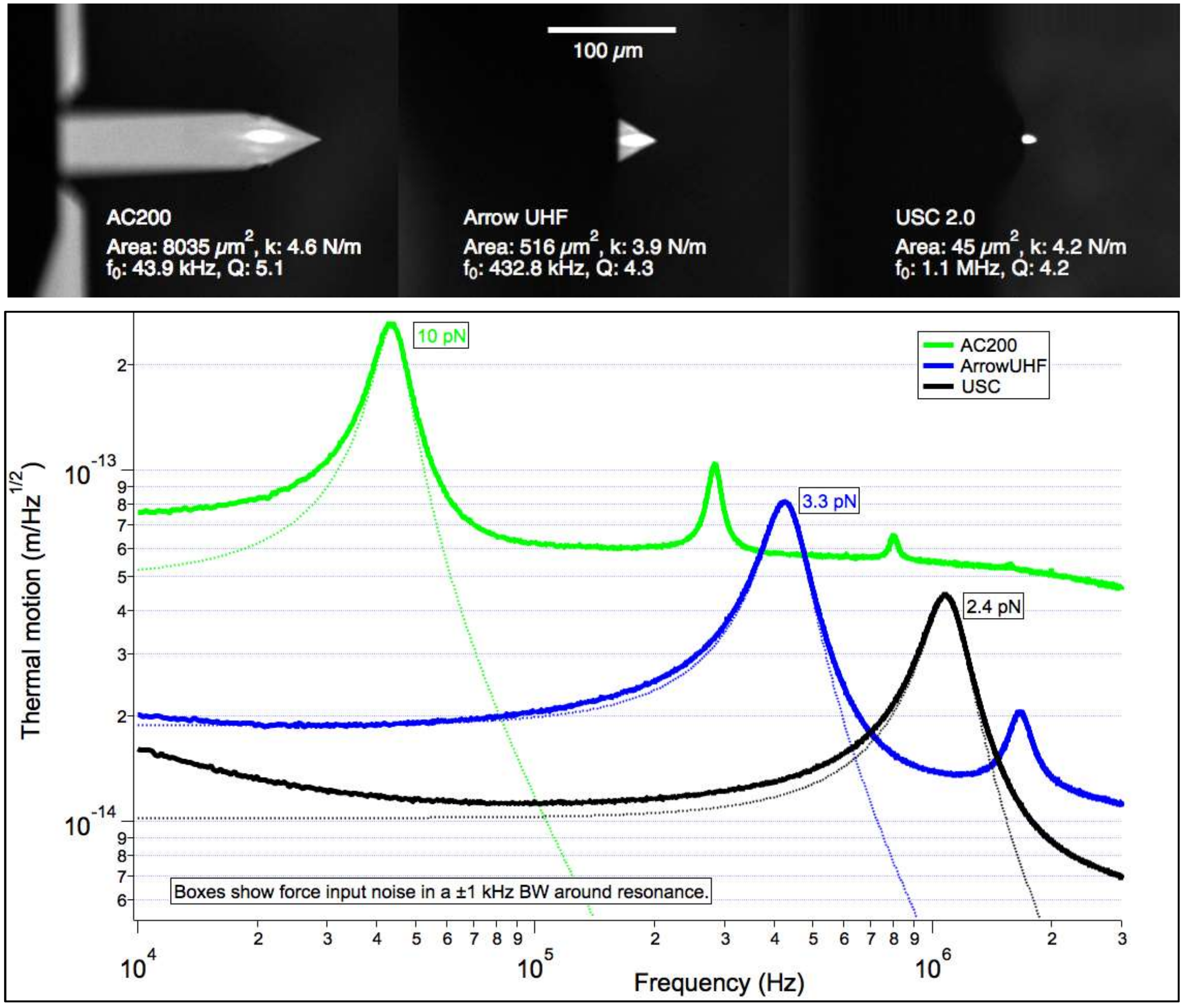


- No, the equivalent filter bandwidth is $\dfrac{f_0}{2Q}$
- Usually Q=200 to 500, so the bandwidth is sub-kHz
- For this example, scan rate ~ $\dfrac{1}{1.3ms}\dfrac{1}{500\,pixels}$ **~ 1.5 Hz**

DNA Fast Scanning


sPP/PS blend spin cast on silicon
Imaged at 80C
30um phase image
6000 pixels by 6000 lines
4 µm

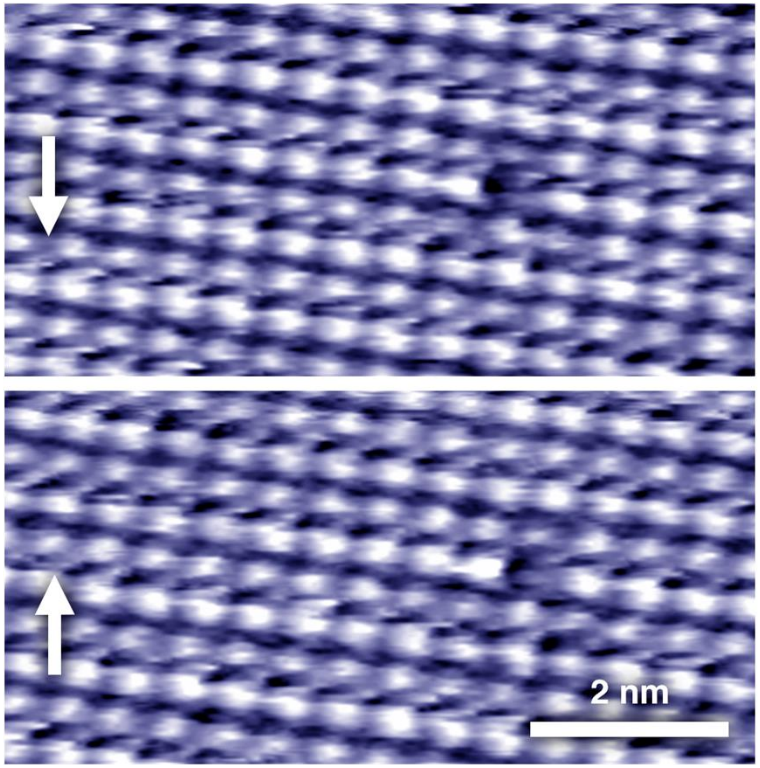
As the cantilevers get smaller…
… better resolution



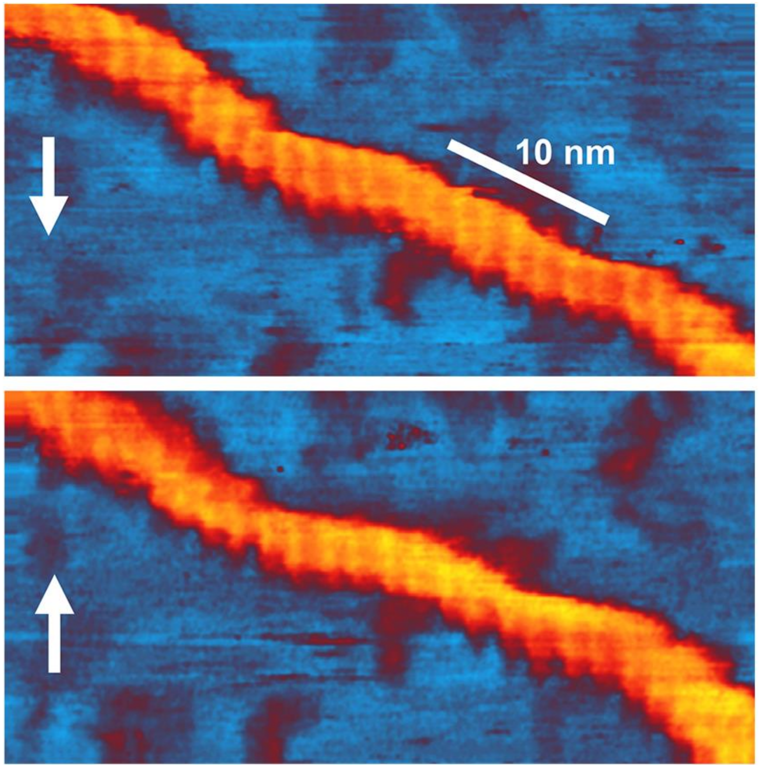
"Smaller and Quieter: Ultra-High Resolution Imaging" **www.AsylumResearch.com/Webinars**

As the cantilevers get smaller…
… better resolution

Atomic point defects



DNA Helix



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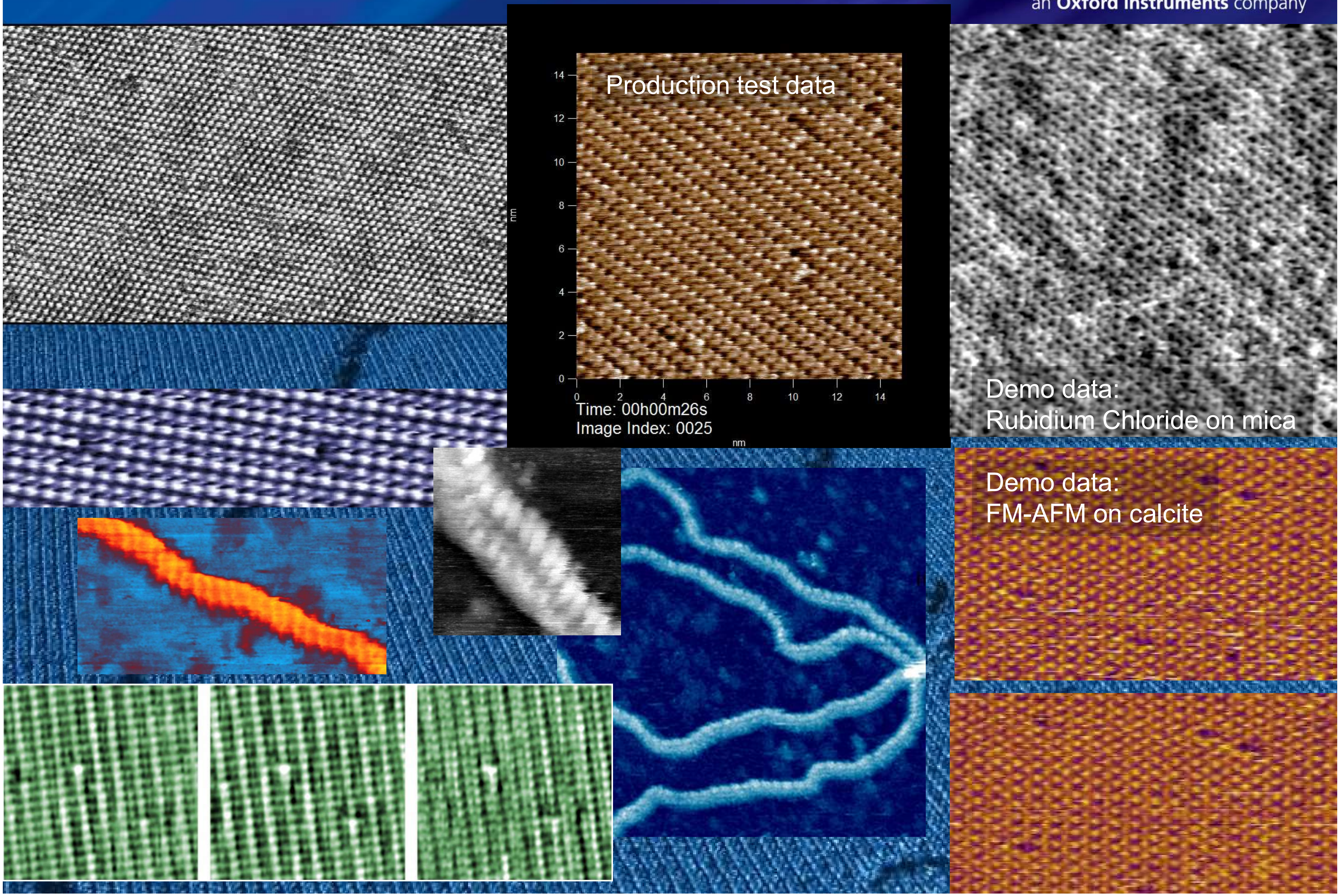
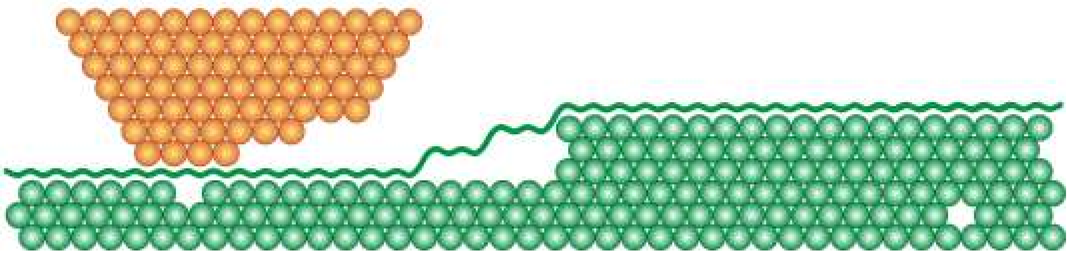
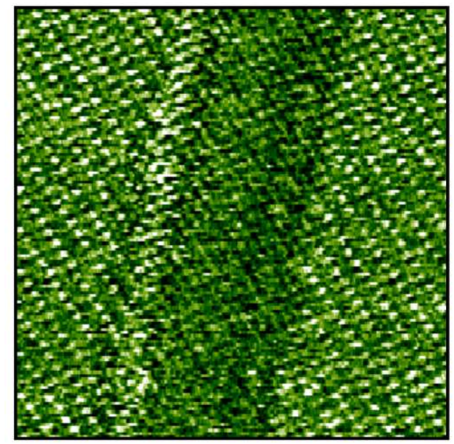
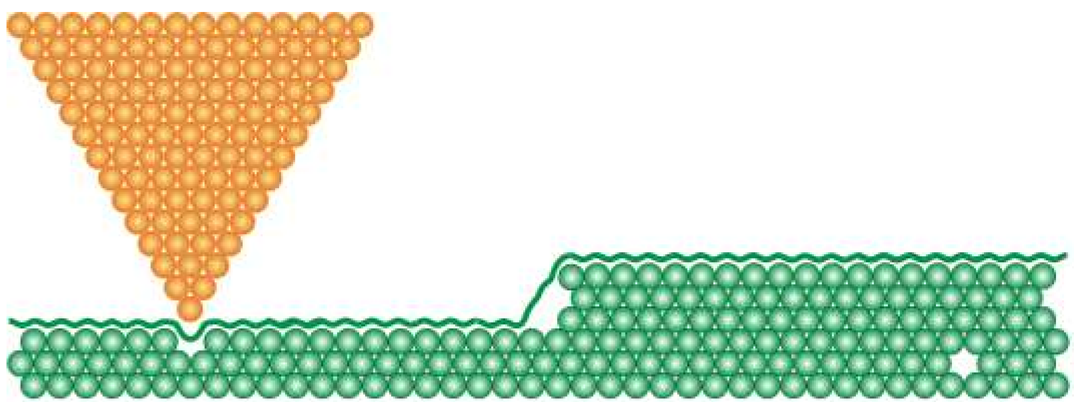
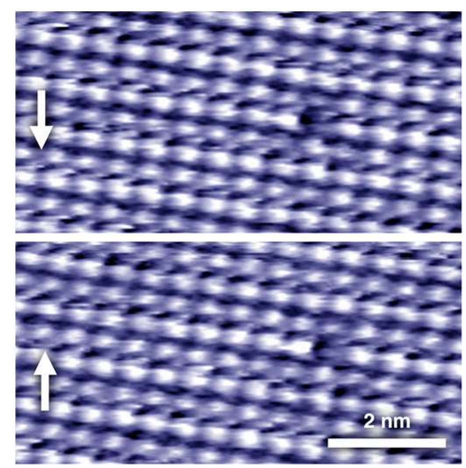


Lattice Versus Point Resolution

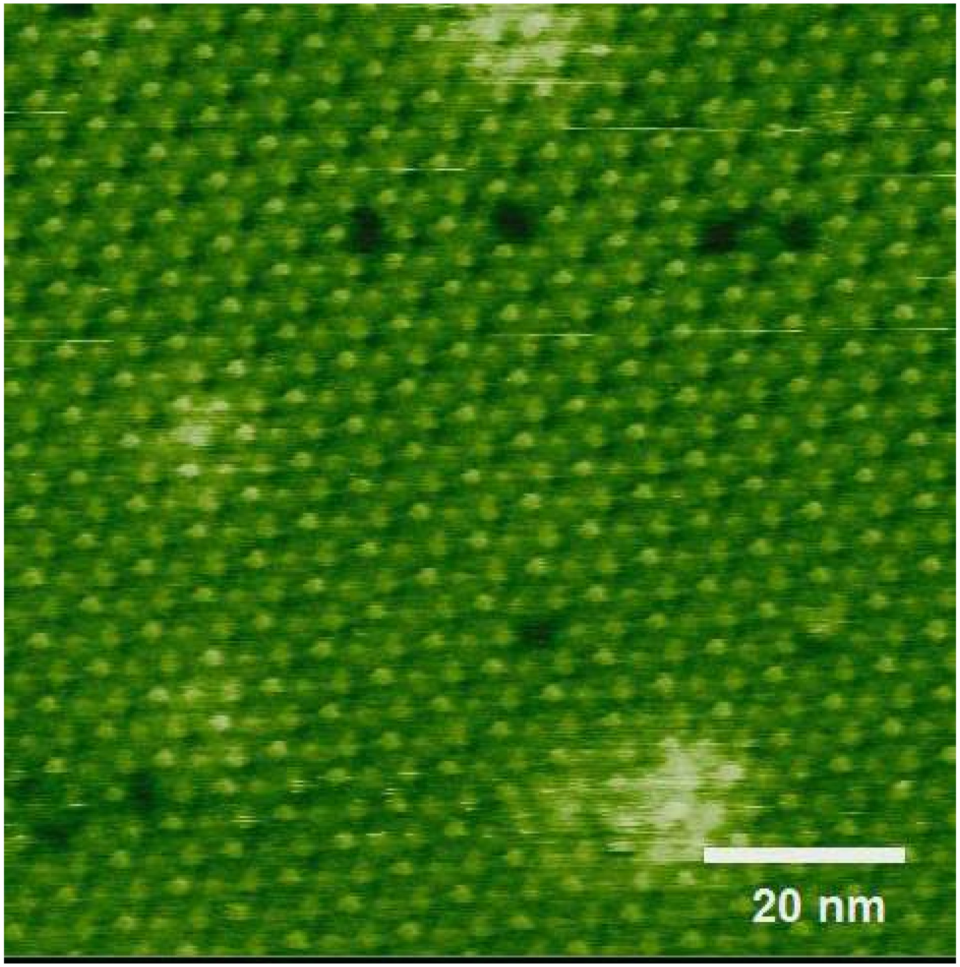








BR Defect Dynamics



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blueDrive Photothermal Excitation
A Better Tapping Mode Drive Mechanism

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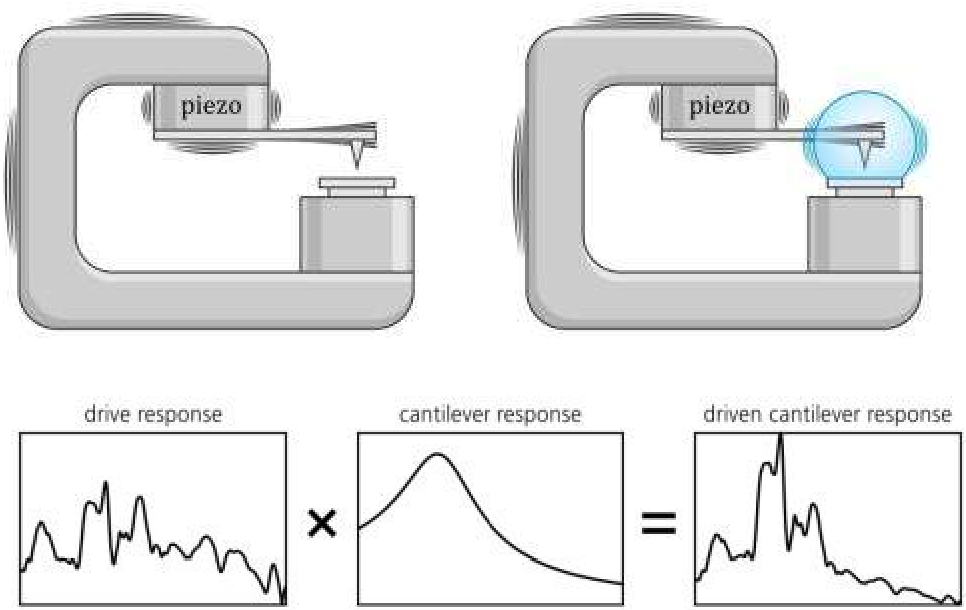
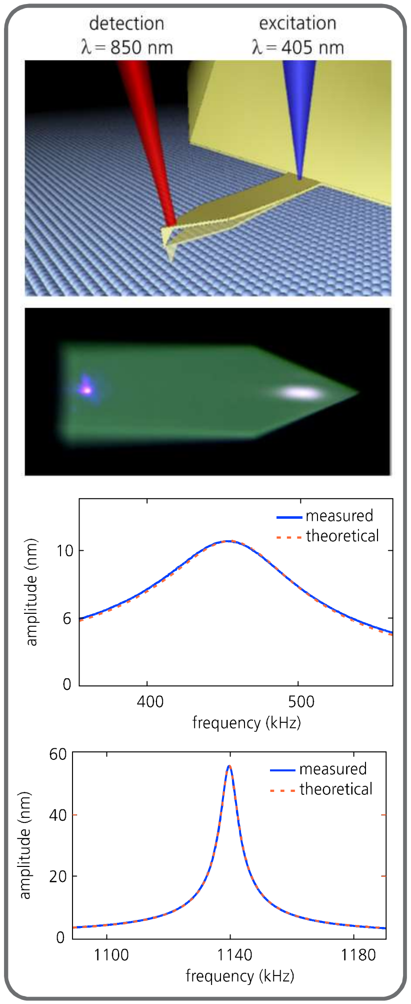


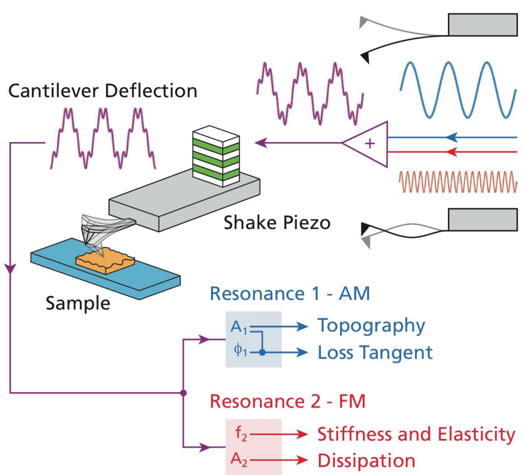
[1] T. E. Schäffer, J. P. Cleveland, F. Ohnesorge, D. A. Walters, and P. K. Hansma, *J. Appl. Phys.* **80**, 3622 (1996).

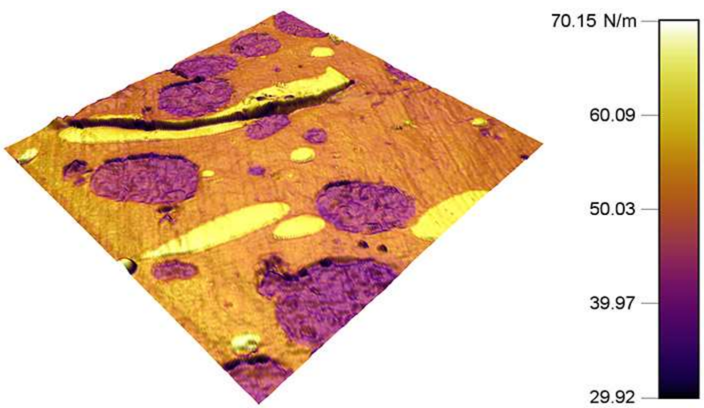


"AFM Imaging and Nanomechanics with New blueDrive™ Photothermal Excitation" **www.AsylumResearch.com/Webinars**

AM-FM Viscoelasticity Mapping

- Tapping Mode (AM)
- Higher resonance oscillation (FM)
- Frequency shifts + Phase shifts give us elastic and viscous information about the tip – sample interactions





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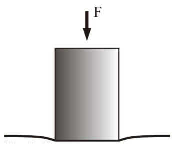
Hertz Model in AM-FM

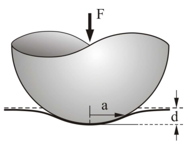
Theoretical study of the frequency shift in bimodal FM-AFM by fractional calculus

Elena T. Herruzo and Ricardo Garcia*

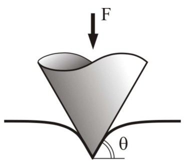
$$F_{punch}(\delta) = 2E_{punch}^{eff} R\delta$$

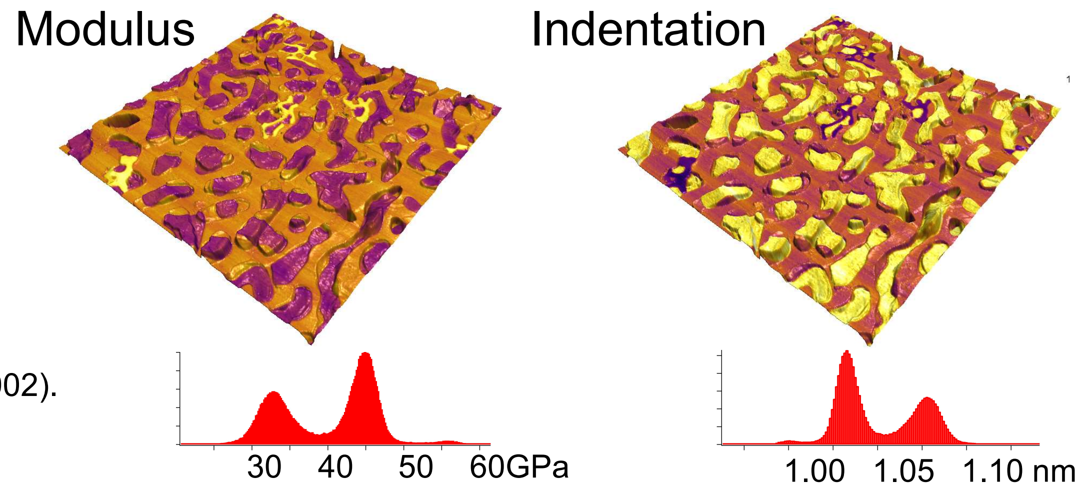


$$F_{sphere}(\delta) = \frac{4}{3} E_{eff}^{sphere} \sqrt{R}\,\delta^{3/2}$$



$$F_{cone}(\delta) = \frac{2E_{cone}^{eff}}{\pi \tan\theta} \delta^2$$





Basaran and Jiang, Mechanics of Materials 34 349 (2002).

High Speed AM-FM Modulus mapping

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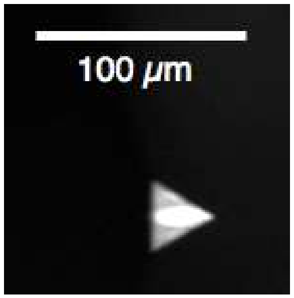
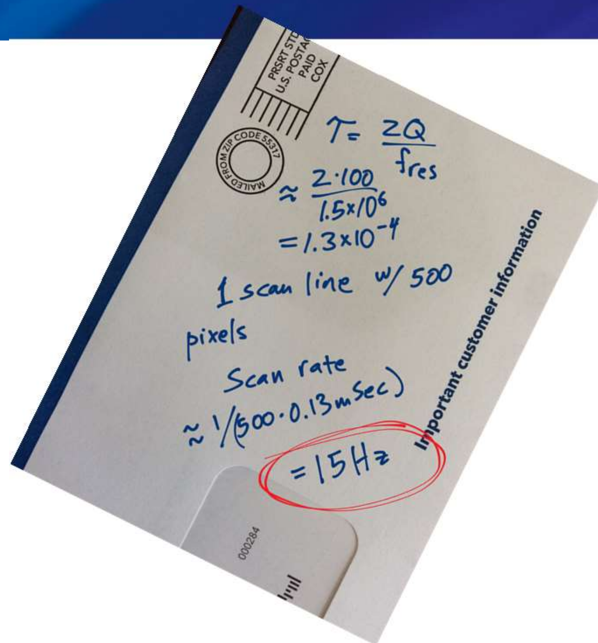
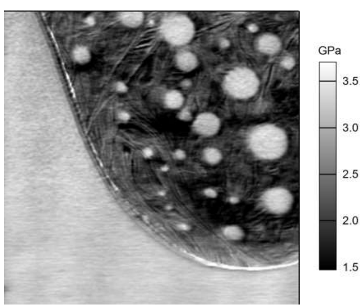


Q ~ 100
f_{res} *~1.5MHz*

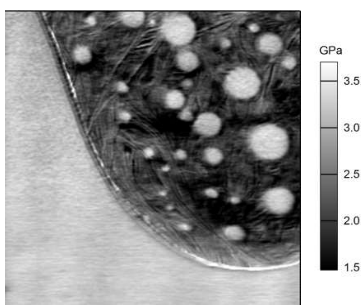


- AM-FM Speed limit:
  - first resonance Q is always the speed limit
  - Or if the second resonance is above or detector bandwidth

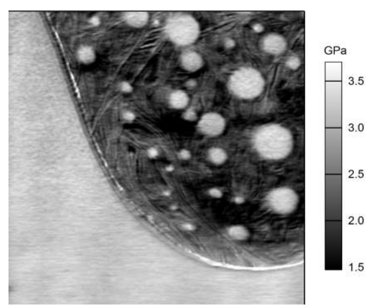
1Hz line-scan
256 sec



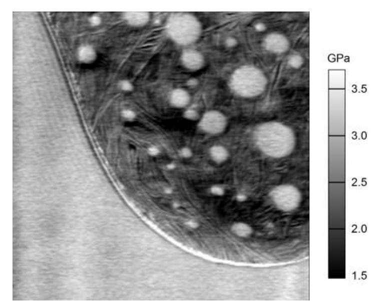
2Hz
128 sec



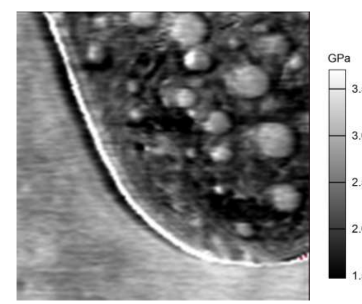
20 Hz
12.8 sec



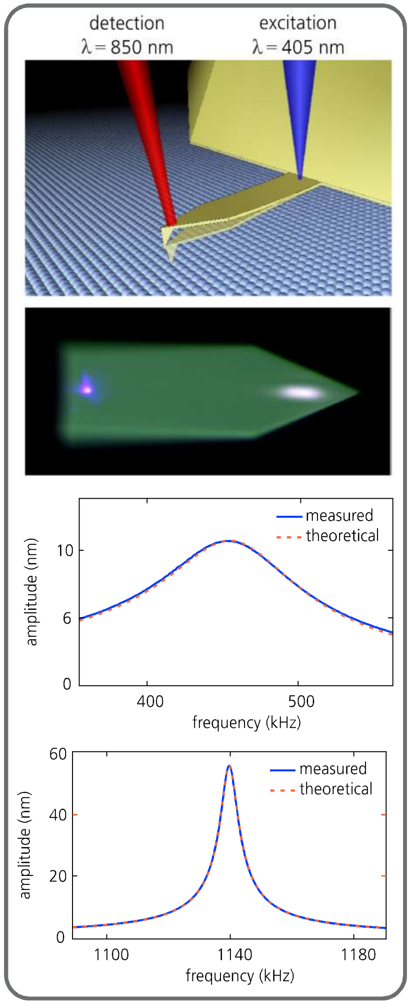
26 Hz
9.7 sec



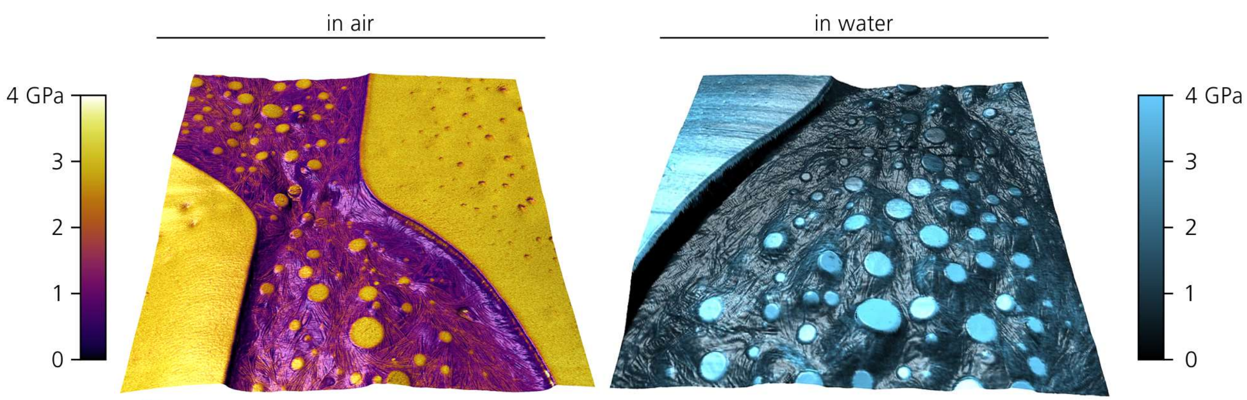
78 Hz
1.6 sec



blueDrive – Enabling Nanomechanics in Air and Liquid



Polystyrene (PS) /polycaprolactone (PCL) thin film on mica




Thank you!