blueDrive™ Photothermal Excitation

Remarkably simple, stable, and quantitative tapping mode operation

Asylum Research

Introduction

Asylum Research's **blueDrive** Photothermal Excitation option for the **Cypher**™ atomic force microscope (AFM) family makes tapping mode techniques simpler, more stable, and more quantitative. Tapping mode is by far the dominant choice in the world of AFM, measuring not just topography, but also mechanical, electrical, and magnetic properties. Typically, piezoacoustic excitation is used to drive the cantilever oscillation. Though piezo drive is favored for design simplicity, the response of the cantilever is often far from ideal. Asylum's blueDrive excitation mechanism produces an almost perfect response by directly exciting the cantilever photothermally. This provides significant performance and ease of use benefits for all tapping mode techniques.

How it works

blueDrive actuates cantilevers using photothermal excitation. In short, a second laser in addition to the usual deflection sensing laser beam is focused onto the cantilever. Modulation of the laser power directly causes vibration of the cantilever (Figure 1). The predominant mechanism of excitation is the generation of thermally-induced stresses near the base of the lever, though heating near the tip is negligible.

blueDrive leverages the modular design of the Cypher AFM family by introducing the blue laser, associated optics and positioning mechanics in a compact module that inserts into the standard Cypher S or Cypher ES optical path. The blue laser spot can be positioned independently relative to the primary spot or both can be moved in tandem with SpotOn™ automated laser alignment. The laser power can be tuned to accommodate varying drive requirements for operation in air, water and highly viscous fluids.

Simple, clean cantilever tunes

AFM cantilevers have simple frequency responses in theory. In practice though, the response of cantilevers using piezo drive is notably distorted even in air, as it drives mechanical resonances of the AFM. In liquid, additional factors make the response even worse.

Because it uses light, blueDrive excites only the cantilever, not other mechanical components in the AFM. This produces an exceptionally clean response (Figure 2). This enables simple, reliable automated cantilever tuning, even in liquids and other challenging conditions.

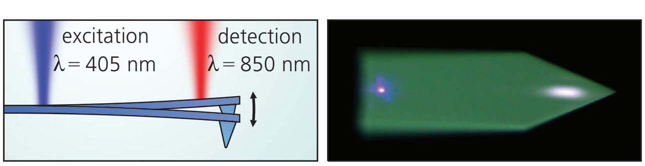

Figure 1: blueDrive concept, sketch (left), actual top-view optical image (right) showing the laser focus positions.

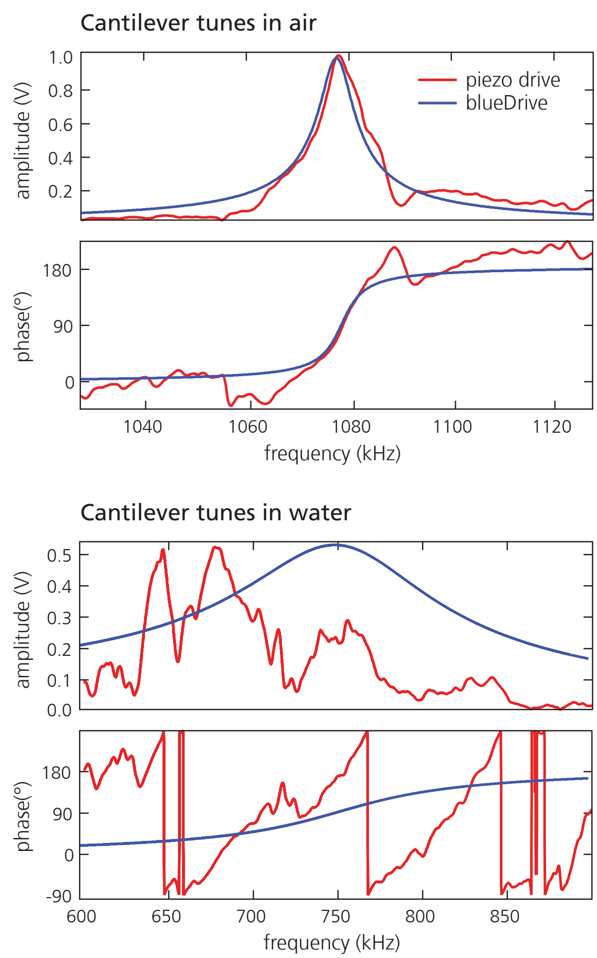

Figure 2: Cantilever response of an ArrowUHFAuD measured using piezo drive and blueDrive in air and in water. While the piezo drive response is far from ideal, the blueDrive response closely matches the thermal response.

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Remarkably stable imaging

Piezo-driven cantilever responses are not only distorted, but they also vary with time. As the response drifts relative to the setpoint, the tip-sample force changes. It can be difficult to distinguish true sample dynamics from artifacts of this drift.

The direct excitation provided by blueDrive is highly immune to drift in the cantilever response. The imaging force remains stable throughout the experiment and under full control. This enables stable imaging over extended durations with no need to readjust the amplitude setpoint (Figure 3). The phase response also remains stable, making it more straightforward to interpret.

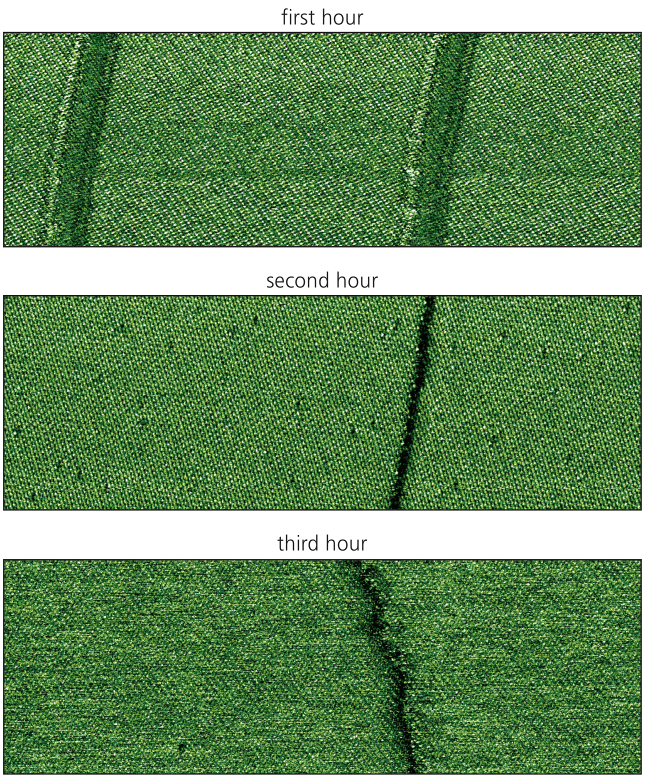

Figure 3: blueDrive was used to image calcite atoms and step edges in water for several hours with no user intervention. Because blueDrive provides a constant driving force, changes in the atomic resolution contrast can be confidently attributed to slight rearrangements of the tip apex. Interestingly, these tip apex changes led to higher resolution imaging in the second hour, when well resolved atomic point defects could be observed.

More quantitative results

The cantilever response, amplitude and phase, is interpreted quantitatively in many tapping mode techniques including nanomechanical techniques like AM-FM Viscoelastic Mapping, Loss Tangent Imaging, and Contact Resonance Viscoelastic Mapping. Often, these analyses assume a clean cantilever response (e.g. simple harmonic oscillator model). The accuracy of the derived physical information is therefore limited by the quality and stability of the cantilever response.

The measured resonance using blueDrive is incredibly clean and consistent with the theory for both AM-FM and contact resonance. Therefore the frequency, phase and quality factor can all be measured and tracked with greater accuracy and precision, yielding more accurate material properties.

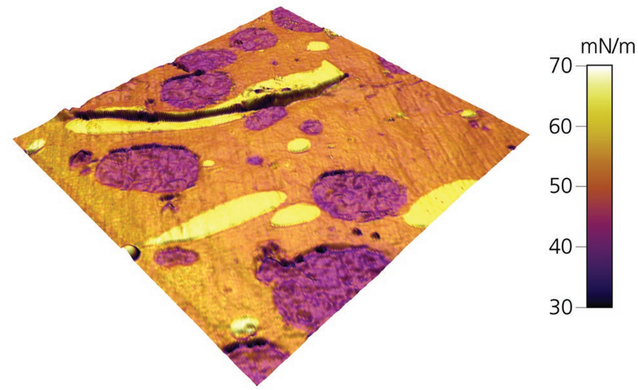

Figure 4: Ternary polymer blend imaged with AM-FM Viscoelastic Mapping mode using blueDrive excitation. Stiffness data is overlaid on topography, 15 µm scan. Sample courtesy of D. Yablon and A. Tsou, ExxonMobil Research and Engineering, Corporate Strategic Research.

Specifications

- User-adjustable blueDrive DC power in five ranges, 0.1 mW, 0.3 mW, 1 mW, 3 mW and 10 mW
- Drive frequency up to 8 MHz
- Certified FDA/IEC Class 1 (non-hazardous) 405 nm laser diode with fail-safe interlocks

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