Fundamentals of Atomic Force Microscopy
Part 2: Dynamic AFM Methods

Week 5, Lecture 5
Dynamic AFM in Liquids II

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From the last lecture

- Tip-sample forces in liquids
- Electrostatic + van der Waals forces (DLVO theory Derjaguin-Landau-Verwey-Overbeek)
  - Hydration forces
  - Hydrophobic interactions/Nanobubbles
  - Steric forces
Cantilever dynamics in liquids

- Resonance frequency and Q-factor

- Resonance freq in water can be 3-5 times less than in air.
- Surrounding fluid adds inertia and damping.
- It is tempting to assume that the dynamic AFM theory based on point mass model can be used here too using different Q factor.
Cantilever dynamics in liquids

- **Eigenmodes**

- Added liquid mass dilutes the effect of tip mass
- Stiffness of second mode in water is much smaller than in air

Mechanisms and observables are different!


- Acoustic vs. direct (magnetic)excitation

- Fluid-borne excitation

- Structure-borne excitation
Acoustic vs. direct (magnetic) excitation

The dither piezo, the chip holder, the chip are all “sub-structures” with their own resonances.

As a result the base motion for cantilever is not constant with drive frequency.

These peaks generally have Q factors around 10.

So in air cantilever Q>100 so no problem and a clean peak appears.

However in water cantilever Q<5 so the sharpest peaks are in fact the substructure resonances.

Each peak corresponds to the resonance of a substructure.

\[ z_{\text{base}}(t) = Z_0 \sin(\omega t) \]

But \[ Z_0 = Z_0(\omega) \]
“Solving” the forest of peaks problem

  - Brought dither piezo much closer to cantilever

  - Inserted clay damper

- Asakawa, Fukuma, Rev. Sci. Instrument, 80, 103703, 2009
  - Acoustic impedance mismatch using PEEK+flexure stage
How does a tip tap in liquids?

Many difference in approach curves between air and liquids

How does a tip tap in liquids?


Experiments:
- 0.3 N/m rectangular lever
- 0.1 N/m triangular lever