Fundamentals of Atomic Force Microscopy
Part 2: Dynamic AFM Methods

Week 1, Lecture 1
Introduction to Dynamic AFM

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The “force” in AFM is the tip-sample interaction between 100’s of tip and 100’s of sample atoms.
Disadvantages of static AFM

- Static AFM measures force as a function of Z
- The position of the tip where the forces balance is given by
  \[ F_{ts}(Z+q) = k_c q \]
- Range of “d” values inaccessible due to snap-in and pull-off
- Non-unique F-d for a given F-Z
- Large lateral forces while scanning
How to measure small forces between an AFM tip and a sample?

Static “spring balance”

Dynamic “oscillator based sensor”

Measuring force via cantilever static mechanics

Sensing force gradients by cantilever dynamics
A set of diverse AFM methods where cantilever is driven at a mechanical resonance.

Dynamic AFM methods

- Dynamic AFM methods
- Freq. modulation AFM atom identification
- Kelvin Force Microscopy
- Scanning Tapping mode or Amplitude Modulation AFM

Kelvin Force Microscopy
S. Magonov, and J. Alexander
Beilstein Journal of Nanotechnology, 2, 15, 2011

Freq. modulation AFM atom identification
The point mass model

- The tip motion $q(t)$ in the point-mass model must be identical to that of the actual cantilever.
- $\frac{1}{2} kq^2$ captures the potential energy stored in the bending of the lever.
- $\frac{1}{2} m (\dot{q})^2$ captures the total kinetic energy of the oscillating lever + tip.
- Resonance frequency $\omega_0$ of point-mass model must equal that of the actual probe.

**Point mass model**

- First, consider the tip motion without $F_{ts}$

  **Free body diagram**

$$k \, q(t) + c \, \frac{dq}{dt} = c \, \ddot{q}$$

- Effective mass 'm'
- Effective spring constant 'k'
- Damping coefficient 'c'

- From Newton's law
  “Simple harmonic oscillator”

$$m \ddot{q} = -k \, q - c \, \dot{q}$$

Or

$$m \ddot{q} + c \, \dot{q} + k \, q = 0 \quad (1)$$

- Differential equation – 2nd order, linear, autonomous