Instrumentation

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Optical beam deflection detection Method

• Force Sensing method
  ◆ tunneling detection
  ◆ capacitance detection method
  ◆ interferometry method
    ✓ somewhat complicated
  ◆ optical beam deflection detection method
    ✓ most commonly used method
    ✓ laser diode(λ=670nm)
    ✓ bicell photodiode
**Detection mechanism**

- L: distance between PSD and cantilever
- \( \vartheta \): incident angle with z axis in the yz plane
- \( \varphi \): the deflection angle of cantilever by \( F_{\text{ext}} \)
- \( \delta z \): change of z coordinate of cantilever by \( F_{\text{ext}} \)
- \( \lambda \): length of cantilever

\[
\Delta x \approx 2L \cos \vartheta \left( \frac{\delta z}{\lambda} \right)
\]

\[
\Delta y = 0
\]

\[
\Delta z \equiv -2L \cos \vartheta \left( \frac{\delta z}{\lambda} \right)^2
\]
For $L=2cm$, $\theta=45^\circ$, $\lambda=200\mu m$

$$\Delta x \cong 140\delta Z$$

Design of Mechanical Parts

* design consideration
  * rigidity and stability
    - mechanically stiff and symmetric
  * head
    - optical beam deflection system
    - metal box for preamplifier
  * base
    - scanner with XY-translational stage
    - tip-sample approaching system
  * optical microscope
    - long-working-distance objective
    - CCD camera with video monitor
tip-sample approaching system

- coarse approach
  - two thumbscrews
- fine approach
  - stepping motor (1.8°/pulse)
  - micrometer (0.5mm/turn) with worm gear (1/80)
  - approaching rate: 40Å/pulse

scanner

- piezoelectric tube with sample holder
- XY-translational stage
- maximum scan area: 40μm×40μm
- calibration
  - Michelson-Moley interferometry
Scanning Force Microscope

video monitor
cantilever

▫ commercial cantilever with ‘V’ shape

▫ contact mode

✓ Si$_3$N$_4$, k=0.064N/m, $\omega_0$=17kHz
✓ microlever : pyramidal tip

▫ noncontact mode

✓ doped Si, k=2.1N/m, $\omega_0$=109kHz
✓ ultralever : conical tip
Electronics Parts

- block diagram of SFM electronics
  - feedback circuit
  - scan size controller and PZT driver
  - stepping motor controller
  - computer interface
  - rms-to-dc converter
  - two lock-in operation
• PZT tube driving circuits
  ✷ high voltage amp. for X-Y piezo
  ✔ X_in : inputs from D/A converter via size and offset controller
  ✔ +x_HV:200V-600V
  ✔ -x_HV:600V-200V
  ✔ Δx_HV:-400V - +400V
✧ high voltage amp. for Z-piezo
✓ Z_in: feedback output, output from computer via D/A converter
✓ z_HV: 0V - 300V
I/O interface
- 8255 PIO(programmable input/output)
- A/D converter
- multiplex(SPC 16s)
  - A-B, data, set value, scan size, rms etc.
- D/A converter
  - x scan, y scan, z reference and bias
- feedback ON/OFF
- pulse signal for stepping motor
Software

- data acquisition
  - 256×256 pixels
  - simultaneous acquisition of two data
  - sectioning profile
  - monitoring of force and amplitude
force spectroscopy
  ✷ amplitude-frequency curve
    ✓ selecting operation frequency
  ✷ force-distance curve
    ✓ force set in contact mode
  ✷ amplitude-distance curve
    ✓ selecting operation mode in ac mode
  ✷ amplitude-bias curve
    ✓ scanning potentiometry application