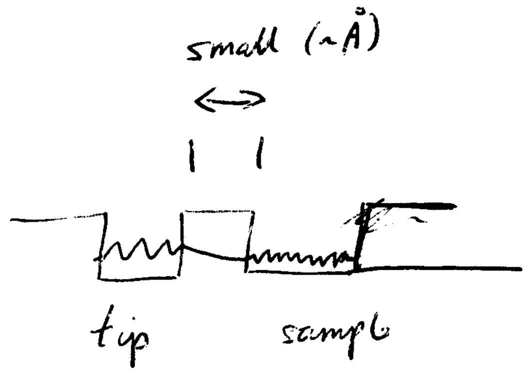
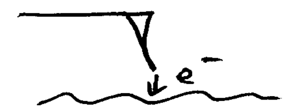


① QM Tunnelling

STM

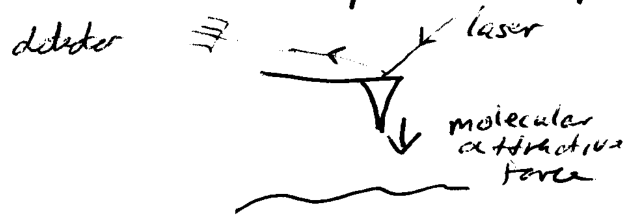




current flows when tip brought close enough to the sample surface for electron wavefunction in tip to overlap with surface. e^- tunnels through vacuum barrier. Current a very sensitive fn of separation $I(x) \sim e^{-x}$
Can Adjust cantilever height using piezos.

AFM

no current involved $\Rightarrow$ can use insulating samples.
Measure deflection of cantilever using reflected laser.
Uses Van der Waals attraction between tip and sample to bend cantilever.



VdW also very sensitive fn of tip-surface separation.

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② (a)

$$E = \frac{1}{2}mv^2 = \frac{p^2}{2m}$$

de Broglie: $\lambda = \frac{h}{p} \Rightarrow p = \frac{h}{\lambda}$

$$E = \frac{h^2}{2m\lambda^2}$$

$$\lambda^2 = \frac{h^2}{2mE} \Rightarrow \lambda = \frac{h}{\sqrt{2mE}}$$

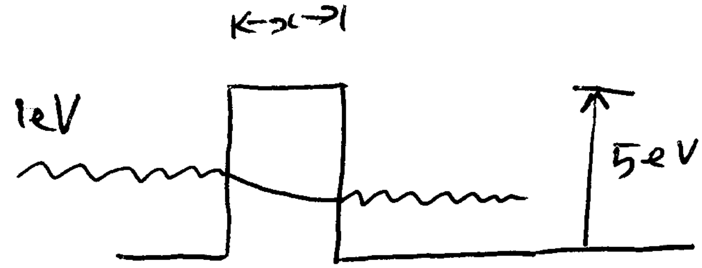
$$= \frac{6.6e{-34}}{\sqrt{2 \; 9.1e{-31} \; 5e4 \; 1.6e{-19}}}$$

$$= 5.47e{-12}\ m$$

$$= 5.5\ pm$$

Interatomic spacing typically 1Å–5Å which is greater than λ.
(so can use e^- to probe atoms)

(3)



$T(E) \propto e^{-2\alpha x}$ where x is barrier width

$\alpha = \frac{\sqrt{2m(U-E)}}{\hbar}$ — $(U-E)$ is (barrier height − e⁻ energy) $= (5-1) = 4eV$

say

$T(E) \propto = A e^{-2\alpha x} = A e^{-2\alpha_E x}$

↑ some const

$$\frac{T(1.5)}{T(1)} = 5 = \frac{A e^{-2\alpha_{1.5} x}}{A e^{-2\alpha_1 x}}$$

$$5 e^{-2\alpha_1 x} = e^{-2\alpha_{1.5} x}$$

$$\log 5 + (-2\alpha_1 x) = (-2\alpha_{1.5} x)$$

$$\log 5 = (\alpha_1 - \alpha_{1.5}) 2x$$

$$x = \frac{\log 5}{2(\alpha_1 - \alpha_{1.5})}$$

$$\alpha_1 = \frac{\sqrt{2m(5-1)}}{\hbar} = 1.027e10$$

$$\alpha_{1.5} = \frac{\sqrt{2m(5-1.5)}}{\hbar} = 9.61e9$$

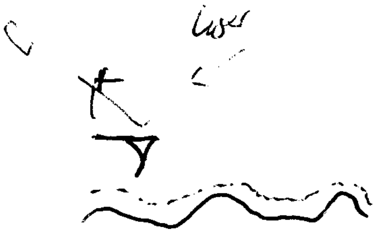
$$\alpha_1 - \alpha_{1.5} = 6.59e8$$

$\rightarrow x = 1.22e-9$

↑ check this number!

(4)

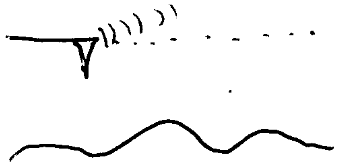
contact mode:



Tip touches surface and tracks the changes in topography whilst keeping force constant. "constant force imaging". Probes short-range atomic forces.

non-contact mode:

vibrating tip freq ν



Tip farther from surface ← ∴ Probes long-range atomic forces. Keeps height constant & measures changes in force. The changes in force change the resonance frequency of the tip. Less likely to crash surface.

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(5)

$$E = \frac{k_B T}{2}$$ ← Boltzmann

Thermal vibration amplitude A

for a spring, max vibration amplitude when all energy in spring (mass at rest) $E = \frac{1}{2} k A^2$ ← spring const

$$\frac{k_B T}{2} = \frac{k A^2}{2} \Rightarrow A = \sqrt{\frac{k_B T}{k}}$$

$$= \begin{cases} 0.743\ \text{Å} & T = 400\text{K} \\ 0.326\ \text{Å} & T = 77\text{K} \end{cases}$$

← kelvin

so get much better res at lower temps.

⇒ often cool w/ liquid He

(6)

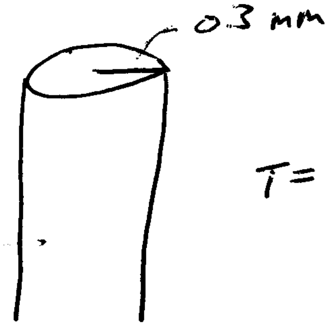
Ta is type I superconductor

nb critical magnetic field a Std-temp

↓

$B_c(0) = 0.824\,T$

$T_c = 4.47\,K$



$T = 4.2\,K$

(a) $B_c(4.2K) = B_c(0)\left[1 - \left(\frac{T}{T_c}\right)^2\right]$ from lectures

$= 0.824\left[1 - \left(\frac{4.2}{4.47}\right)^2\right]$

$= 9.7e{-3}$ Tesla

(b) $B = \frac{\mu_0 I}{2\pi r}$

μ_0 ← permeability of free space

r ← dist from center(?) of wire (Hmm.....)

$I_c = \frac{2\pi B_c r}{\mu_0} = \frac{2\pi\,(9.7e{-3})\,(0.3e{-3})}{4\pi e{-7}} =$ ~~17911 A~~ 14.568 A

↑ Huge! I have my doubts...

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(7) NbTi is type II superconductor.

$B_c(4.2) = 15\left[1 - \left(\frac{4.2}{9.3}\right)^2\right] = 11.94\,T$ Much bigger!

$I_c = \frac{2\pi\,(11.94)\,(0.3e{-3})}{4\pi e{-7}} = 17911\ A$

↑ really Huge!

(8) Don't do this – we haven't done super Pairs.