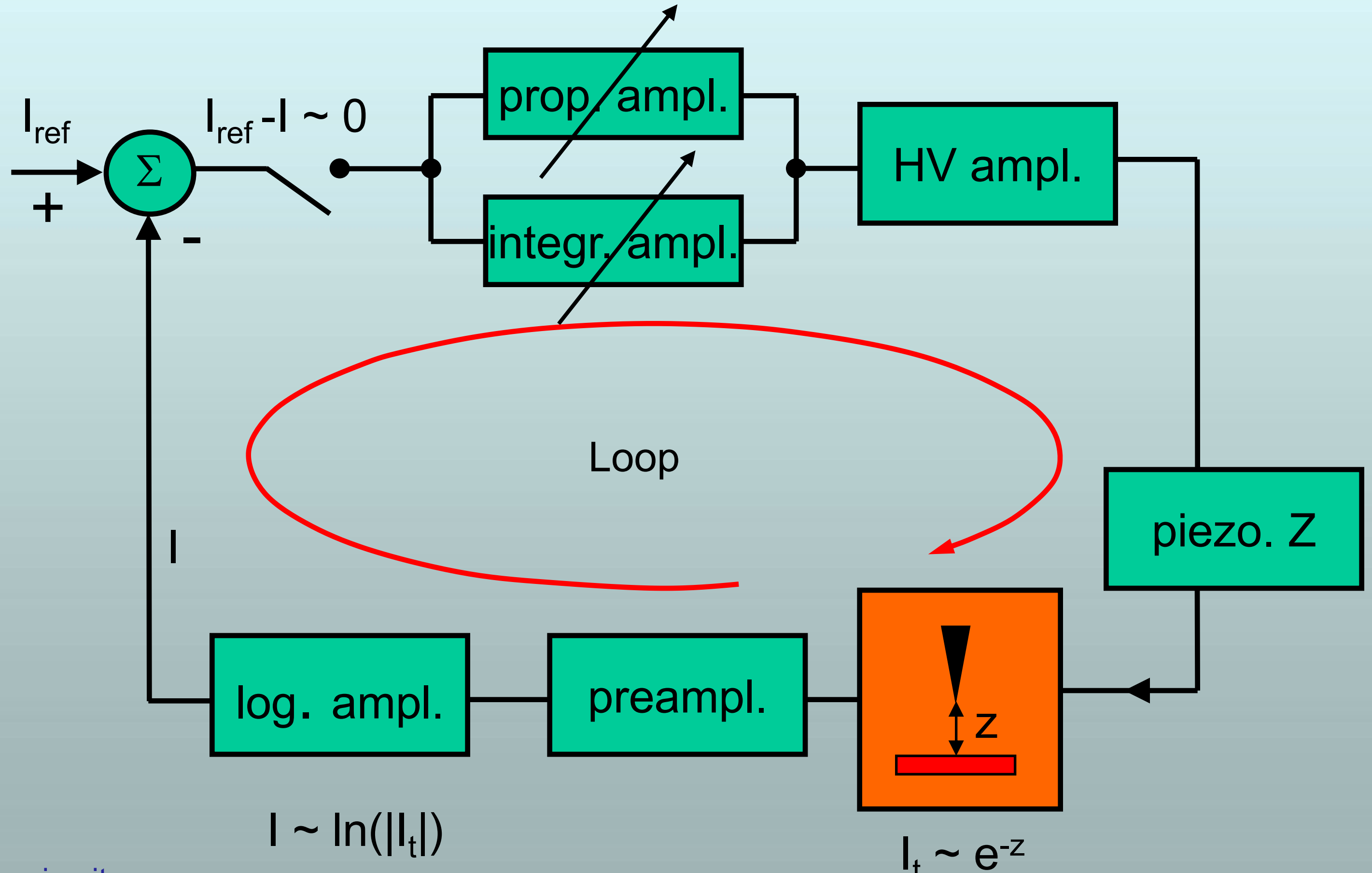
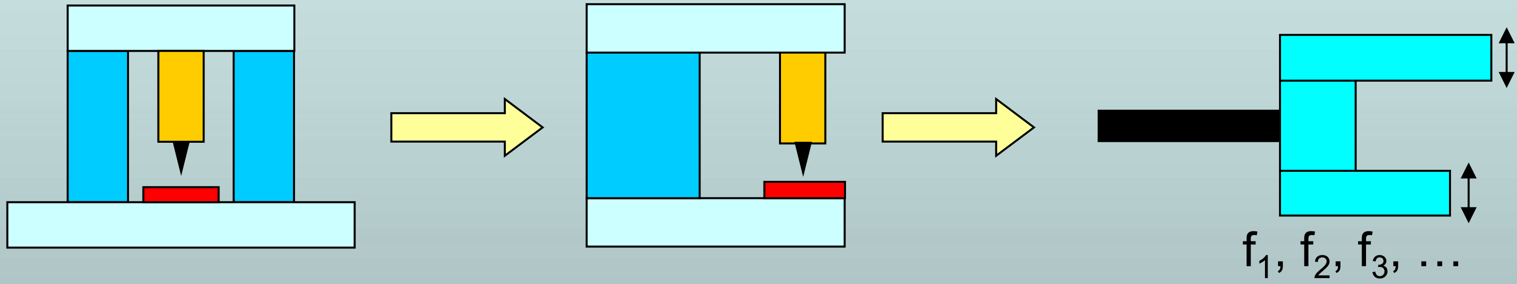
Basics of STM operation - electronics



Sample bias circuit
not shown

Microscope as a set of mechanical resonators

Most important mechanical parameters:
- resonant frequency,
- mechanical coupling with other parts

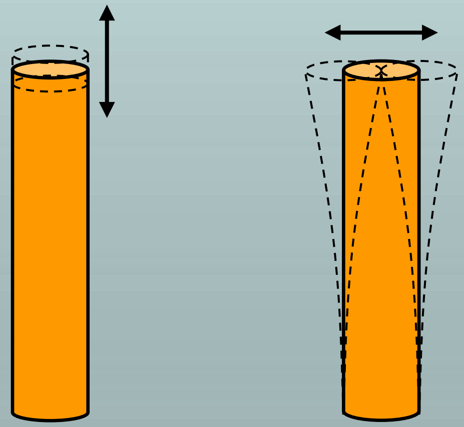


Demanded properties of well designed STM:
- high and well separated resonant frequences of particular parts,
- low quality of resonance

Minimal (required) frequency of resonance

For 400 lines x 400 pixels x 1 picture /30 sec.
frequency band of f = 5333 Hz is required.
Mechanical system of STM (critically dumped) remains stable if resonant frequency is larger than fx2 = 8377 Hz.
Z – control requires even larger resonant frequency of the scanner tube.

L = 25.4 mm
D = 6.5 mm
w = 0.7 mm



f_1 = 30 kHz

f_2 = 3 kHz

For scanner tube:

1. use short tube (low scanning range),
2. short tip,
3. low mass of the tip.

Electronic feed-back cotrol

What is right feed-back?

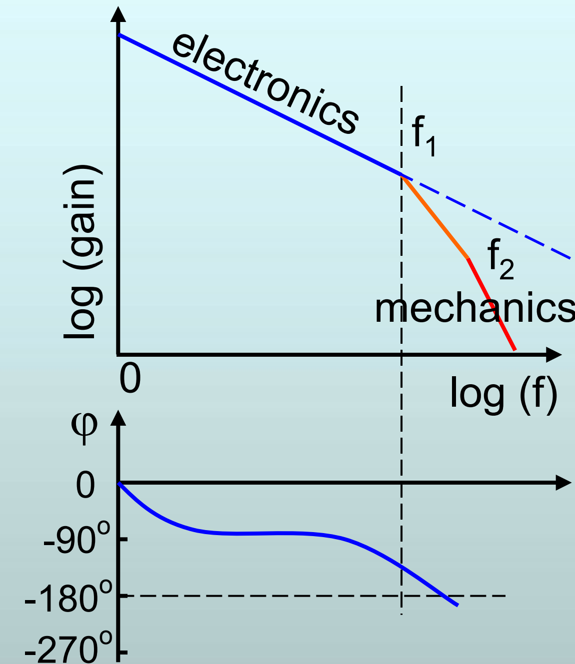
*

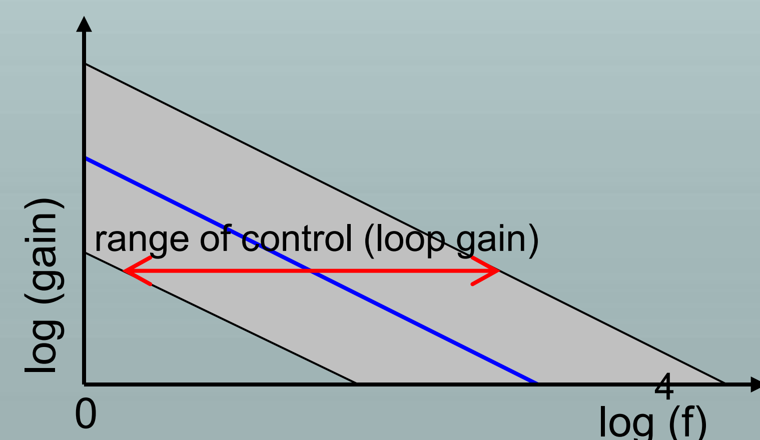
electronics + mechanical parts act as low-pass filters

*

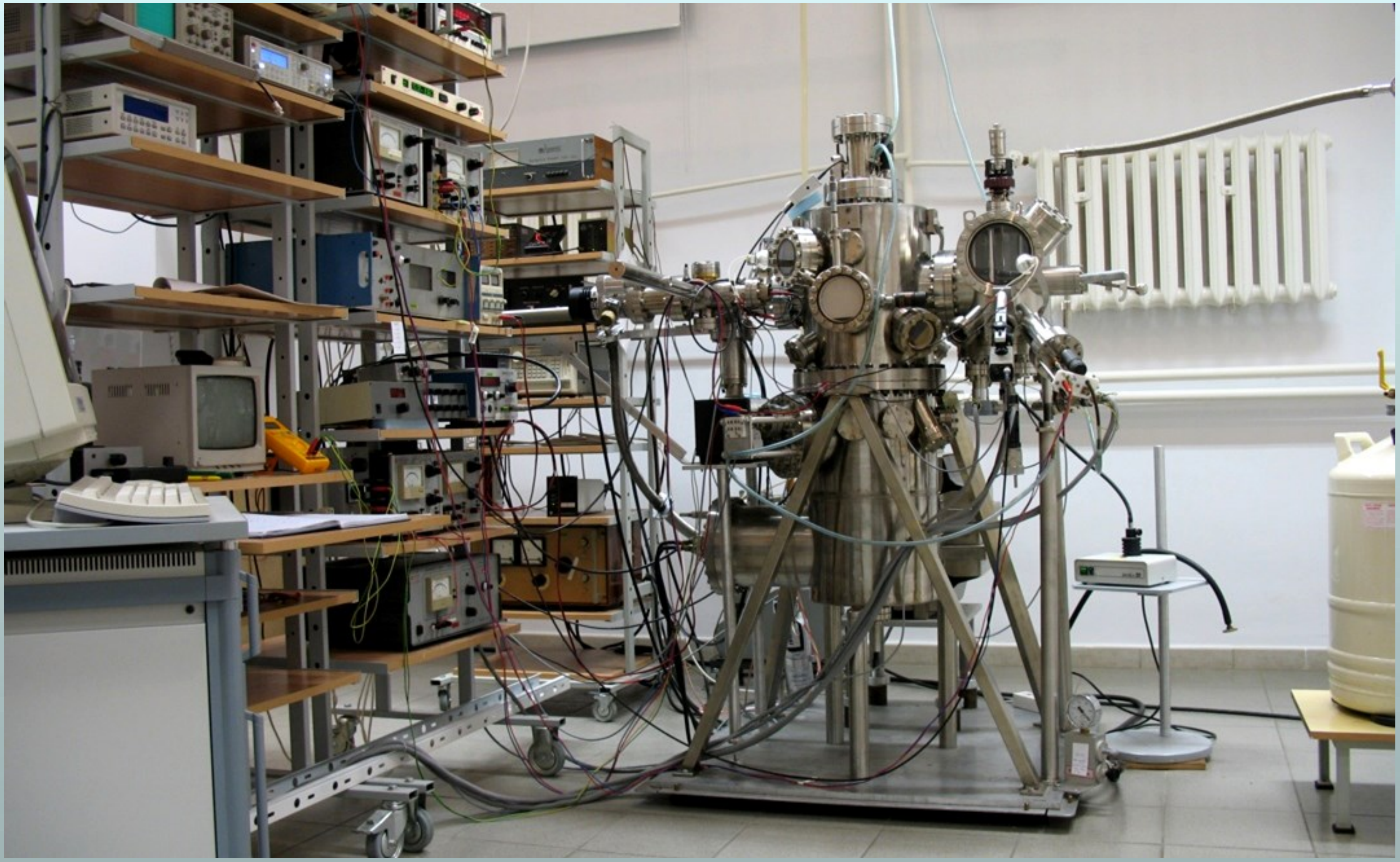
strong (fast reaction) for topographical meas.
weak (slow reaction) for current measurement
no feed-back for spectroscopy

The gain has to be sufficiently low to avoid change of the negative feed-back into positive feed-back at high frequences.

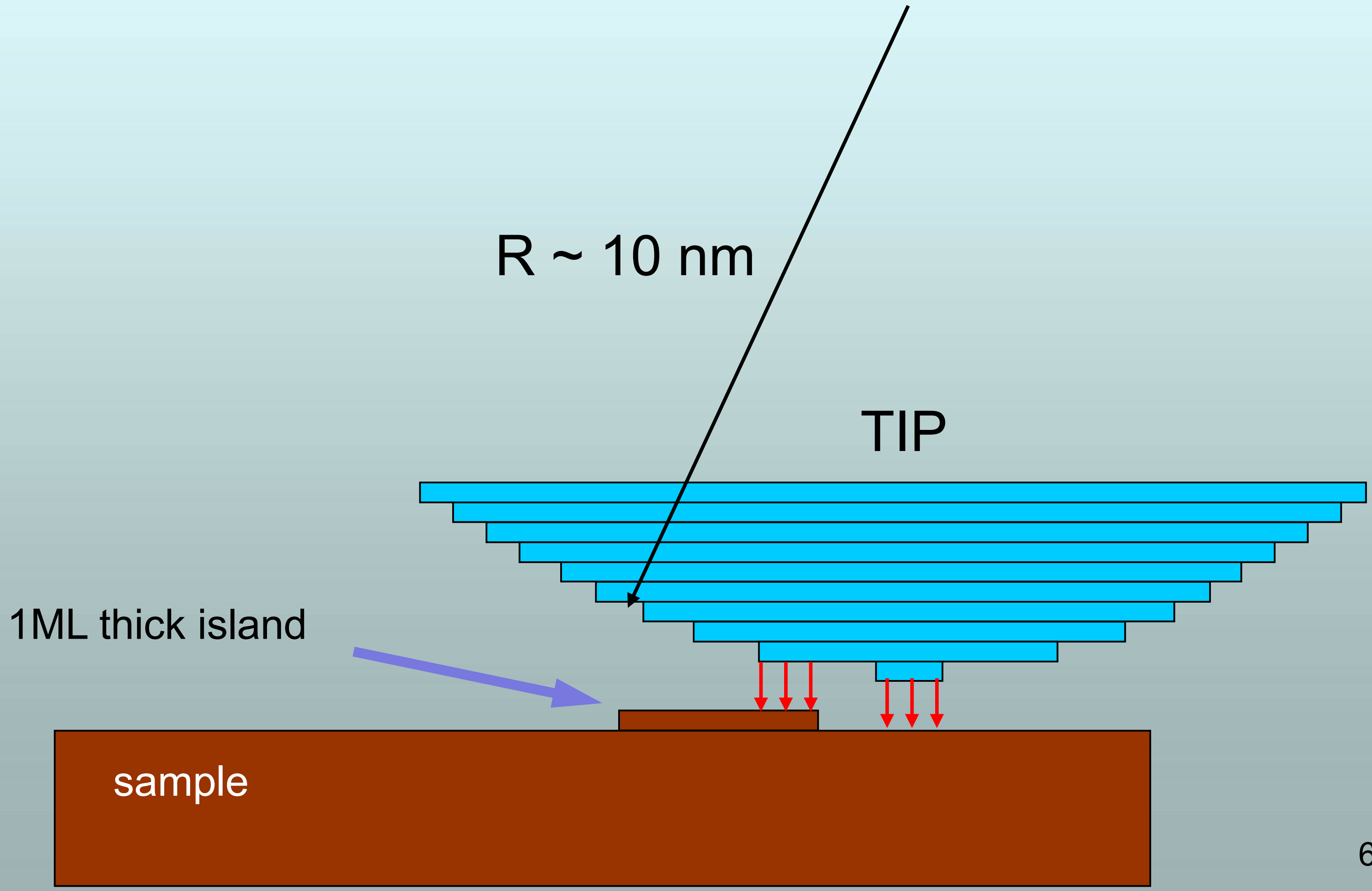




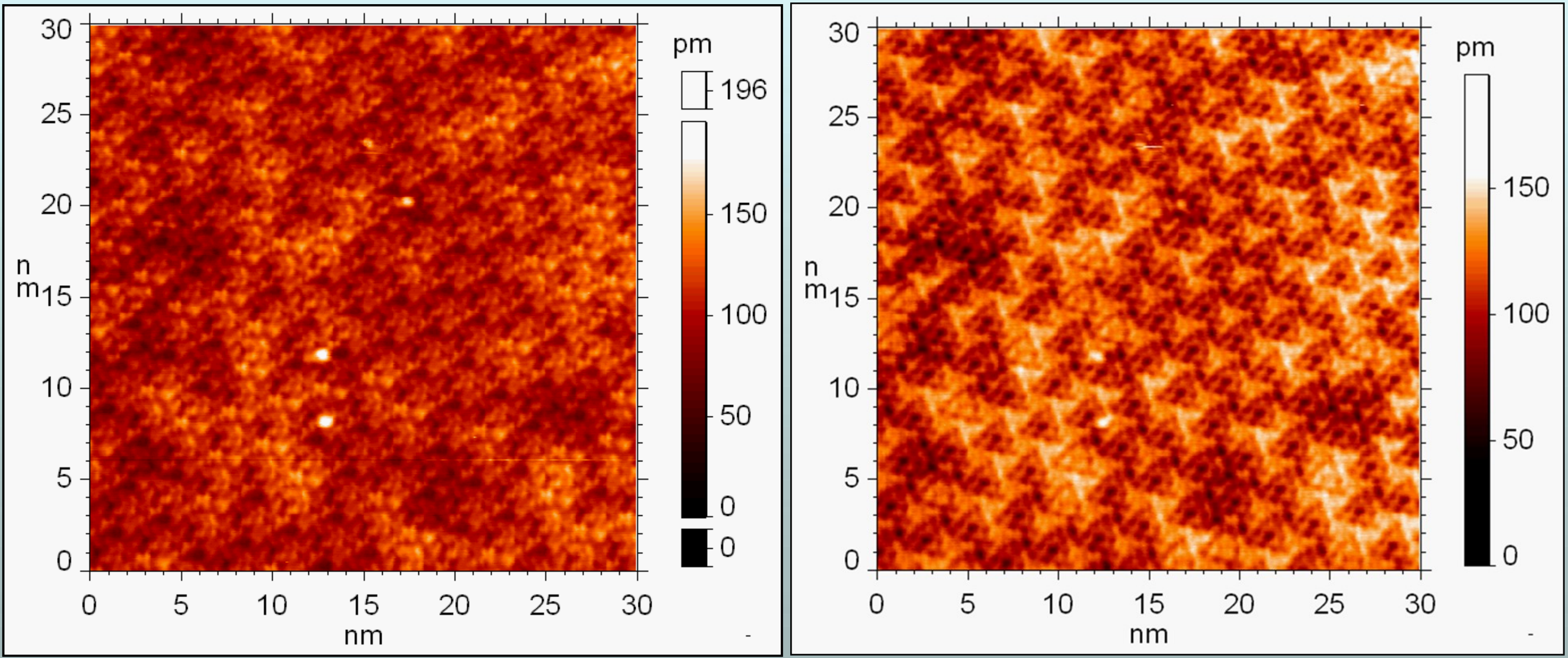
Microscope at UMCS



Tip size vs atomic structures - scale preserved

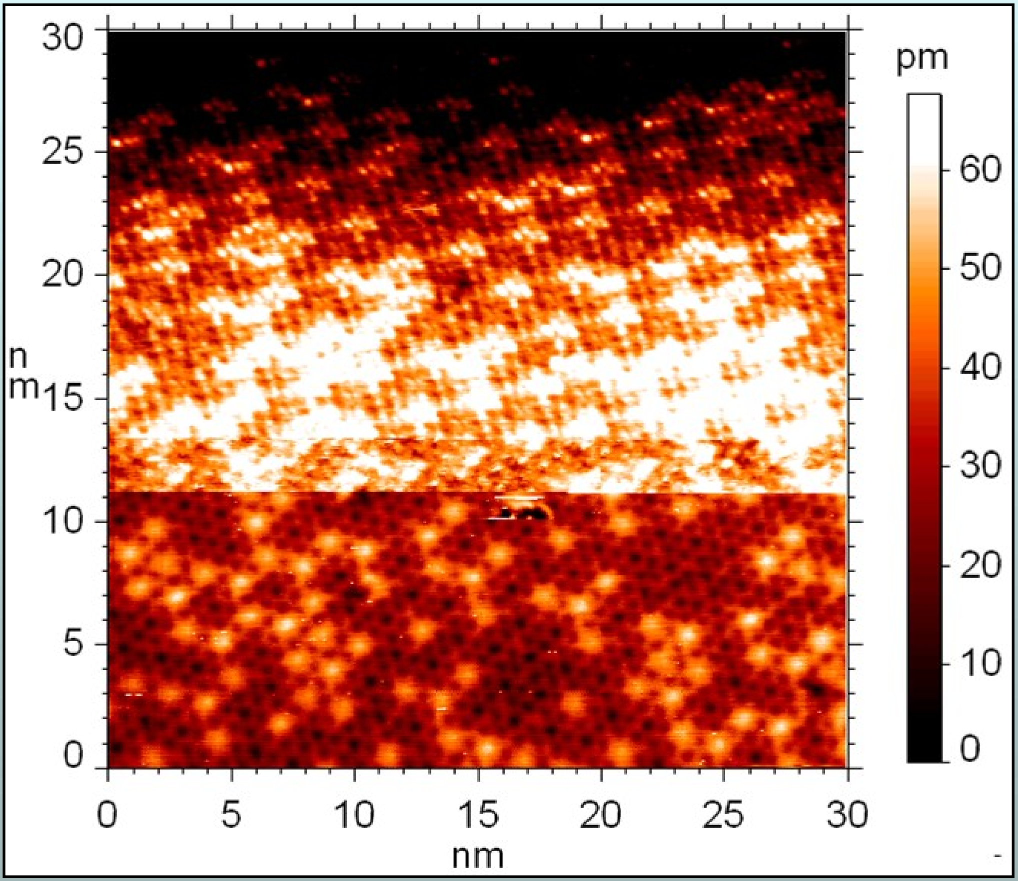


Typical false images - blunt tip vs sharp tip



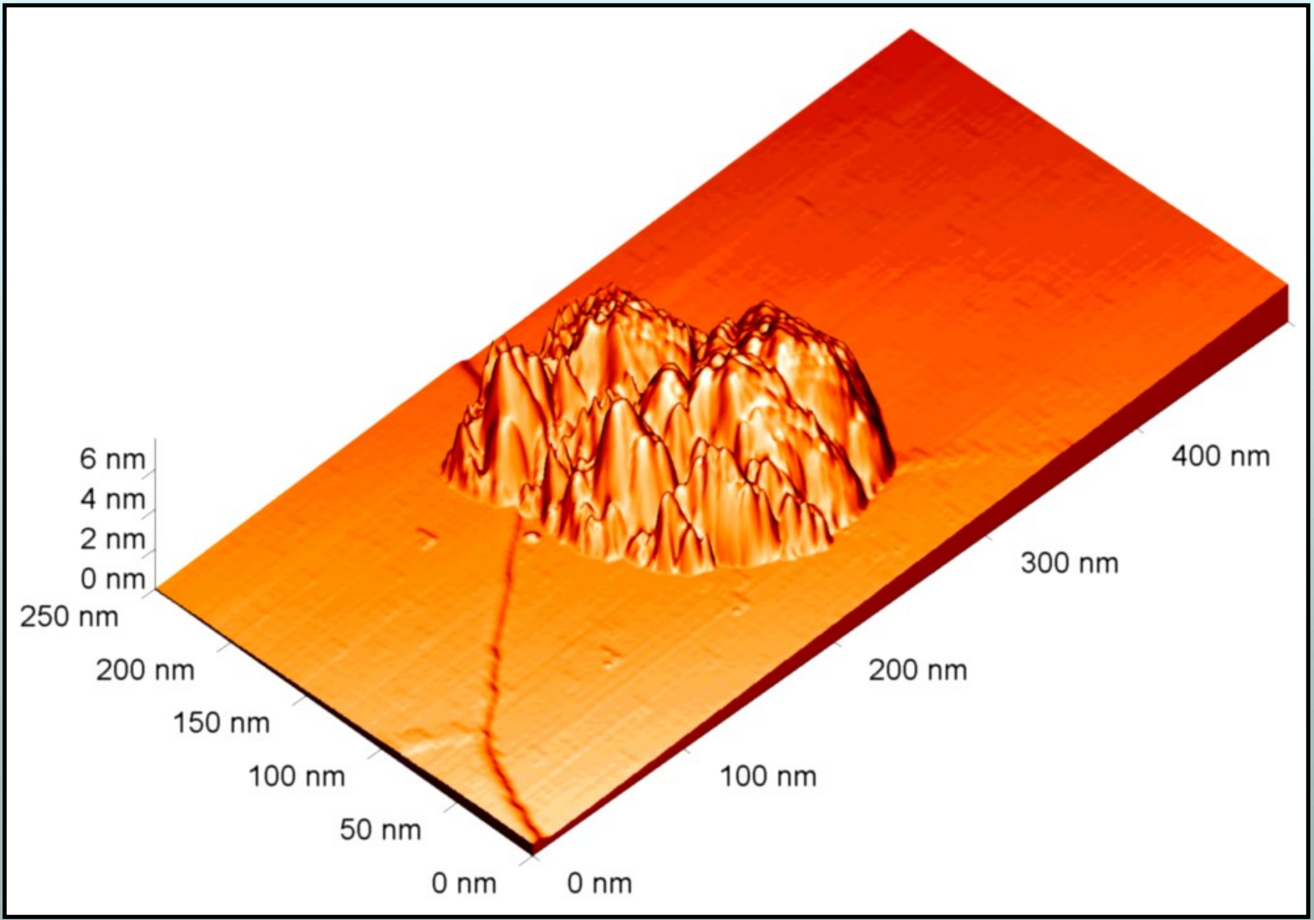
STM images of the same area of Si(111)6x6-Au surface recorded with blunt (left) and sharp (right) tip.

Tip damage during scan



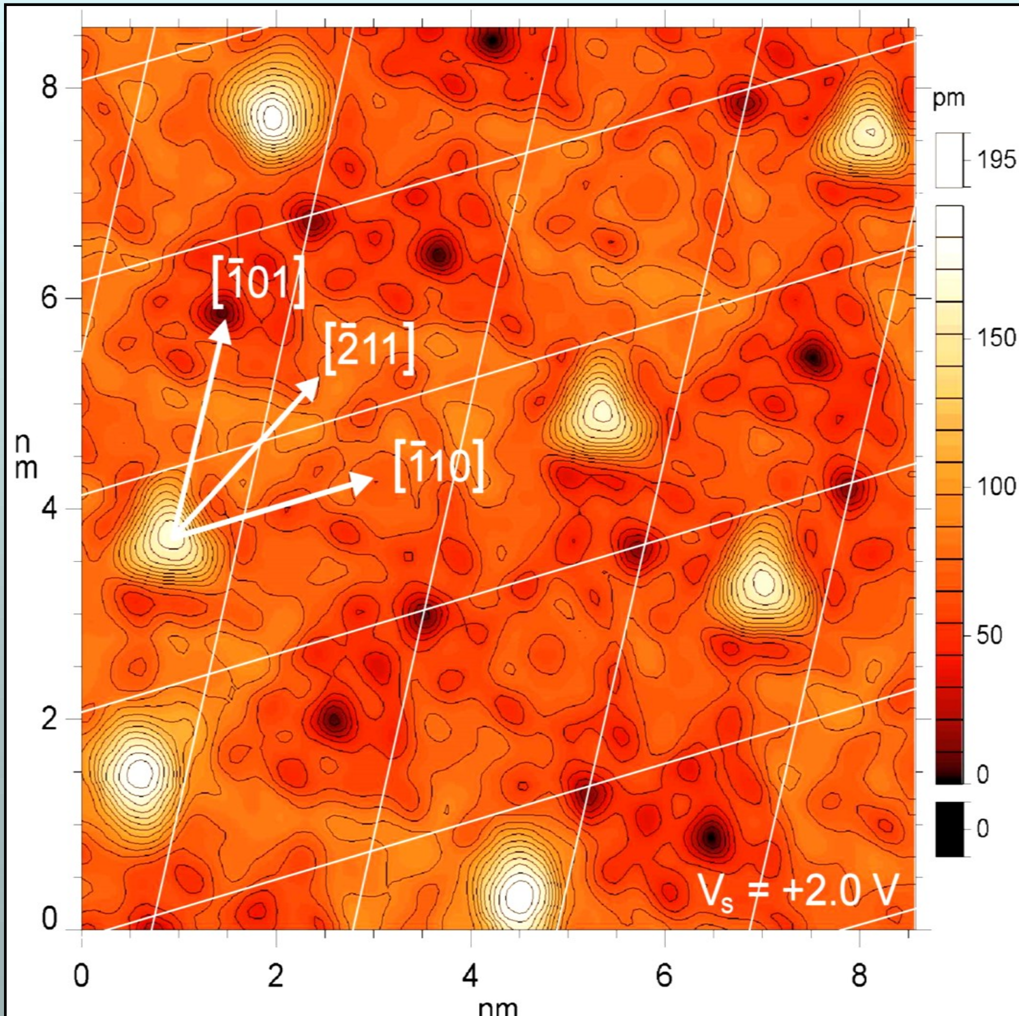
STM image of Si(111)6x6-Au surface. The sample is scanned from bottom to top. Sudden lost of the resolutiuon occurs due to capture by the tip of some particle.

Blunt tip - contamination



STM image of the place where a short current pulse
of 10V, 0.2 nA to a blunt/contaminated tip was applied.

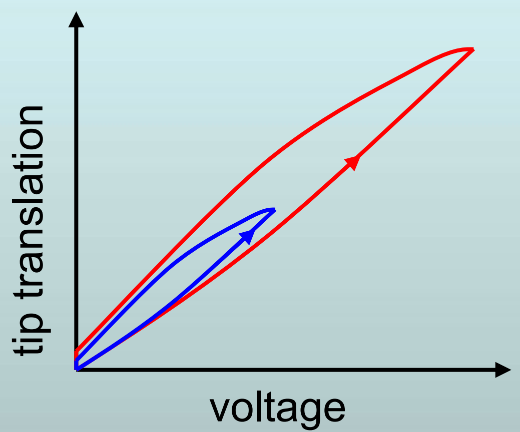
Example of extremely sharp tip

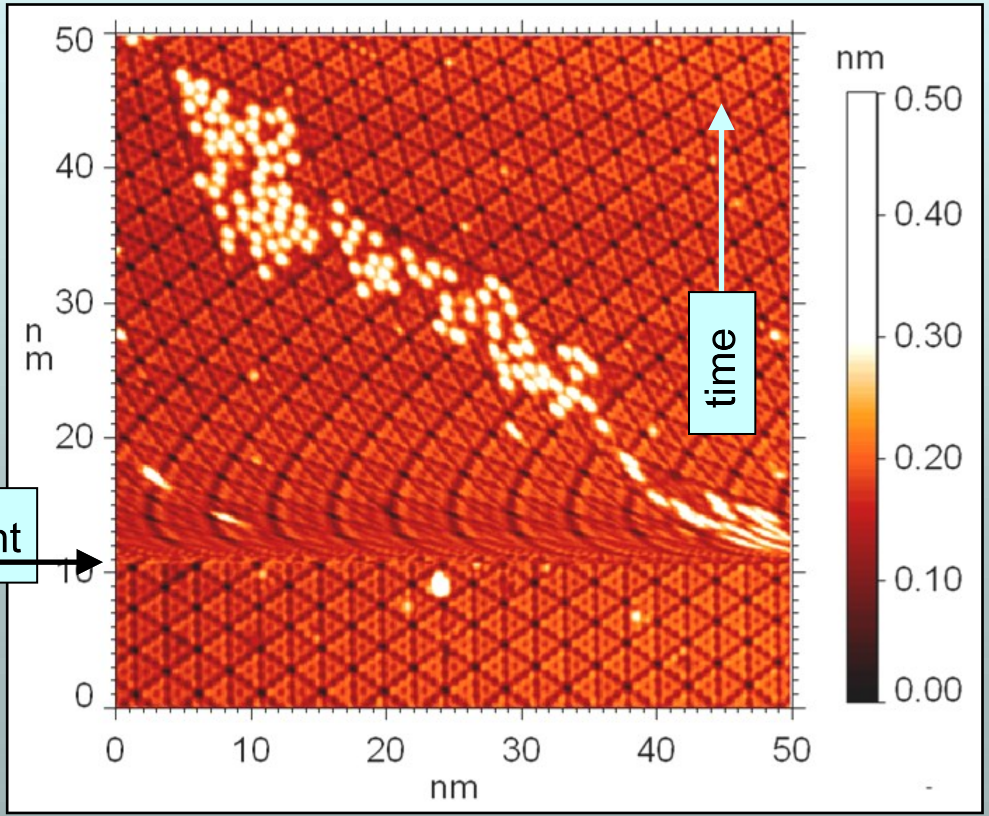


This STM image shows Si(111)-6x6-Au surface with 7 Pb atoms on it.

The atoms occupy different atomic positions and hence form various orbitals. Three-fold symmetry of the substrate is clearly seen for atoms in the middle.

Thermal drift and histeresis of scanner

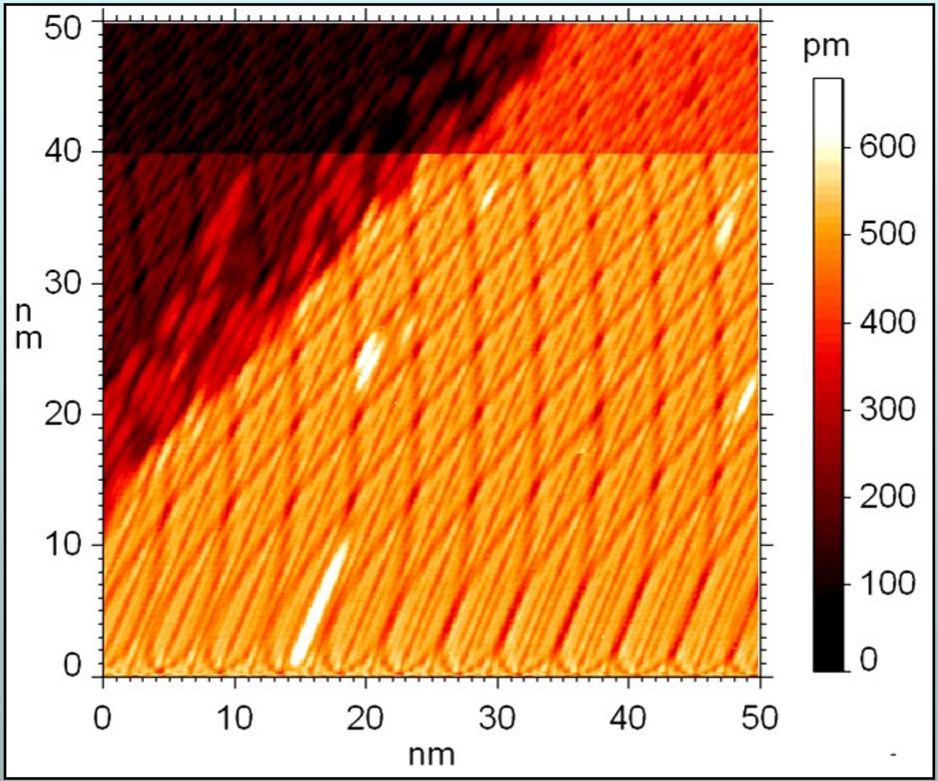




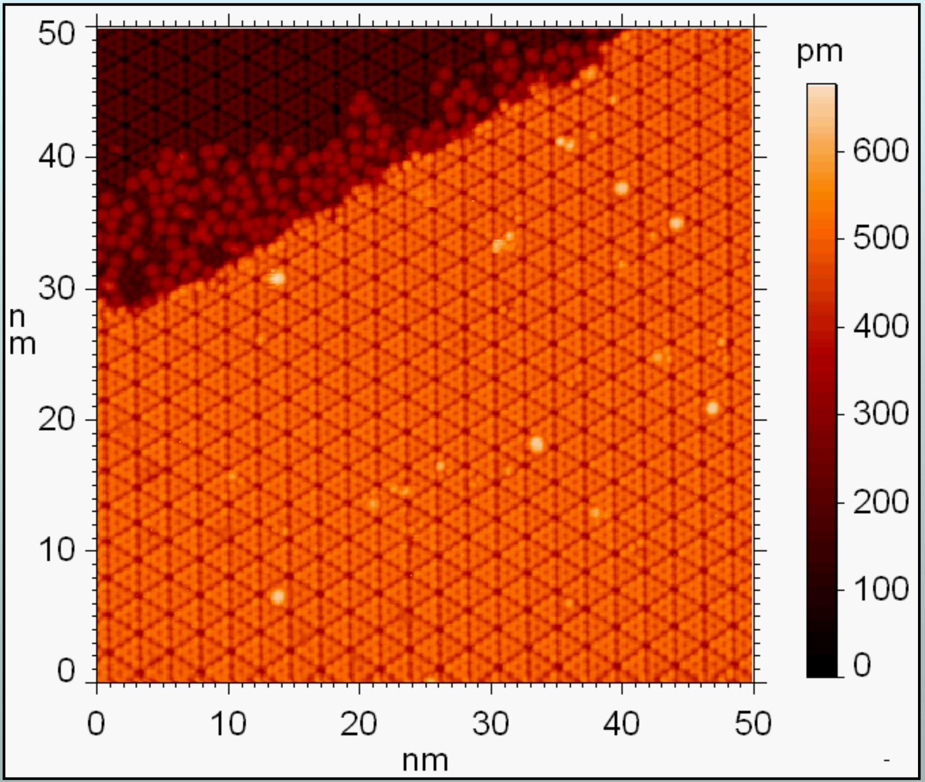
tip suddenly moved 20 nm to the right

scanning velocity 227 nm/s
scanning time ~ 3 min.
sample scanned from bottom

Thermal drift and hysteresis of scanner



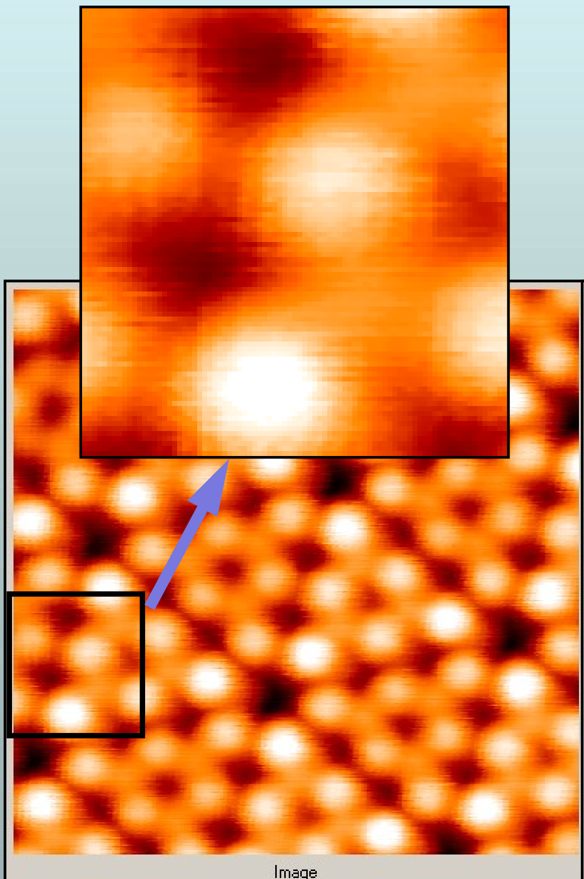
no drift compensation



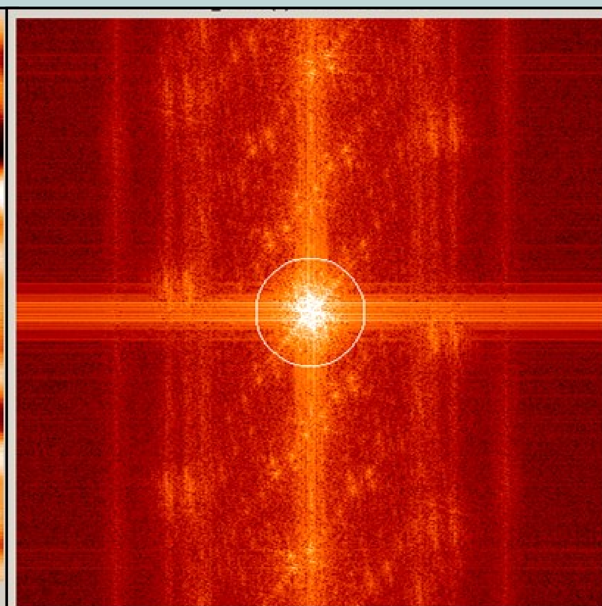
with drift compensation:
Vx = 0.12 nm/s, Vy = 0.15 nm/s

Fourier filter - noise removing

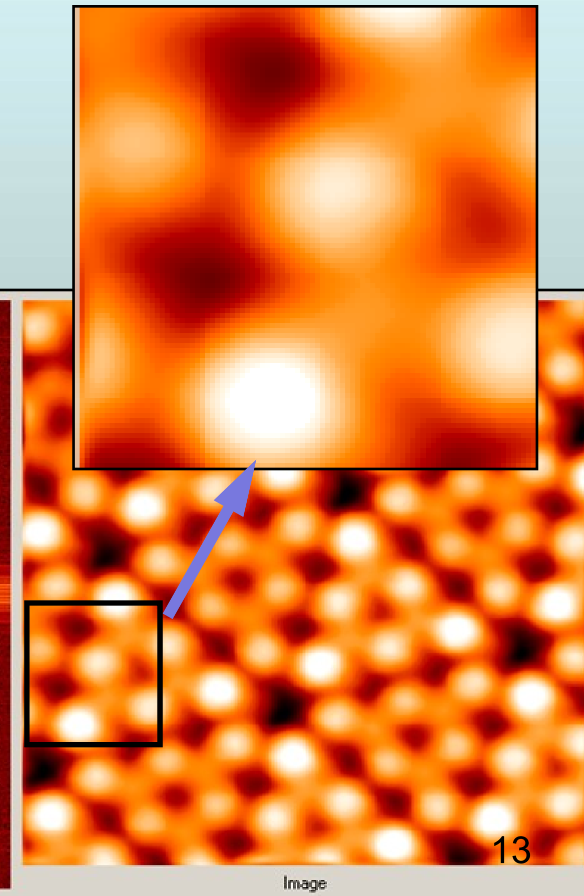
before



the 2D FFT filter
excludes frequences
outside the marked ring

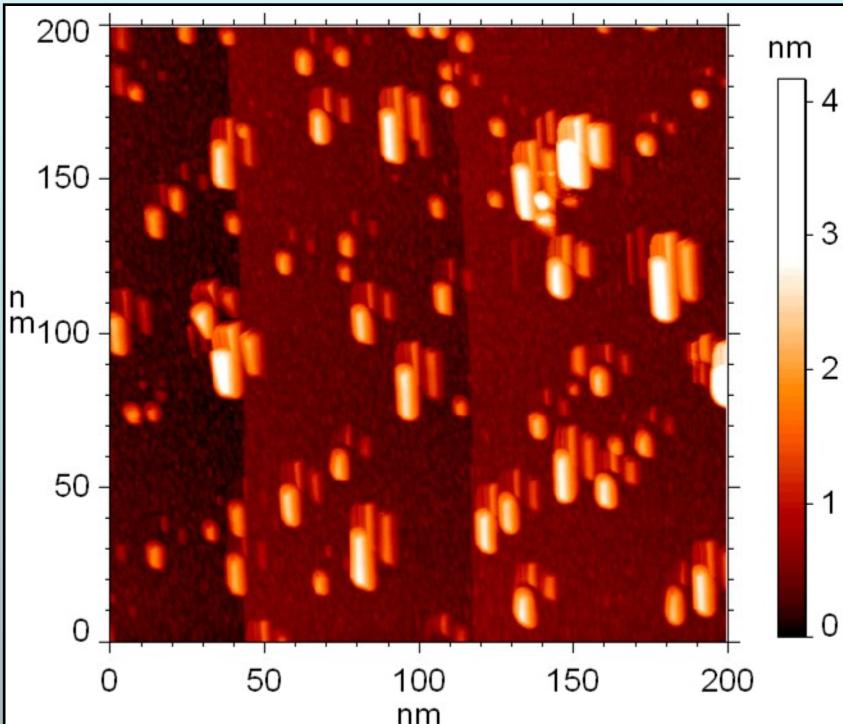


after

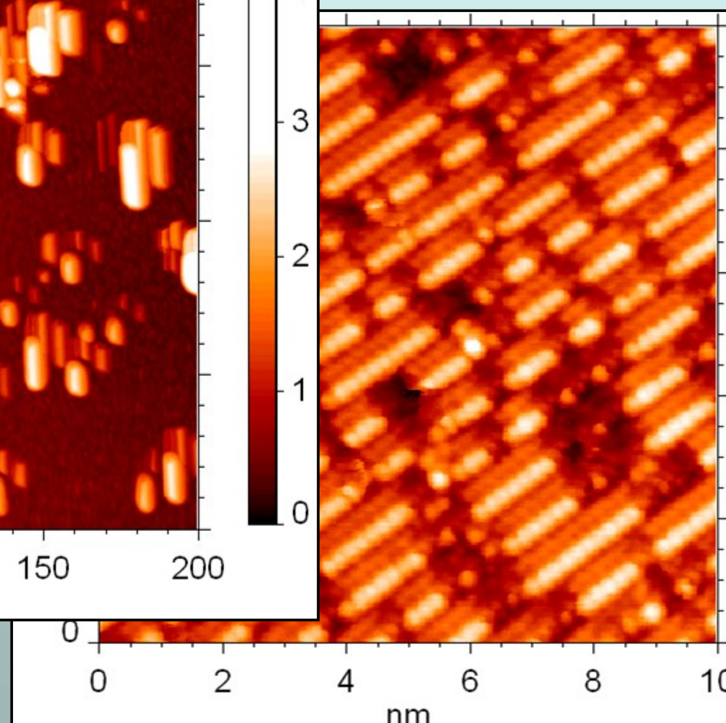


Multiple tip effect

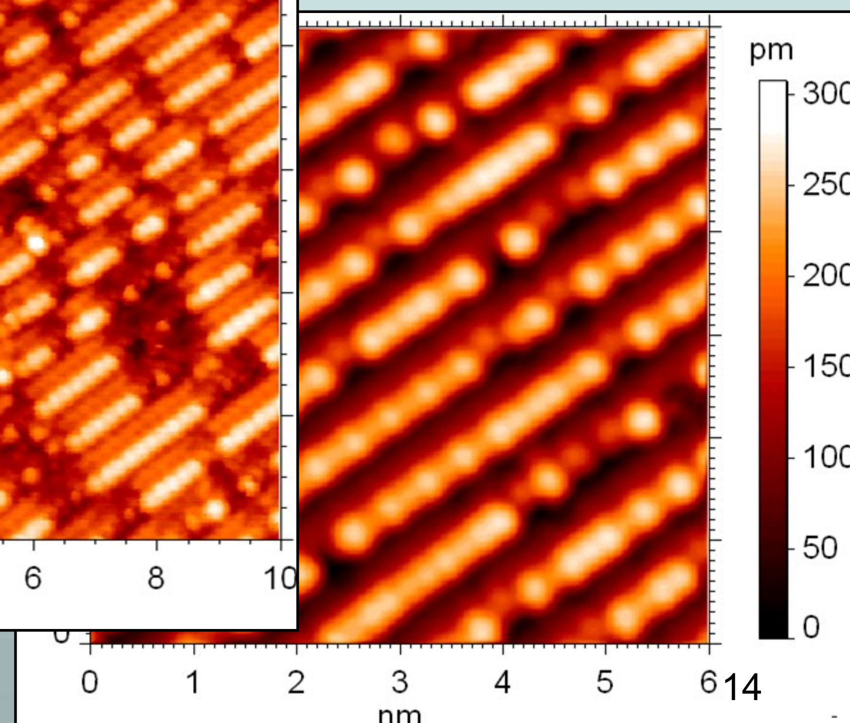
multiple "clones" of Pb islands



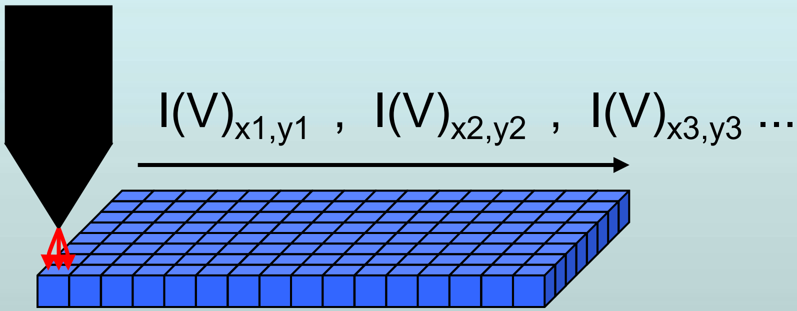
"clones" of Au atomic chains on Si(335)

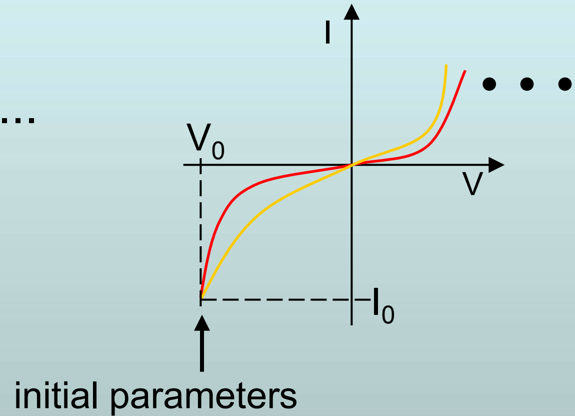


correct image of the Si(335)Au surface



Tunneling spectroscopy (STS)

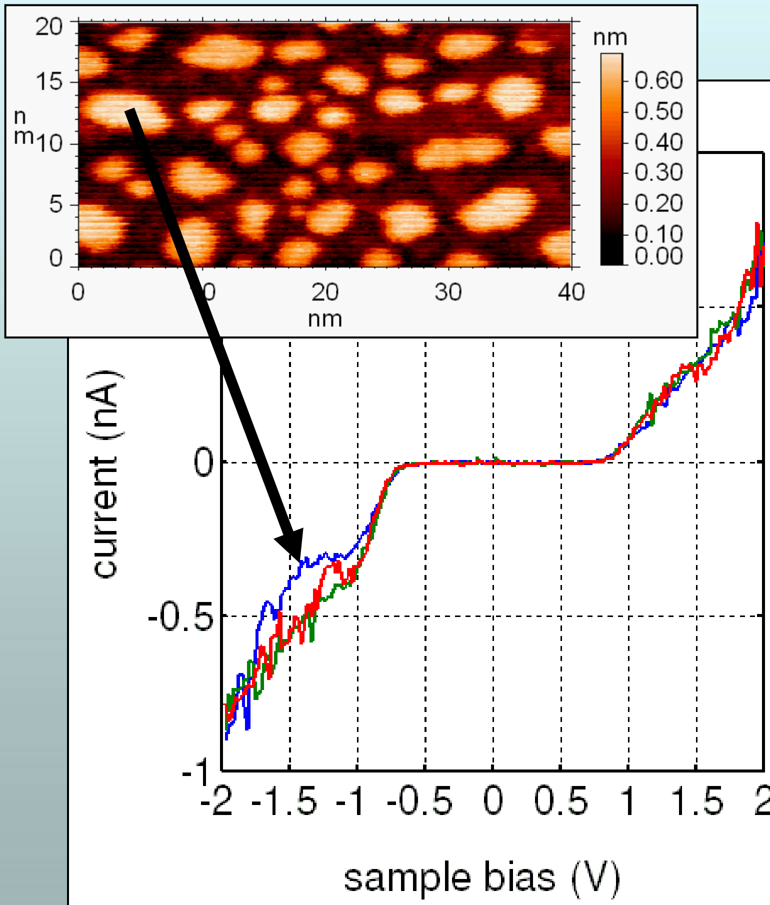




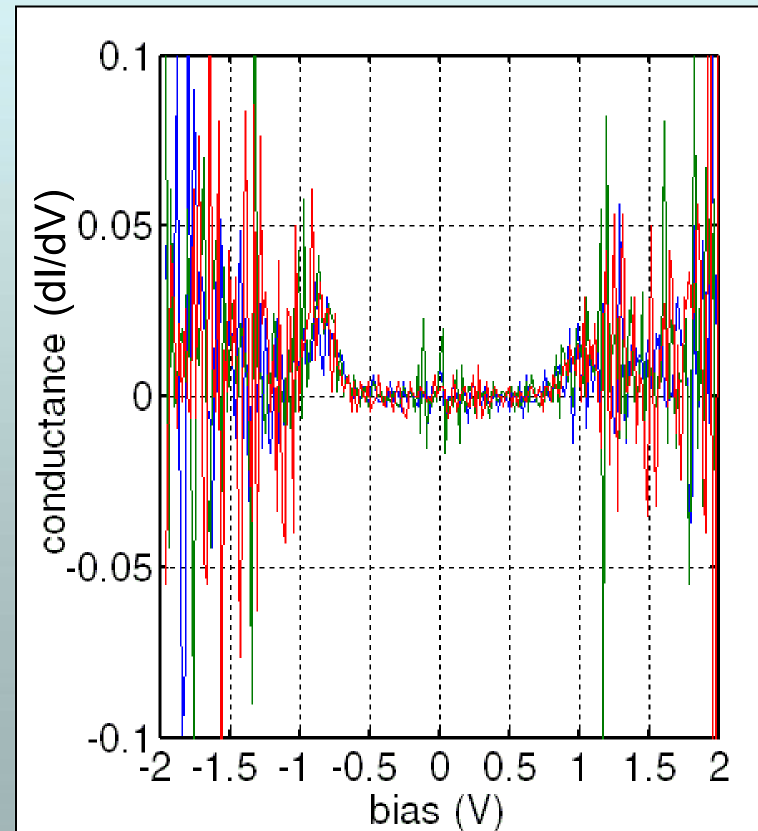
Typical parameters:

1. acquisition time at single point (pixel) ~ 300 μs
2. maximal current up to 10 nA
3. number of I - V pairs for a single curve ~ 100

Spectroscopy - Pb on Si(111)6x6-Au

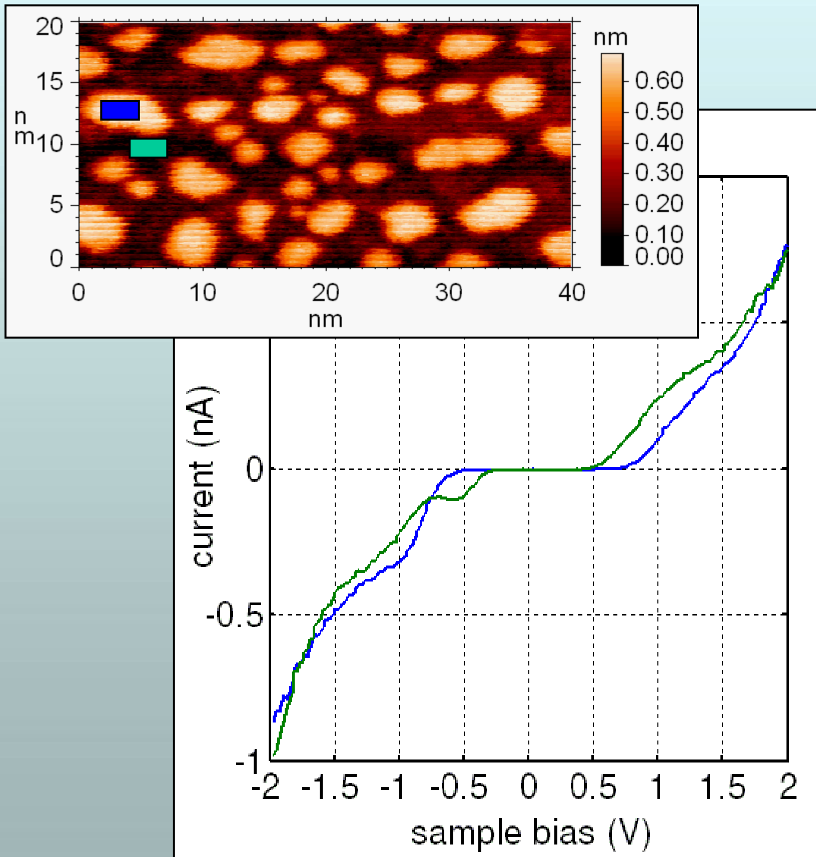


I(V) curves at 3 different places

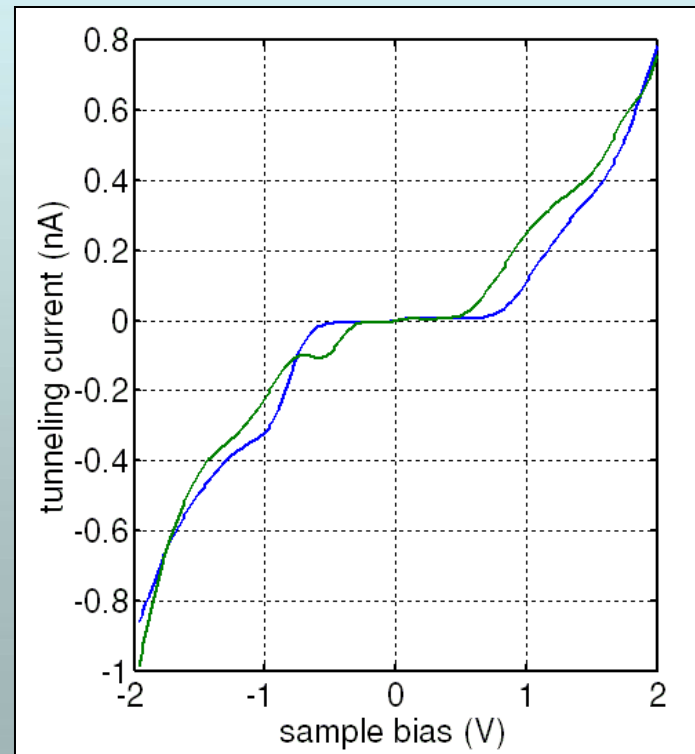


corresponding dI/dV curves

Spectroscopy I(V)

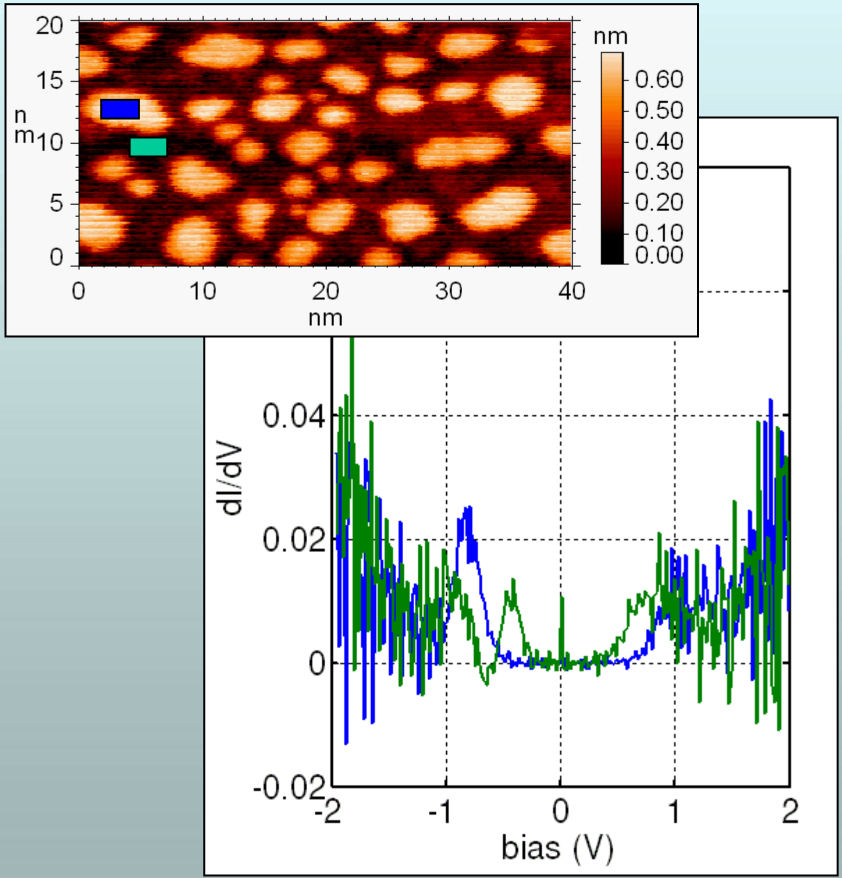


2 x 32 averaged I(V) and ...

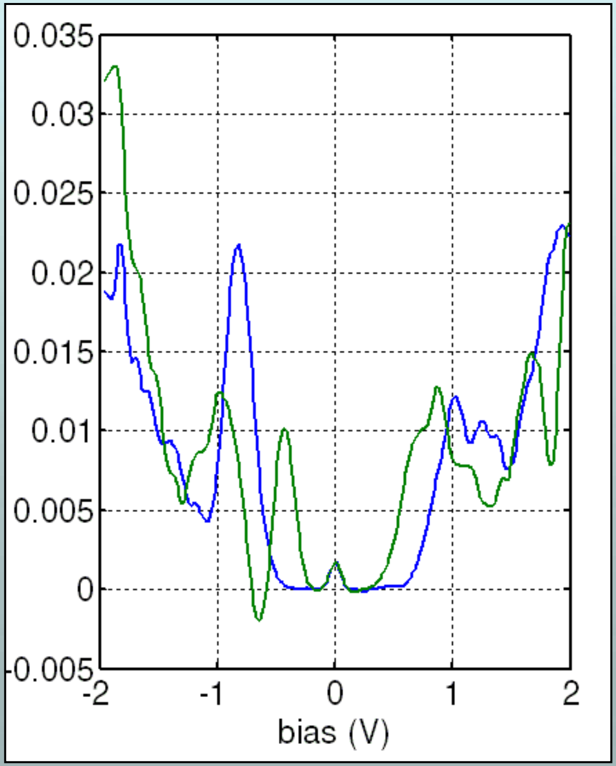


smoothed

Spectroscopy dI/dV



Original curves and ...



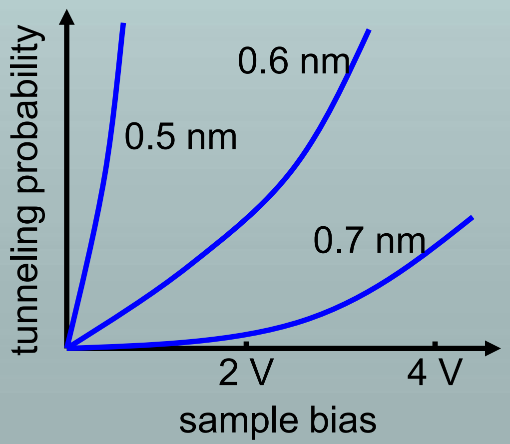
smoothed

Spectroscopy: normalized conductance

$$I \propto \int_0^{eV} \rho(E)T(E,V)dE\,,$$ for small bias: $\longrightarrow$ $$dI/dV \propto \rho(r,V)T(V)\,,$$

Within WKB approximation,
and for free-electron model:

$$T(V) = \alpha V + \gamma V^3 + \ldots$$



$\rho(E)$ – surface density of states of the sample

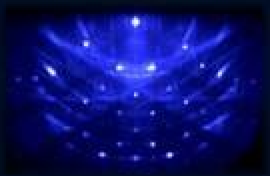
$T(E,V)$ – transmission of barrier at bias V

$\rho(r,V)$ – density of states at tip center

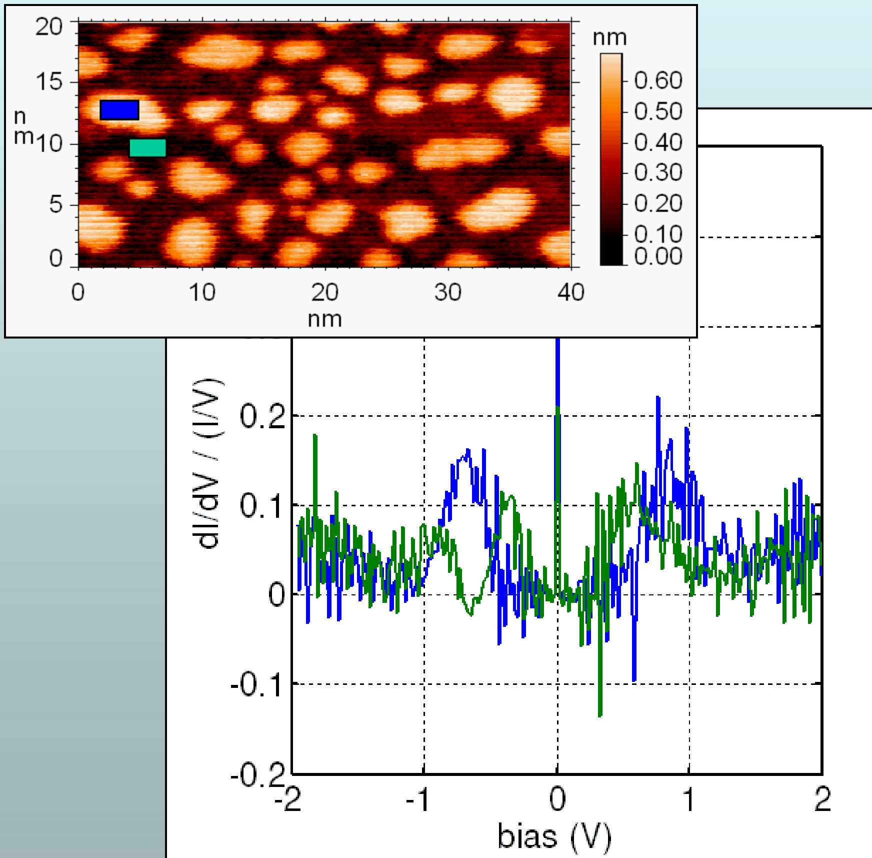
normalized plot

$$d\ln I/d\ln V = (dI/dV)/(I/V)$$

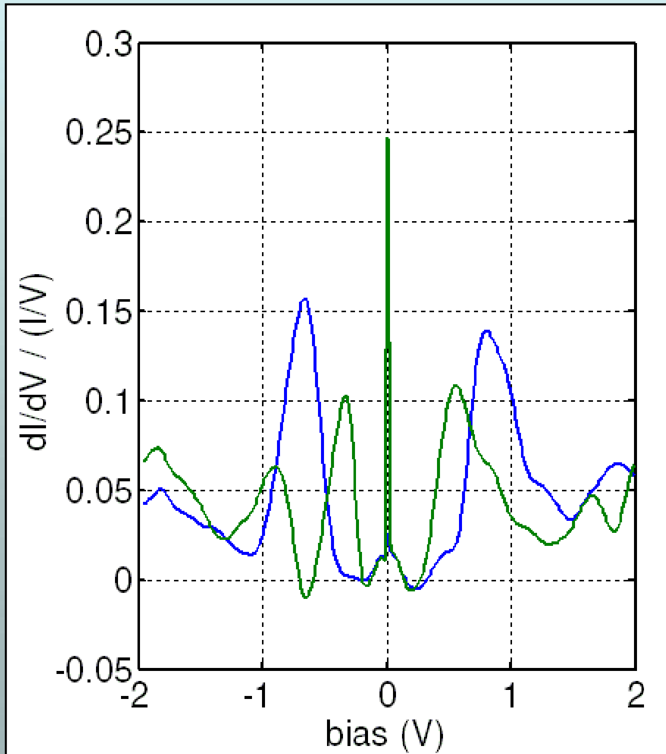
reduces rapid increase of dI/dV due to barrier transmission vs bias dependance



Spectroscopy: normalized conductance



no smoothing



smoothed (compare slide 18)