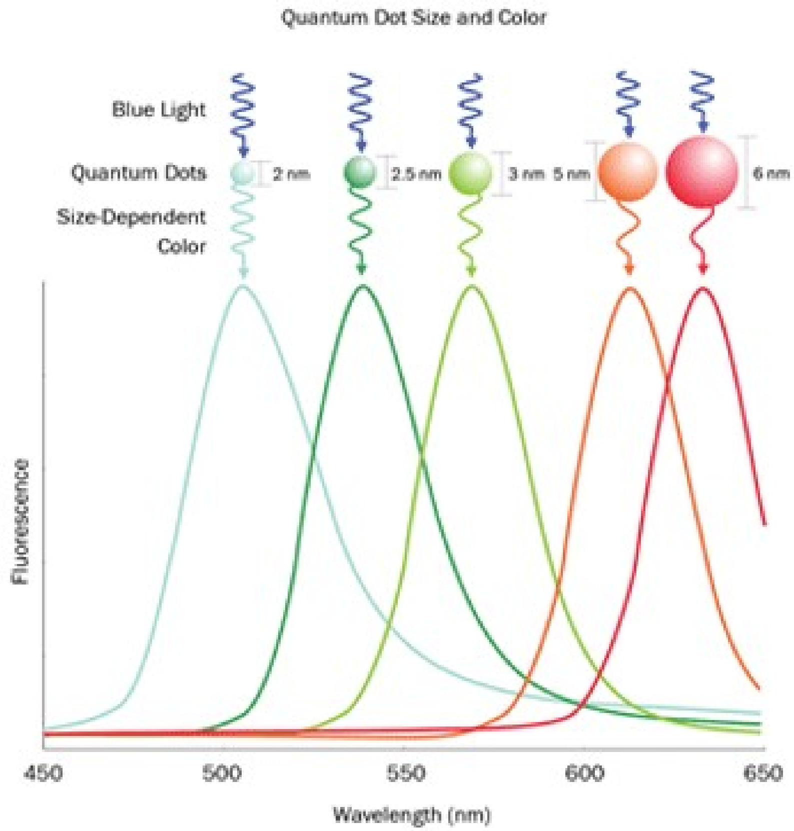
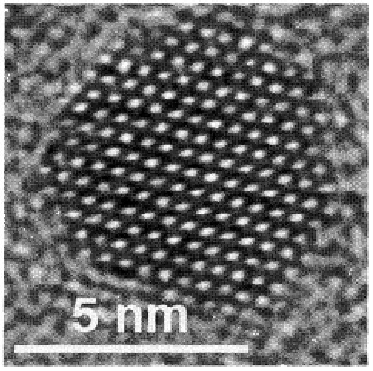
Quantum dots of many colors

Nanophysics built into the properties of bulk matter



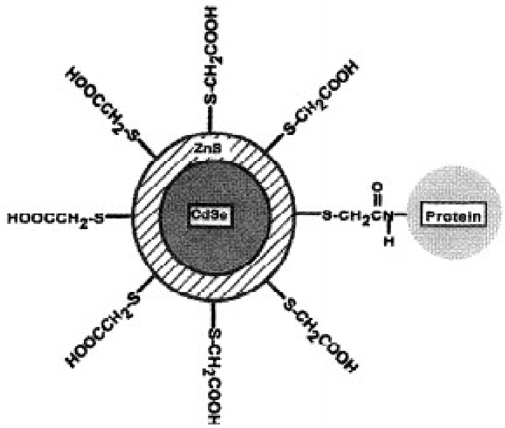
CdSe



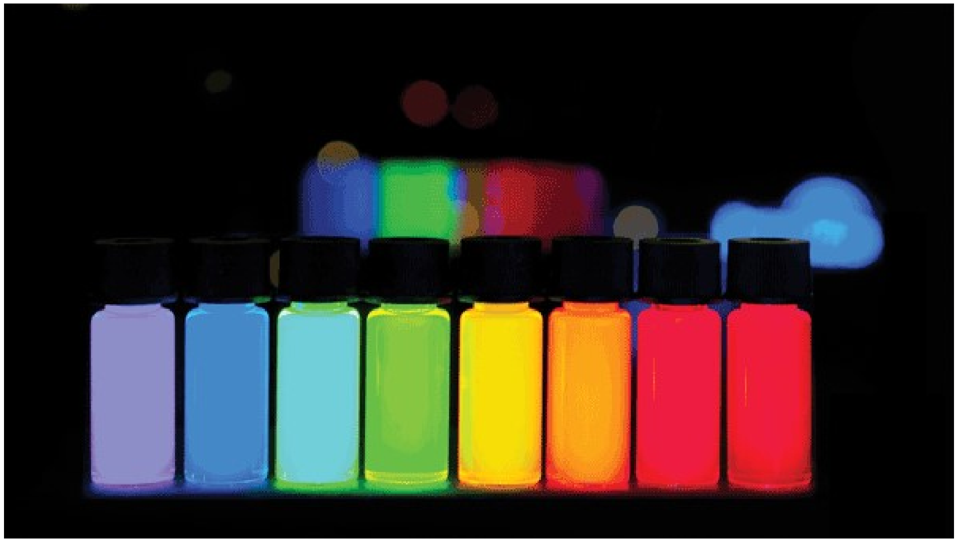
CdSe

Quantum dot size relates to emission wavelength: QDs absorb higher-energy/shorter-wavelength light and downconvert it into lower-energy/longer-wavelength light. The smallest dot represented here, 2 nm in diameter, absorbs the light from a 450-nm blue source and emits at the 500-nm green wavelength; a larger 6-nm-diameter dot emits at the 630-nm red wavelength. Precise control of quantum dots during manufacturing enables the dots to emit light at any wavelength in the visible spectrum. *Photo courtesy of Nanosys.*

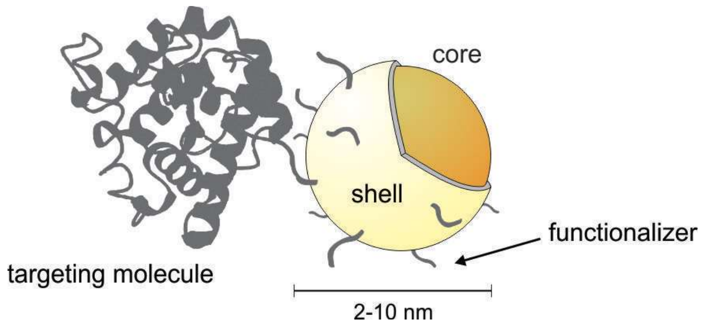
QDs Up Display Color, Brightness with Less Power



QD with coating suitable to assure functionalizing water solubility in biological environment

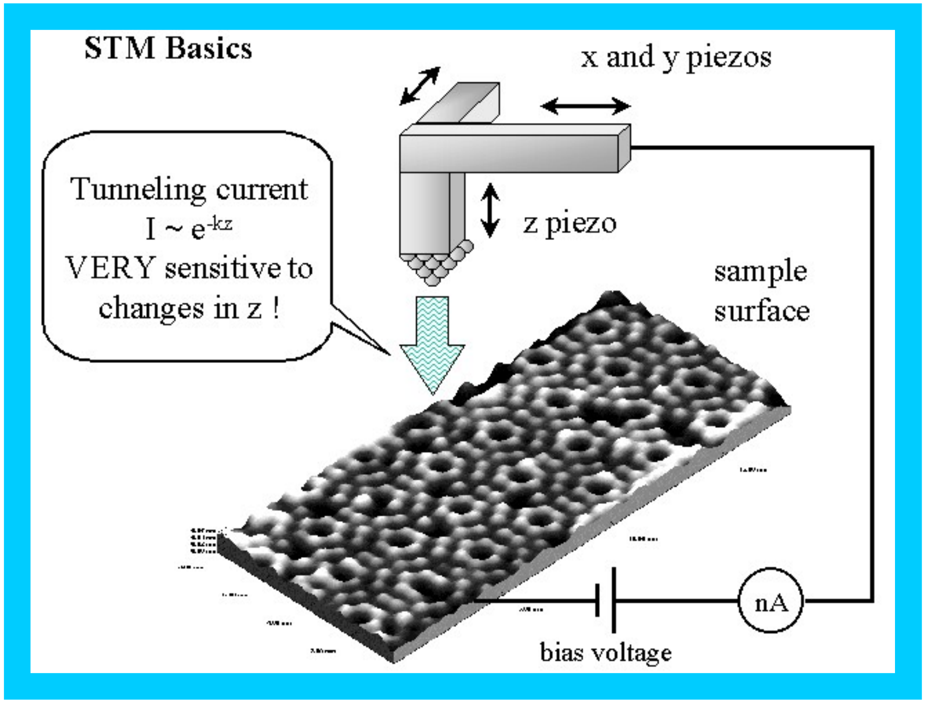


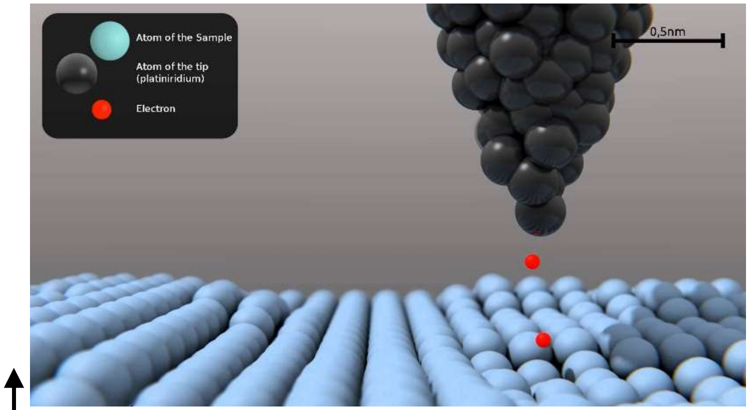
Quantum dots with vivid colors stretching from violet to deep red are currently manufactured on a large scale at PlasmaChem GmbH. Photo courtesy of Wikimedia Commons.

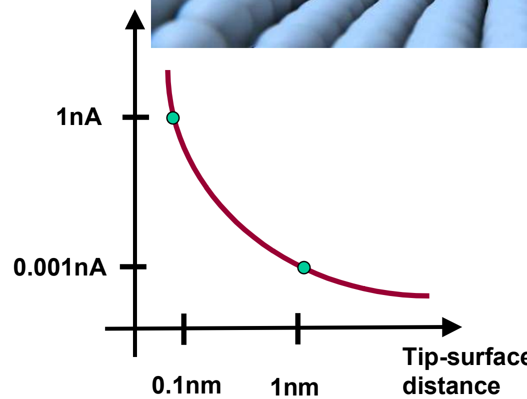


- Quantum Dots in Biomedical Research
  markers of particular types of cells

Scanning tunneling microscopy (STM)







1981: Gerld Binnig, Heinrich Röhrer

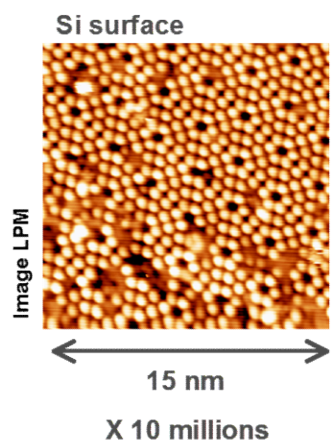
Nobel Prize 1986

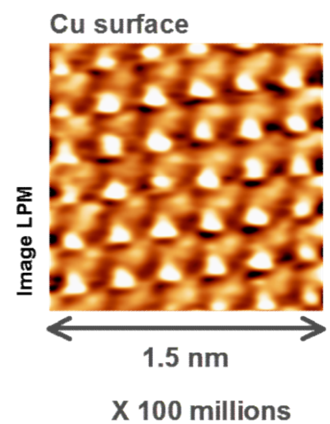
IBM - Zurich

STM:

Looking to atoms…

atomic resolution





STM tip

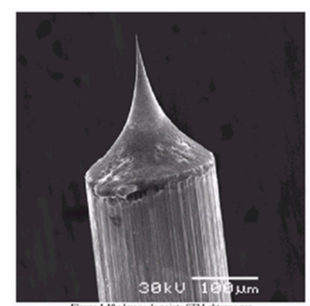
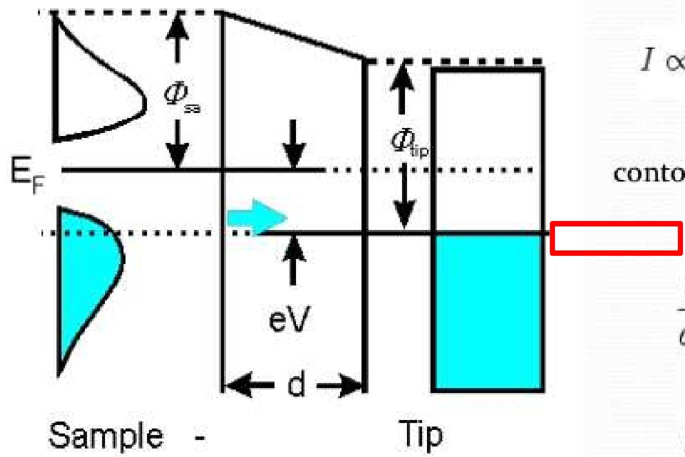


Figure 1.10 : Image de pointe STM obtenue par microscopie à balayage électronique.

Scanning tunneling spectroscopy (STS)



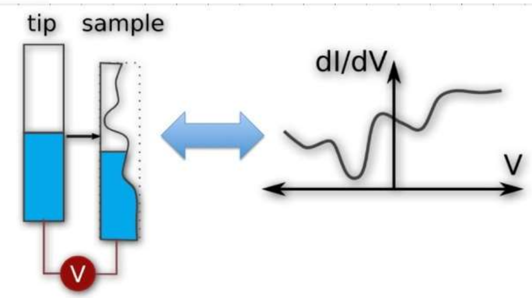
$$I \propto \int_0^{eV} \rho_s(E)\rho_t(-eV+E)dE$$

STM images are
contour **plot of electron density**

k_BT

$$\frac{dI}{dV} \propto \rho_s(E_F - eV)$$

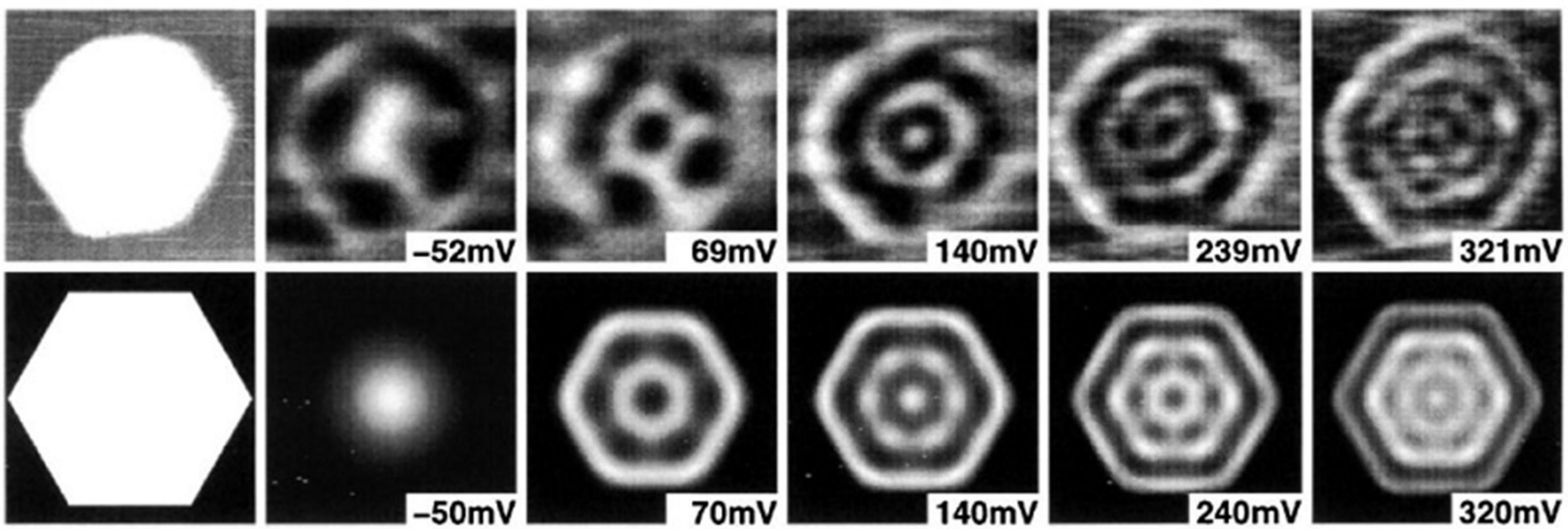
STS leads to the DOS



! Low temperature STM

otherwise k_BT convolution

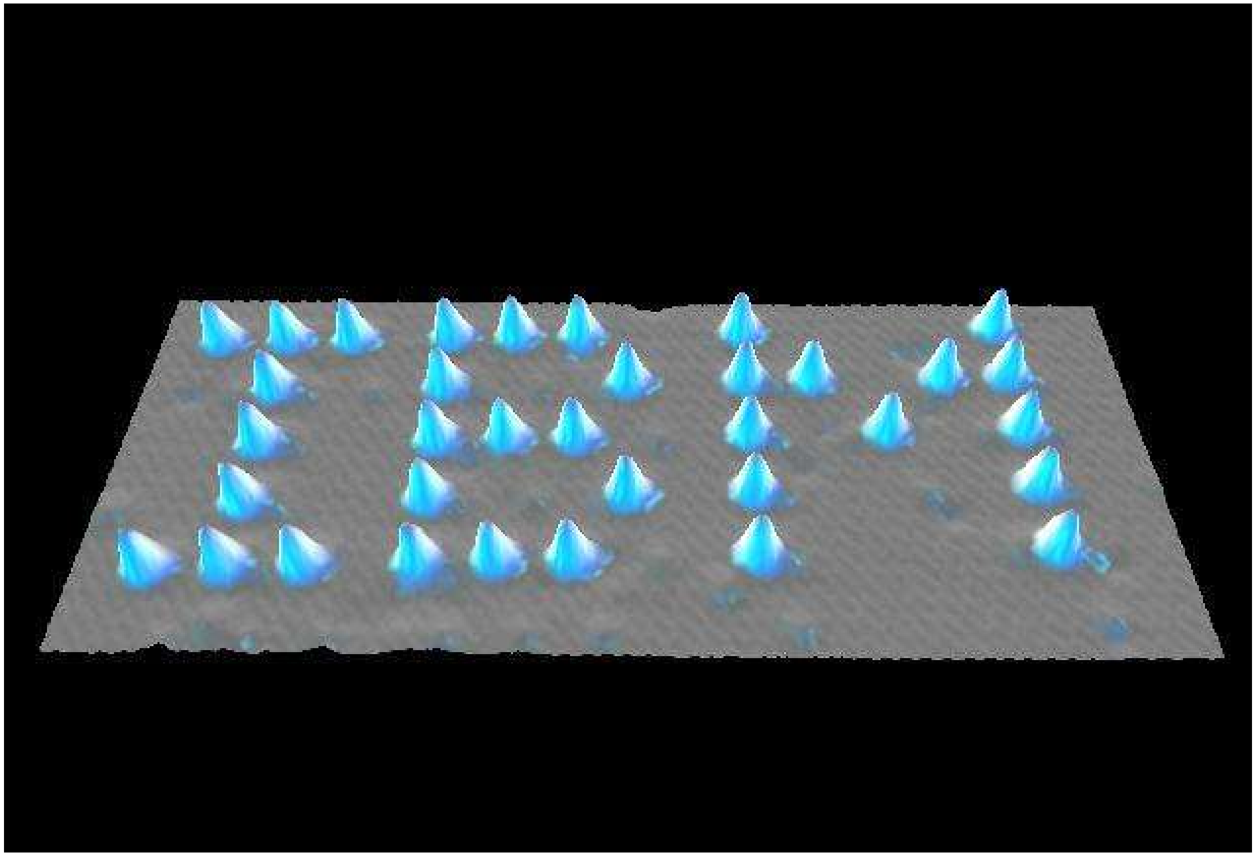
Quenches resolution in energy



Standing electronic waves patterns in Ag islands (94nm^2)

L. Duo, Surf. Science 1998

Moving atoms one by one by STM



Title : *The Beginning*

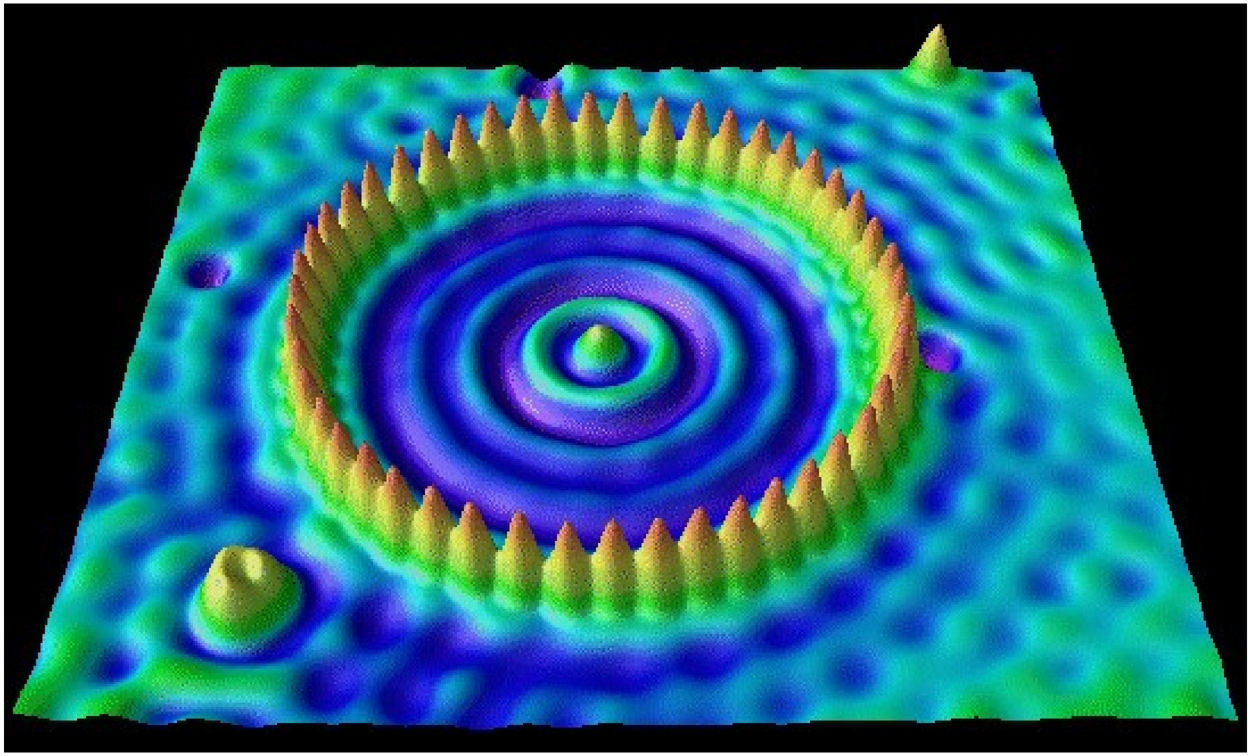
1988 Donald Eigler IBM *Xenon on Nickel (110)*

Artists have almost always needed the support of patrons (scientists too!). Here, the artist, shortly after discovering how to move atoms with the STM, found a way to give something back to the corporation which gave him a job when he needed one and provided him with the tools he needed in order to be successful.

2D finite potential well =» **QUANTUM CORAL**

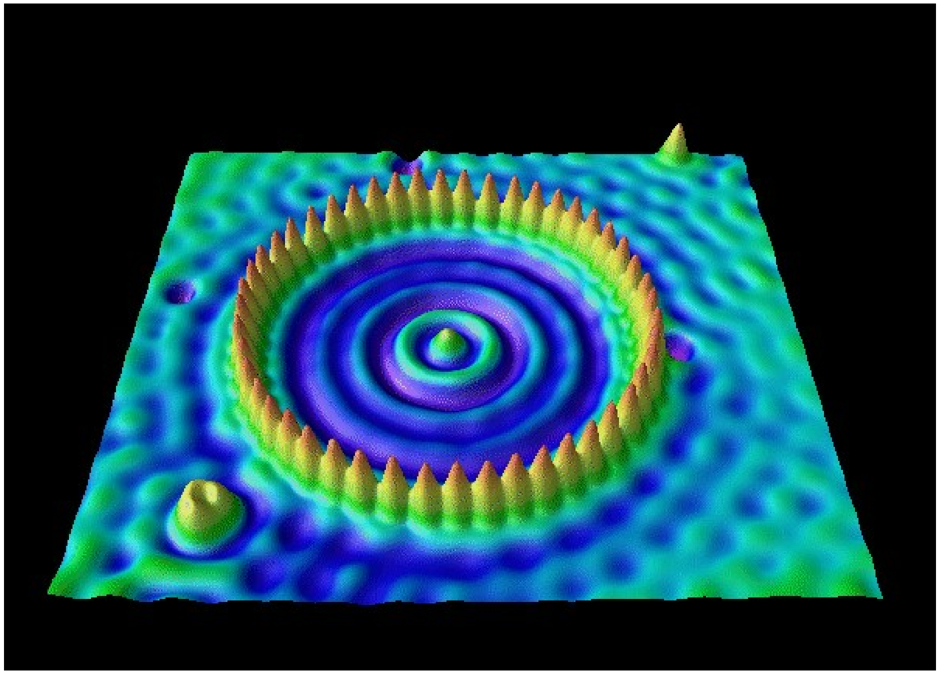
To make this image, 48 iron atoms (shown as yellow peaks) were placed in a circle on a copper surface.
The "elevation" at each point inside the circle indicates the electron density within the circle.
The standing-wave pattern is very similar to the probability distribution function for a particle in a one-dimensional finite potential well:

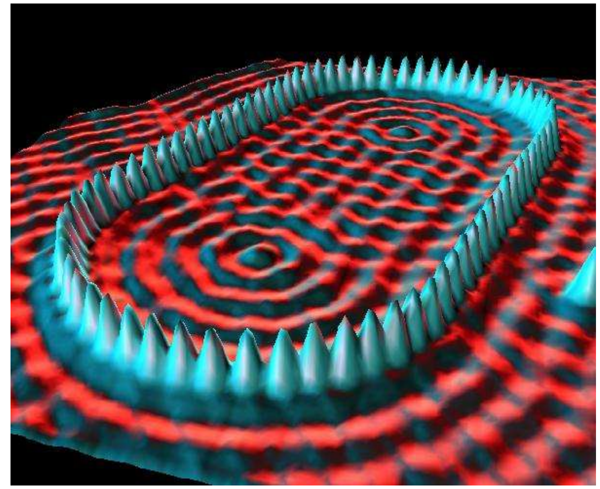
$$e\left|\Psi(x,y)\right|^2$$

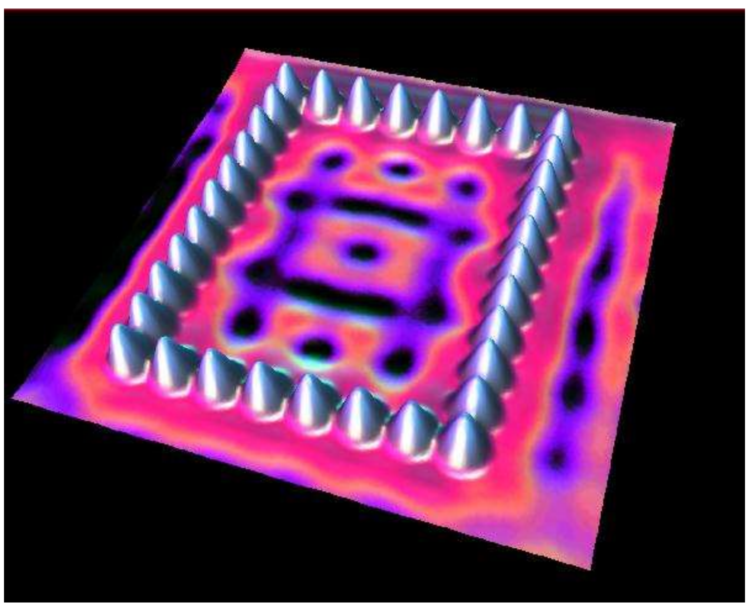


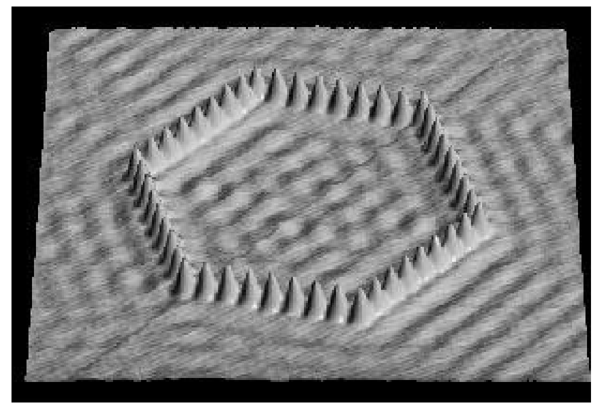
IBM- ***M.F. Crommie, C.P. Lutz, D.M. Eigler, Science 262, 218-220 (1993).***

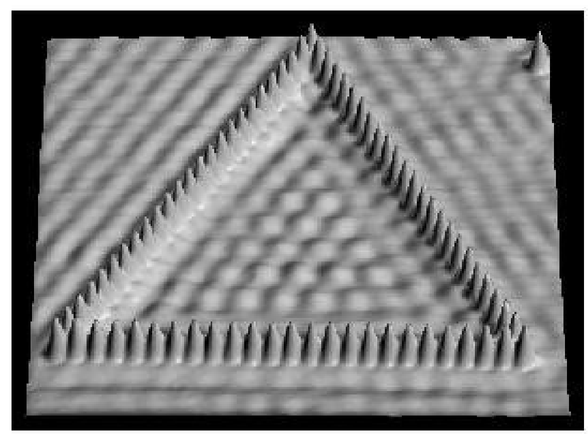
Quantum corrals

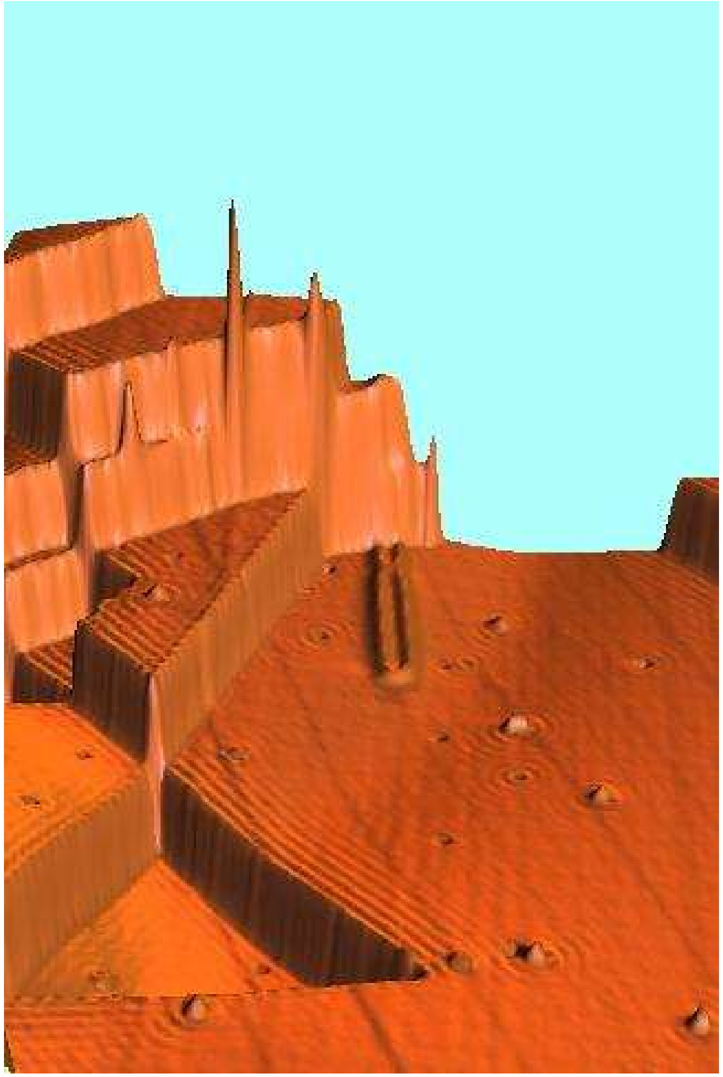










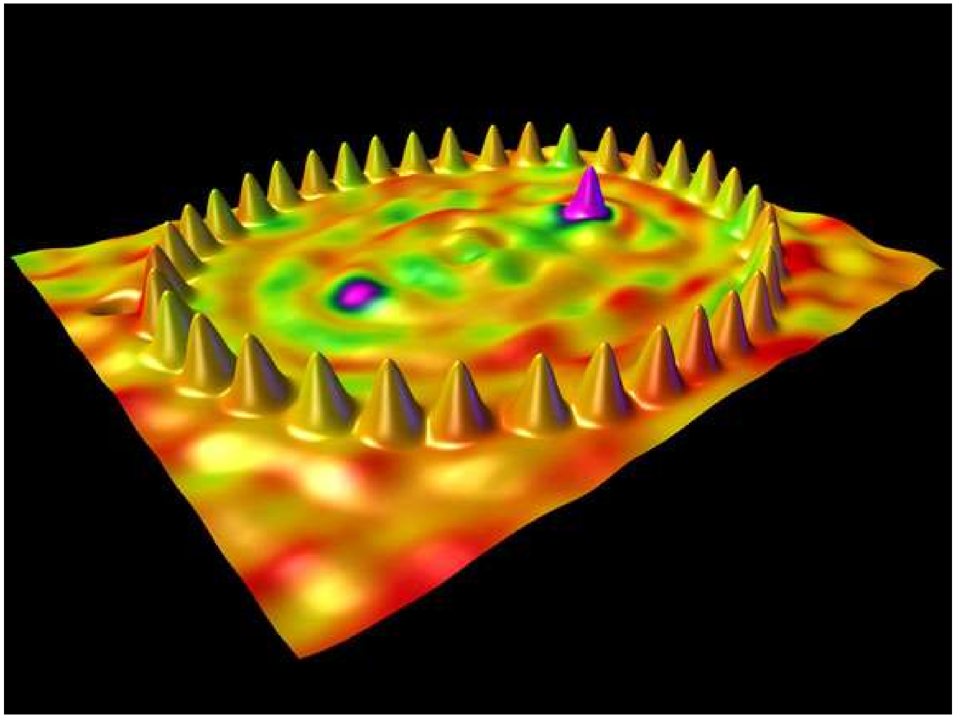


Reminiscent of formal Japanese rock gardens, here we see ripples surrounding features on the copper (111) surface.

The artists' fortunes took a major turn upward when they determined that the ripples were due to "surface state electrons."
These electrons are free to roam about the surface but not to penetrate into the solid. When one of these electrons encounters an obstacle like a step edge, it is partially reflected.

The ripples extending away from the step edges and the various defects in the crystal surface are just the standing waves that are created whenever a wave scatters off of something. The standing waves are about 15 Angstroms (roughly 10 atomic diameters) from crest to crest. The amplitude is largest adjacent to the step edge where it is about 0.04 Angstroms from crest to trough.

Quantum mirage



36 cobalt atoms in an elliptical structure known as a "quantum corral." Electron waves moving in the copper substrate interact both with a magnetic cobalt atom carefully positioned at one of the foci of the ellipse and apparently with a "mirage" of another cobalt atom (that isn't really there) at the other focus.

Donald Eigler IBM Almaden