UNIVERSITY OF NEBRASKA–LINCOLN
Physics & Astronomy

Introduction to Scanning Tunneling Microscopy

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04/24/2014

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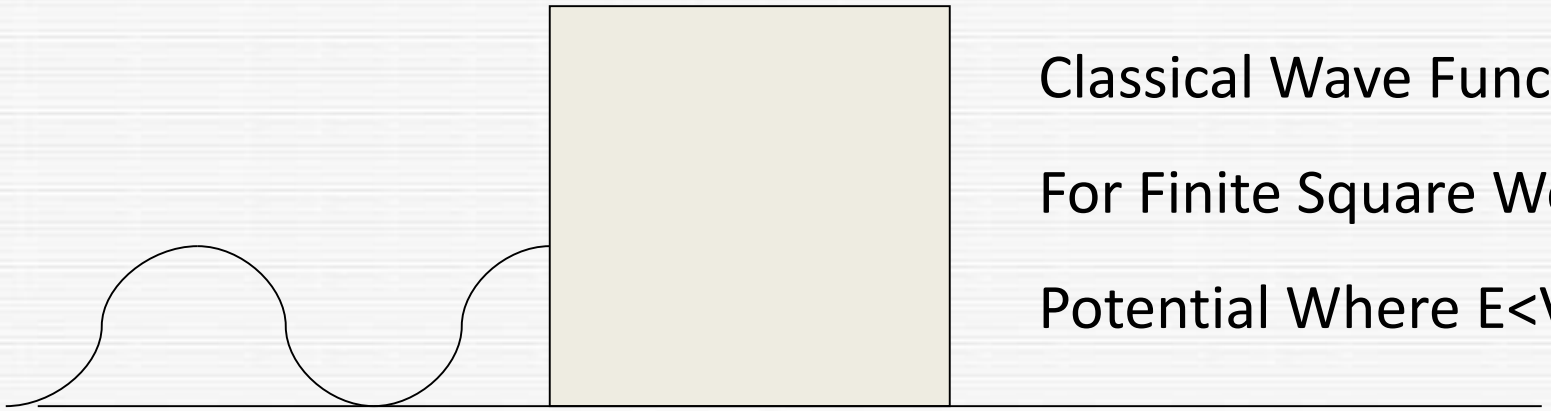
Scanning tunneling microscope

- The scanning tunneling microscope (STM) is a type of electron microscope that shows three-dimensional images of a sample.
- Monitors the *electron tunneling current* between a probe and a sample surface
- What is electron tunneling?
  - Classical versus quantum mechanical model
  - Occurs over very short distances

Quantum Tunneling



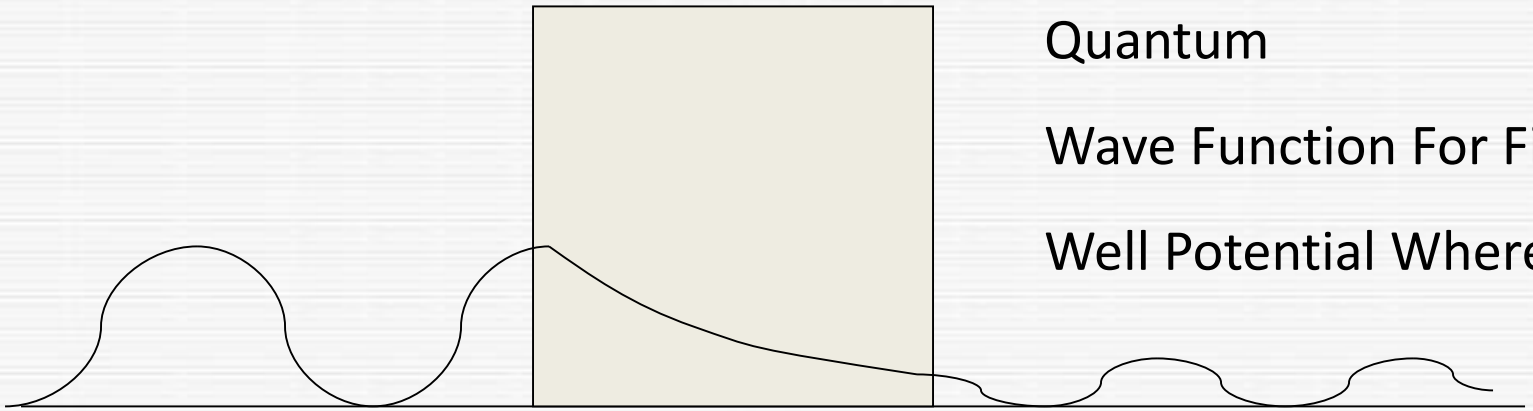
Classical Wave Function

For Finite Square Well

Potential Where E<V

Classically, when an object hits a potential that it doesn't have enough energy to pass, it will never go though that potential wall, it always bounces back.

Quantum Tunneling



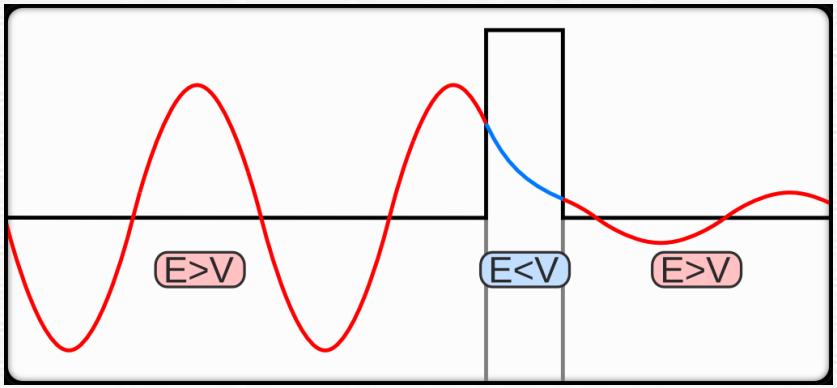
Quantum

Wave Function For Finite Square

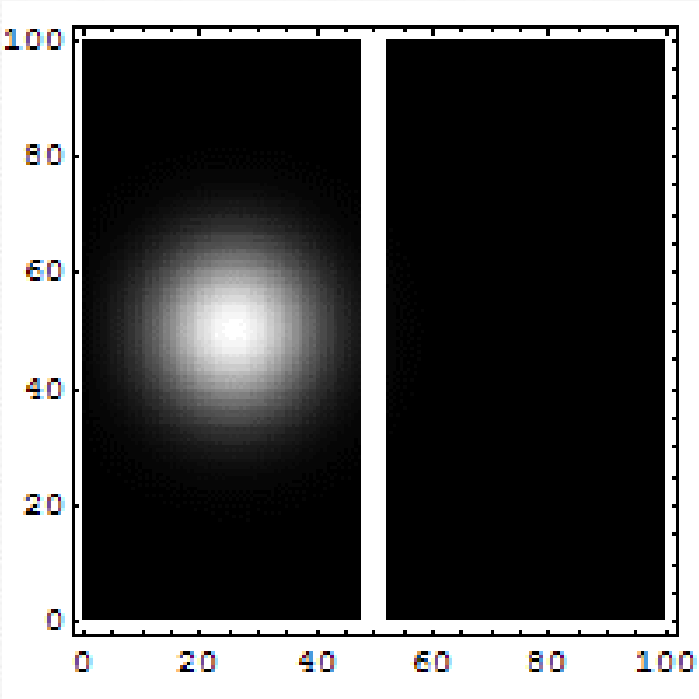
Well Potential Where E<V

- In quantum mechanics when a particle hits a potential that it doesn't have enough energy to pass, when inside the square well, the wave function dies off exponentially.
- If the well is short enough, there will be a noticeable probability of finding the particle on the other side.

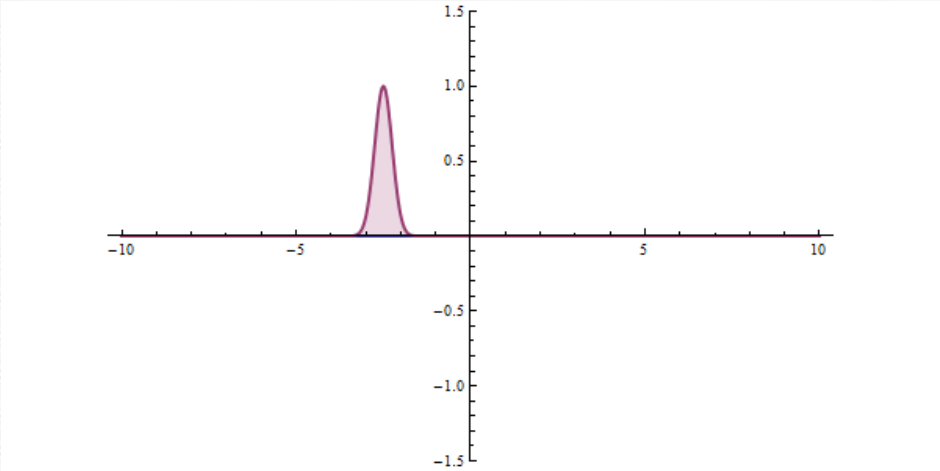
Quantum tunnelling



Quantum tunnelling through a barrier. The energy of the tunnelled particle is the same but the amplitude is decreased

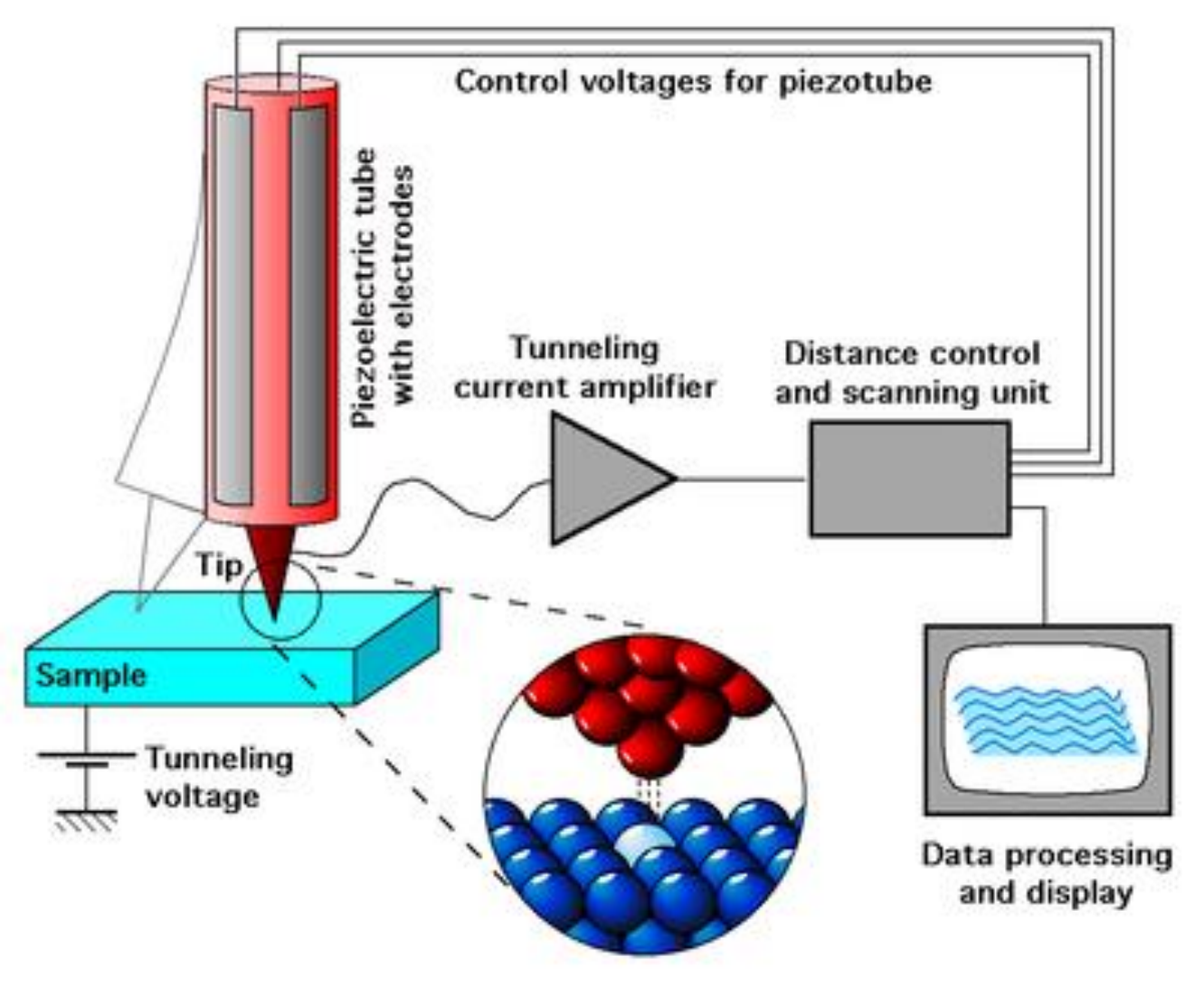


An electron wavepacket directed at a potential barrier. Note the dim spot on the right that represents tunnelling electrons.



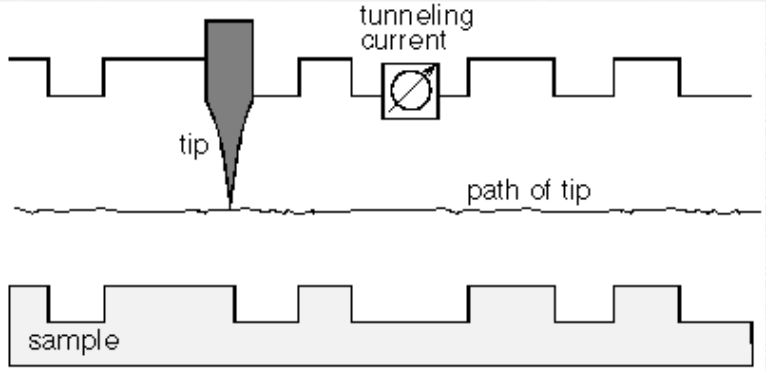
Quantum tunnelling through a barrier. At the origin (x=0), there is a very high, but narrow potential barrier. A significant tunnelling effect can be seen

Schematic of a Scanning Tunneling Microscope

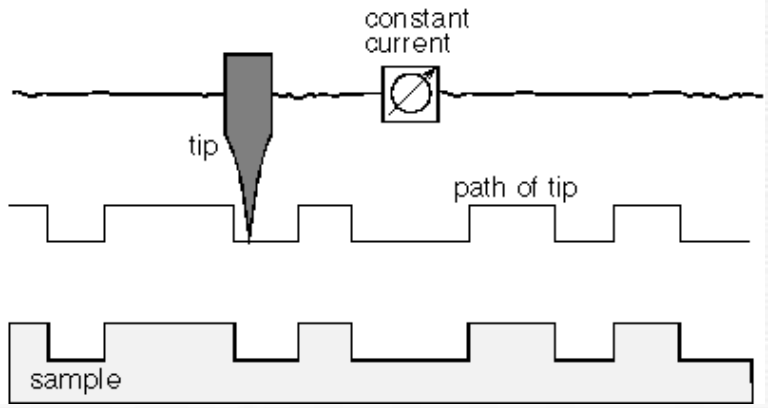


Two Modes of Scanning

Constant Height Mode



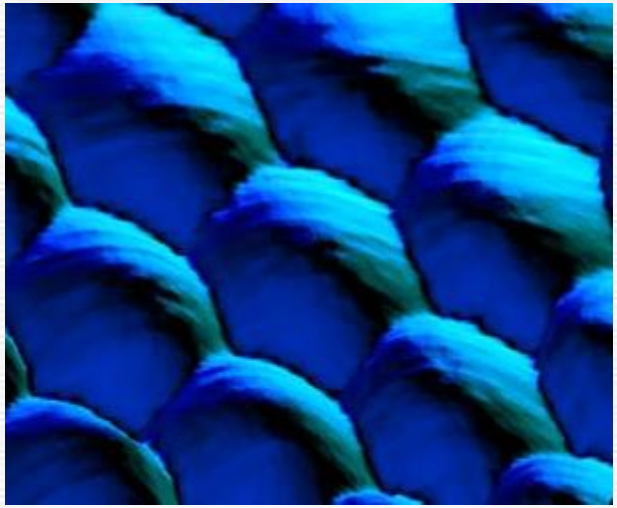
Constant Current Mode



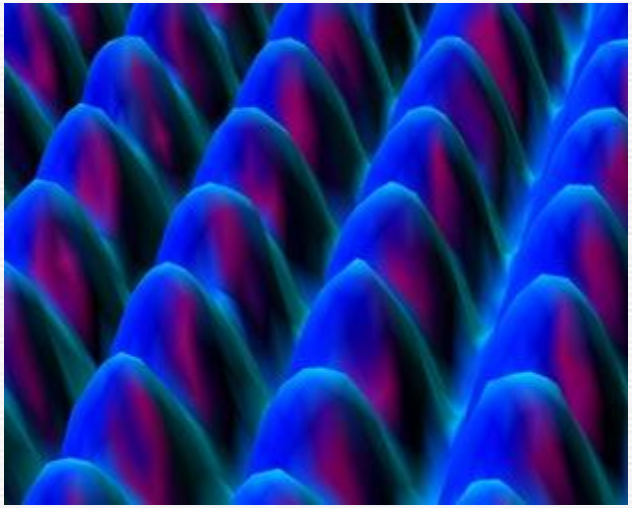
Usually, constant current mode is superior.

Applications

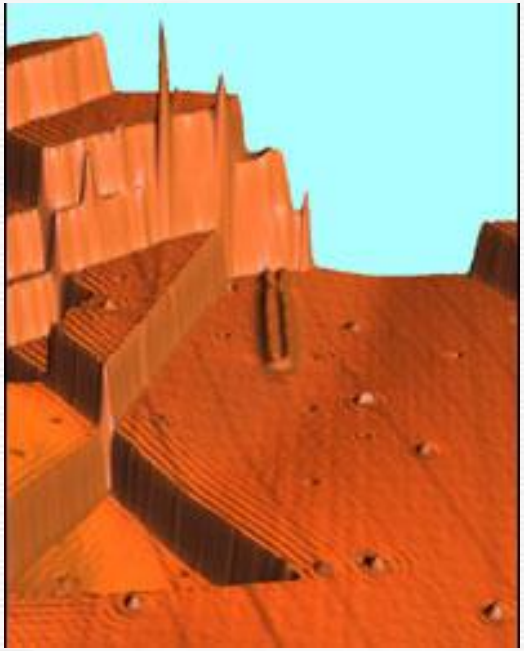
- Due to the remarkable detail and STM can give about the surface of a material, they are very useful for studying friction, surface roughness, defects and surface reactions in materials like catalysts.
- STMs are also very important tools in research surrounding semiconductors and microelectronics.



Surface of platinum.
IBM, Almaden Research Facility



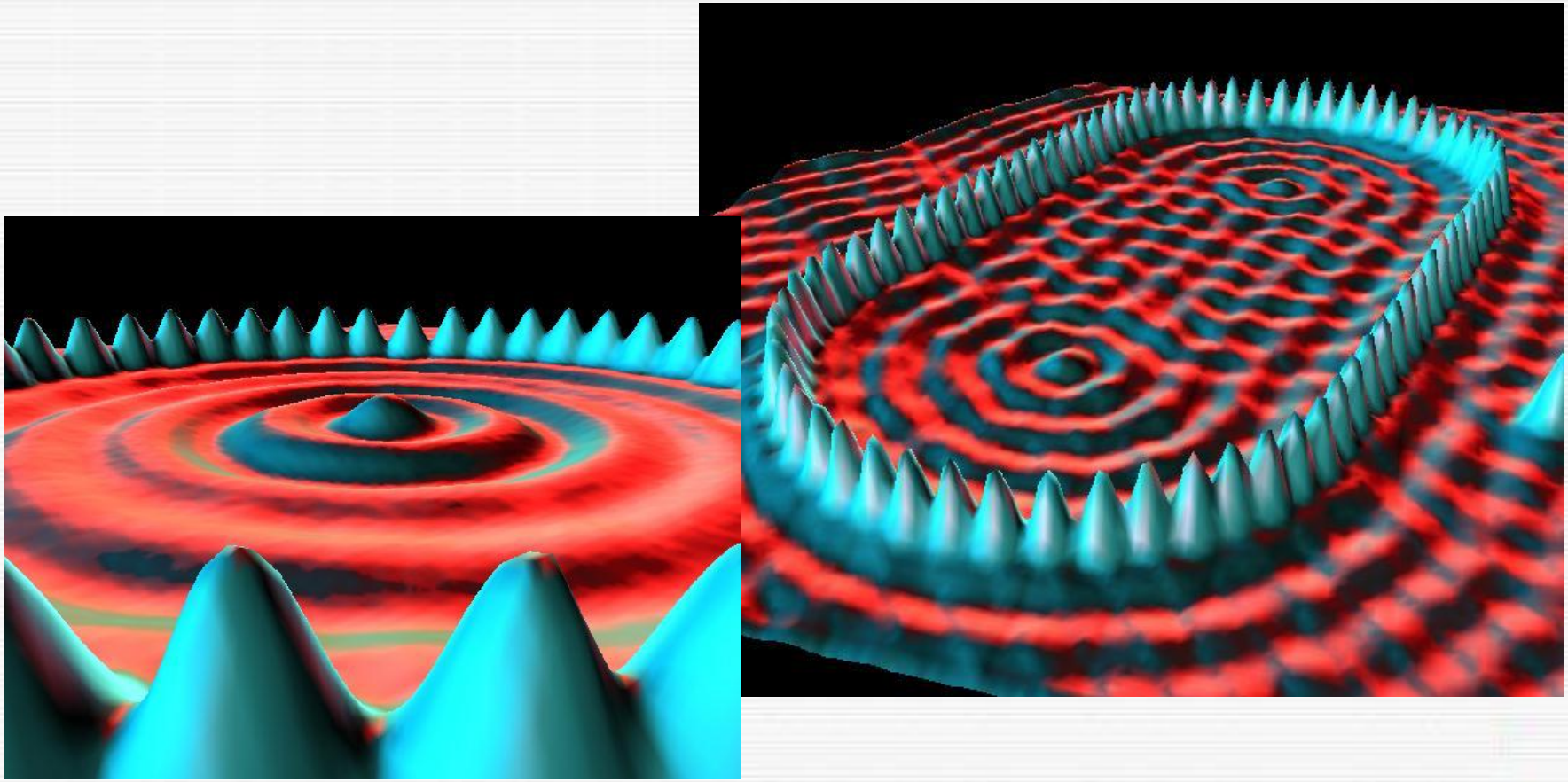
Surface of nickel.
IBM, Almaden Research Facility



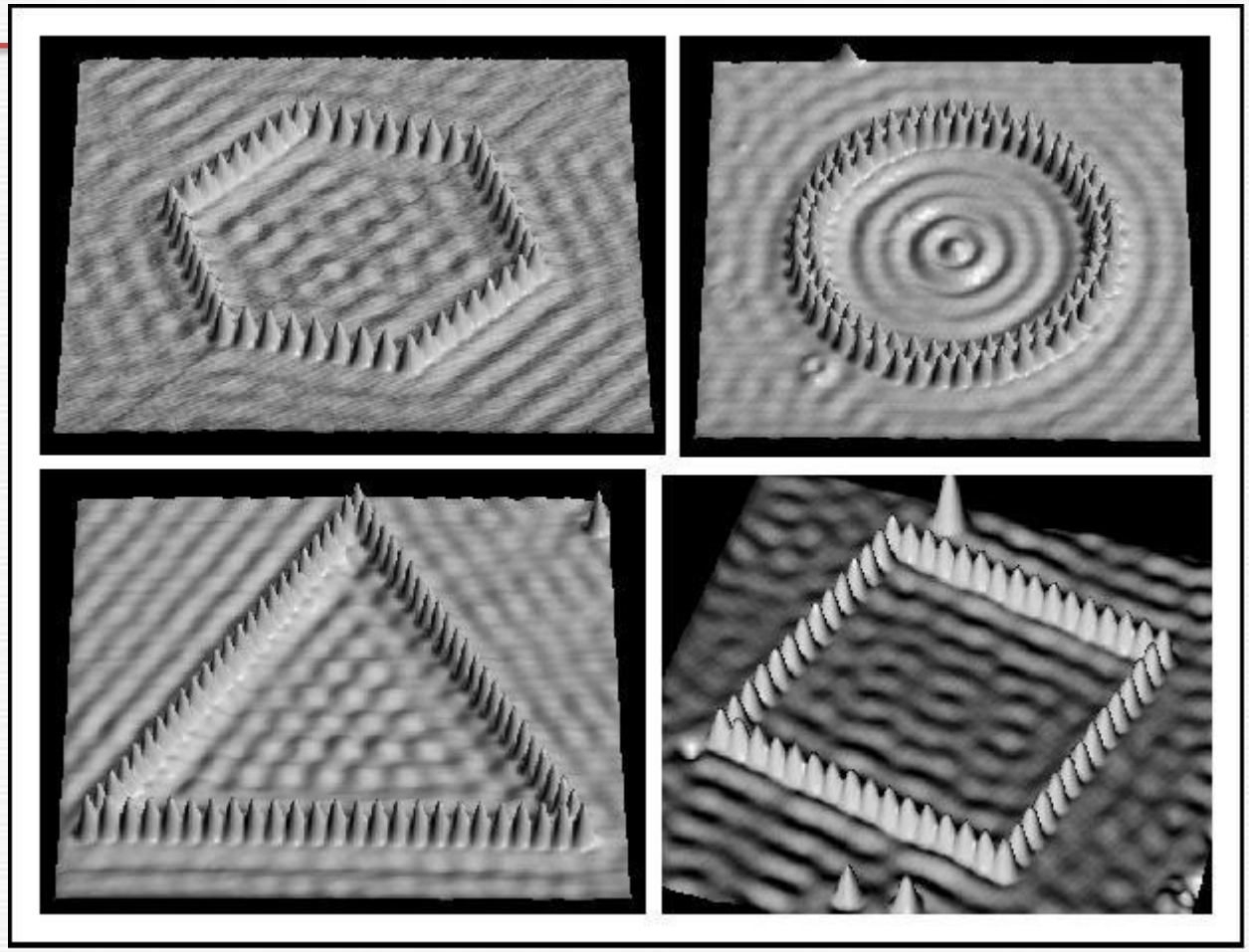
Surface of copper.
IBM, Almaden Research Facility

Quantum Corrals

Imaging the standing wave created by interaction of species

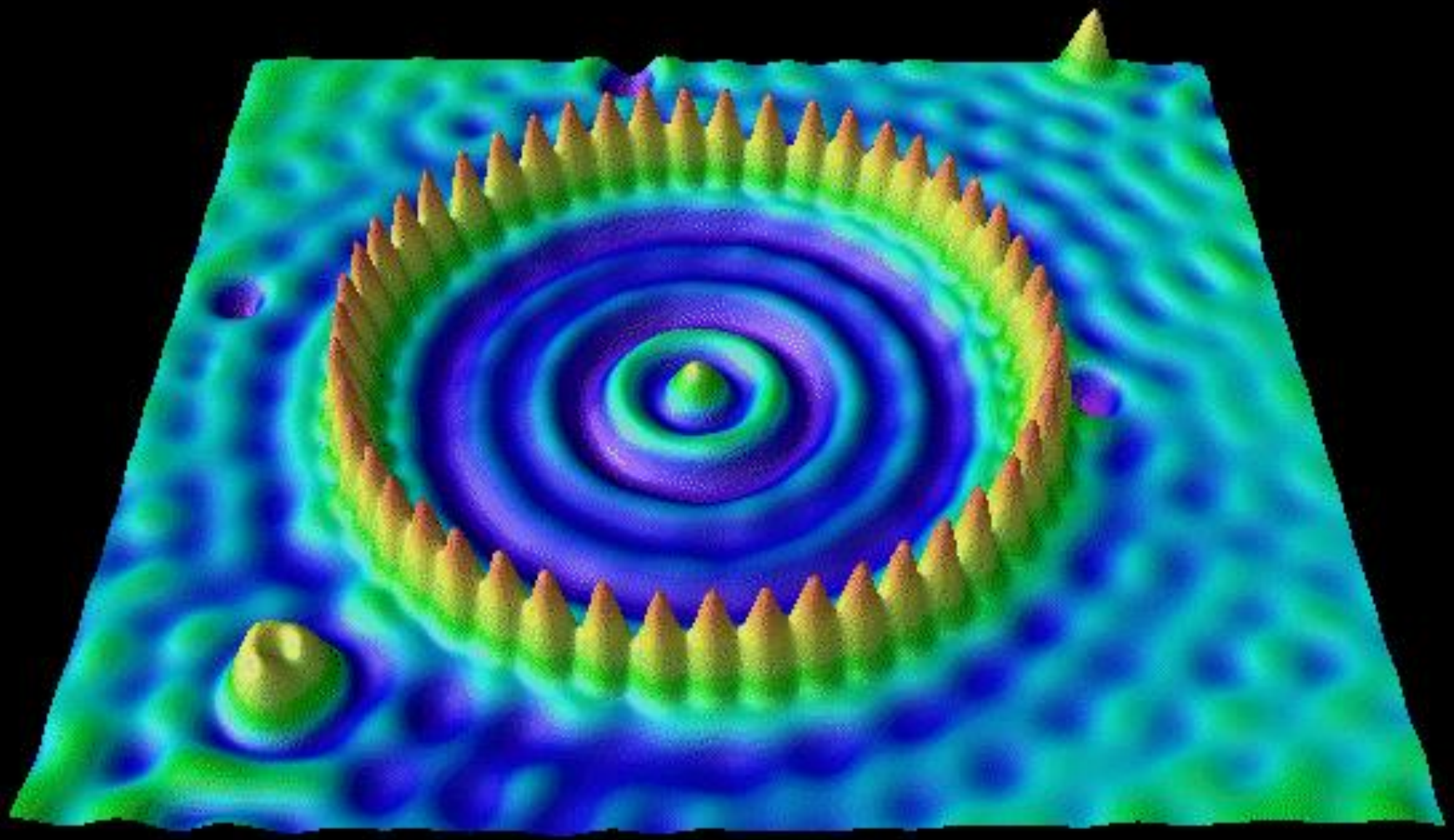


Iron on Copper



The wave effect can be reinforced via constructive interference to create standing waves

Image from an STM



Iron atoms on the surface of Cu(111)

Advantages and Disadvantages

- No damage to the sample
- Spectroscopy of individual atoms
- Relatively Low Cost

- Samples limited to conductors and semiconductors
- Limited Biological Applications: AFM


Thank you for your time!