How To “See” Nano

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Inverse Size Relationship

- To see smaller things, you generally need larger (and more expensive) instruments.
- Range from Eye to Particle Colliders
- Biggest “microscope”: LHC – 16.8 miles in circumference, can see into nucleus.

Human Eye

- Standard Equipment.
- Good for “macroscopic” world.
  - Can see grains of sand.
- Zero cost.
- Fits in head.

Optical Microscope

- Good down to about 0.4 µm.
  - Around the wavelength of visible light.
  - Red light – 0.6 µm
  - Violet light – 0.4 µm
- Fits on a desk.
- $100 - $10,000

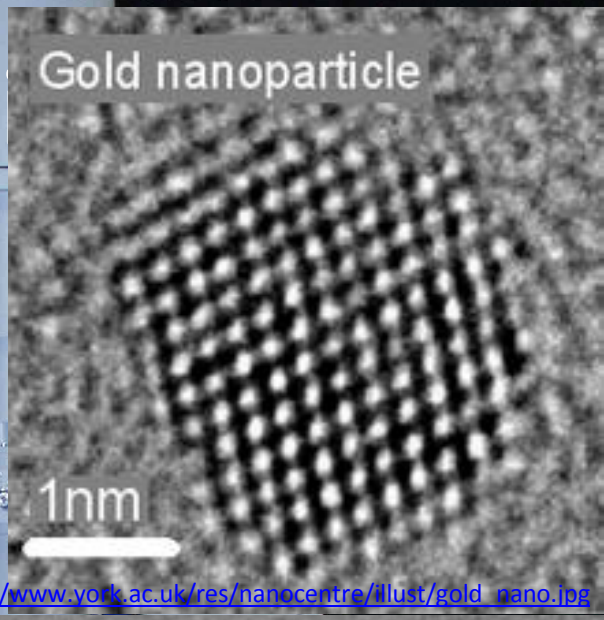
Electron Microscope

- Scanning Electron Microscope (SEM)
  - Like an optical microscope but uses electron "waves" instead of visible light.
- Good down to tens of nm.
- Size of a desk.
- $250,000

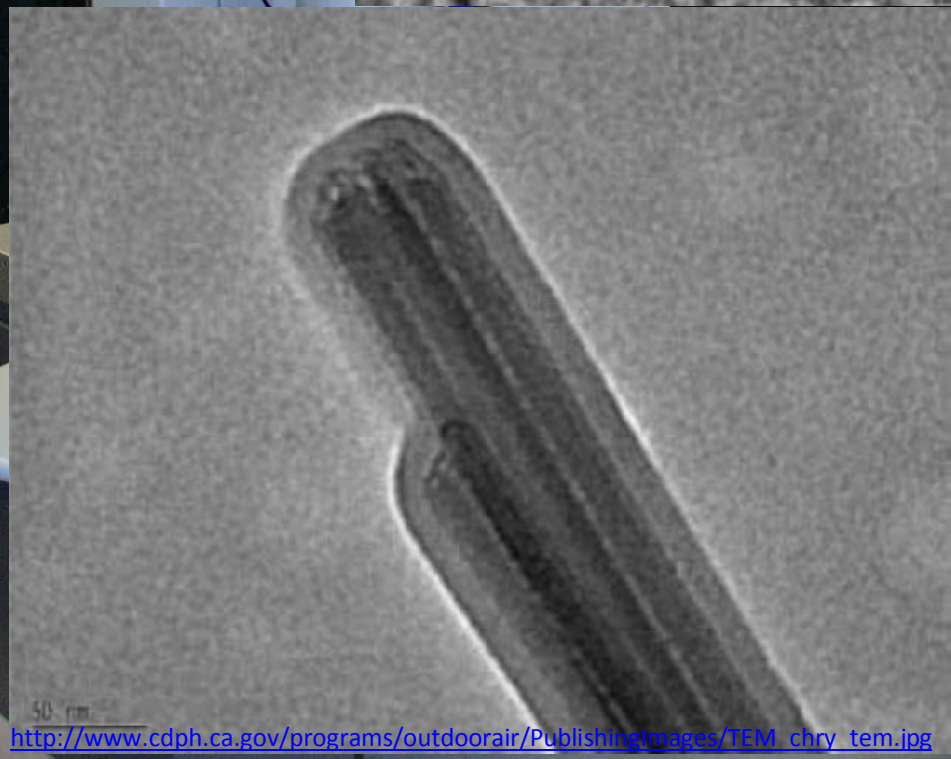
http://commons.wikimedia.org/wiki/File:Neuron-SEM.png

Transmission Electron M

- Like an X-ray
  - Shine electrons through something and look at shadows.
- Good down to atomic size.
- Needs a tall room.
- $500,000 +



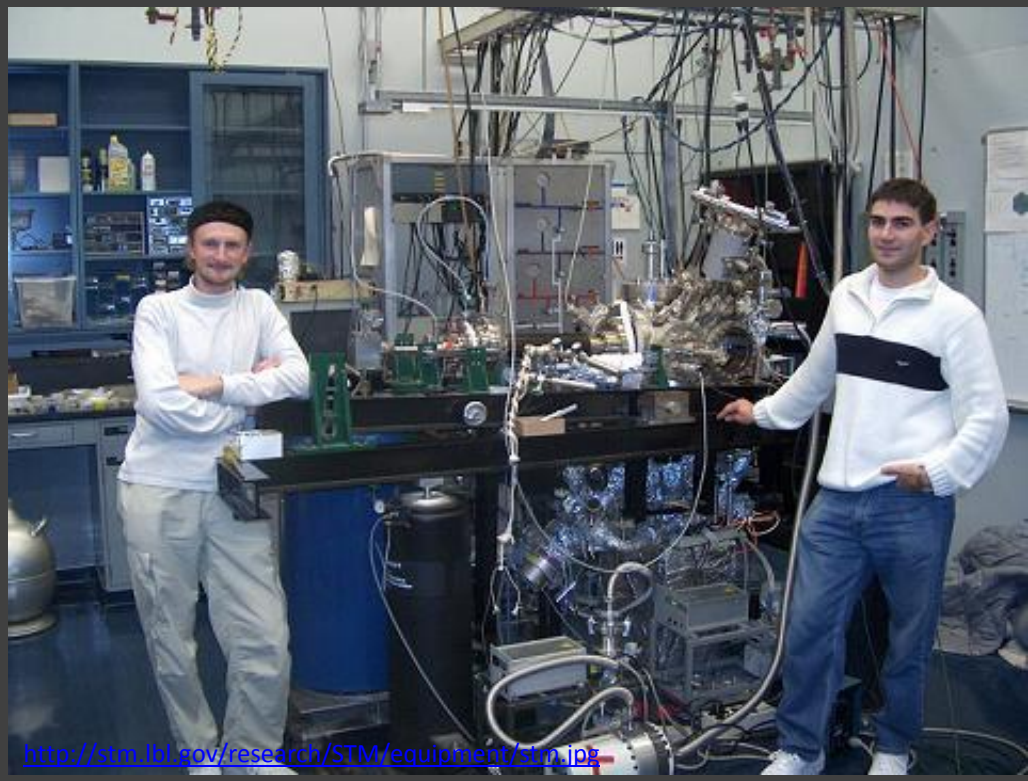
http://www.york.ac.uk/res/nanocentre/illust/gold_nano.jpg



http://www.cdph.ca.gov/programs/outdoorair/PublishingImages/TEM_chry_tem.jpg

Scanning Tunneling Microscopy

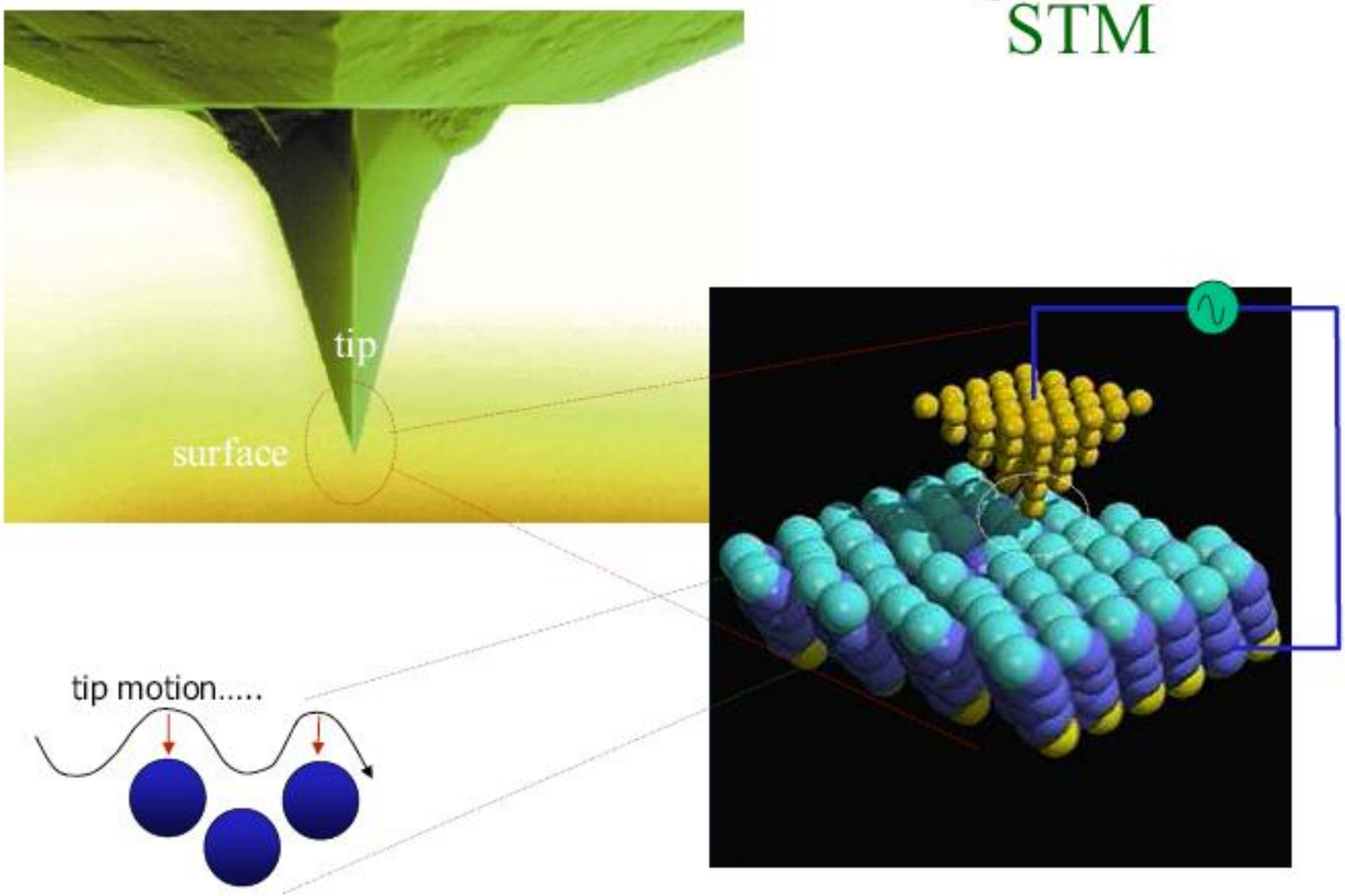
- Uses Quantum Mechanics to make a “picture” of a surface.
- Can image atoms in crystals.
- Needs high vacuum.
- Desk Sized.
- $100,000 - $200,000



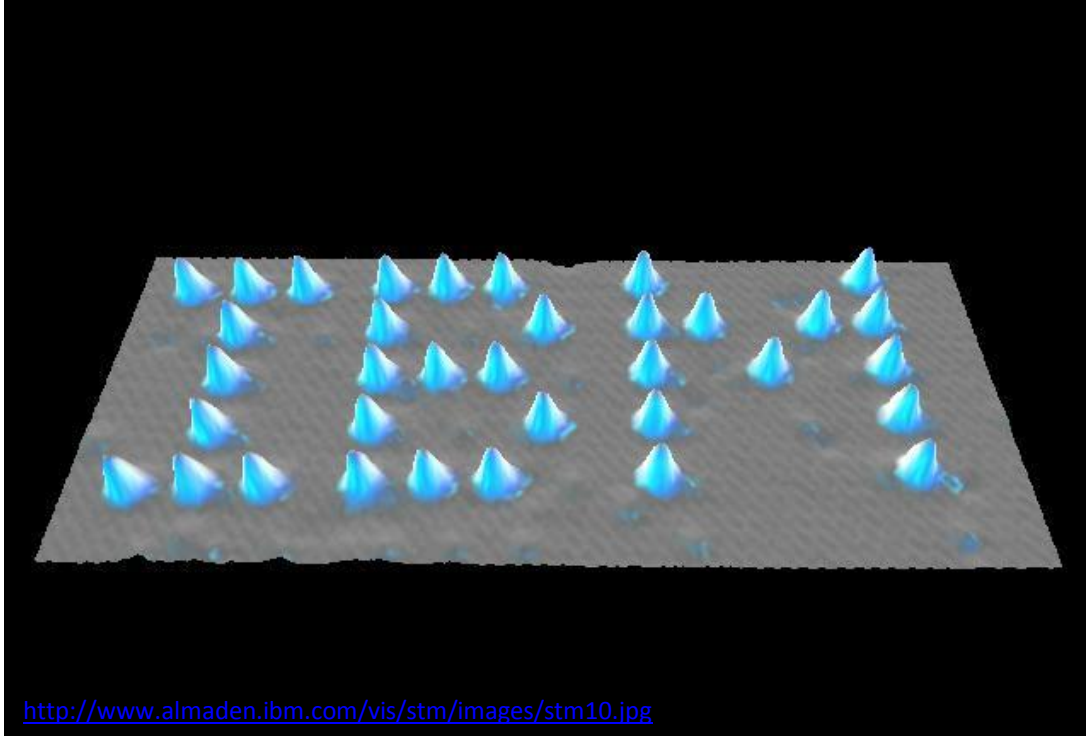
http://stm.lbl.gov/research/STM/equipment/stm.jpg

revolution of tunnelling: Scanning Tunnelling Microscope

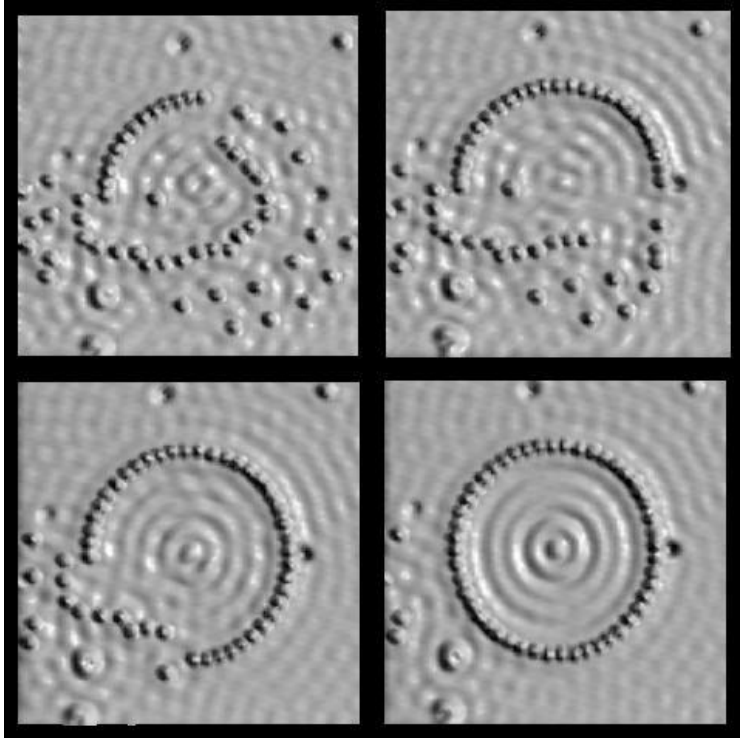
STM

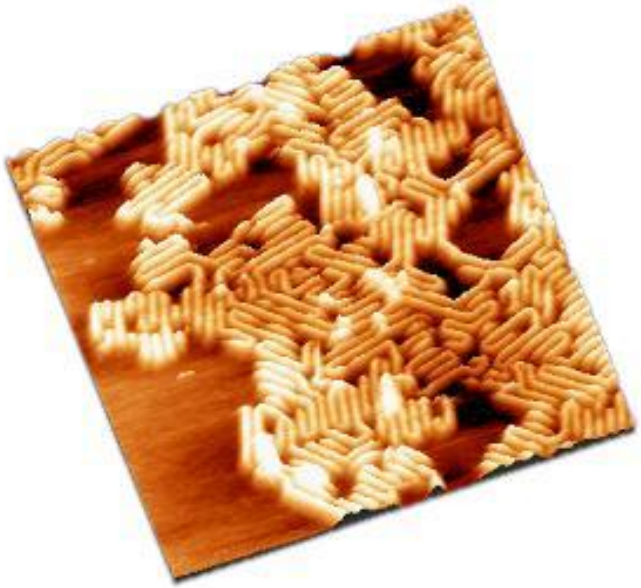


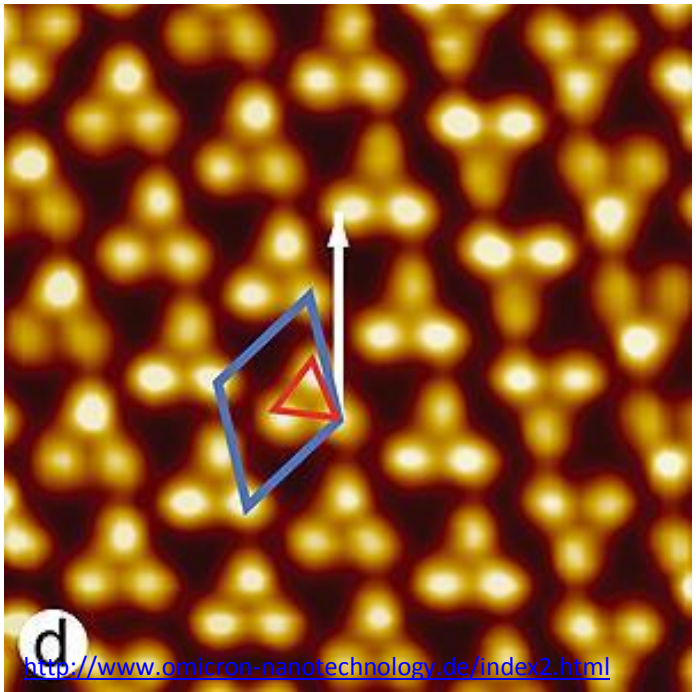
http://nanohub.org/site/wiki/35/pic3_stm.png



http://www.almaden.ibm.com/vis/stm/images/stm10.jpg



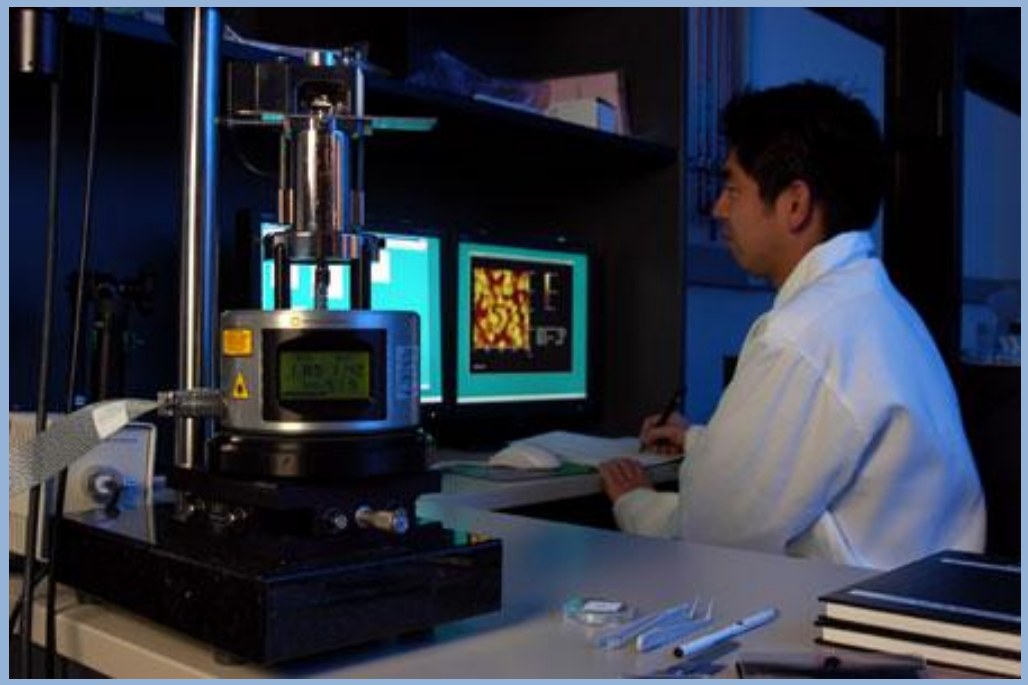


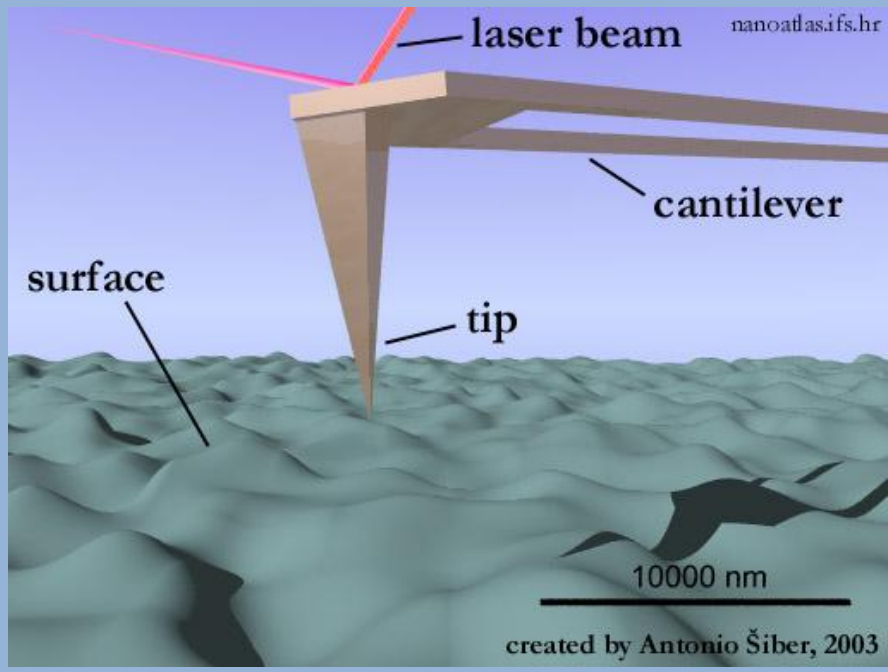


http://www.omicron-nanotechnology.de/index2.html

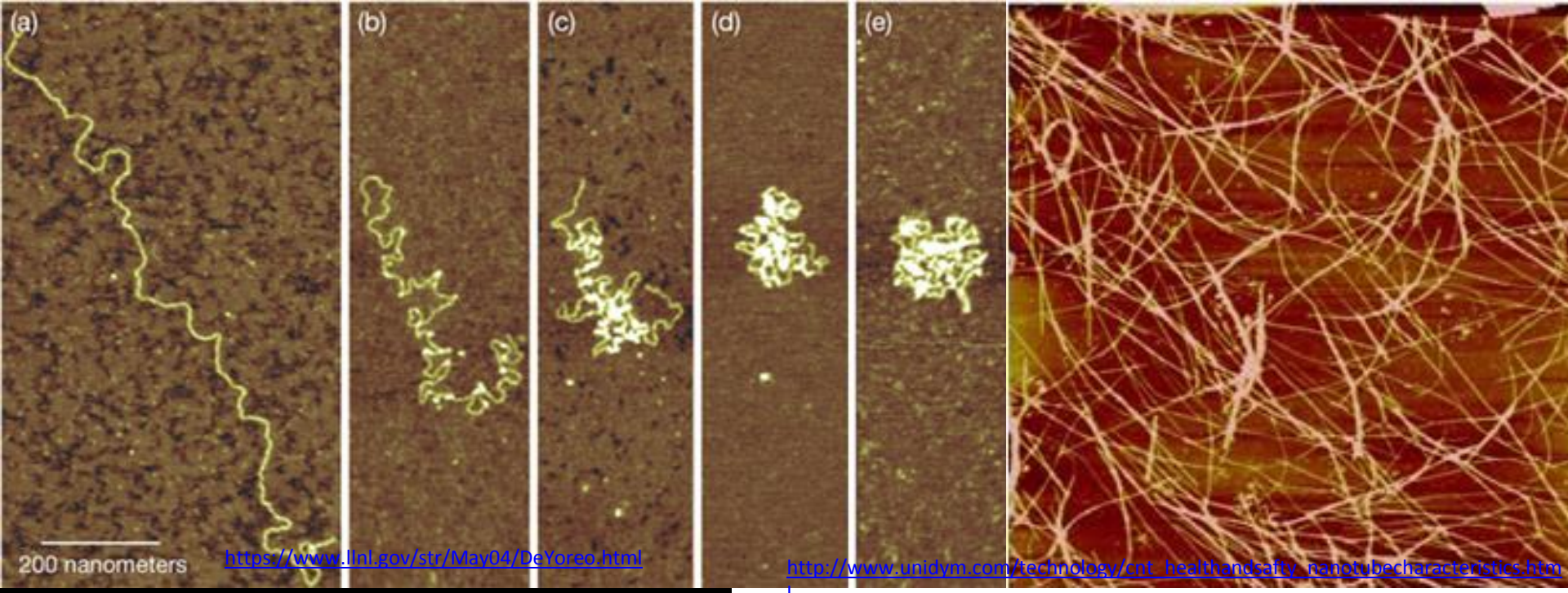
Atomic Force Microscopy

- Like a Phonograph
- Drags a sharp tip across a surface.
  - Looks for deflection.
- Nano resolution
- Desktop
- $50,000 - $500,000





http://www.nanotech-now.com/images/Art_Gallery/AS-AFM.jpg



https://www.llnl.gov/str/May04/DeYoreo.html

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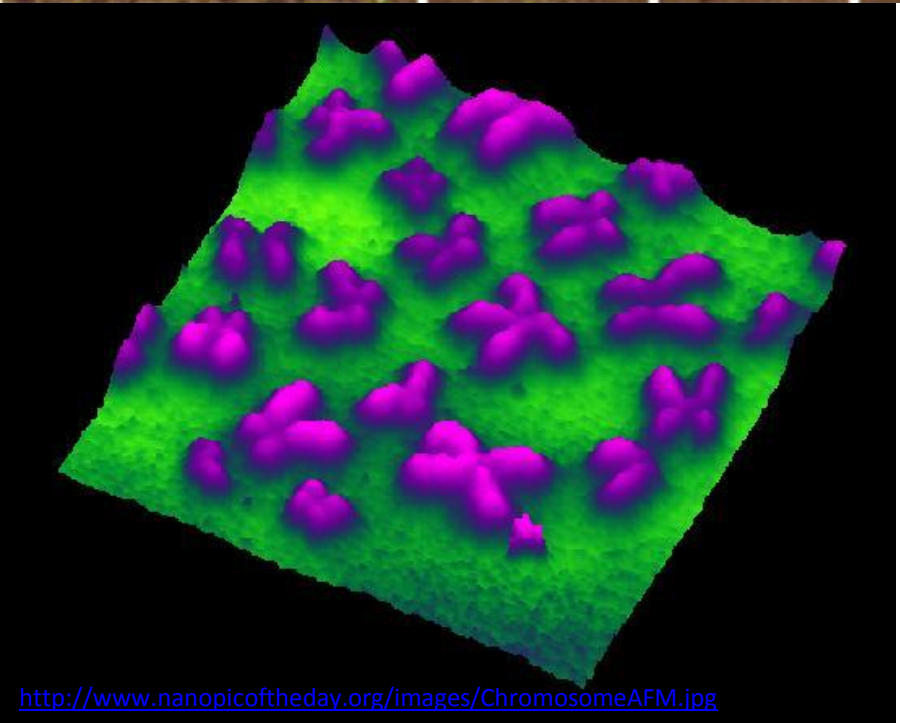

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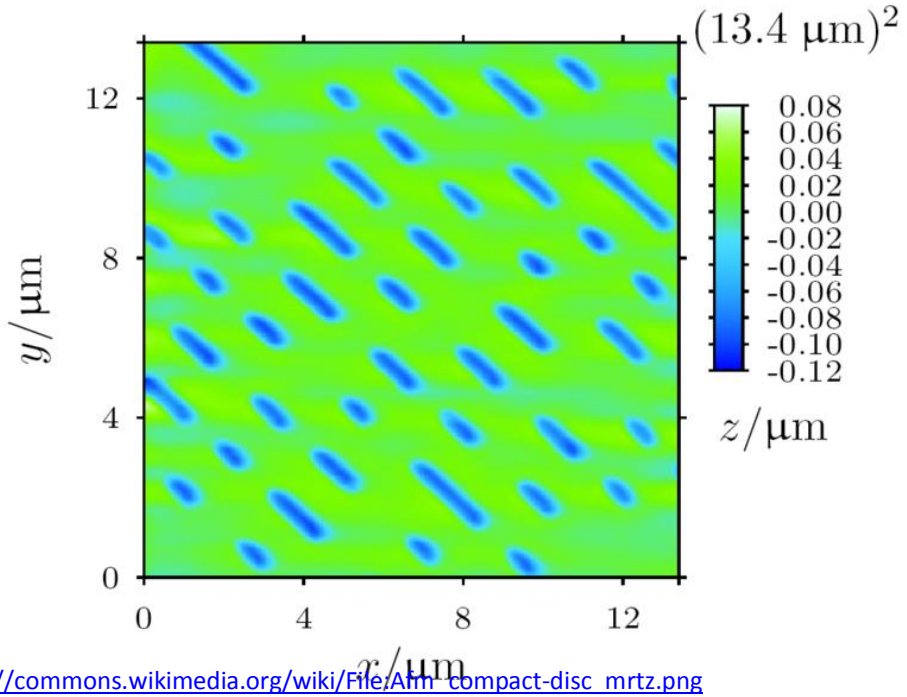

http://commons.wikimedia.org/wiki/File:Afm_compact-disc_mrtz.png

X-Rays

- National Labs
- Short wavelength → can see atomic features.
- Mile-sized facilities.
- $1 - $2 Billion.


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SECTOR 9
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