

基于扫描探针显微镜的分析方法

Manipulation with SPM

Outline

- History
- Techniques
- Application
- Prospect

History

- 1959年, Richard Feynman
“There is plenty of room at the bottom”



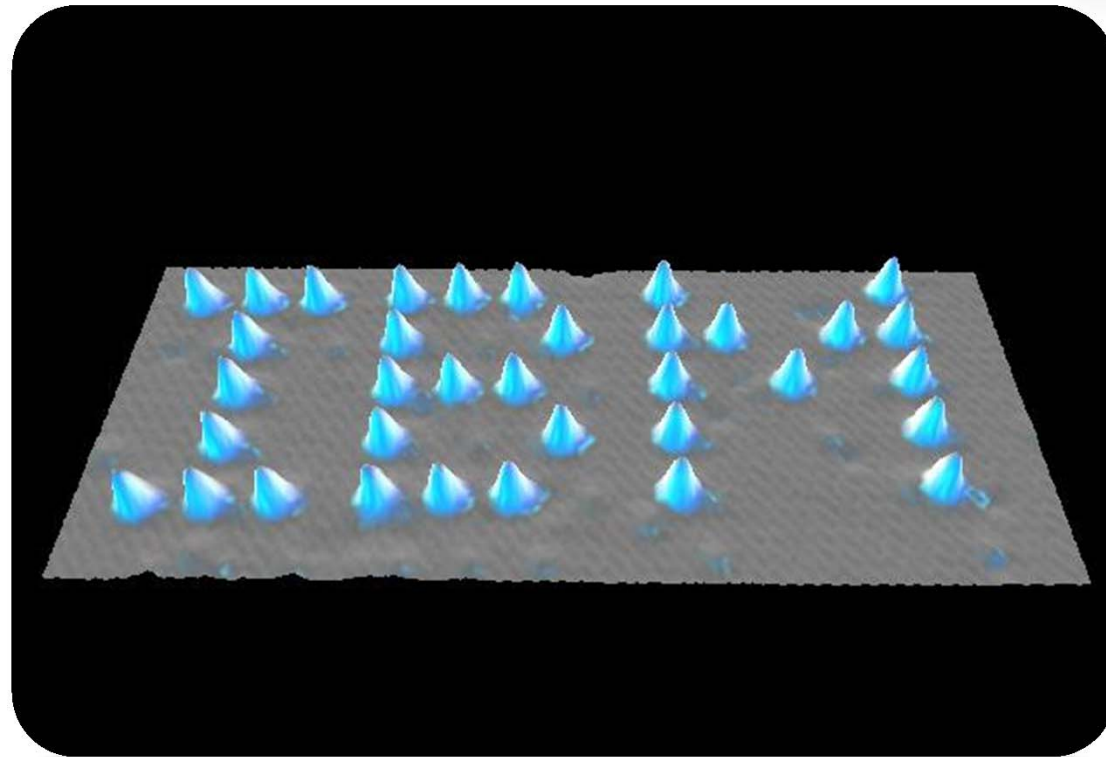
History

- 1986年， Gerd Binnig and Heinrich Rohrer
Invention of STM



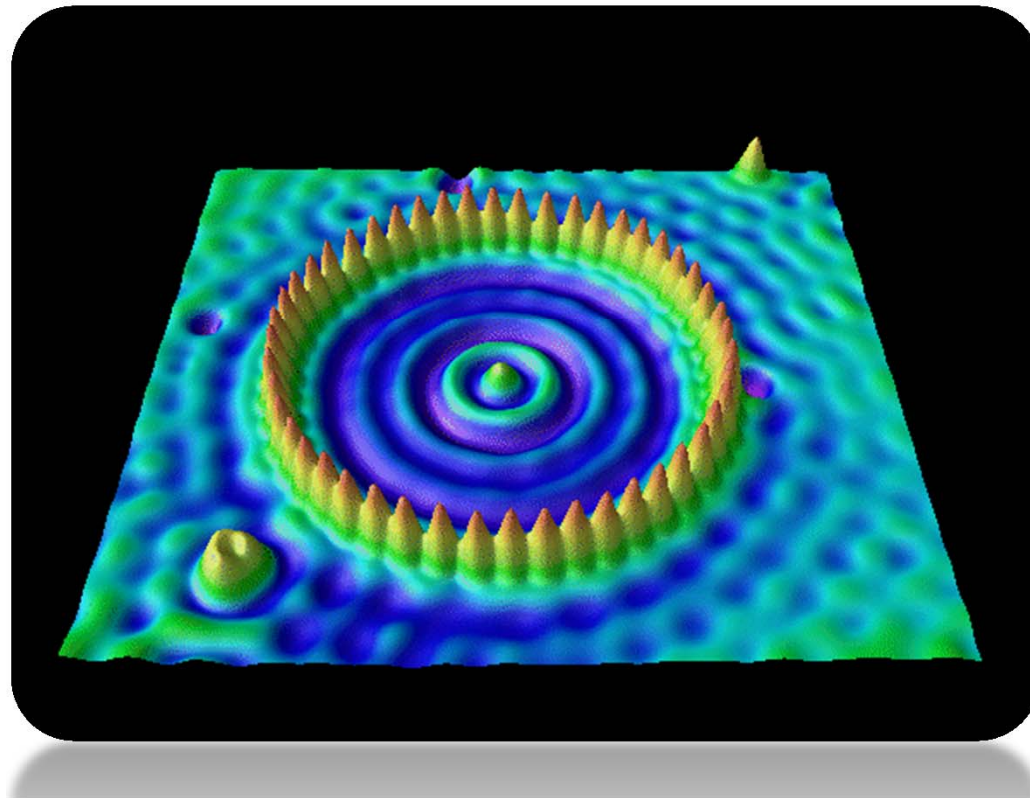
History

- 1989年， Don Eigler at IBM
First Atomic Manipulation



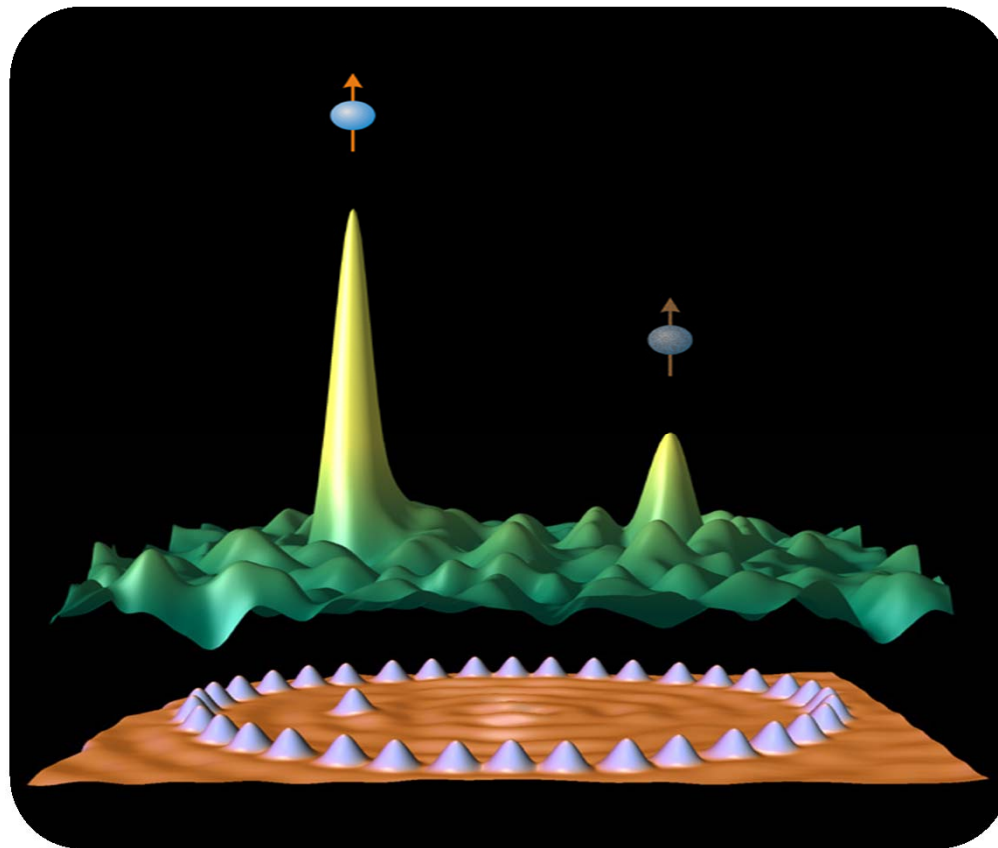
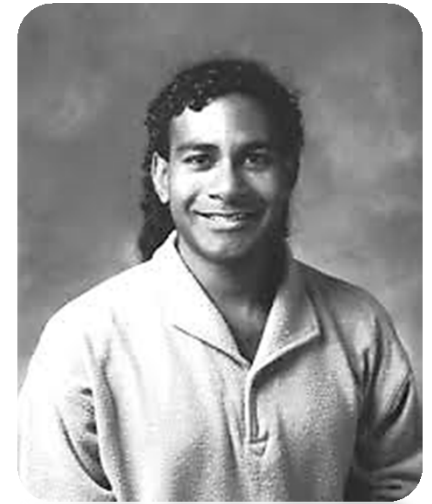
History

- 1993年, Crommie, Lutz, and Eigler
Quantum Corral



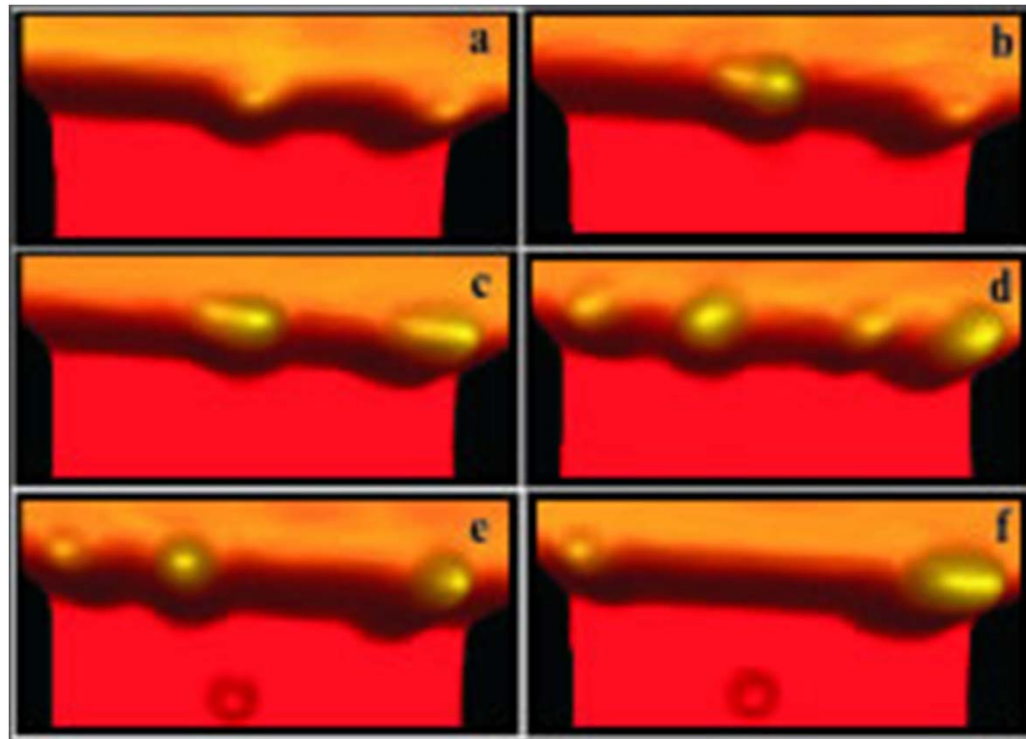
History

- 2000年, Manoharan, Lutz, Eigler
Quantum Mirage



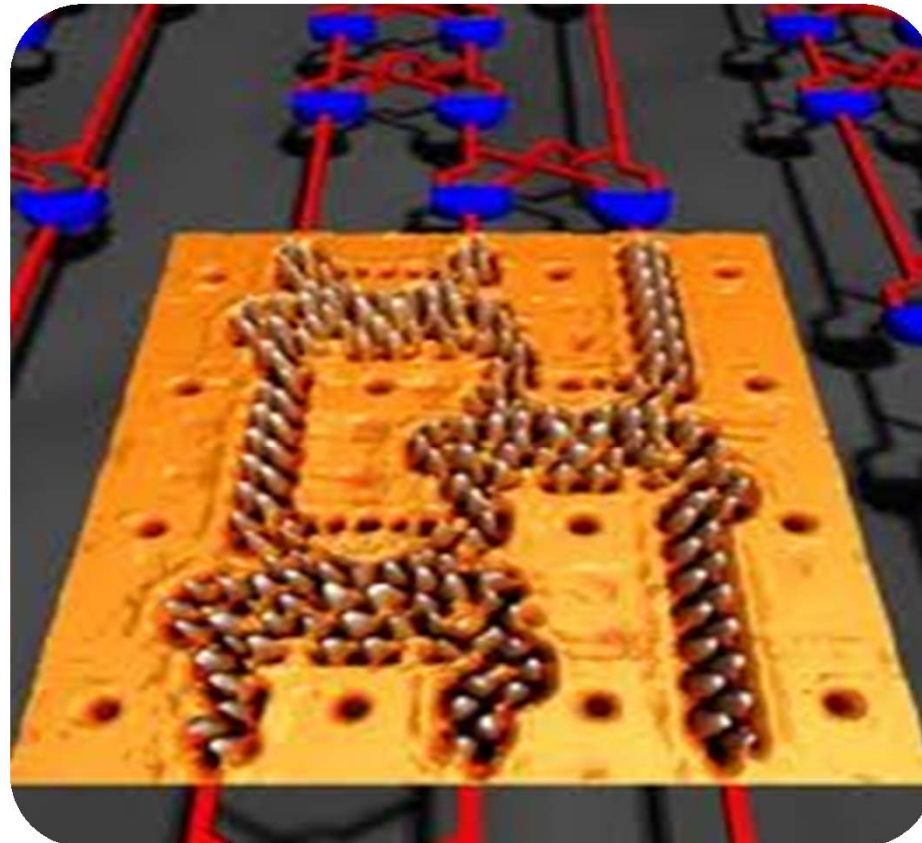
History

- 2000年, S.-W. Hla at Ohio U.
Single Molecular Reaction



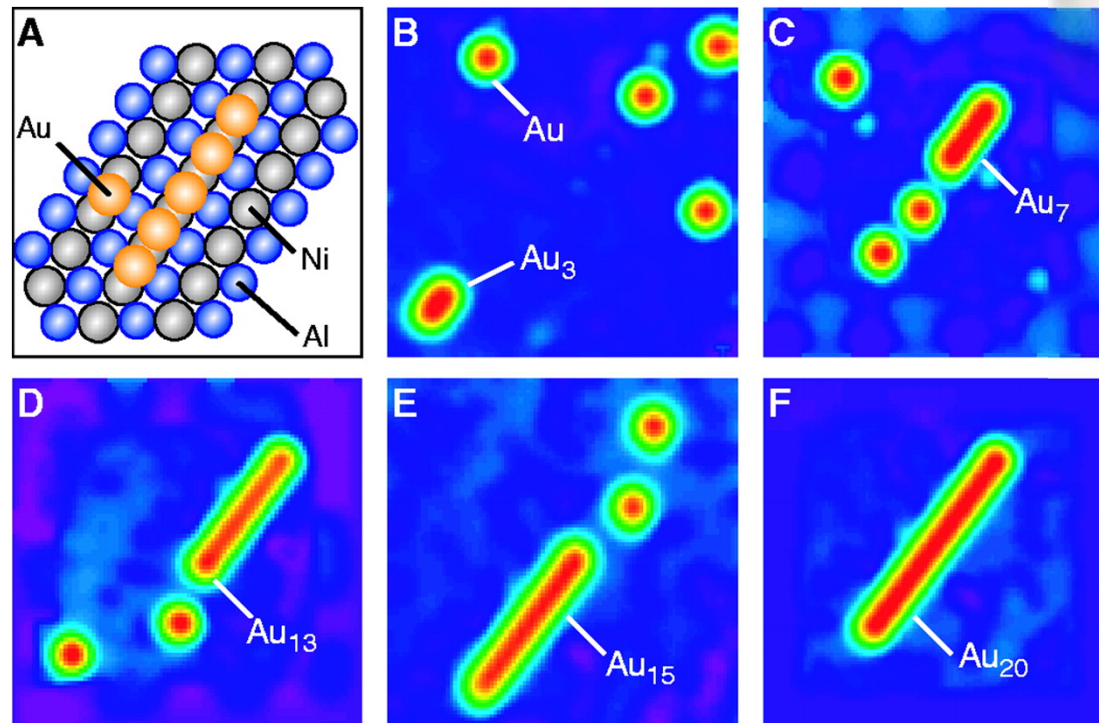
History

- 2002年, Heinrich, Lutz, and Eigler
Molecular Cascades



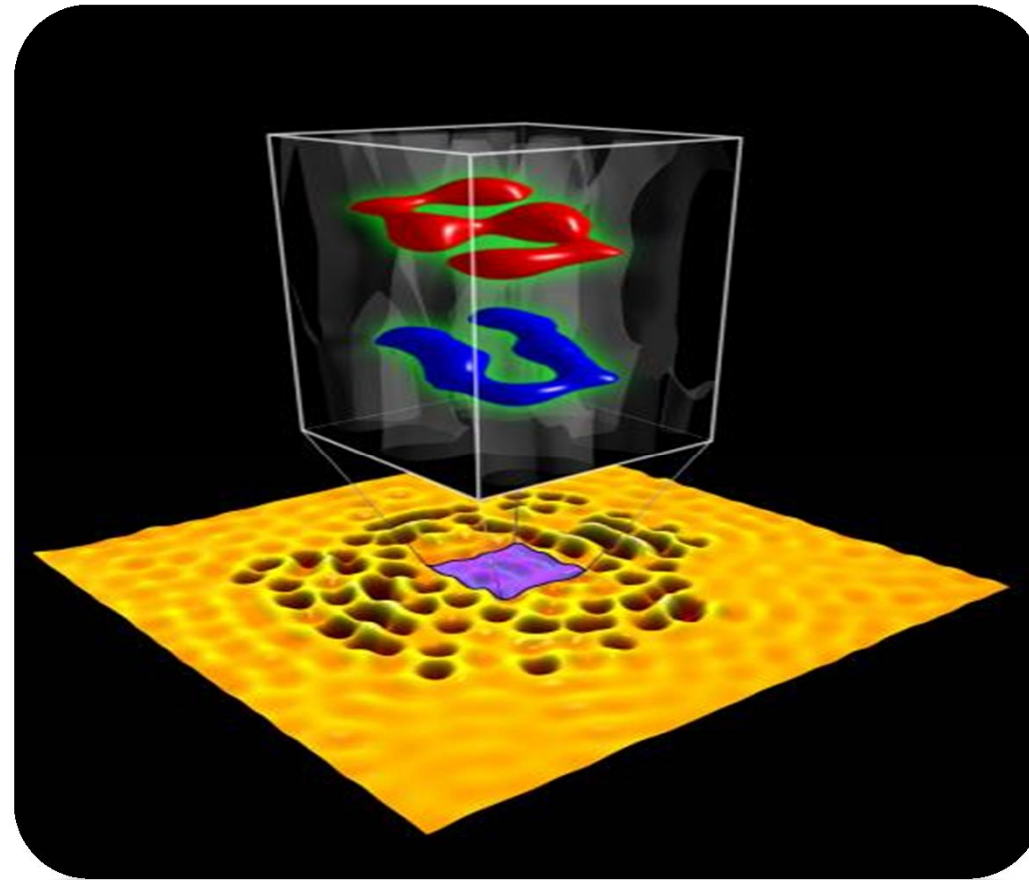
History

- 2002年, Wilson Ho at UCI
Artificial 1D Band Structure

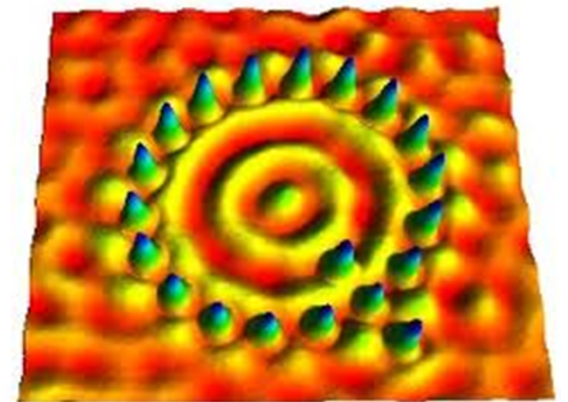
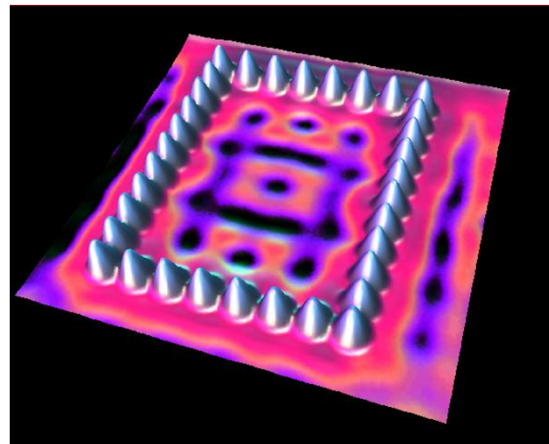
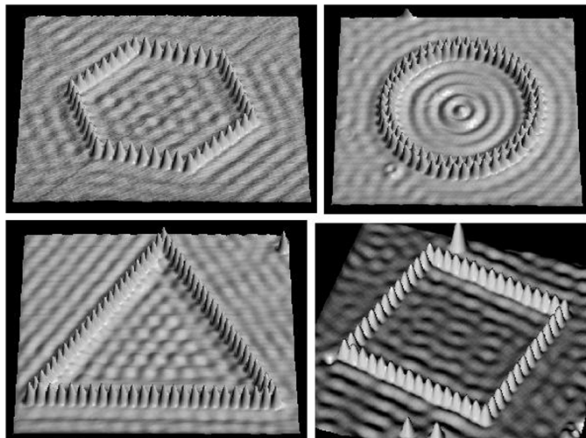
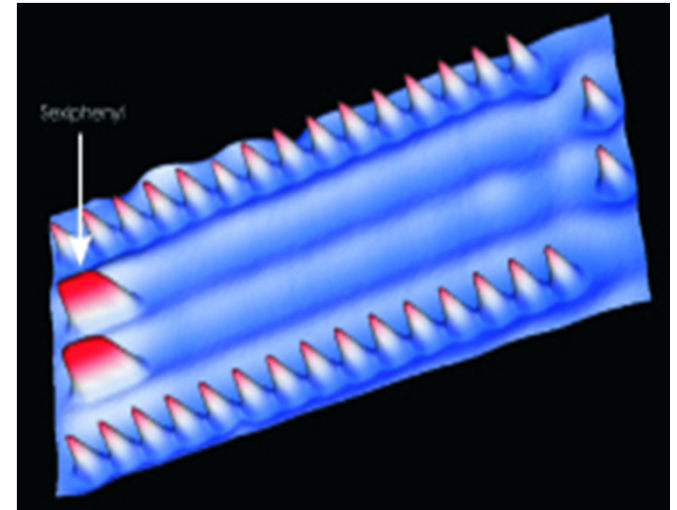
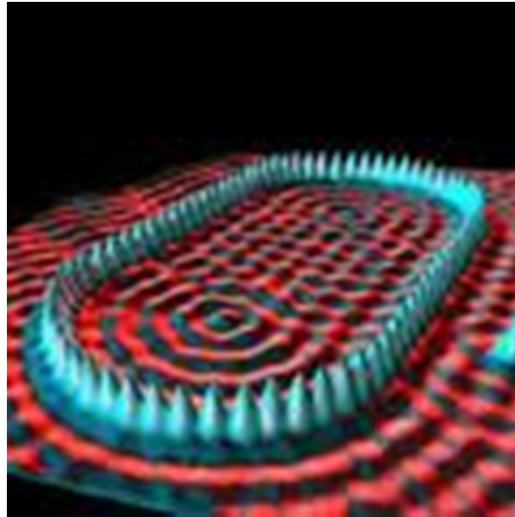
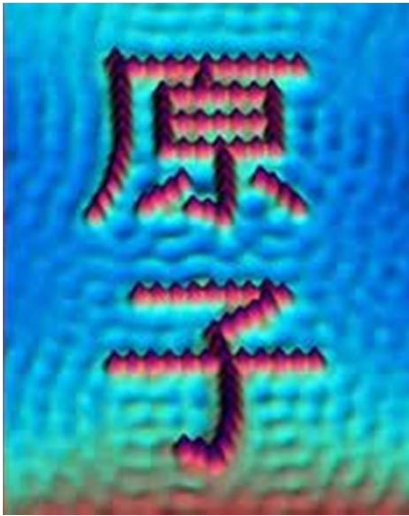


History

- 2009年, Manoharan at Stanford U.
Quantum Holography

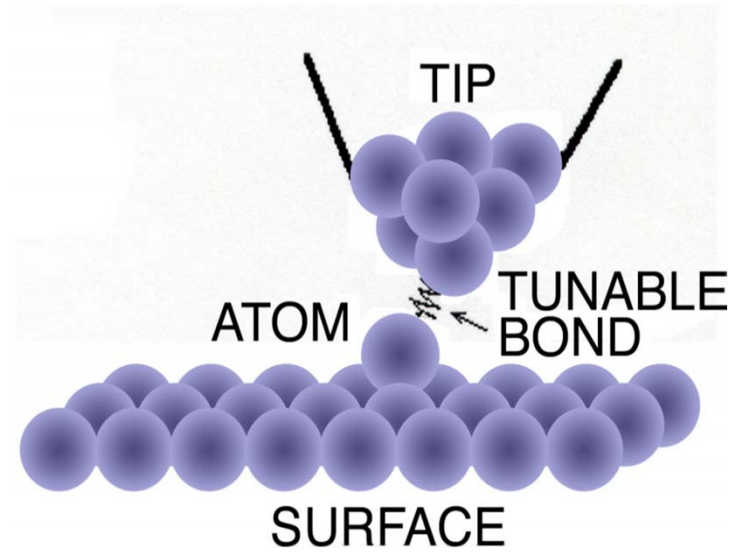
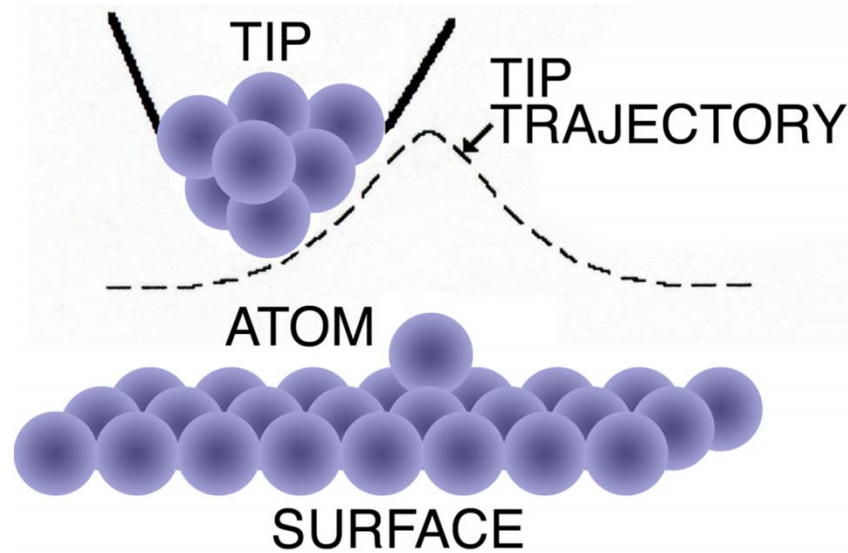


Other Examples



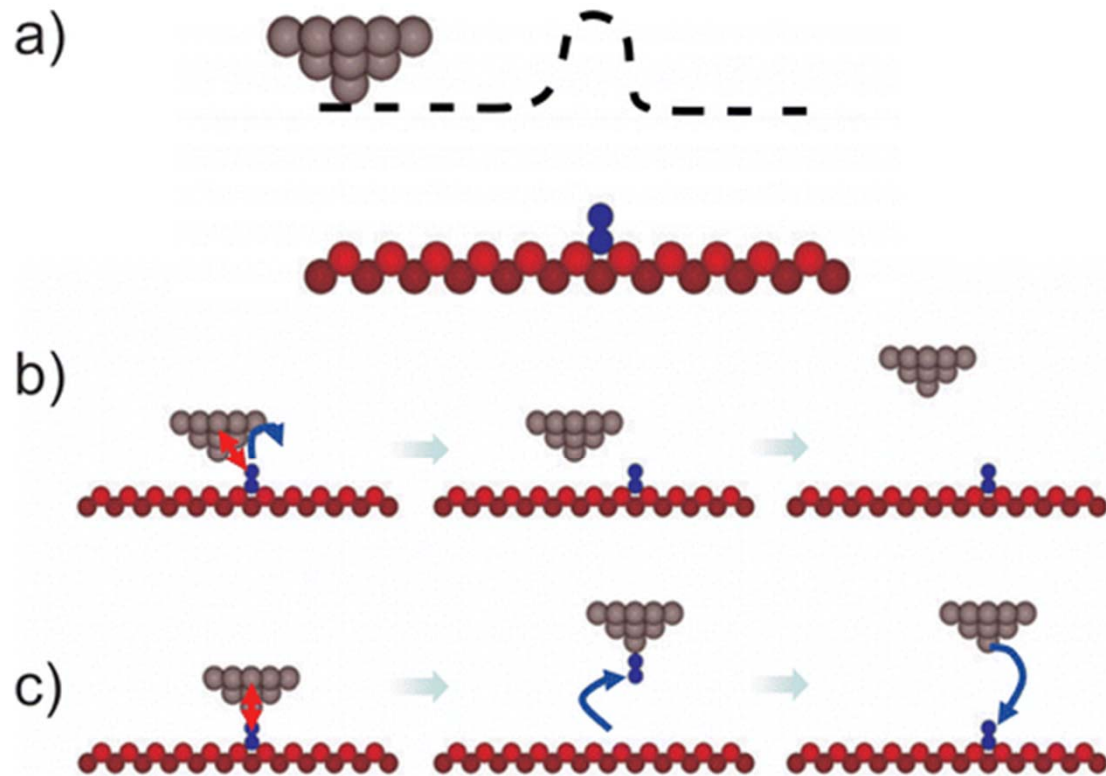
Techniques

- Force between tip and adatom



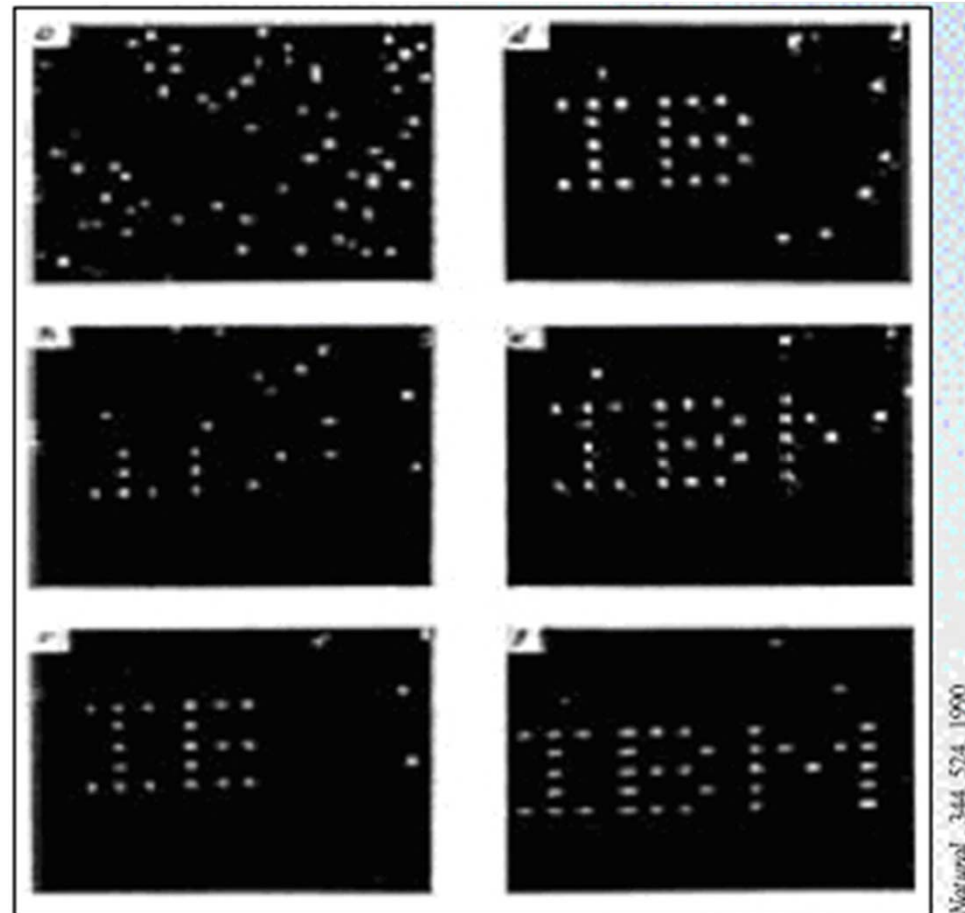
Techniques

- Modes of Manipulation



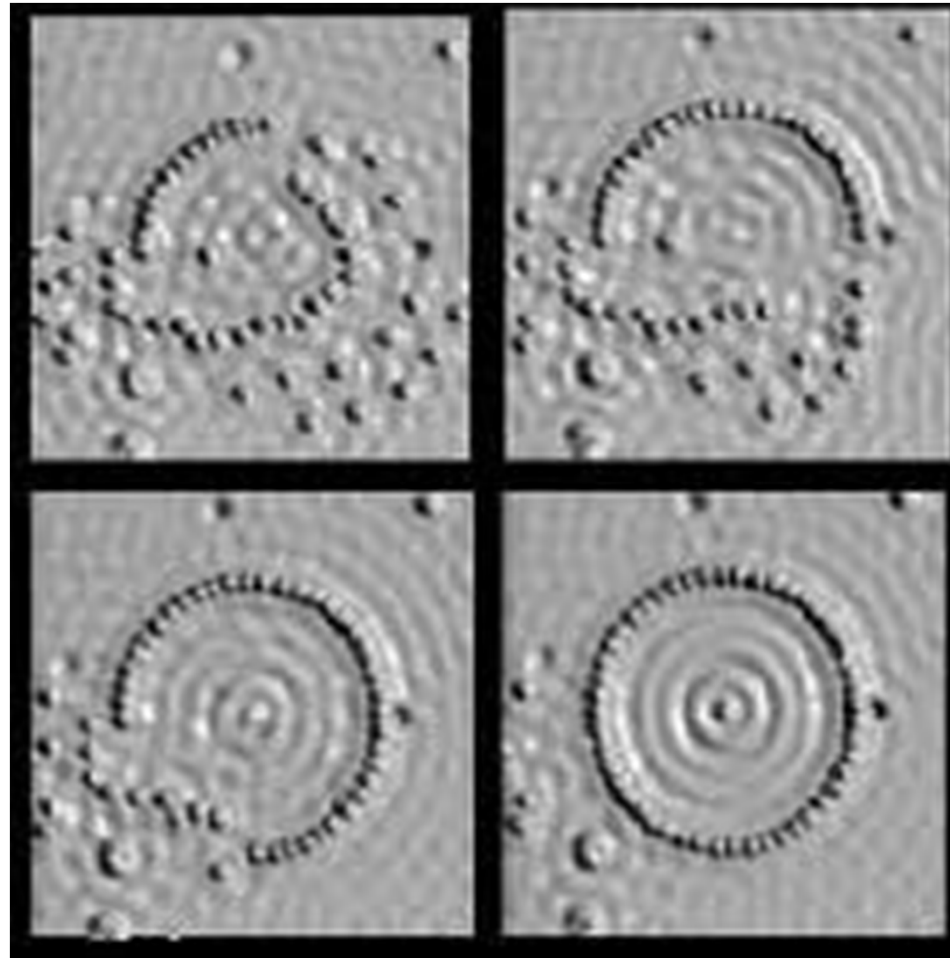
Techniques

- One atom by one atom



Techniques

- One atom by one atom



Techniques

- One atom by one atom

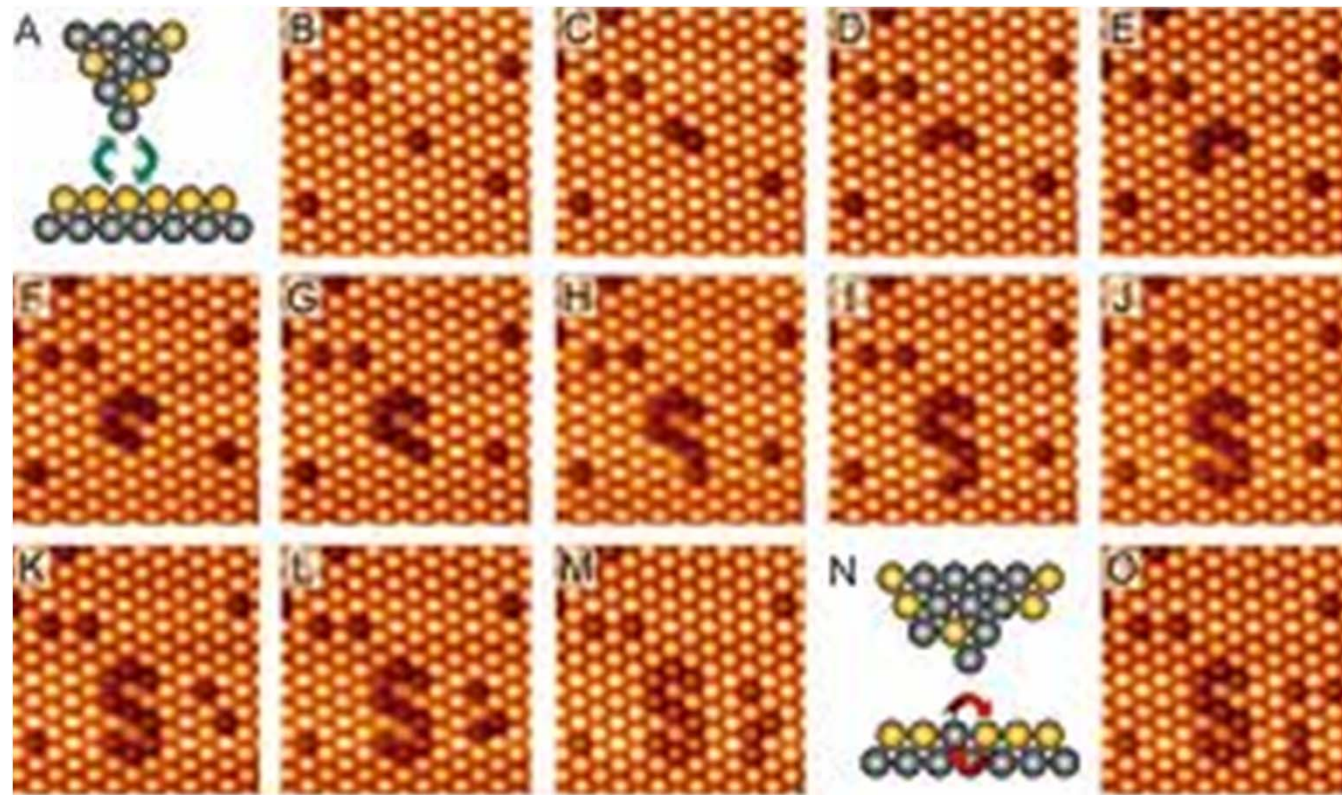
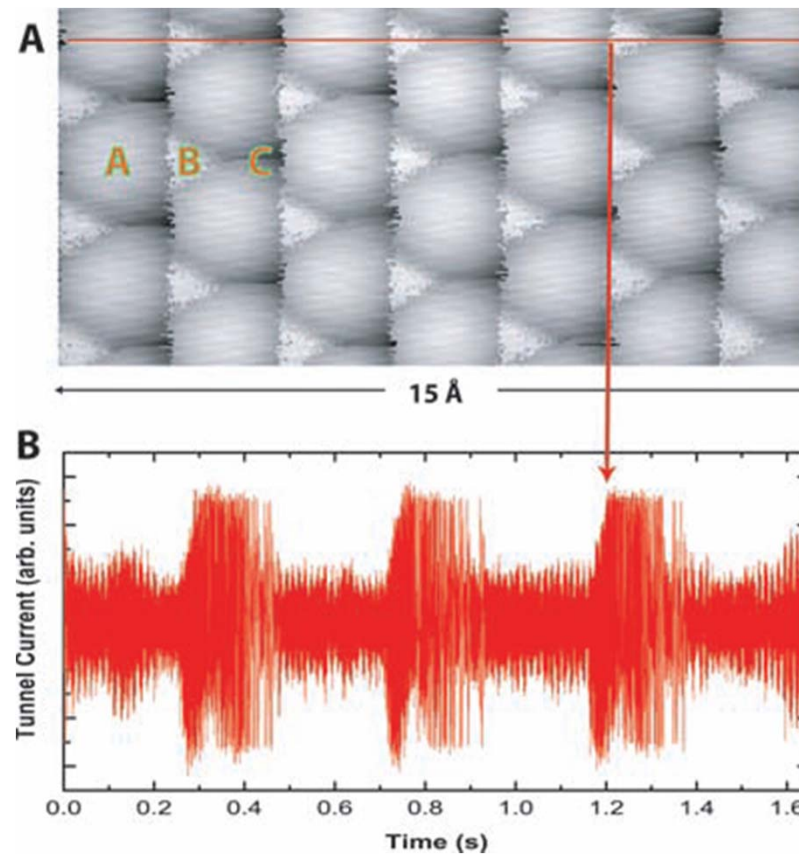


Fig. 3

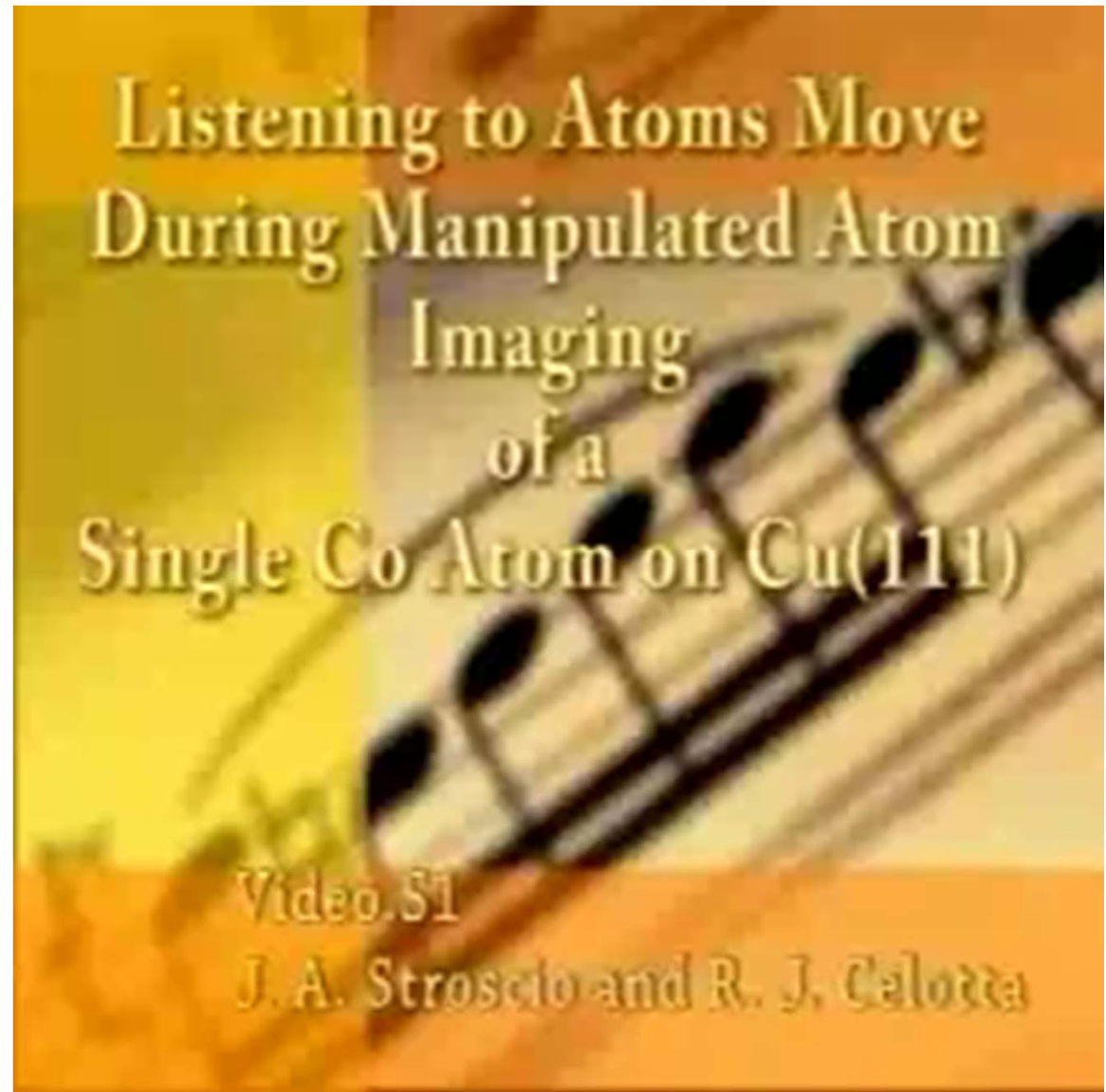
Techniques

- Sound Technique



Techniques

- Sound Technique
Stroschio's movie



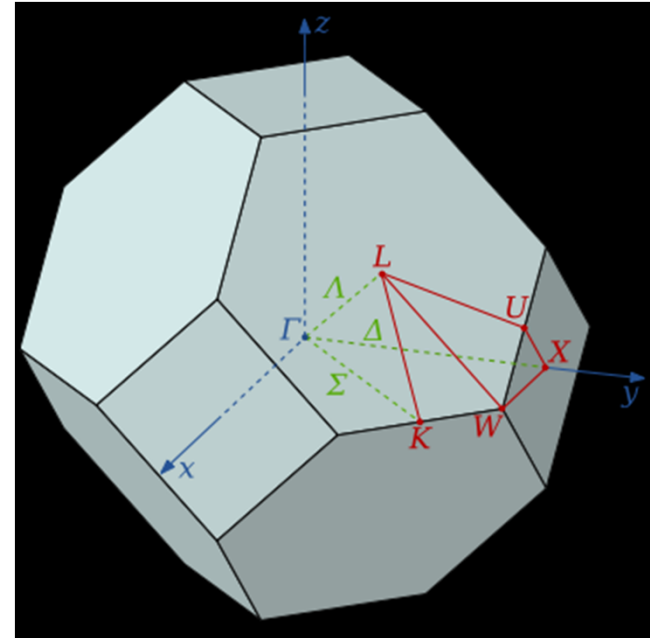
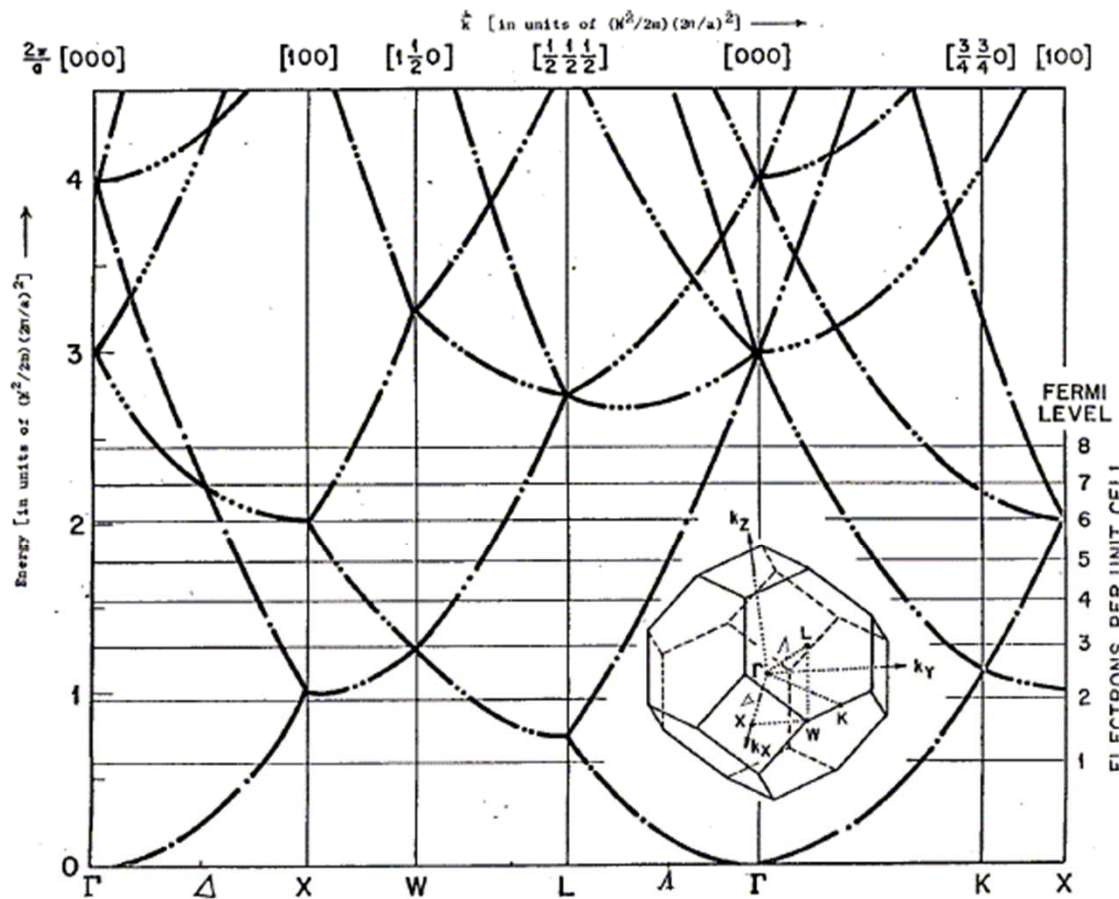
Techniques

- Sound Technique

Don Eigler's talk

Application: Quantum Corral

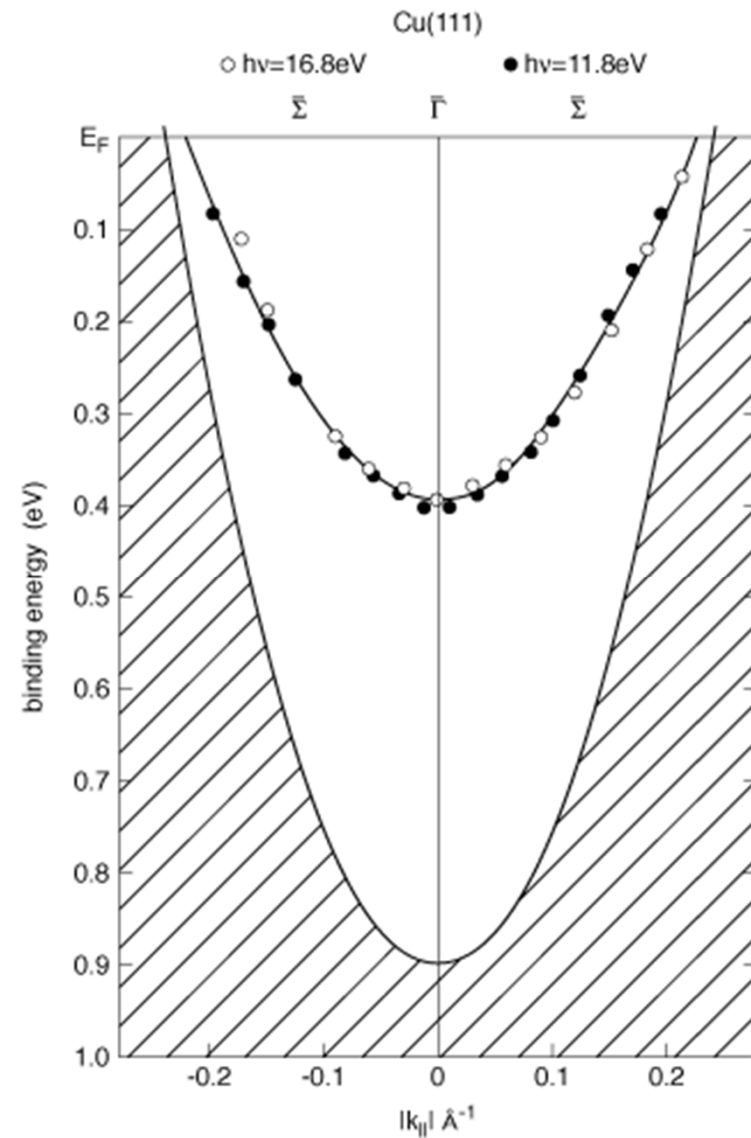
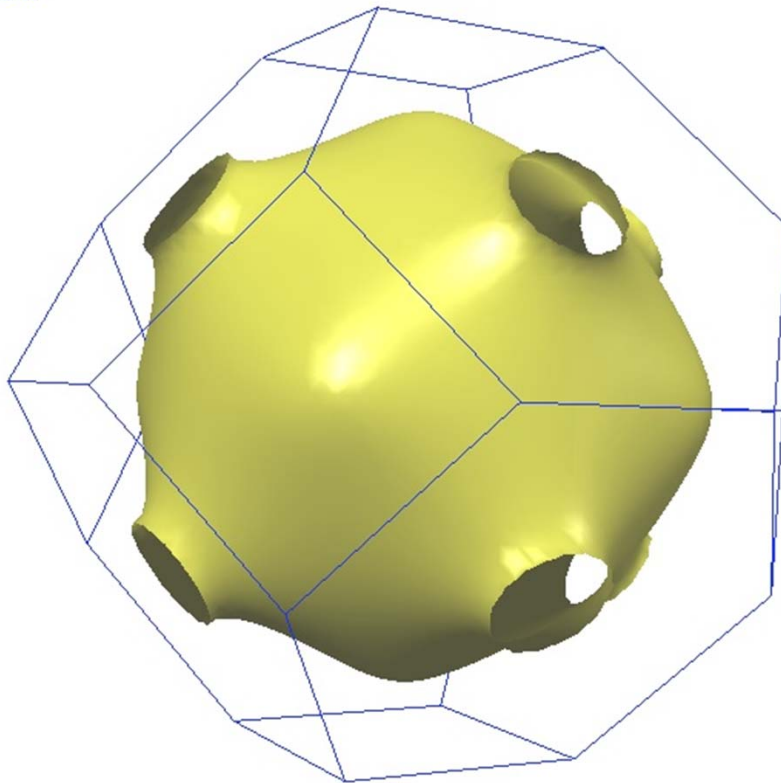
- Band Structure of a fcc crystal



Application: Quantum Corral

- Surface State of Cu(111)

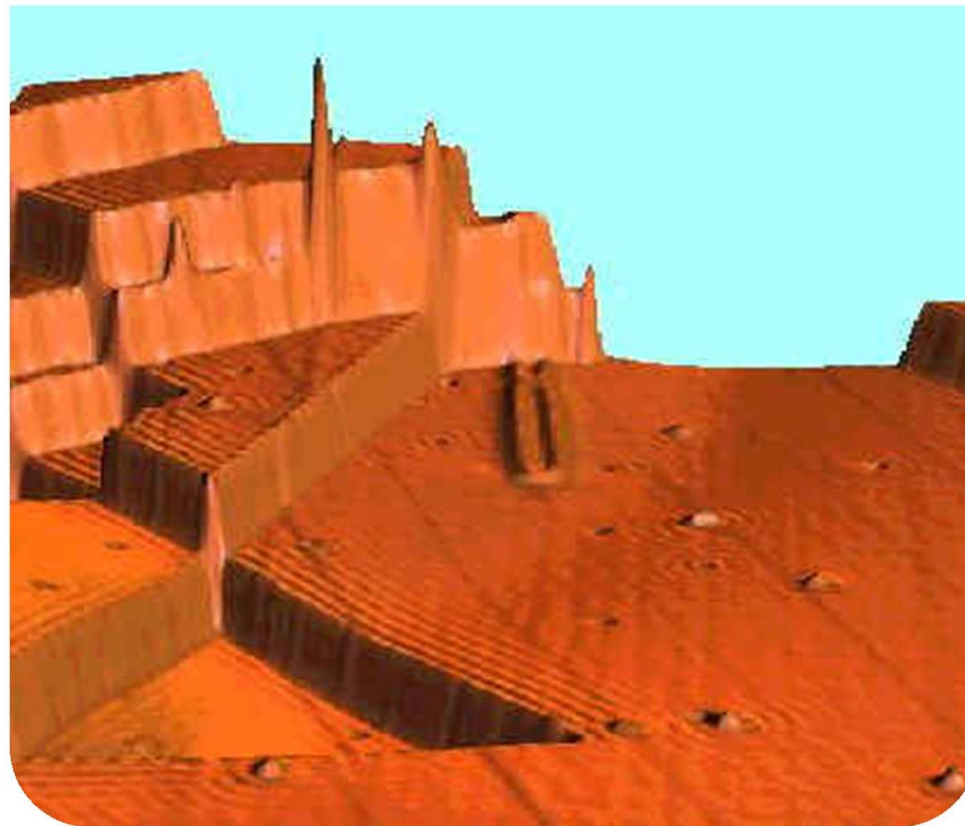
Cu



Application: Quantum Corral

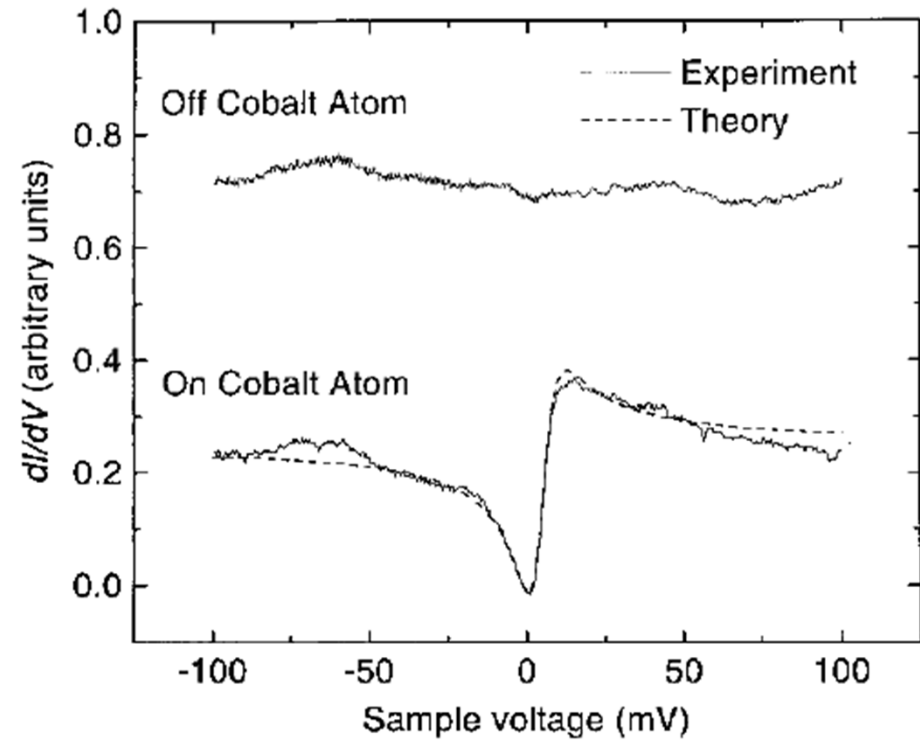
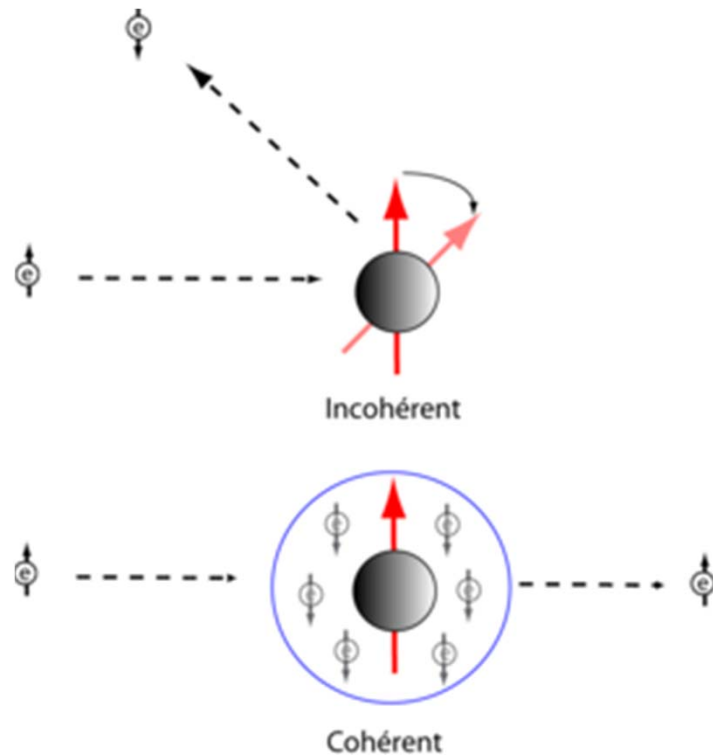
- Scattering Wave

$$\Delta\text{LDOS}(E', \rho) \propto \frac{1}{k_0 \rho} \left[\cos^2 \left(k_0 \rho - \frac{\pi}{4} + \delta_0 \right) - \cos^2 \left(k \rho - \frac{\pi}{4} \right) \right]$$



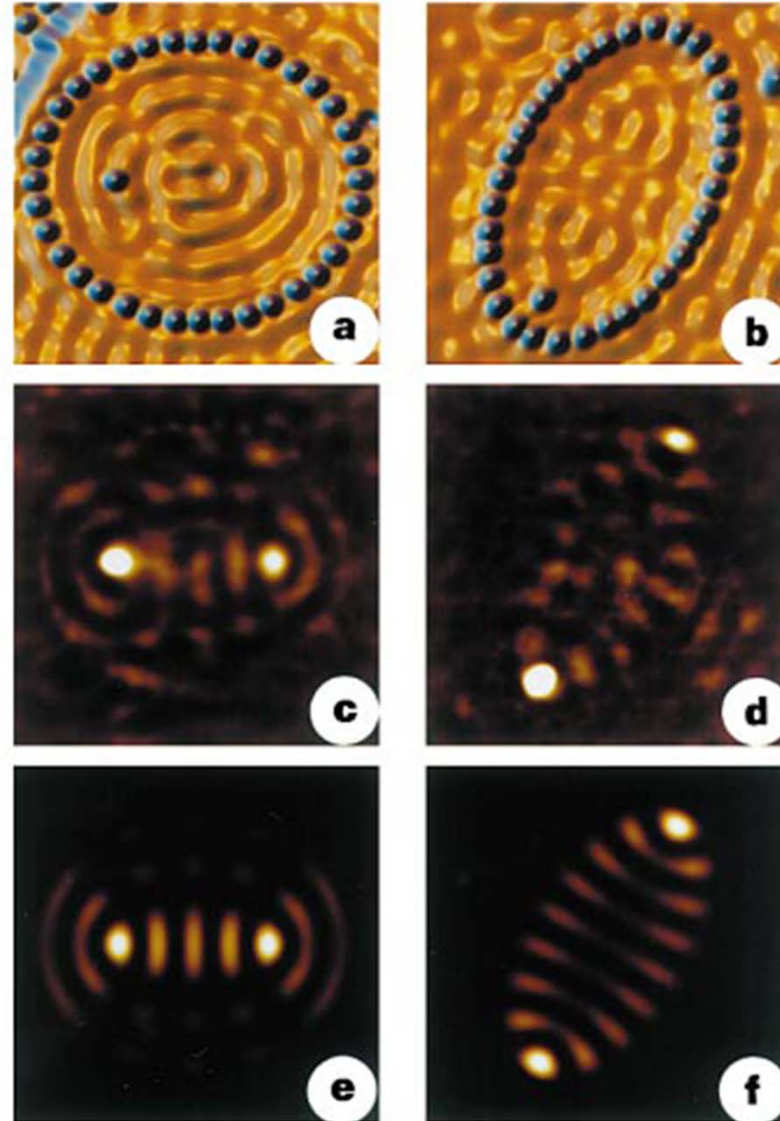
Application: Quantum Mirage

- Kondo Effect

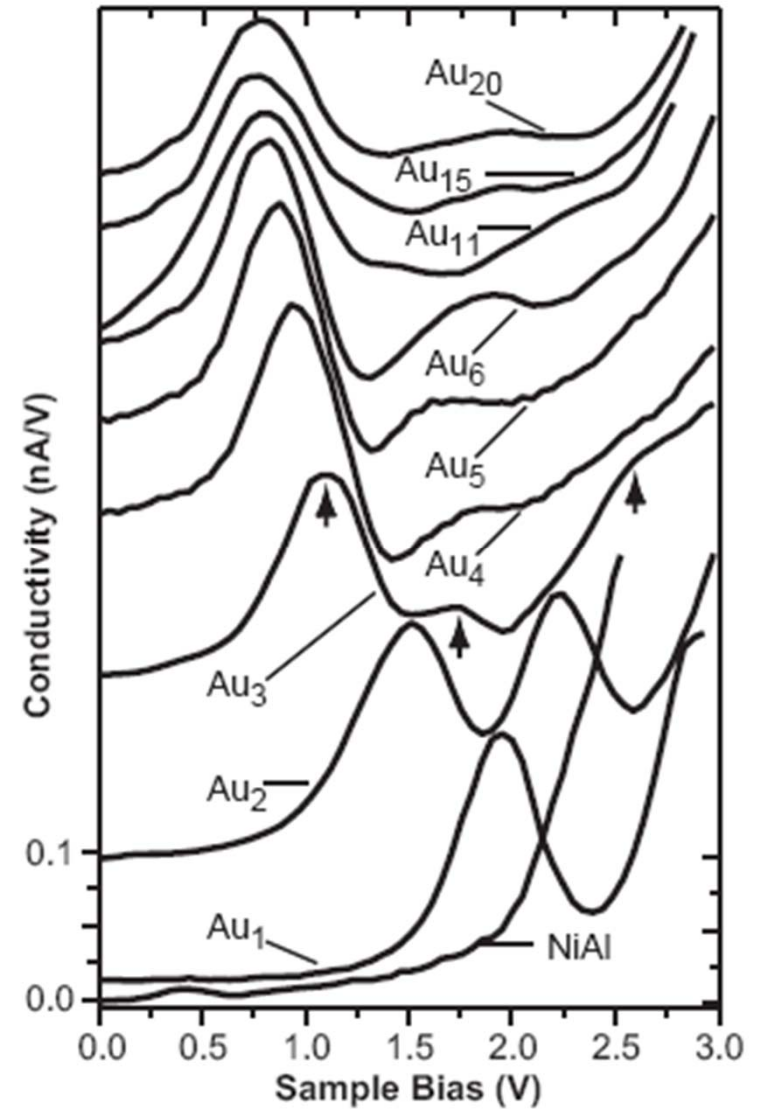
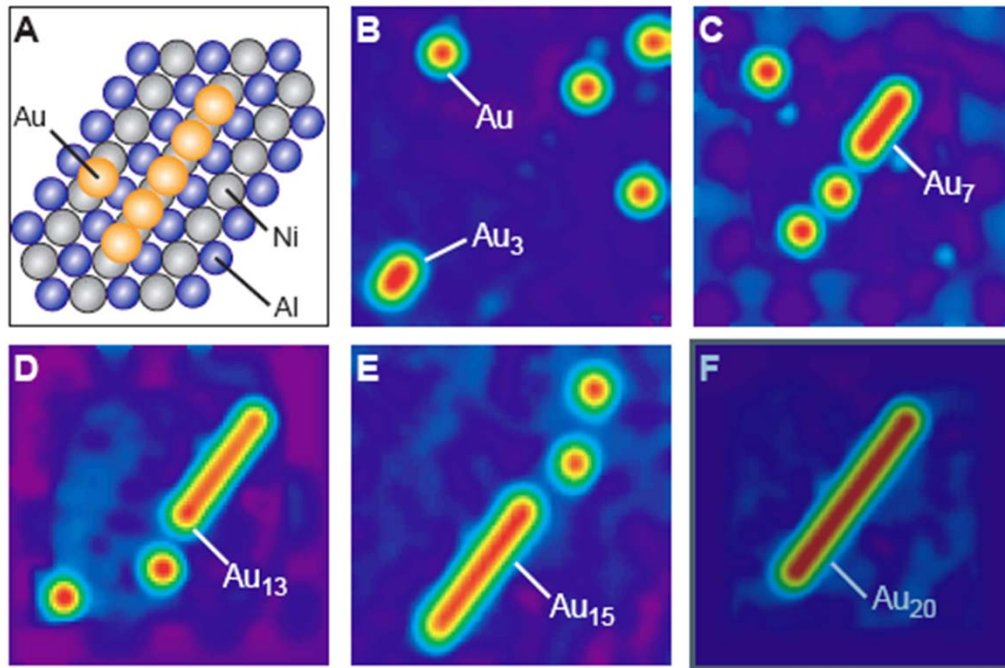


Application: Quantum Mirage

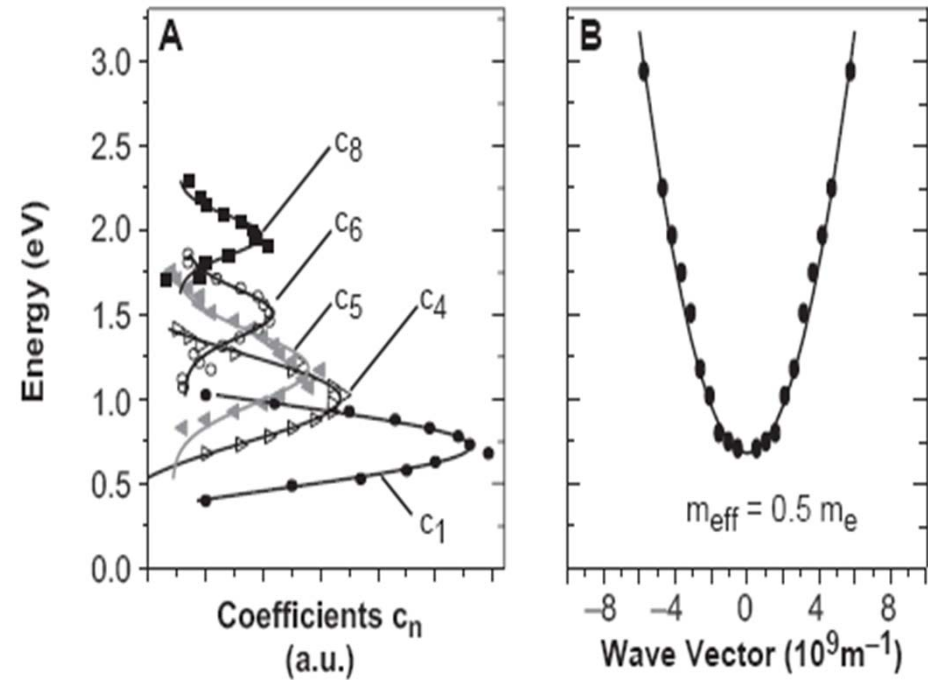
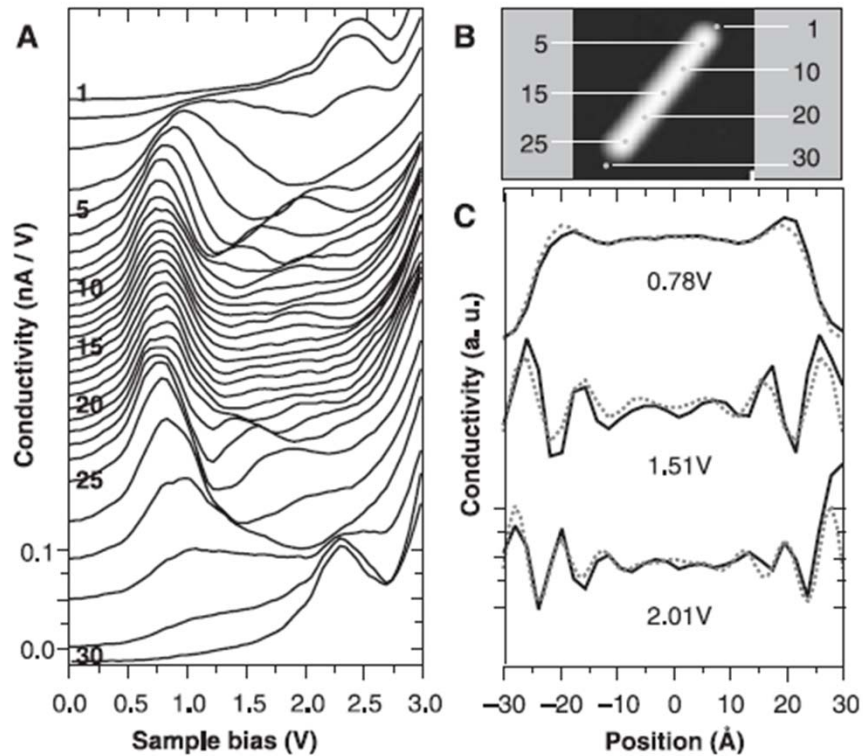
- Coherent Scattering
+ Kondo Effect



Application: 1D band structure

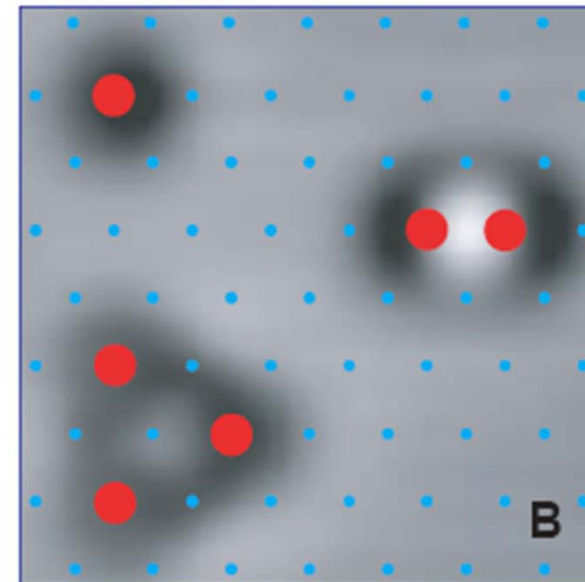
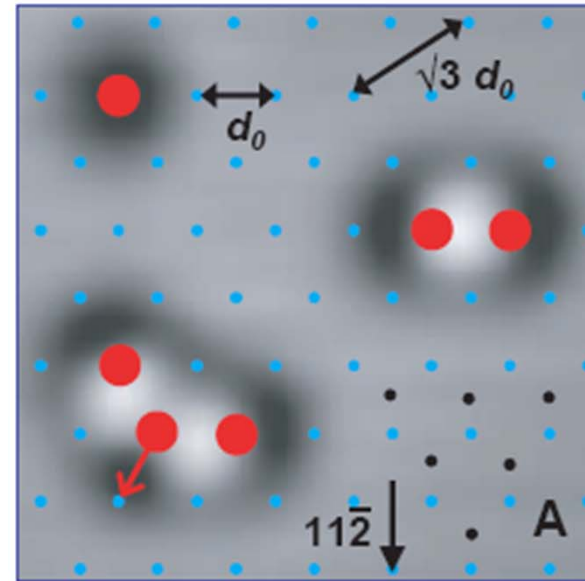


Application: 1D band structure



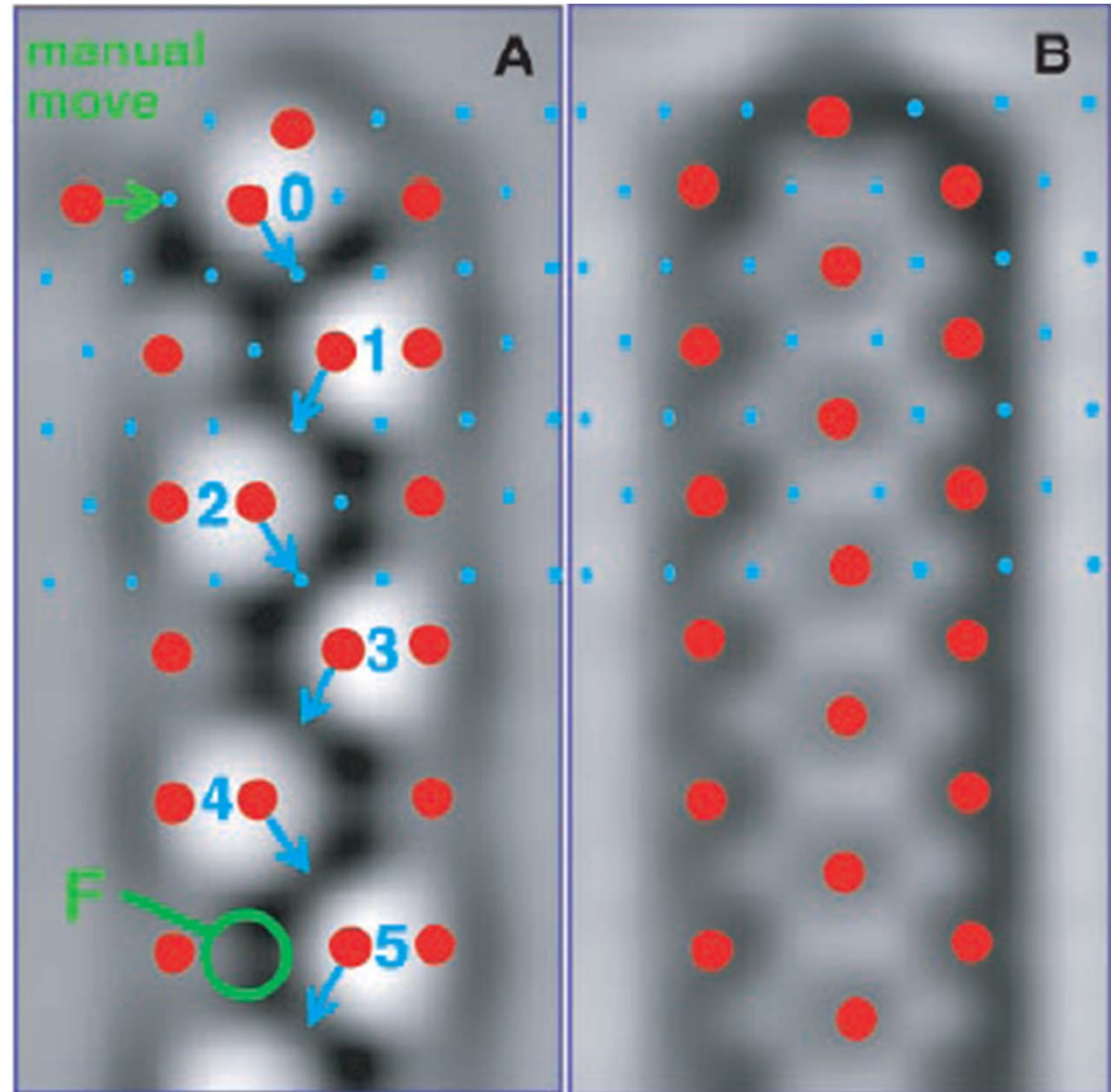
Application: Molecular Cascades

- Unstable trimer structure
CO on Cu(111)



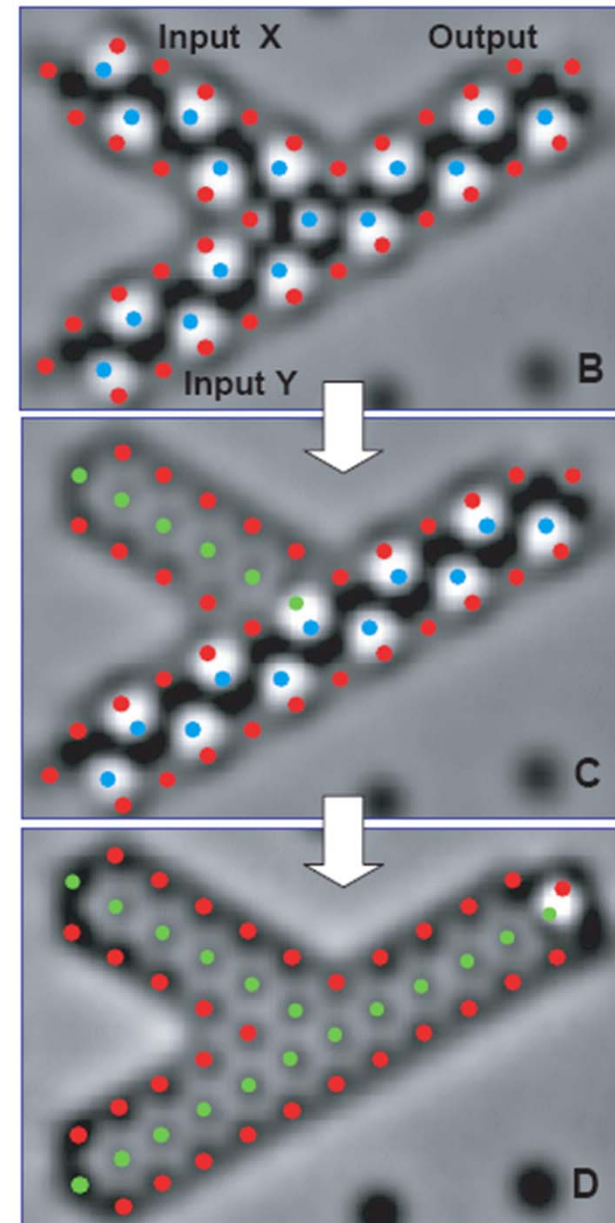
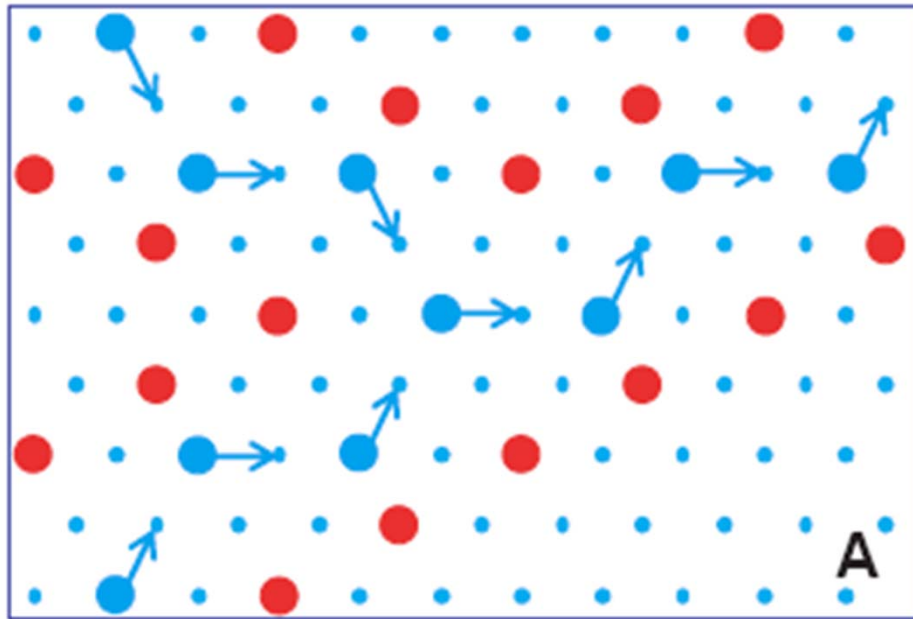
Application: Molecular Cascades

- Linked structure



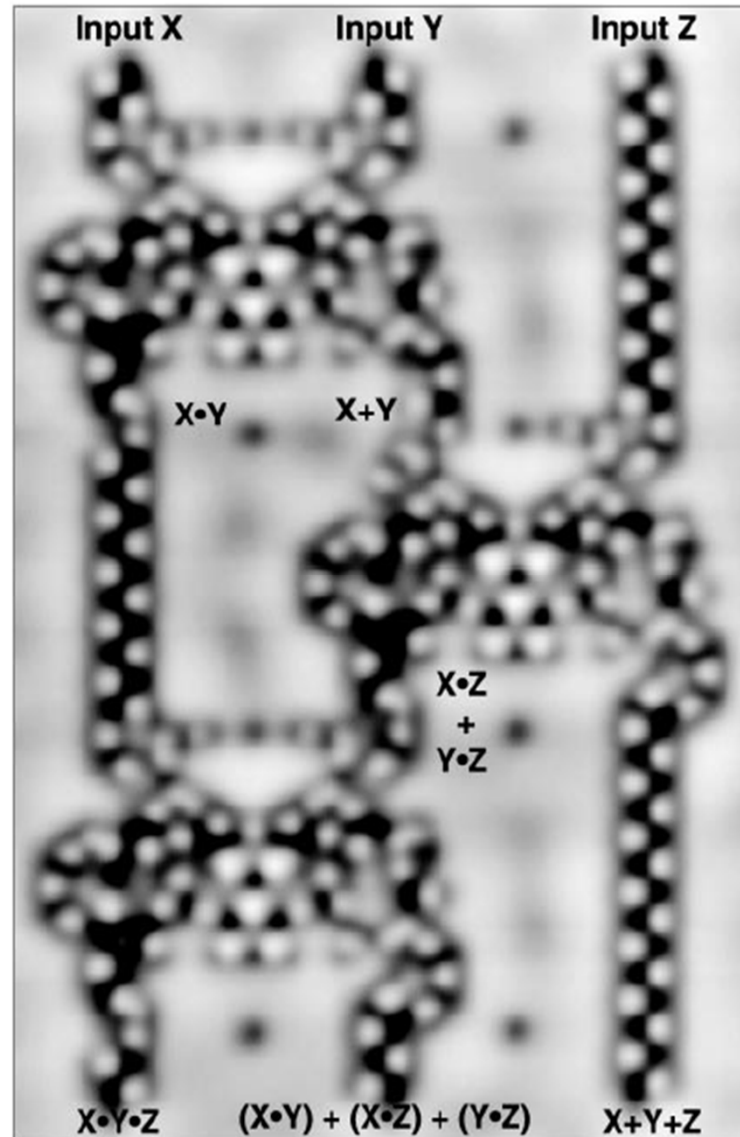
Application: Molecular Cascades

- Logic AND



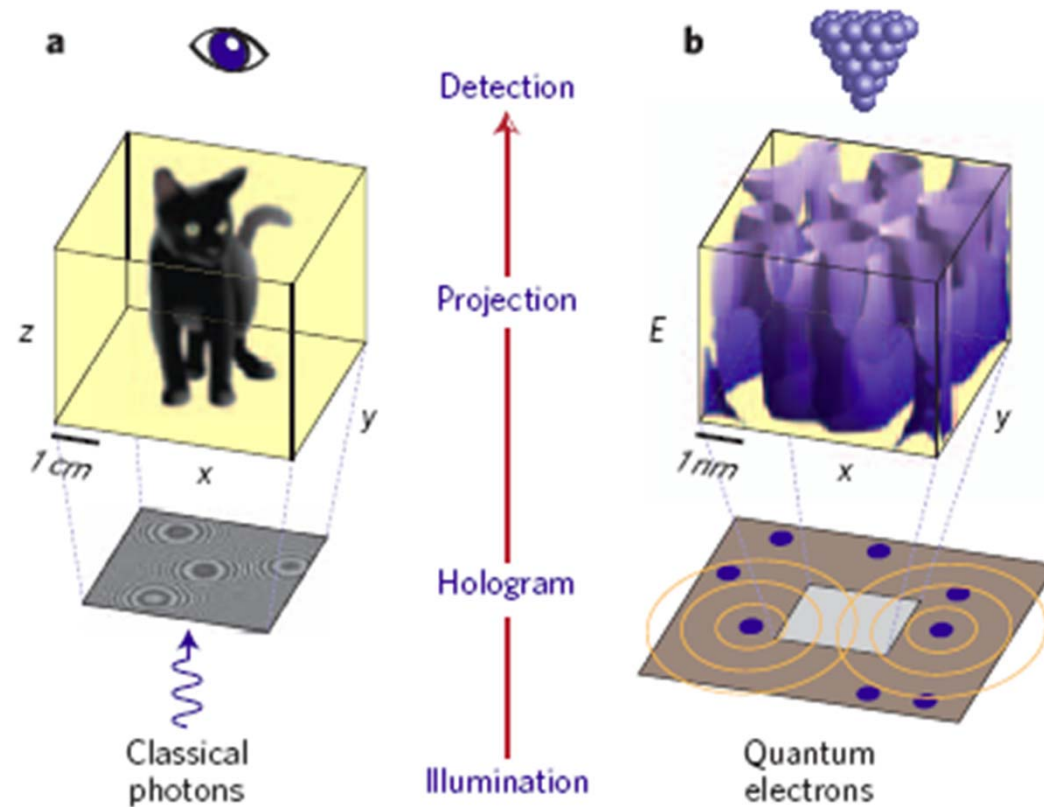
Application: Molecular Cascades

- Basic Circuit Unit



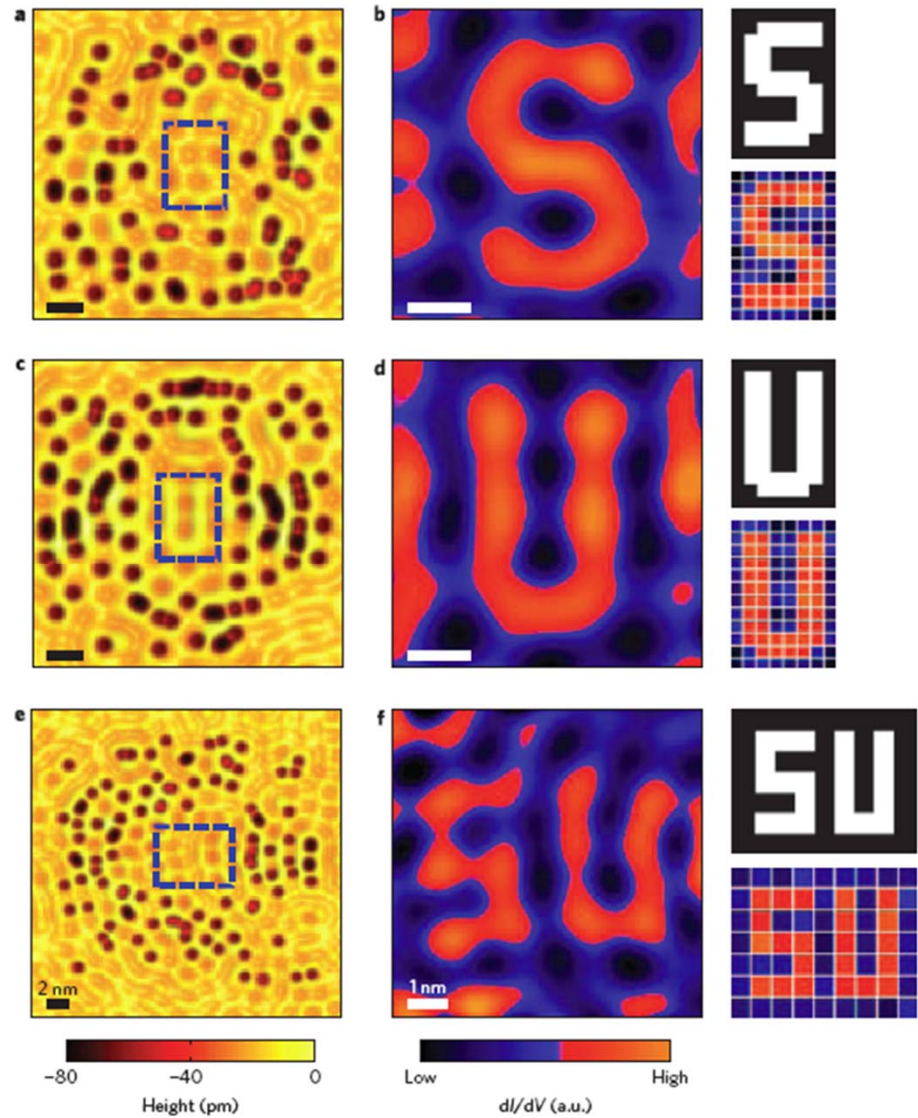
Application: Quantum Holography

- Classical v.s. Quantum



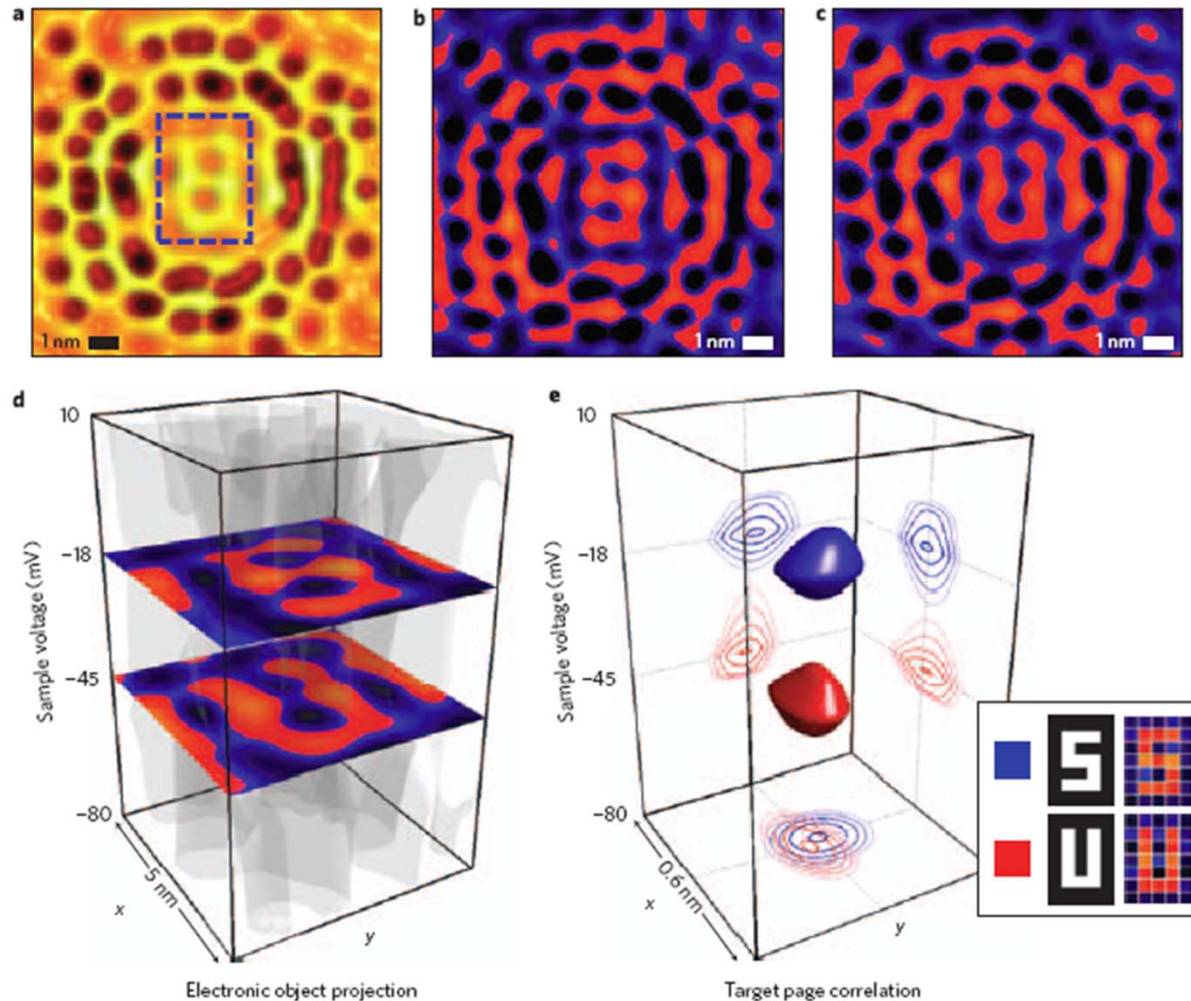
Application: Quantum Holography

- Page encoding
CO on Cu(111)
How to design?



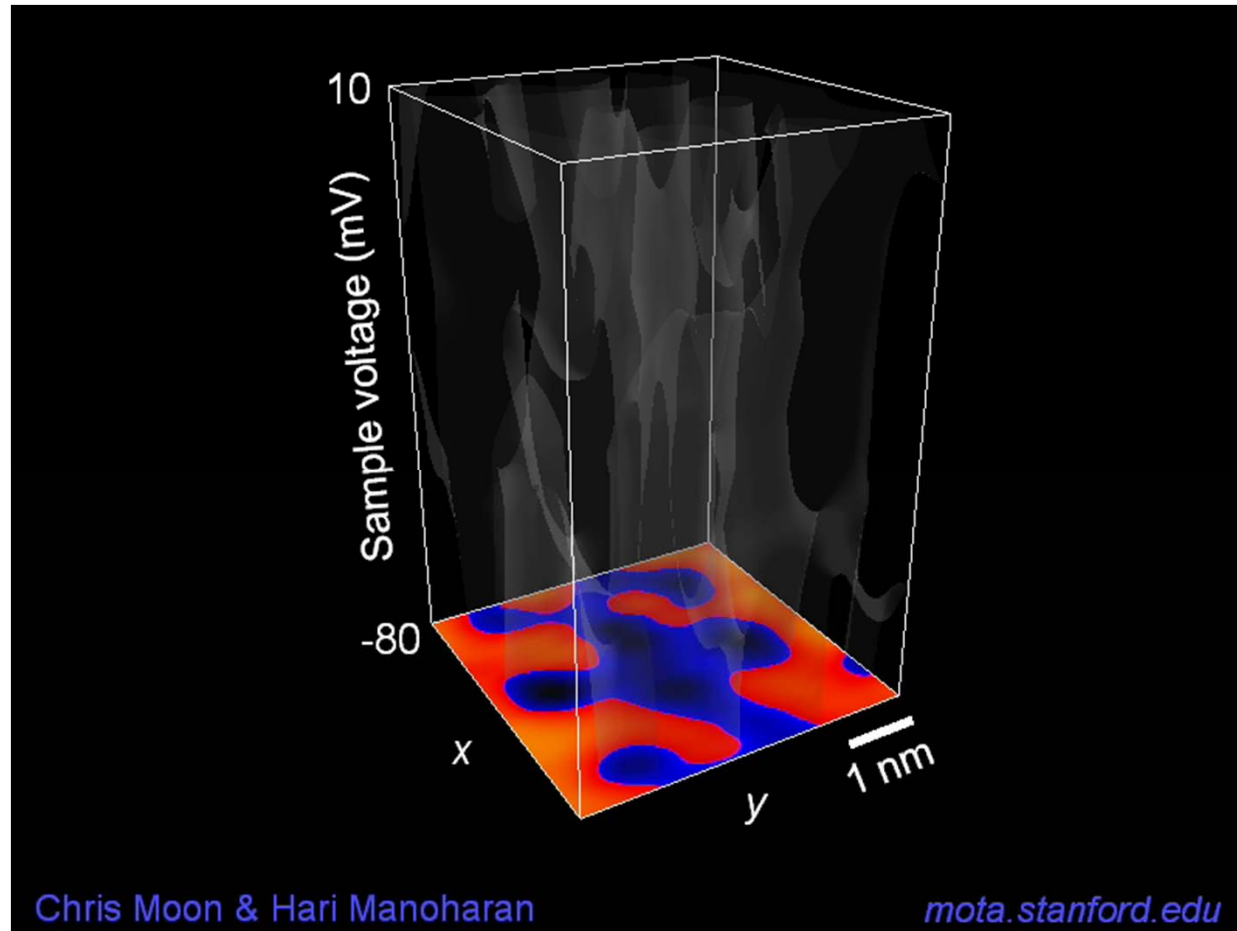
Application: Quantum Holography

- 3D quantum holography



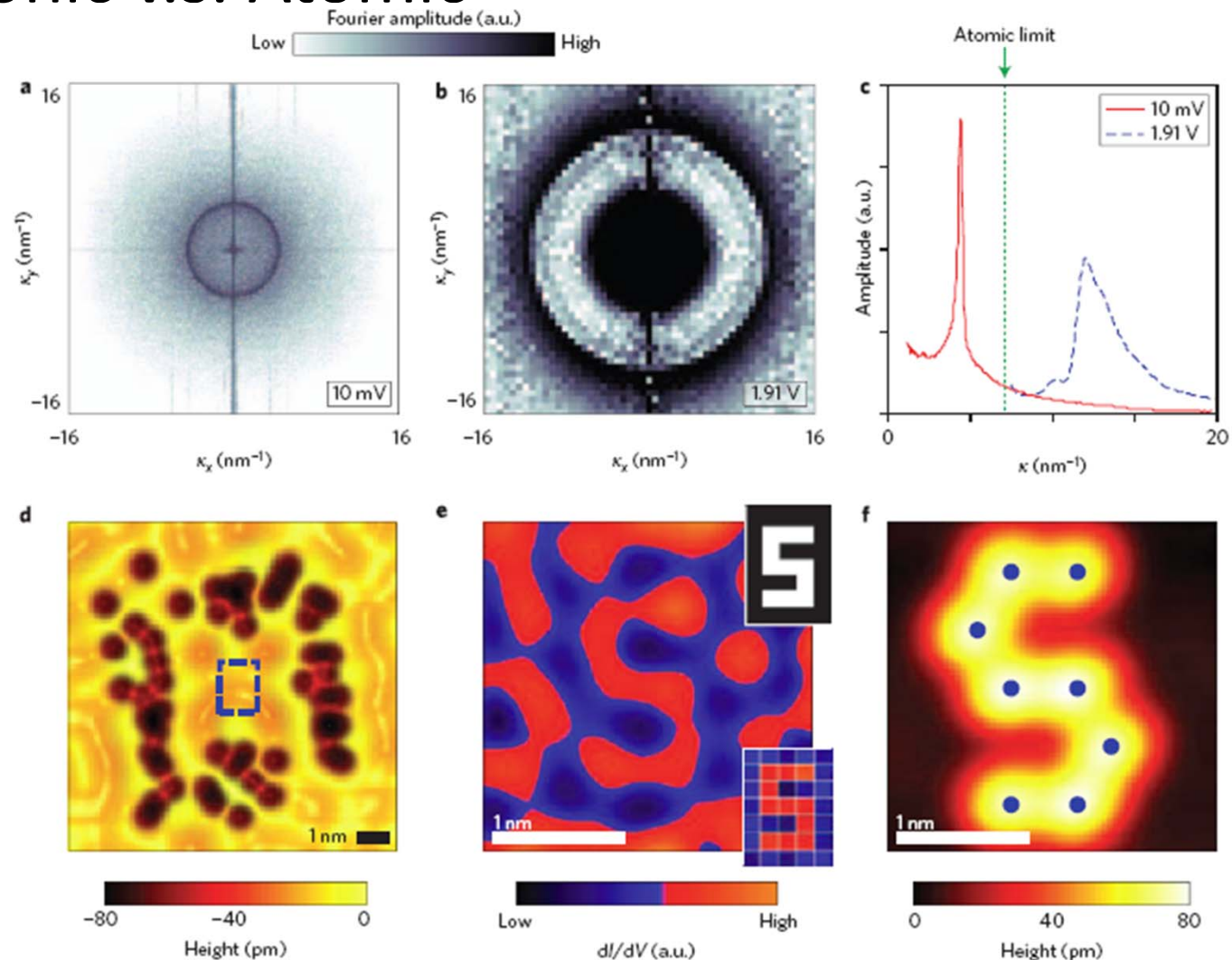
Application: Quantum Holography

- 3D quantum holography
(Movie)



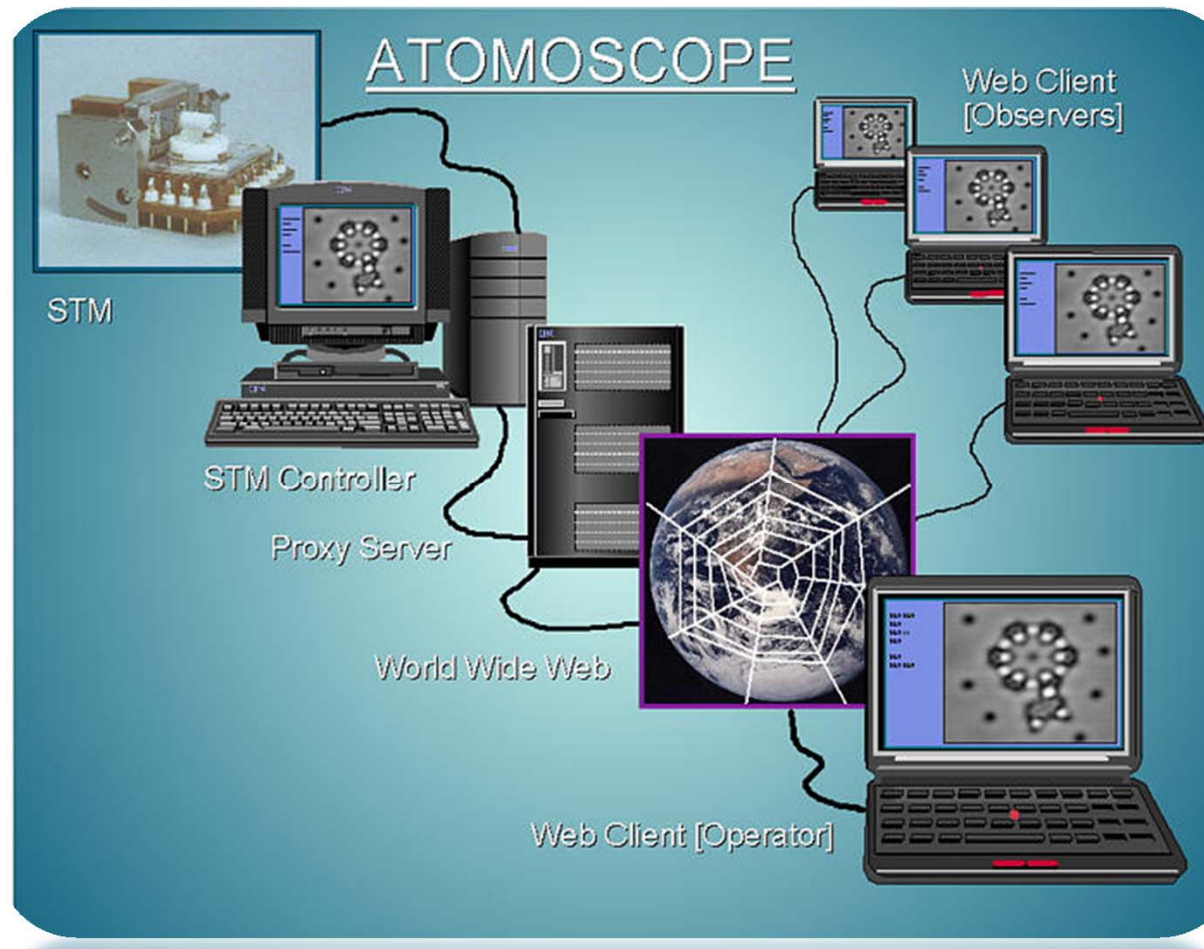
Application: Quantum Holography

- Electronic v.s. Atomic



Development Trend

→ Remote Operation



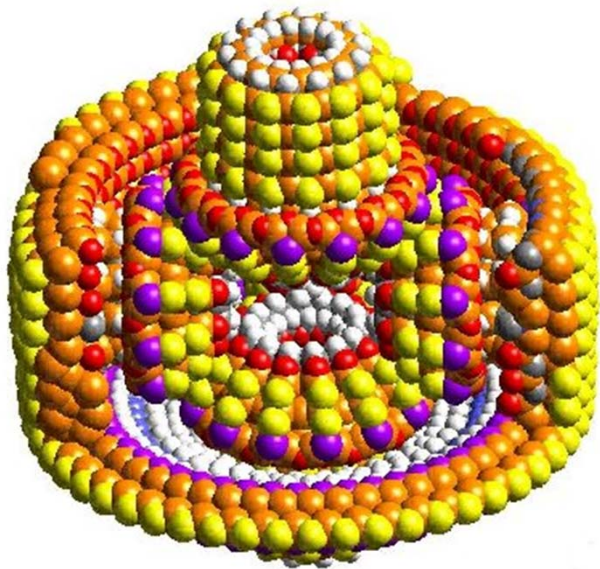
Development Trend

→ Automation

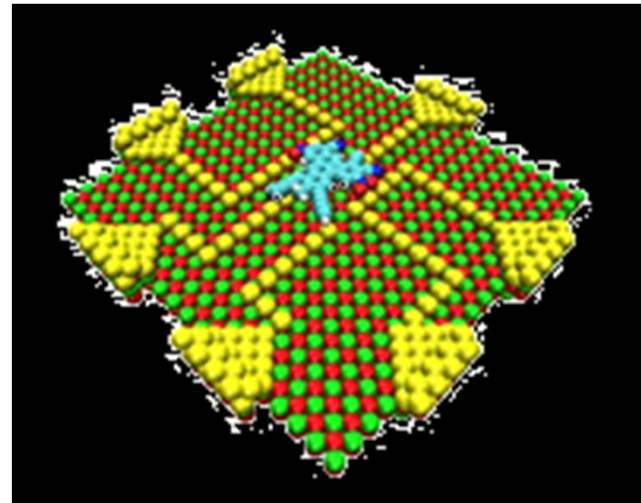
→ 3D Structure

→ Chemical Synthesis

Our Future

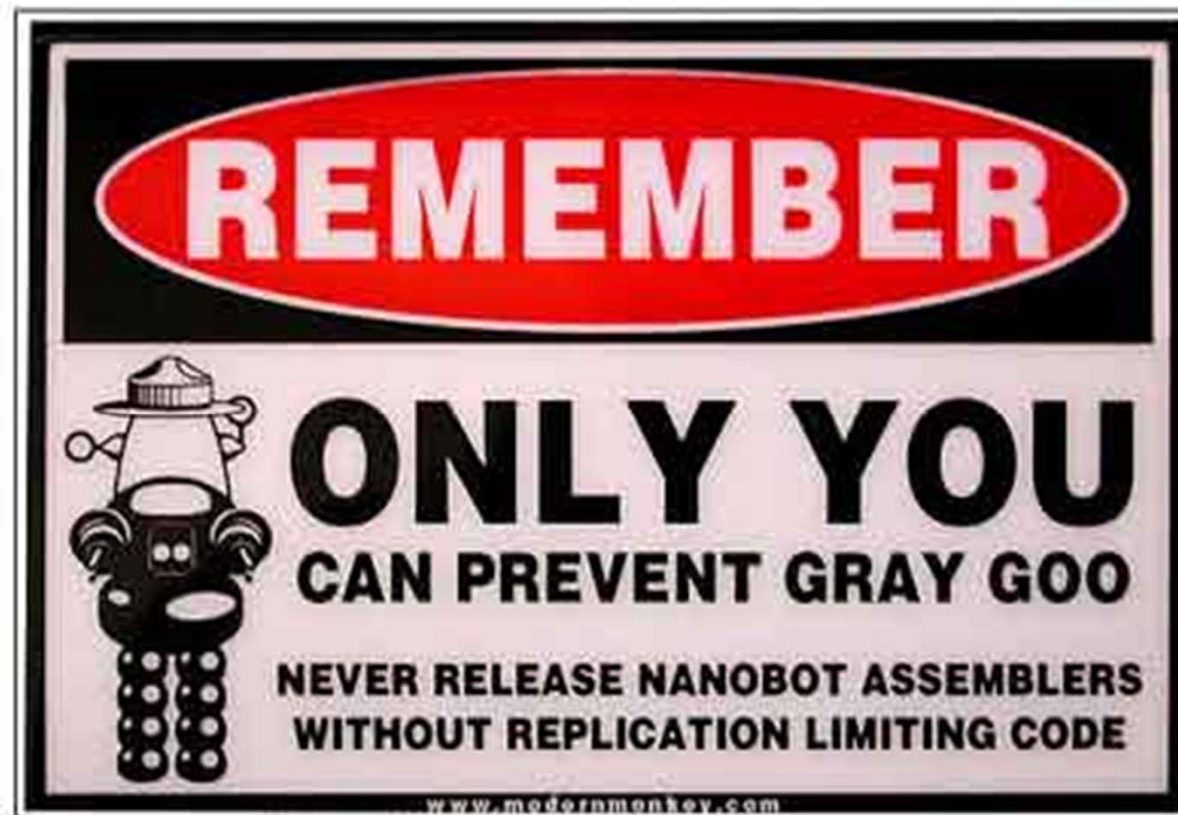


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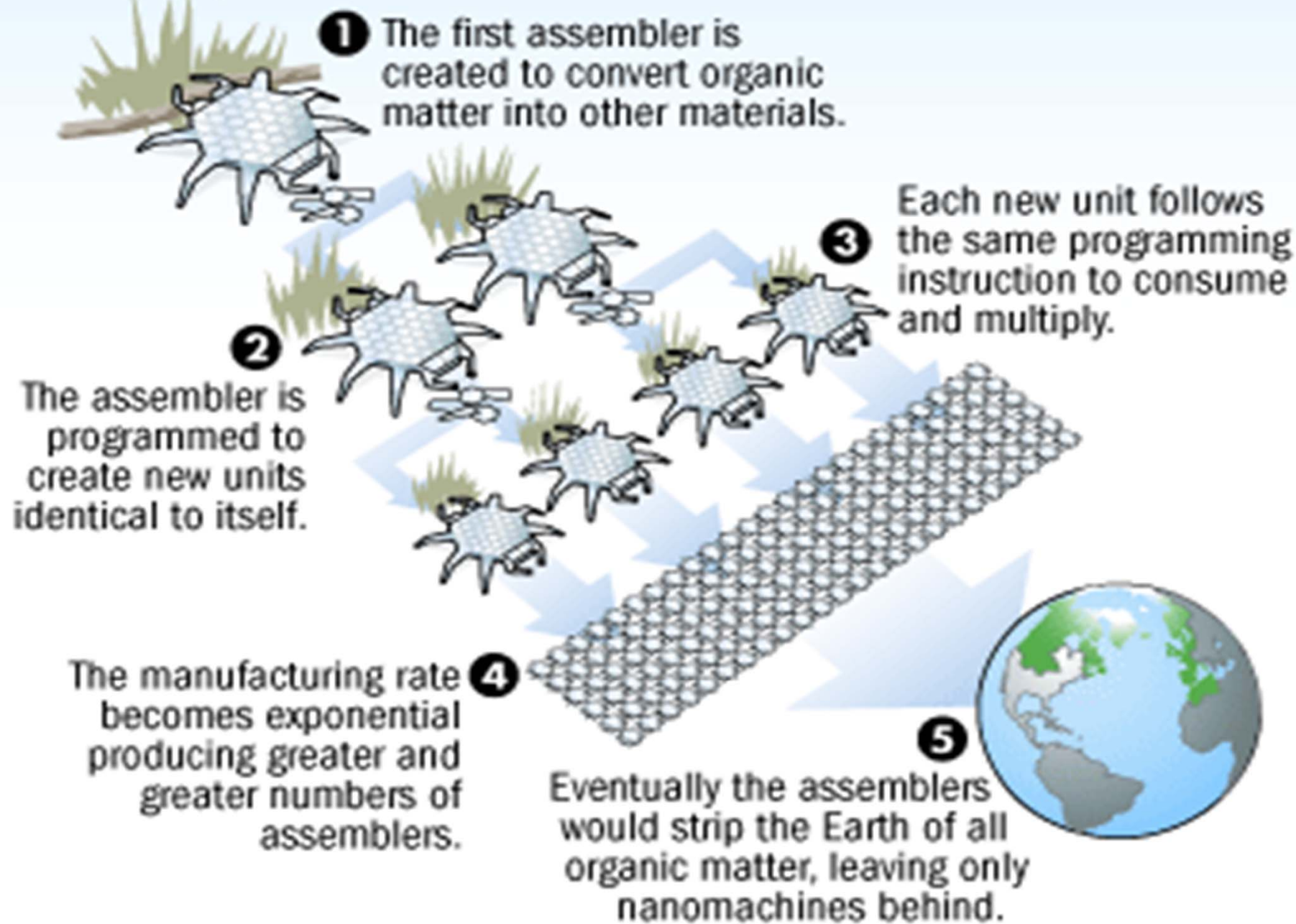
Our Future

Or



The Gray Goo Scenario

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Further Readings

HLA's lecture of atomic manipulation

http://videolectures.net/kolokviji_saw_stm/