Scanning Probe Microscopy

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-Scanning tunneling microscopy

-Force microscopy under ultrahigh vacuum conditions

-Molecular electronics

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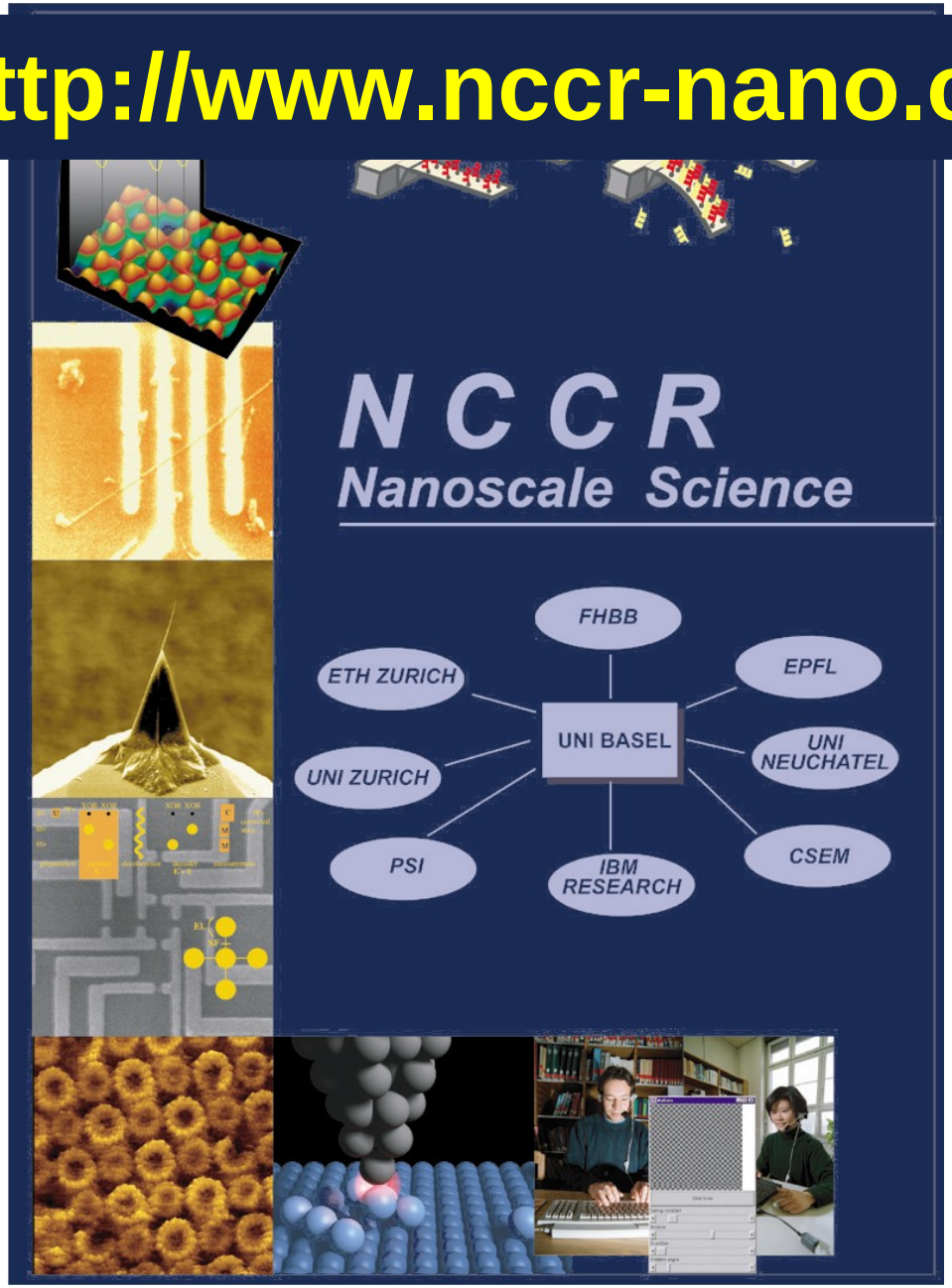
http://www.nccr-nano.org



FNSNF
Schweizerischer Nationalfonds
Fonds national suisse
Swiss National Science Foundation

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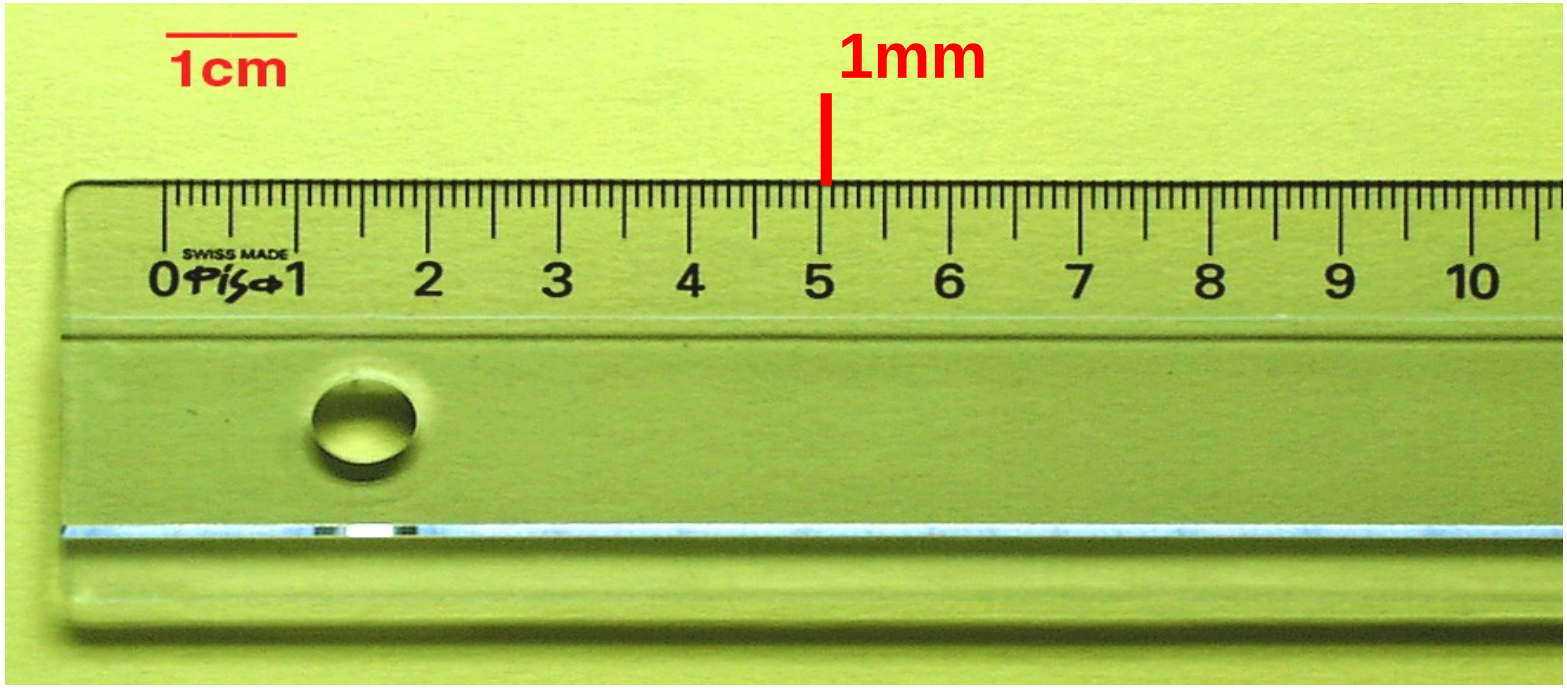
What do scientists mean by Nanoscience?

Prefix “nano”: one billionth of something like a second or a meter.

1 nm = 1 billionth of a meter



1 nm = 1 millionth of a millimeter

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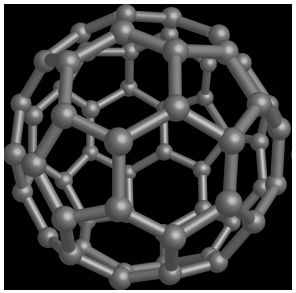
How large?

12‘740‘000m

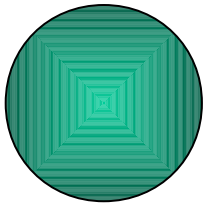
0.22m

: 57‘909‘090



1nm

: 220‘000‘000



0.3nm

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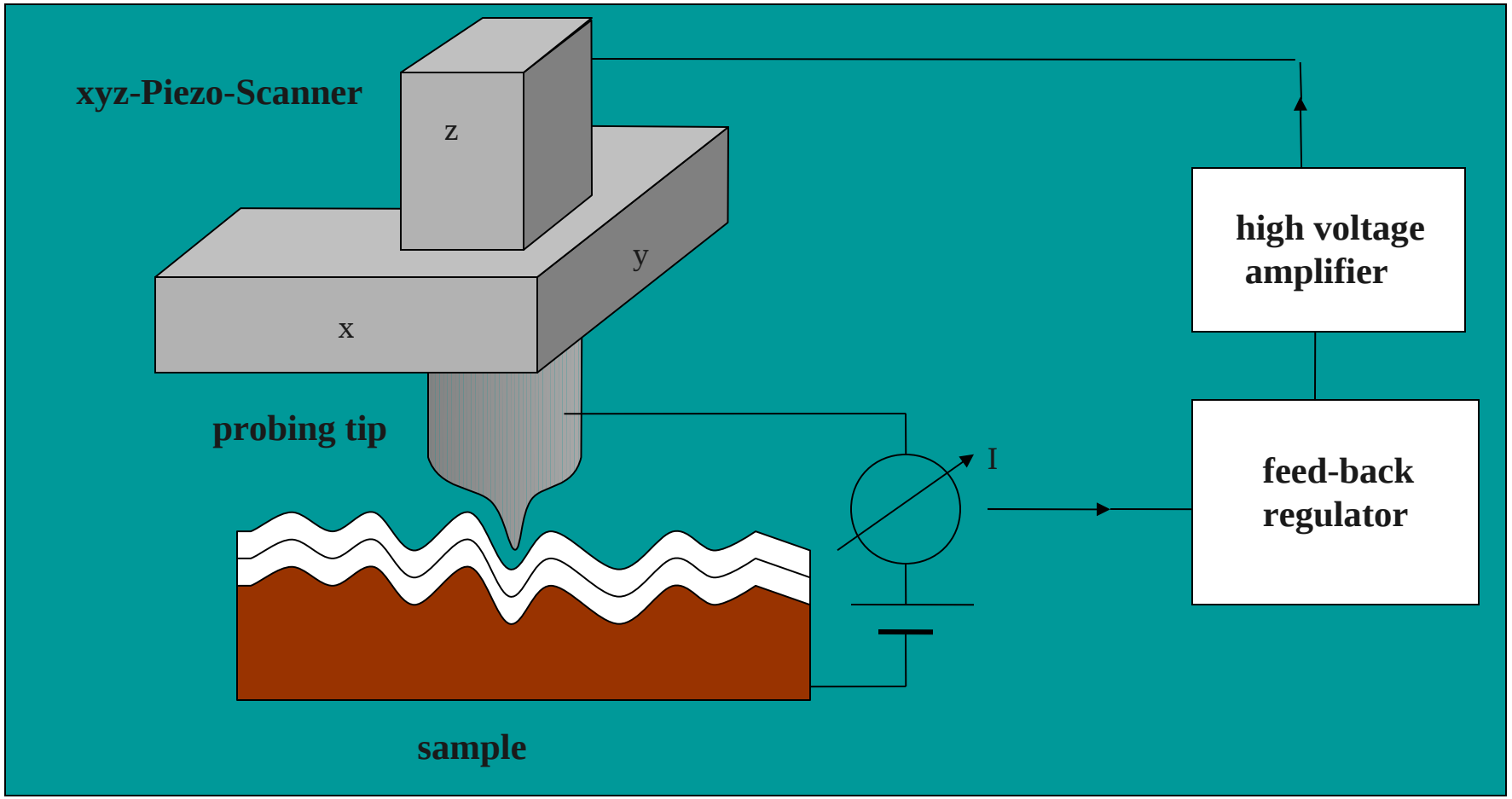
Scanning Tunneling Microscopy (STM)



Feed-back regulator keeps current (pA-nA) constant.
Contours of constant current are recorded.

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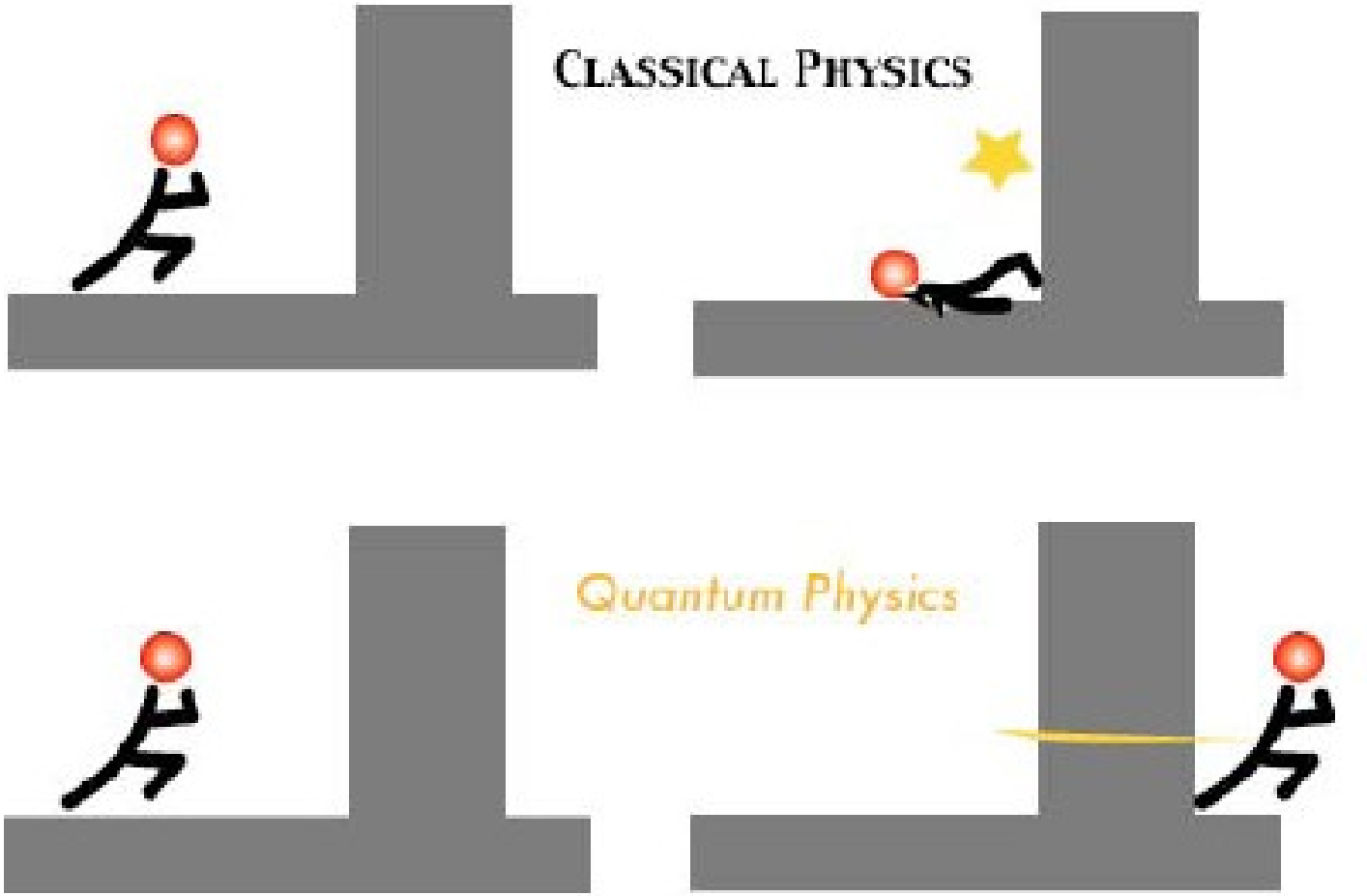
Quantum tunneling



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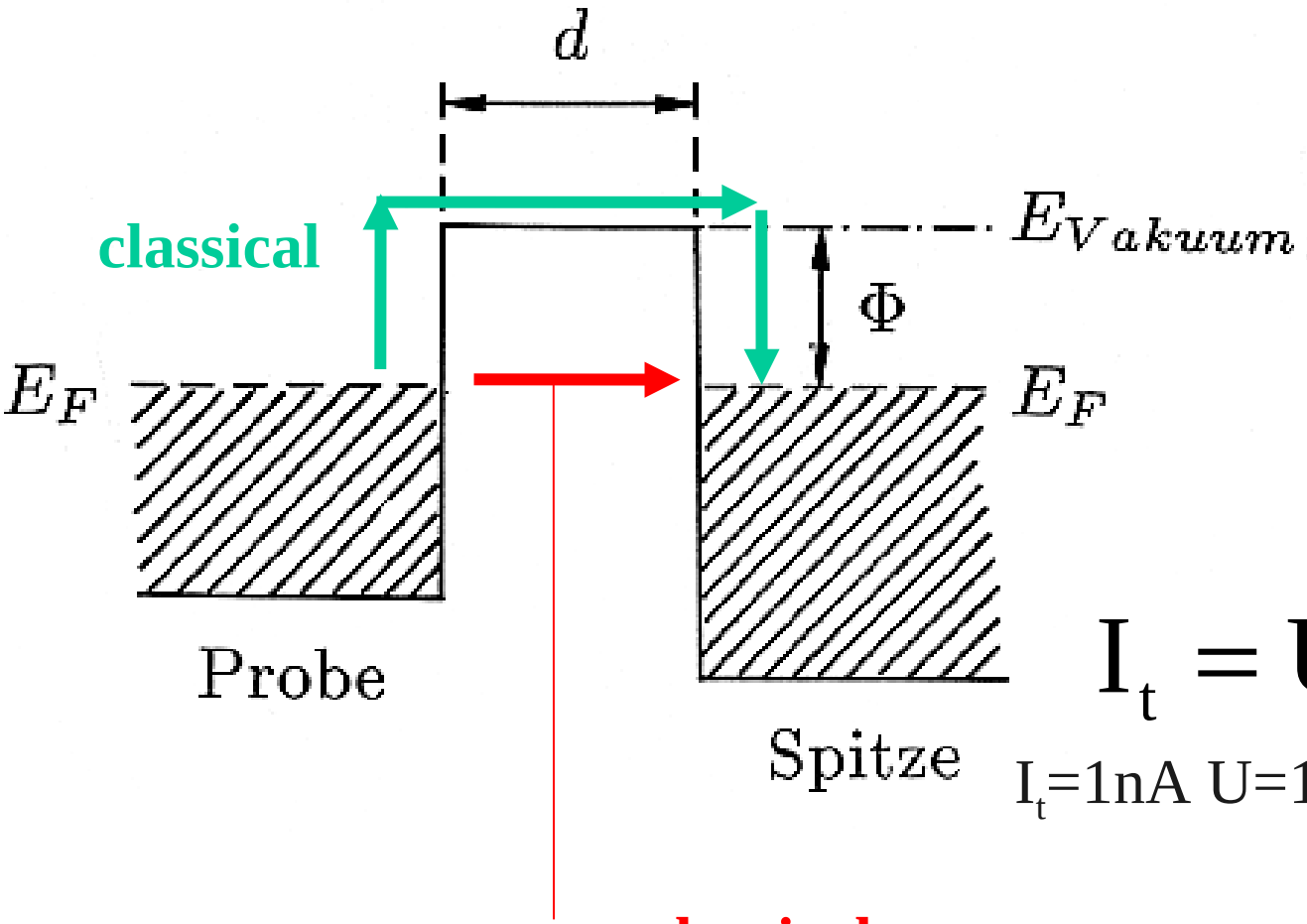
Quantum mechanical tunneling



$$I_t = U \cdot e^{-d/\kappa}$$

I_t=1nA U=1V κ≈ 0.1nm

quantum mechanical: Tunneling current

J. Frenkel, *Phys. Rev.* **B 36**, 1604 (1930)

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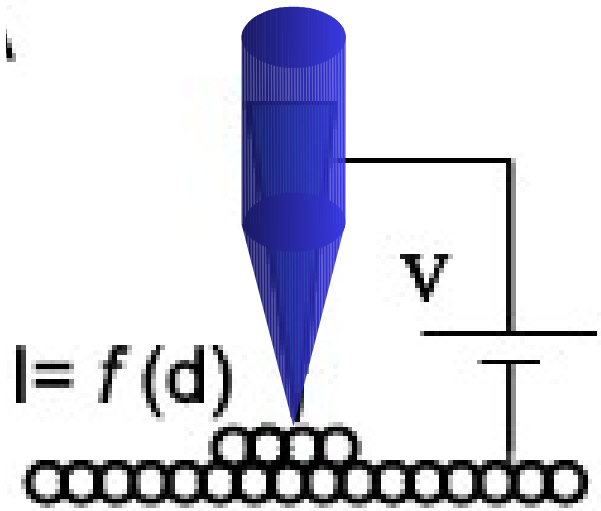

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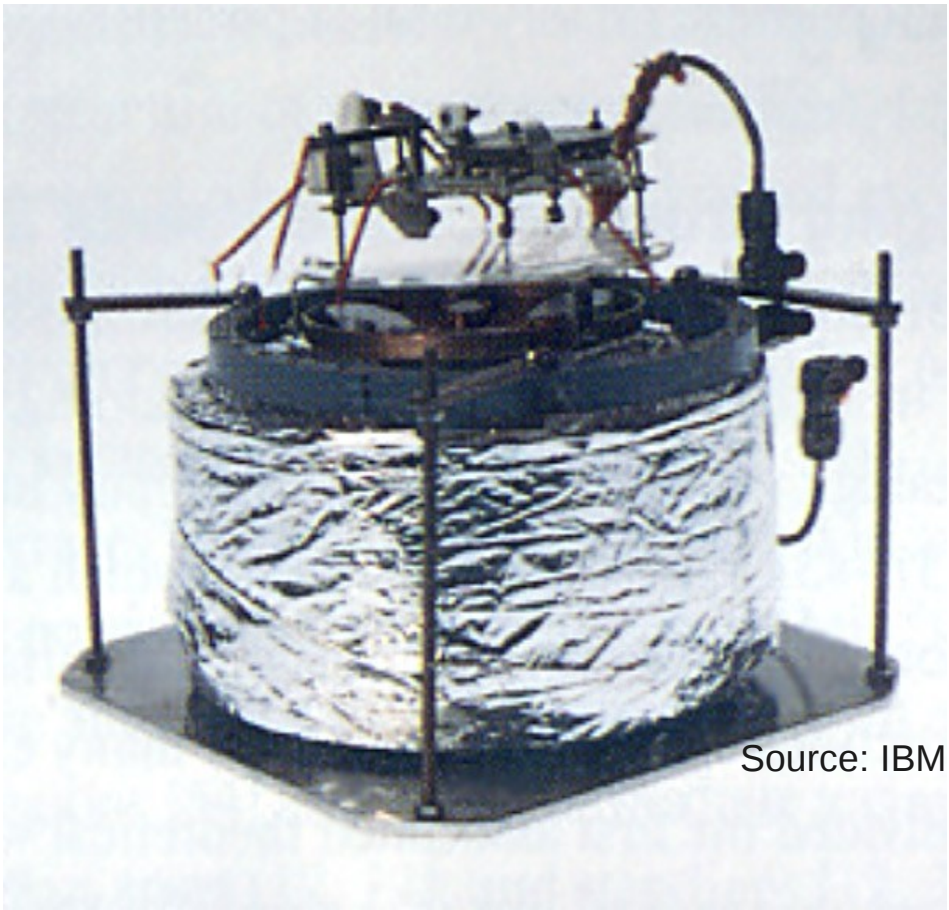
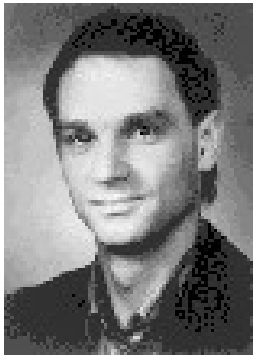
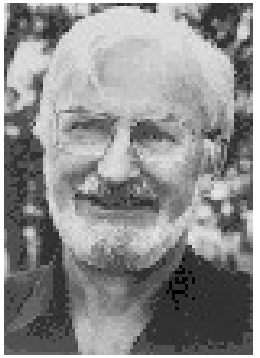
Invention of the Scanning Tunneling Microscope (STM)



Source: IBM





G. Binnig and H. Rohrer
Nobel prize for physics
1986

IBM Rüschlikon
Switzerland

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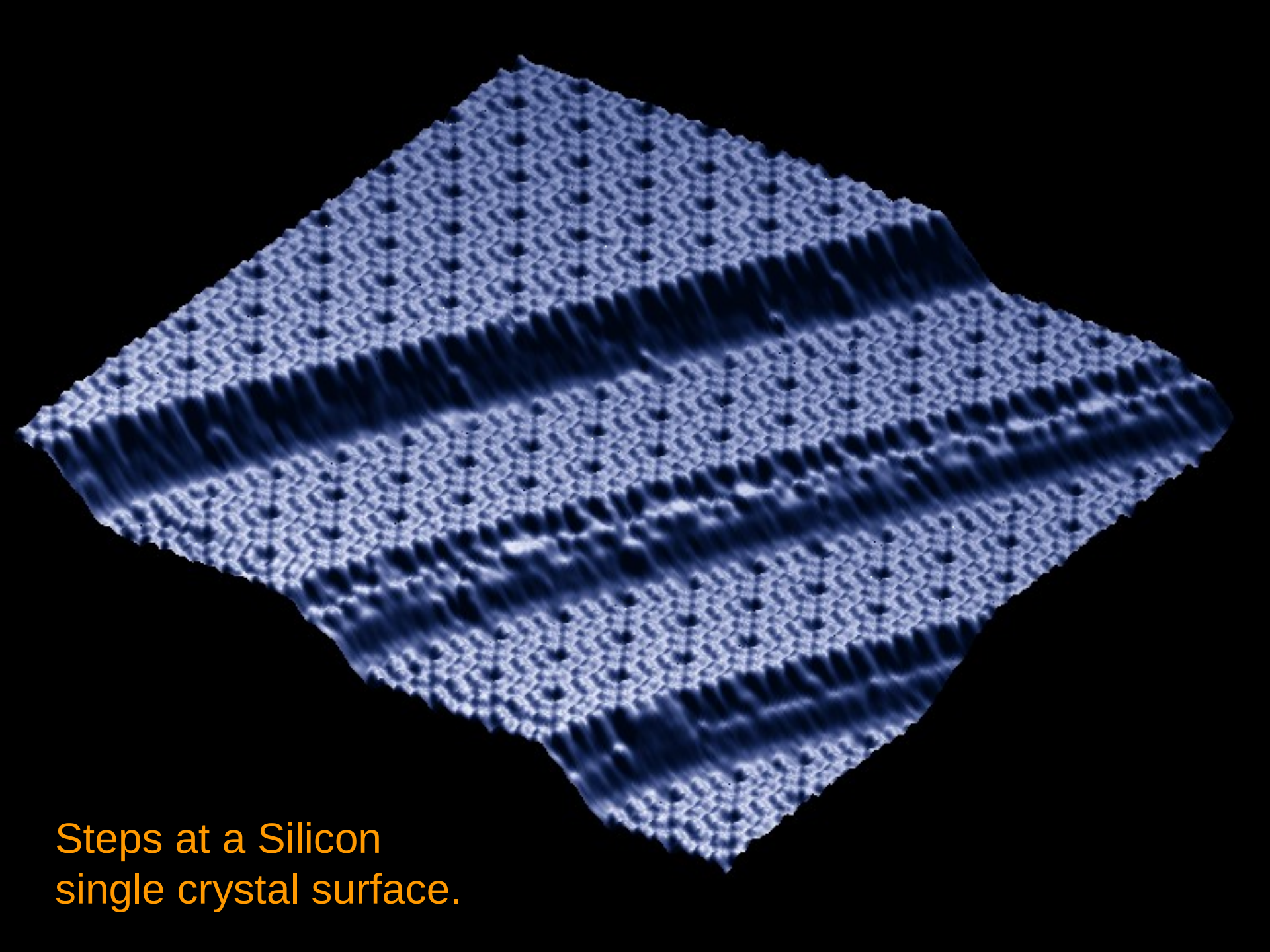
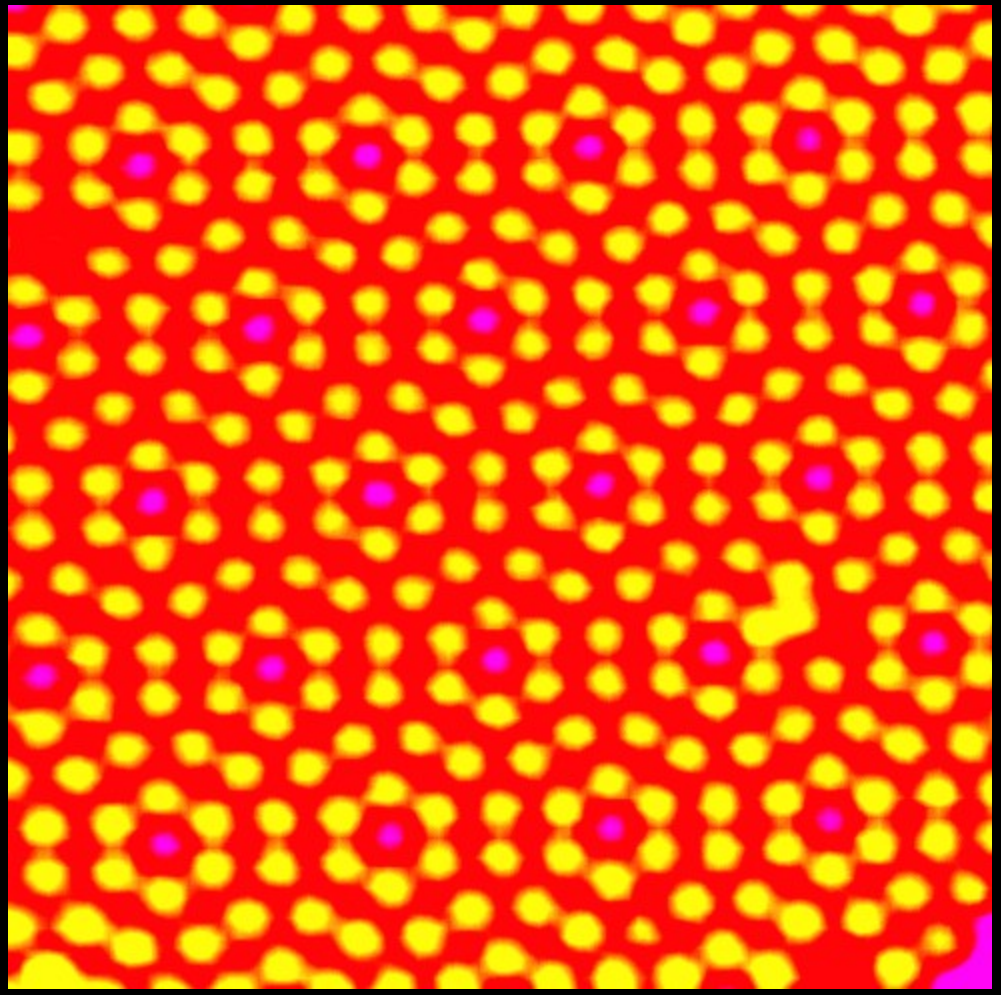
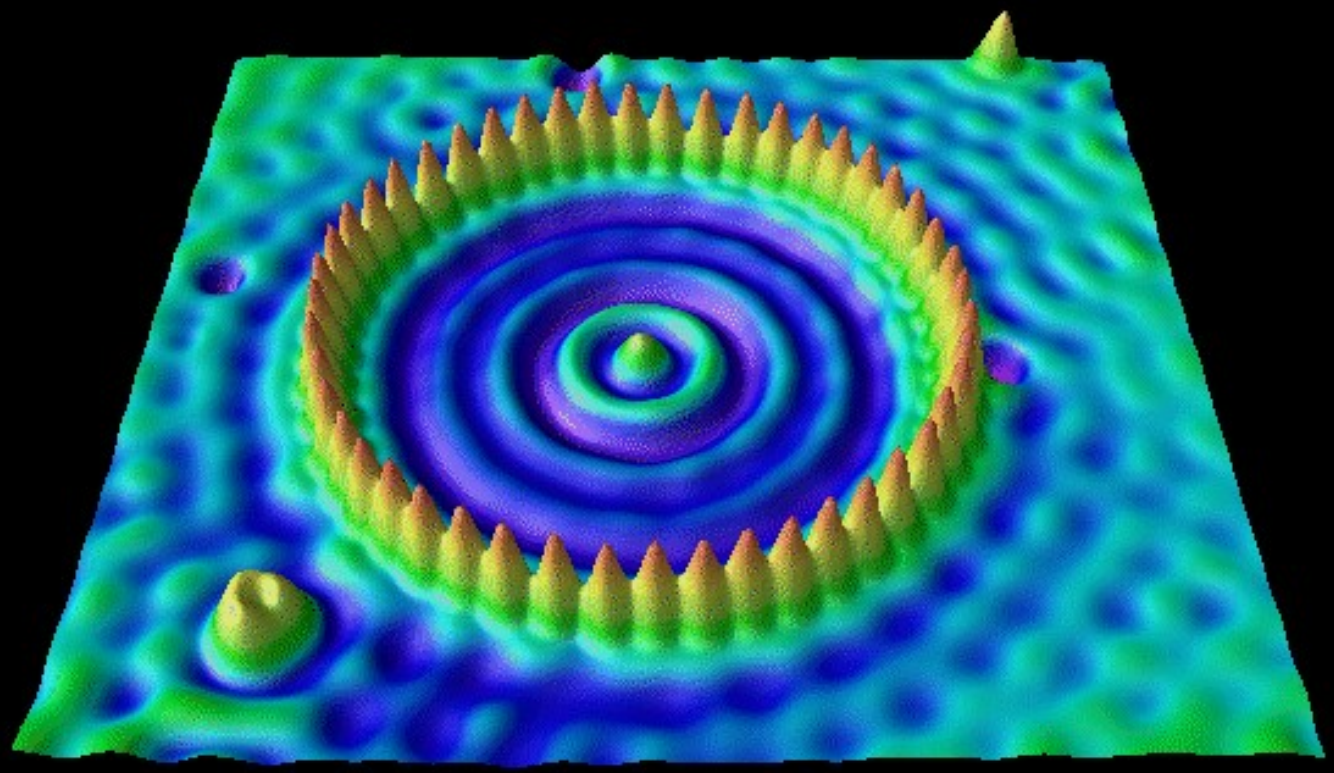


Steps at a Silicon
single crystal surface.

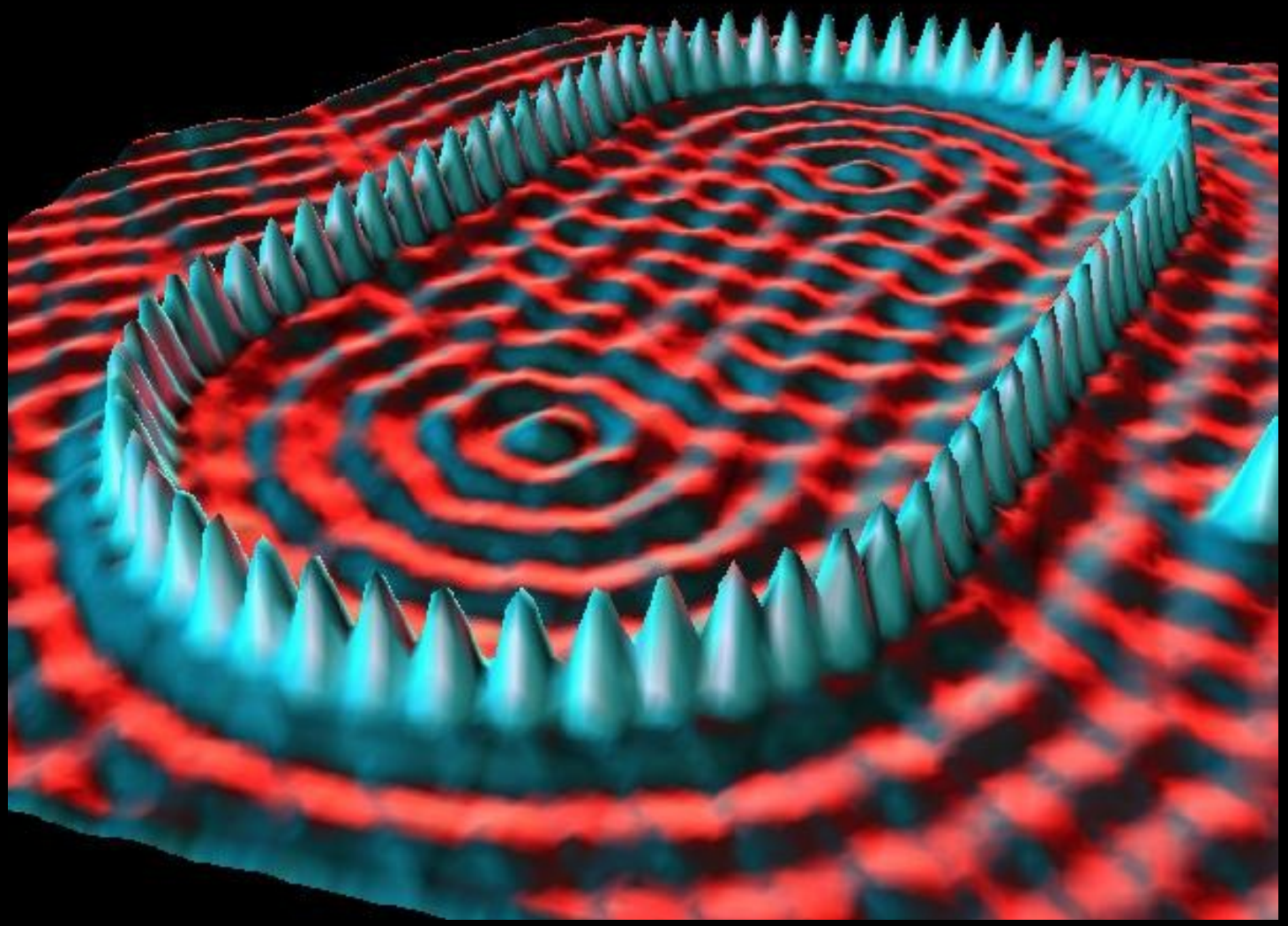


Si(111)7x7 reconstructed surface



48 Fe-atoms on copper (Quantum corral)

D. Eigler, IBM Almaden



Fe atoms on copper

STM for Scools

Nanosurf AG, Liestal: Start-up from the University of Basel

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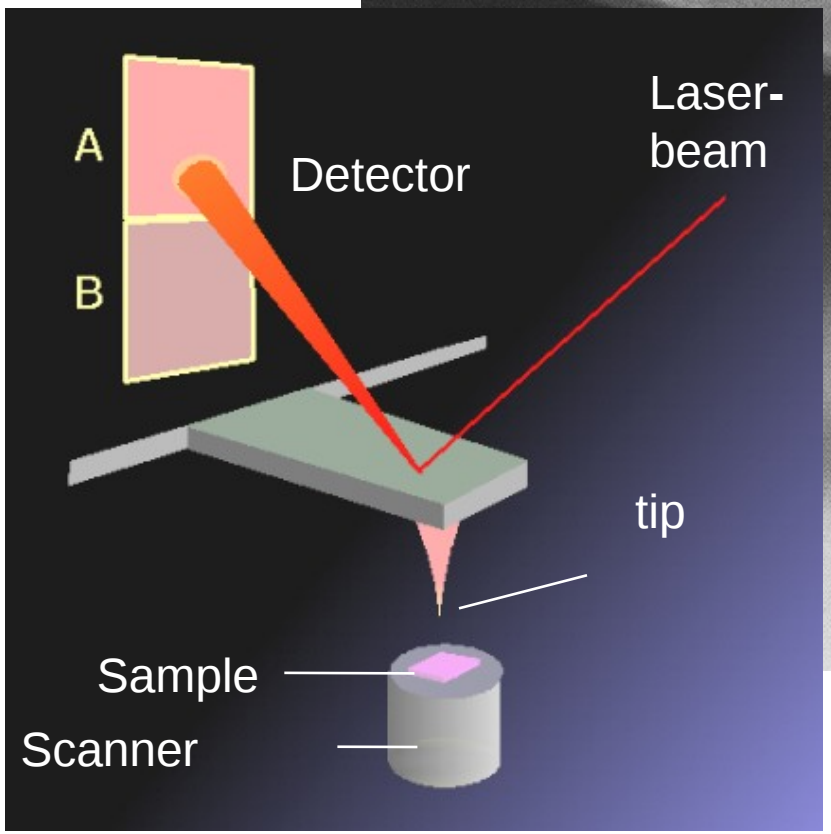
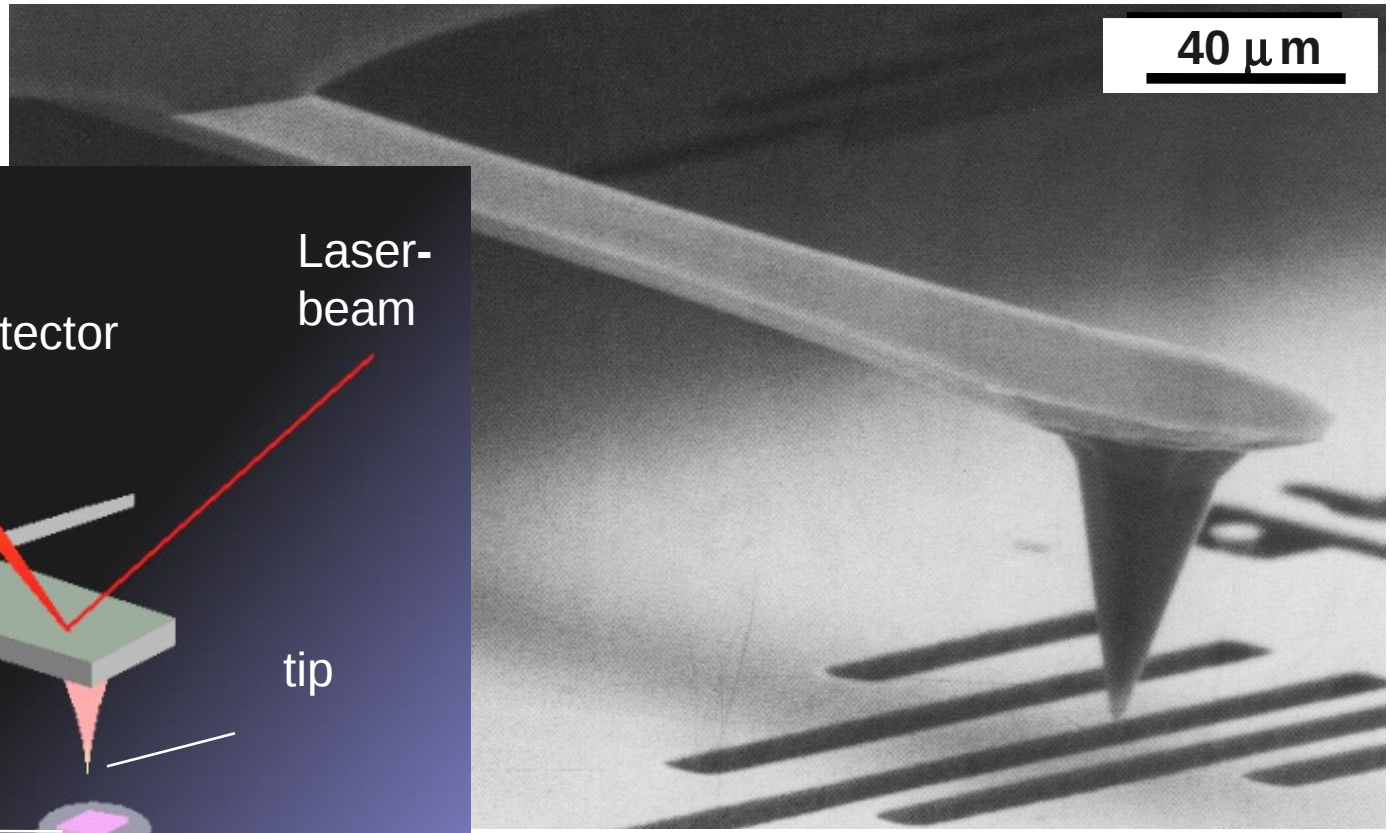
Atomic Force Microscopy (AFM)





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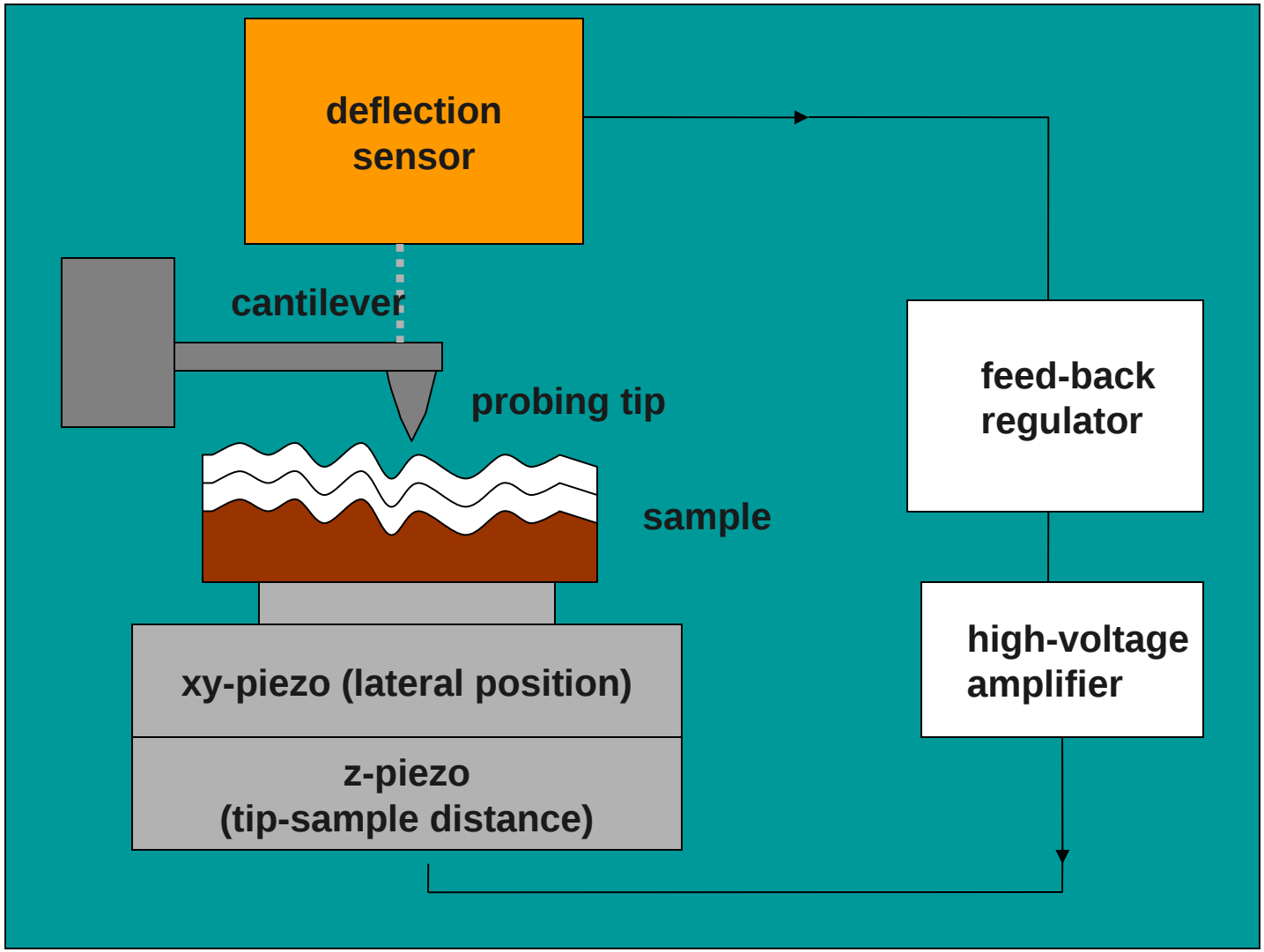
Principle of Atomic Force Microscope (AFM)



Commercial AFMs

Veeco, US

Nanosurf, Liestal, CH

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3 nm

1000 nm

1000 nm

500 nm

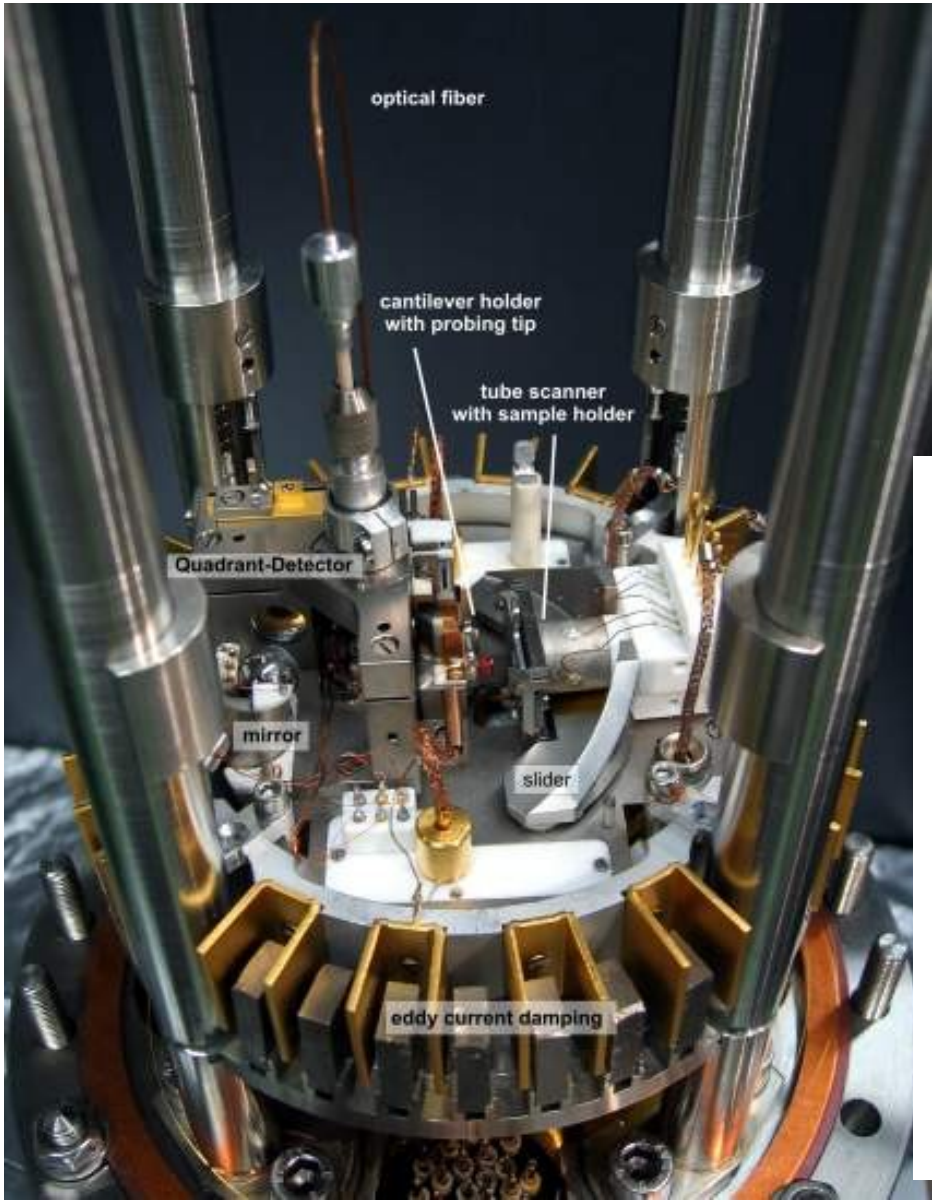
500 nm

0 nm

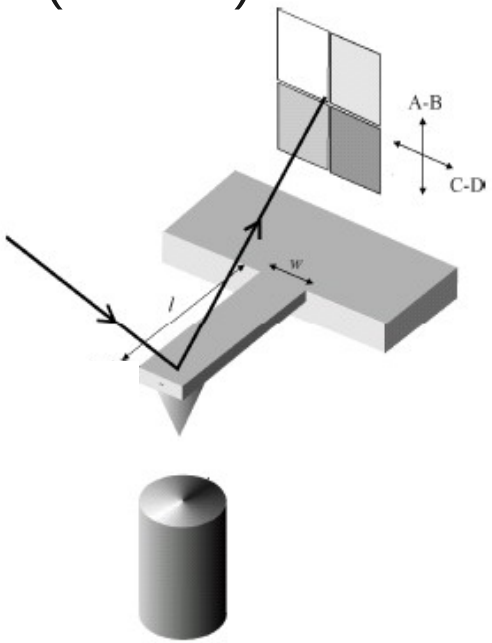
0 nm

Eyeglass

Ultrahigh vacuum force microscope with in-situ preamplifier and stabilized light source



- UHV- chamber with base pressure < 10^{-10} mbar
- room temperature
- Fast in-situ preamplifier (<3MHz)



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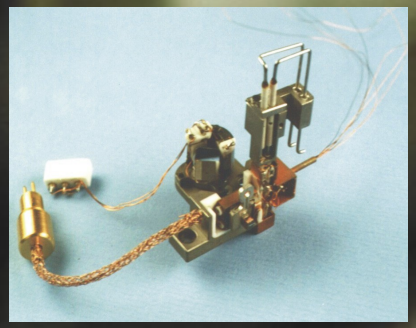
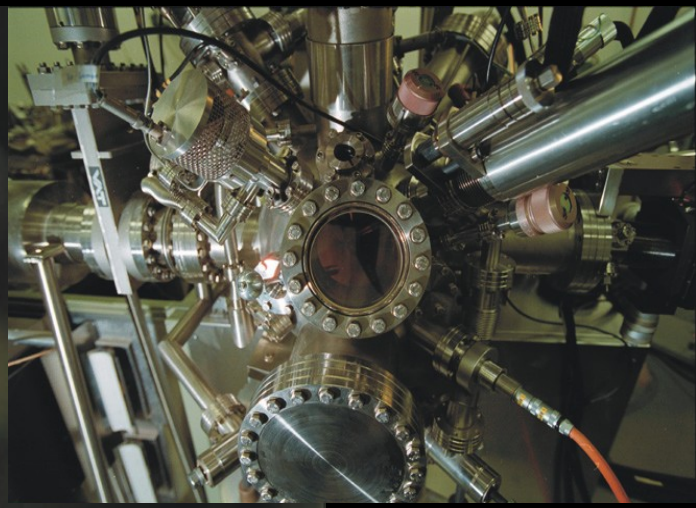
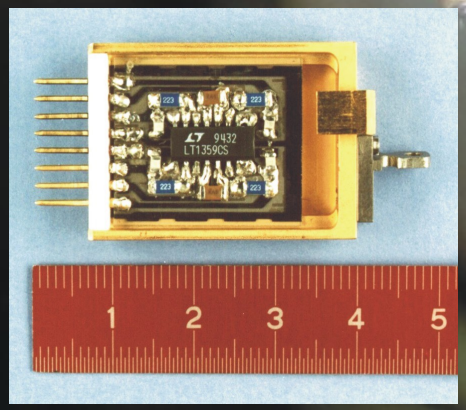
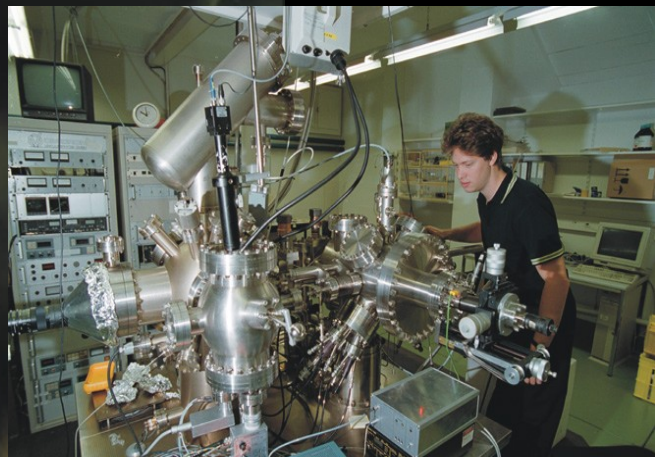
Ultra-sensitive non-contact force microscope combined with STM

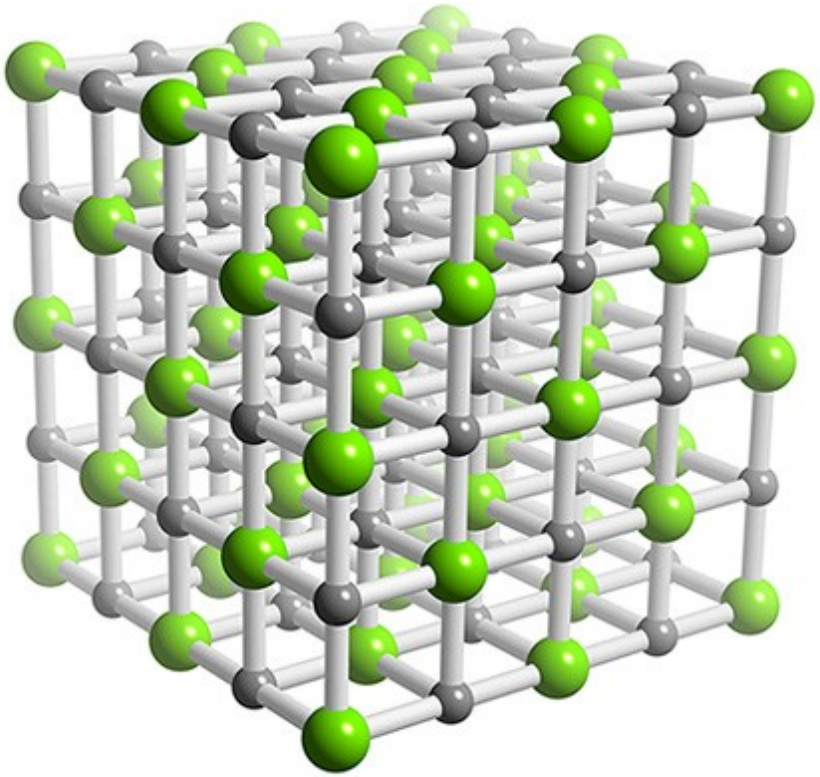








NaCl-crystal



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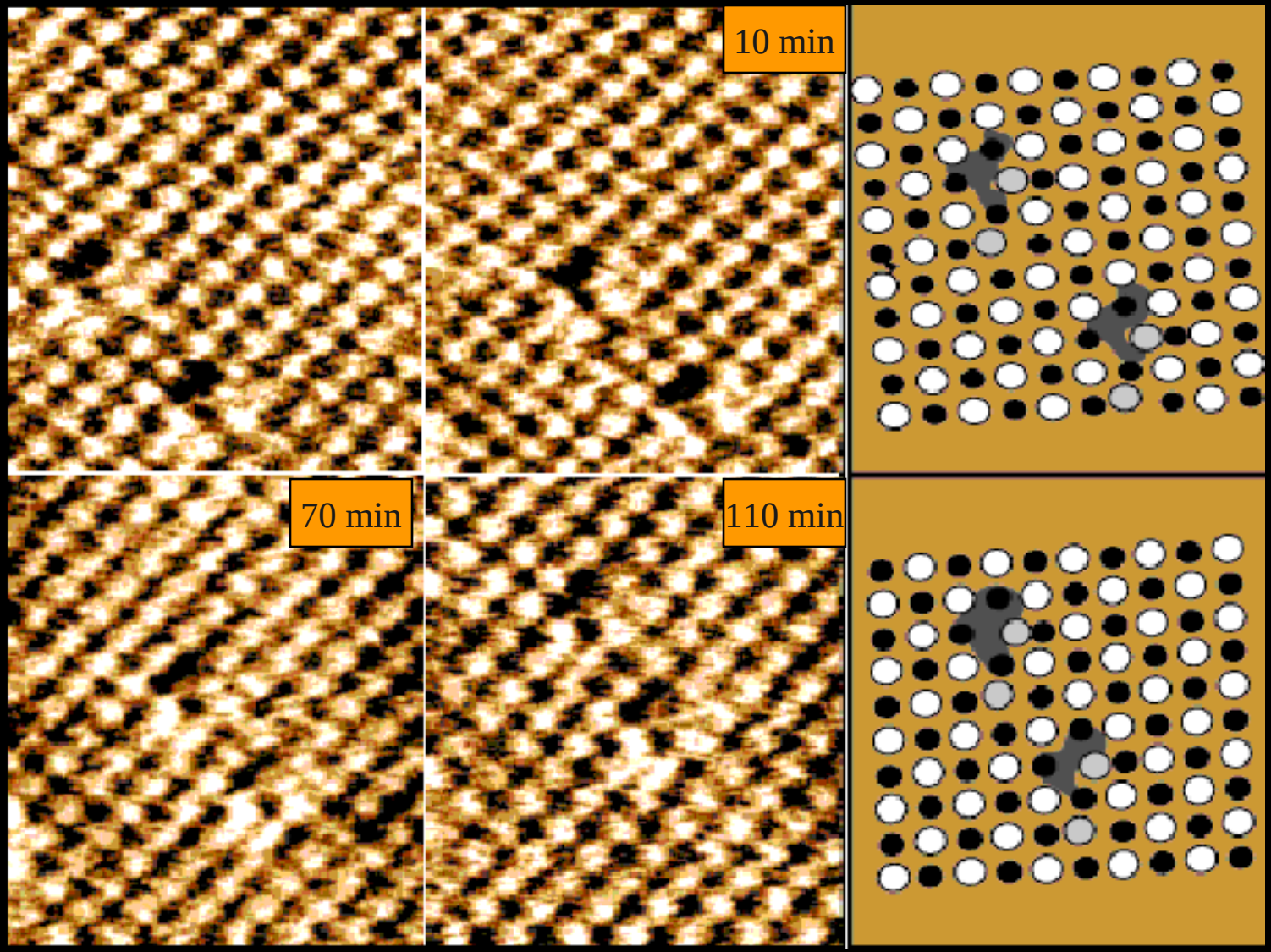
True atomic resolution NaCl(001)

(Insulator surface with point defects)



M. Bammerlin et al., *Probe Microscopy* **1**, 3 (1997)

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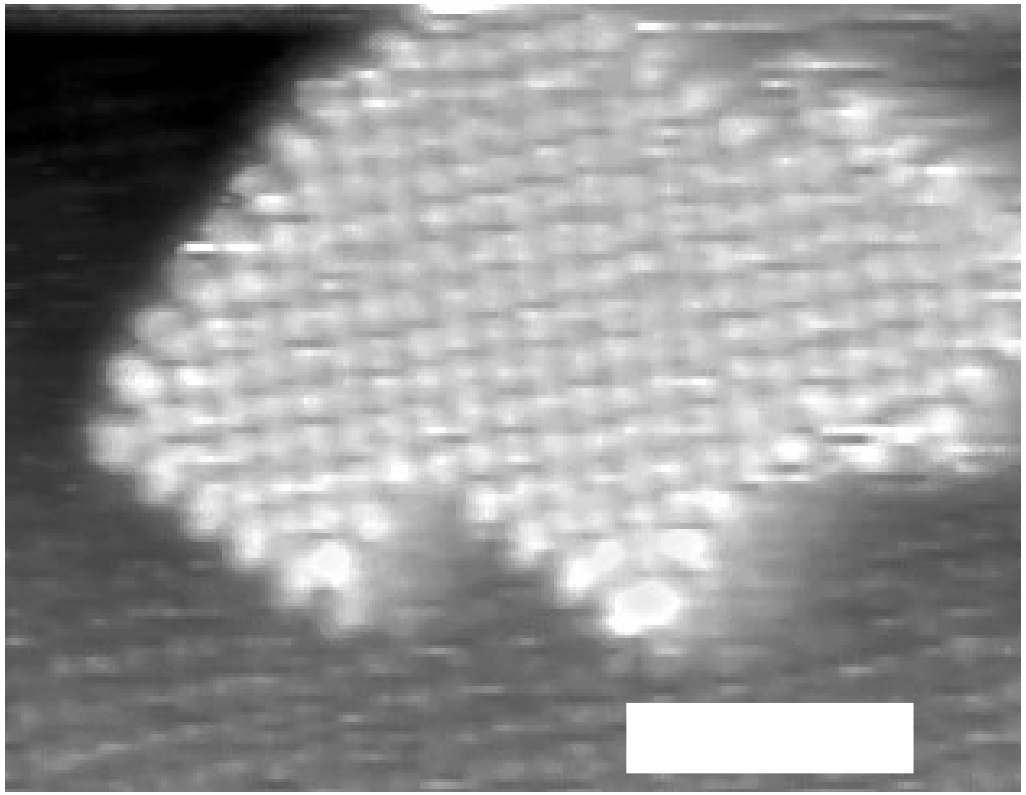
Nano-Switzerland



NaCl-Islands consisting of 120 atoms

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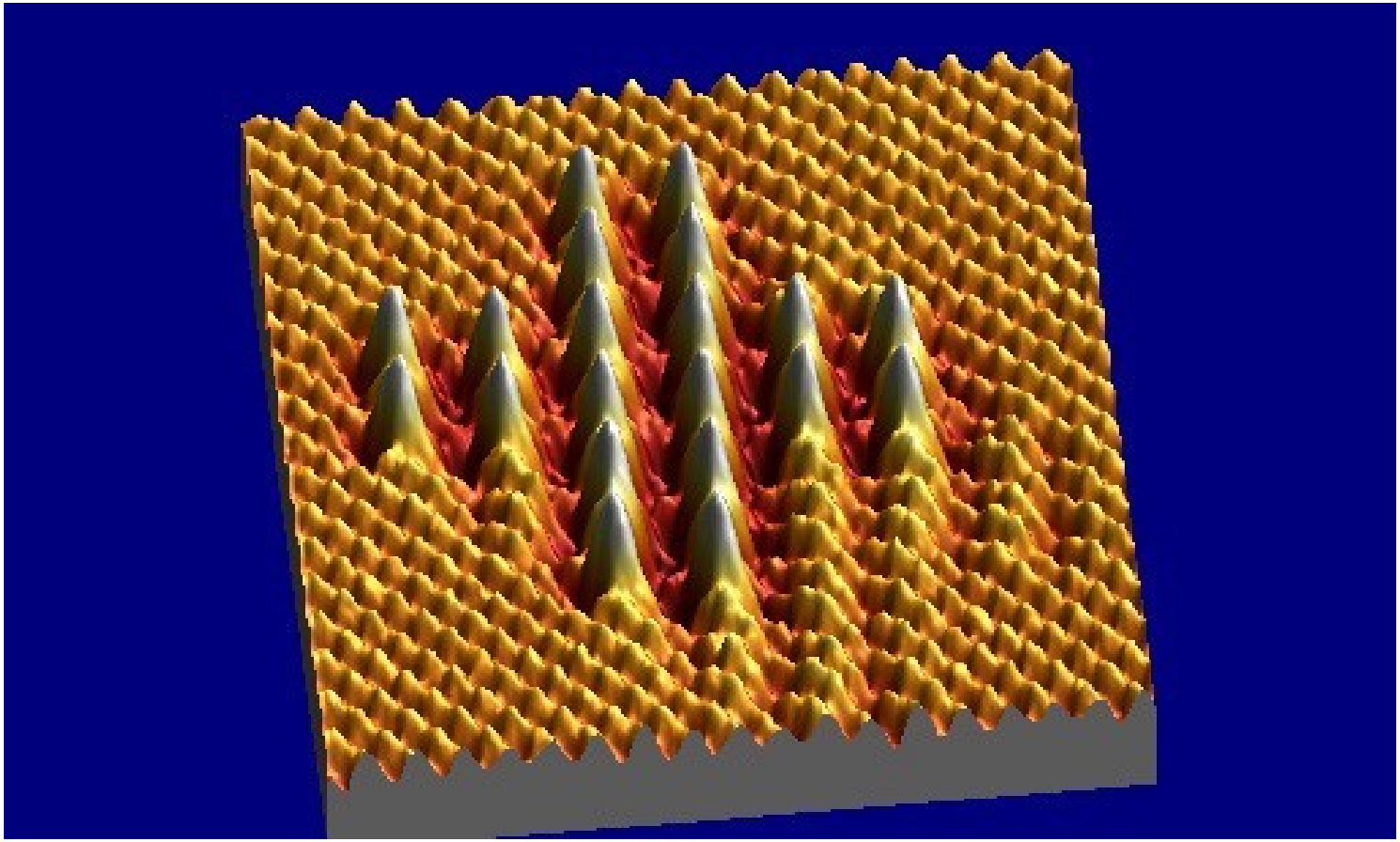
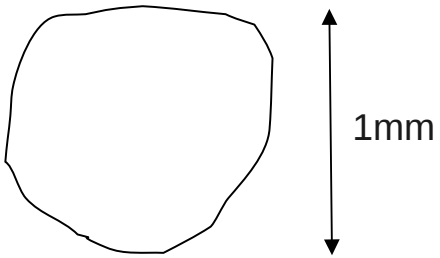
The smallest Swiss Cross: Single Atoms on NaCl(001)



S. Shigeki et al.

Salt grain



One grain salt could store

10‘000‘000‘000 maps on the surface

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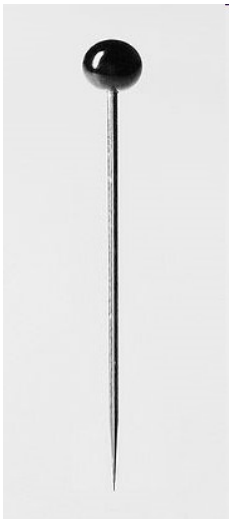
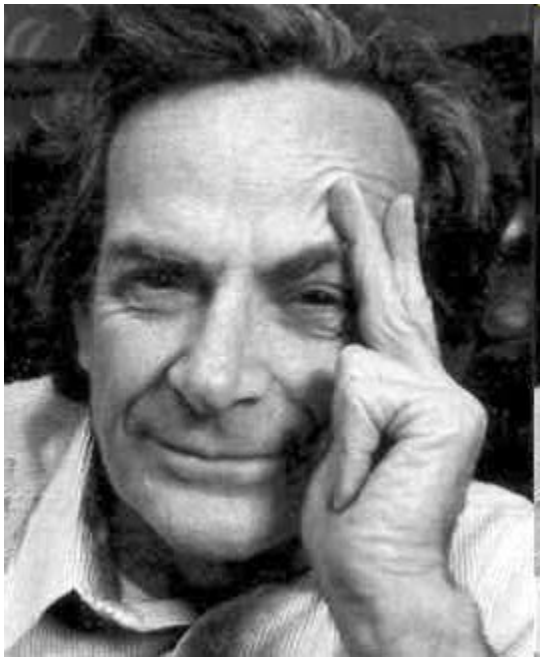
There is plenty of room at the bottom



- Atomic-scale Memory:
-Library on the tip of a needle

-24 millions books = 10^{15} Bits
-1 Bit = 100 Atome = 3 nm^3
$\Rightarrow 3 \cdot 10^{-12} m^3$
$\Rightarrow$ cube with side length of 0.14mm



Richard Feynman
Nobelpreis 1965

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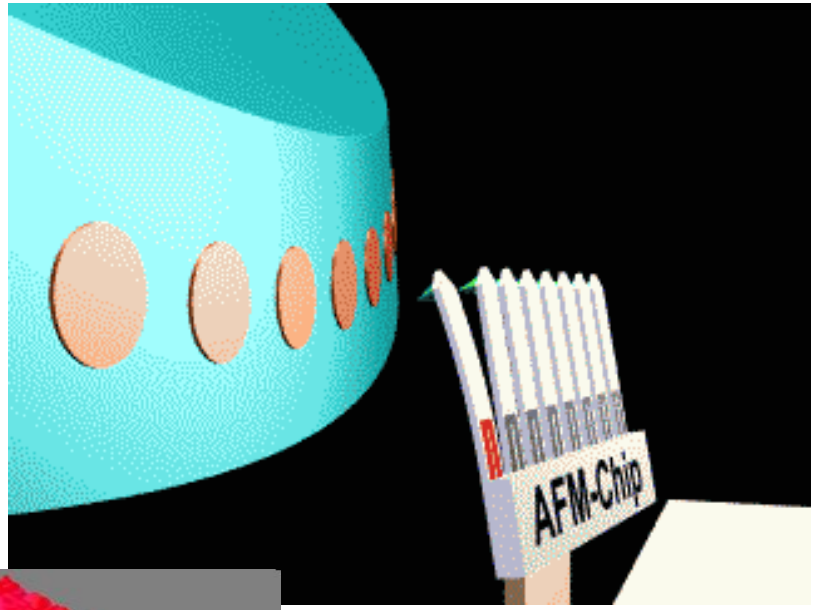
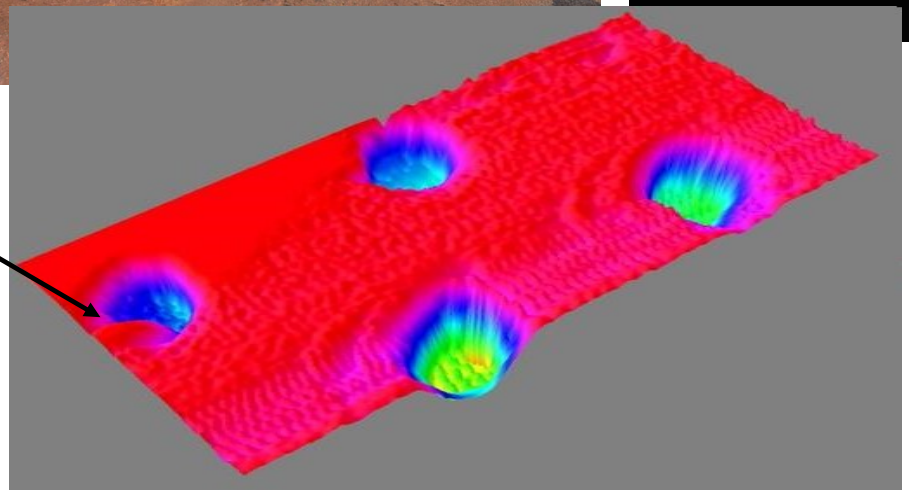
Phoenix Mars Lander: AFM on Mars





1µm-Mars-dust particle

Landed 25th May 2009

AFM from the University of Basel, University of Neuchatel and Nanosurf AG

http://www.nasa.gov/mission_pages/phoenix/main/index.html

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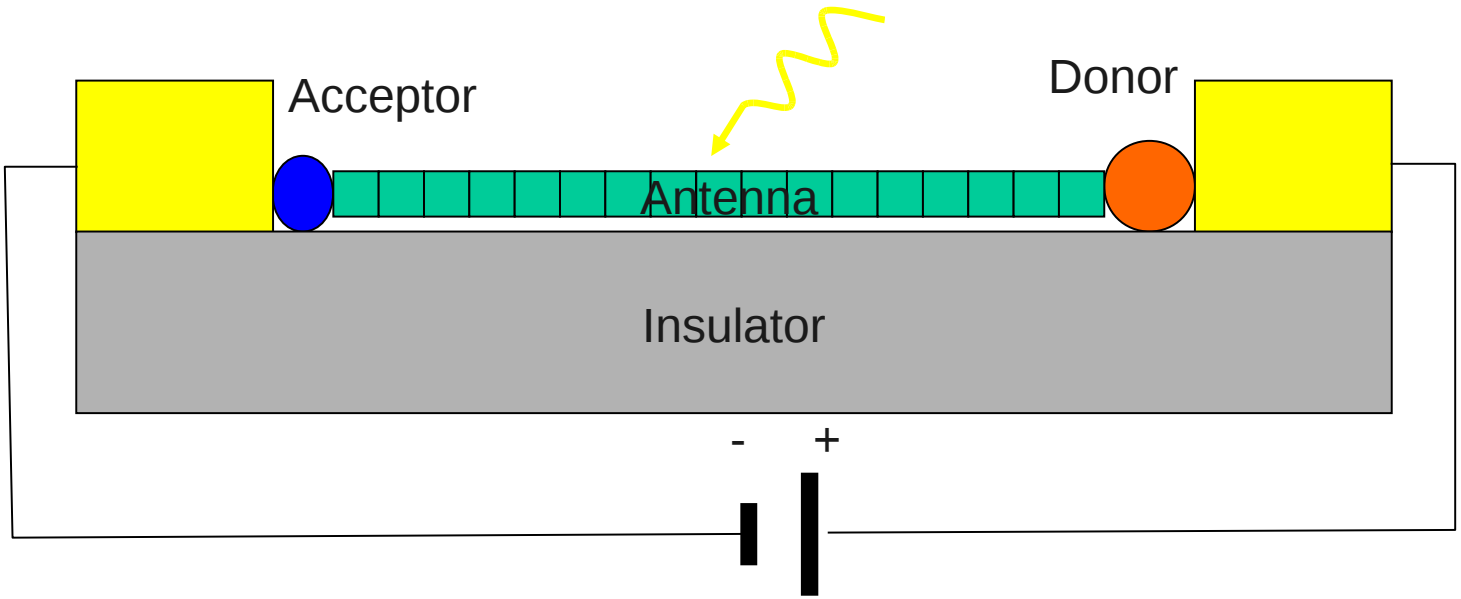
Artificial Light Harvesting Complexes
Novel approaches for photovoltaics



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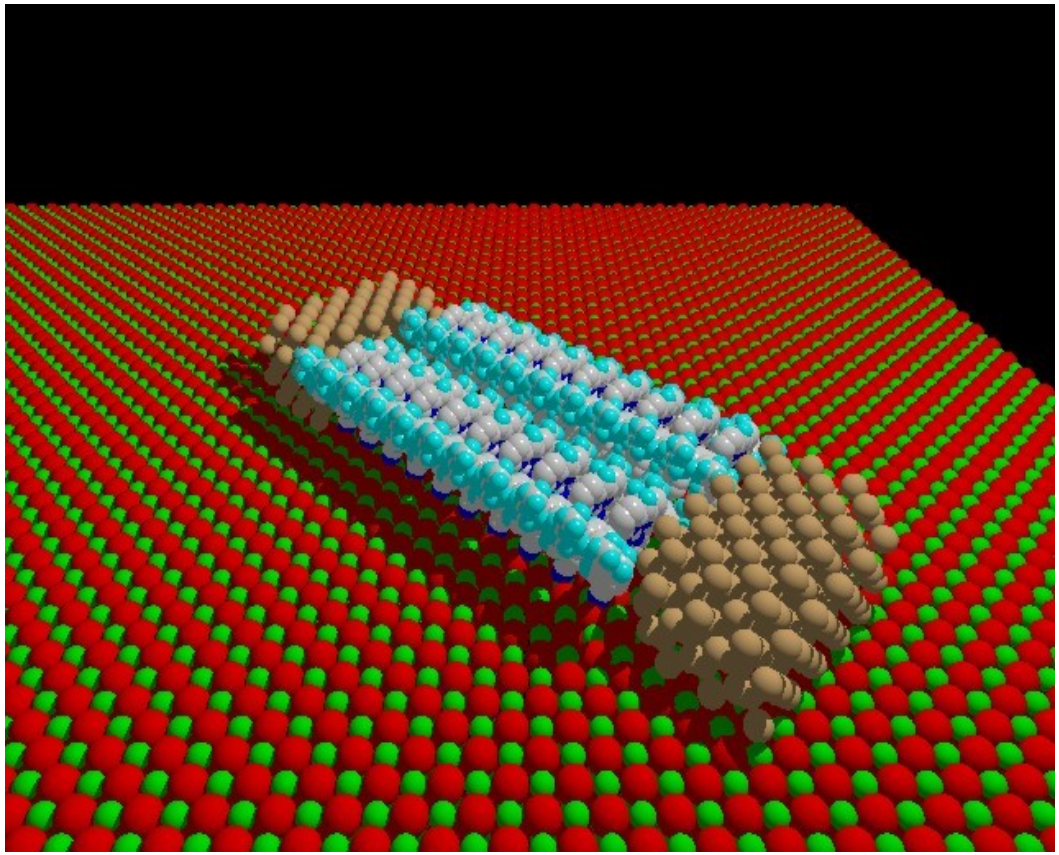
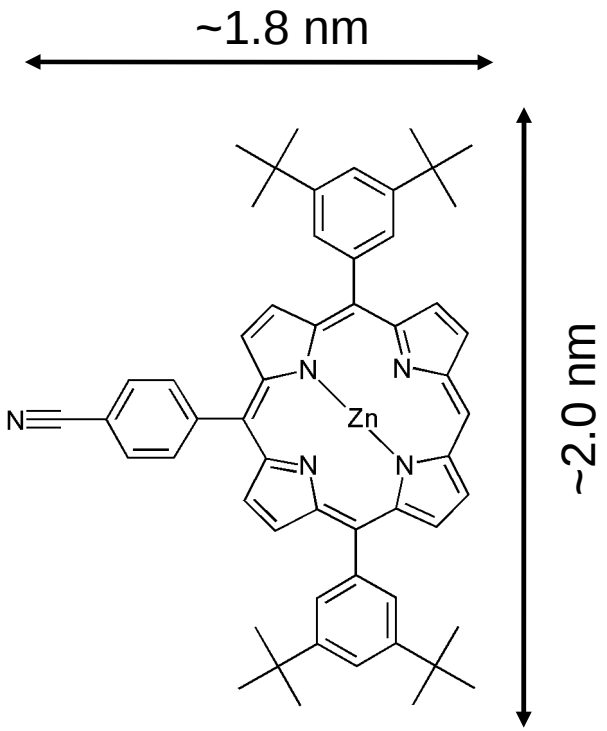
Two Au-nano-islands connected by a molecular wire on an insulator





Cyano end groups help to immobilize the wire
Growth starts at Au-islands and is directed by the substrate in [110]-direction
π-π stacked molecules nearly perpendicular to surface

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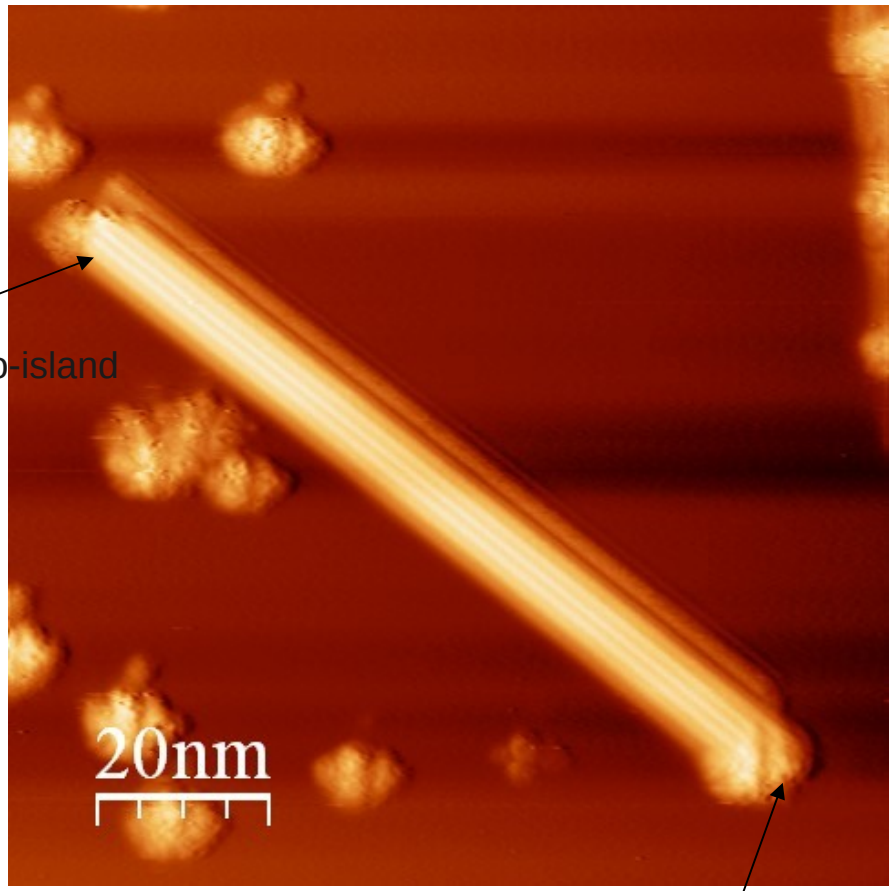
Multi-wire of asymmetric cyano-porphyrins, which connects two Au nano-islands



Spacing between the molecular rows is 2.4nm.
The height of the molecular wire is 1.5nm.
The Au nano-islands are about 10nm in width and 1-1.4 nm high.

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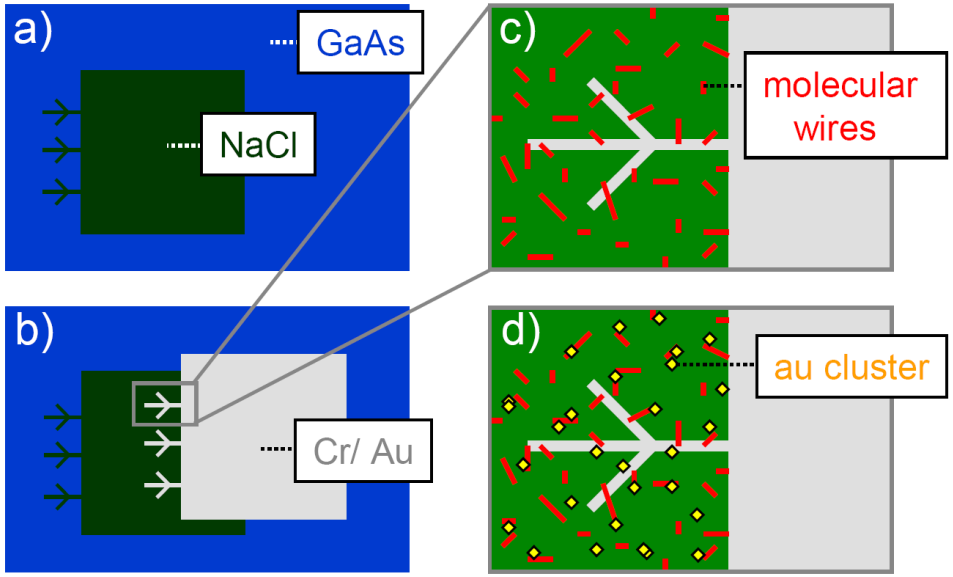
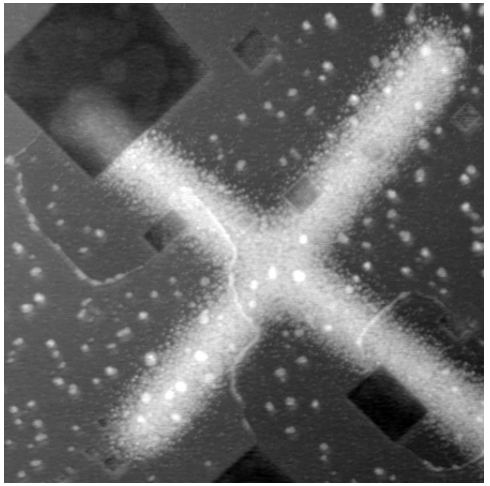
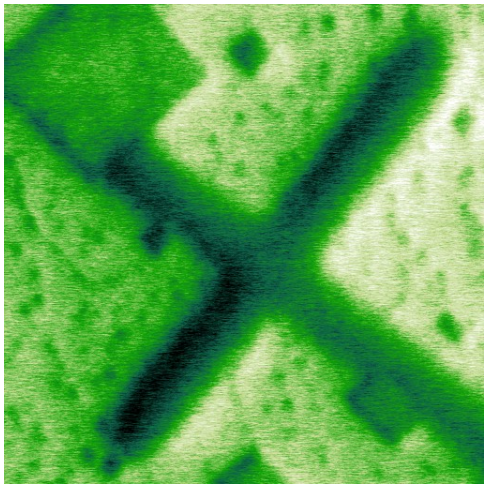
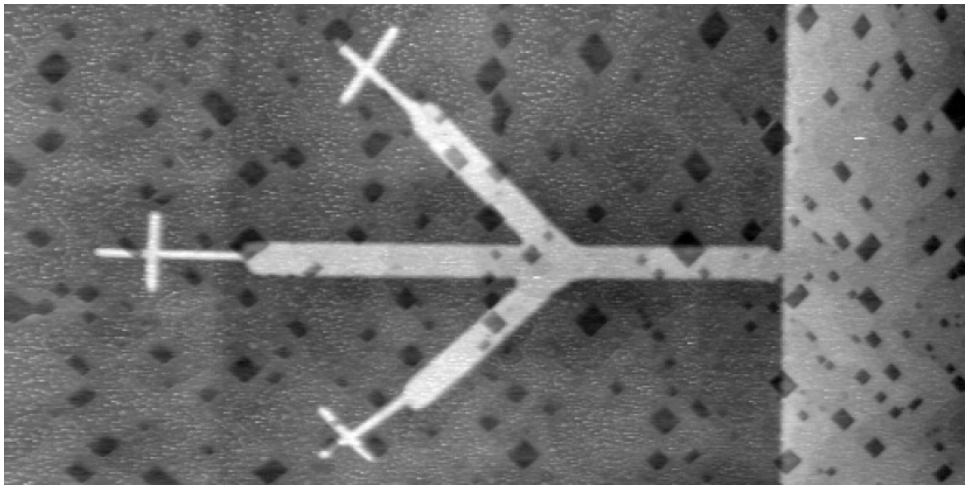
Contacting Molecular Assemblies

Nanostencil (IBM Rüschlikon)









Contacting Molecular Assemblies

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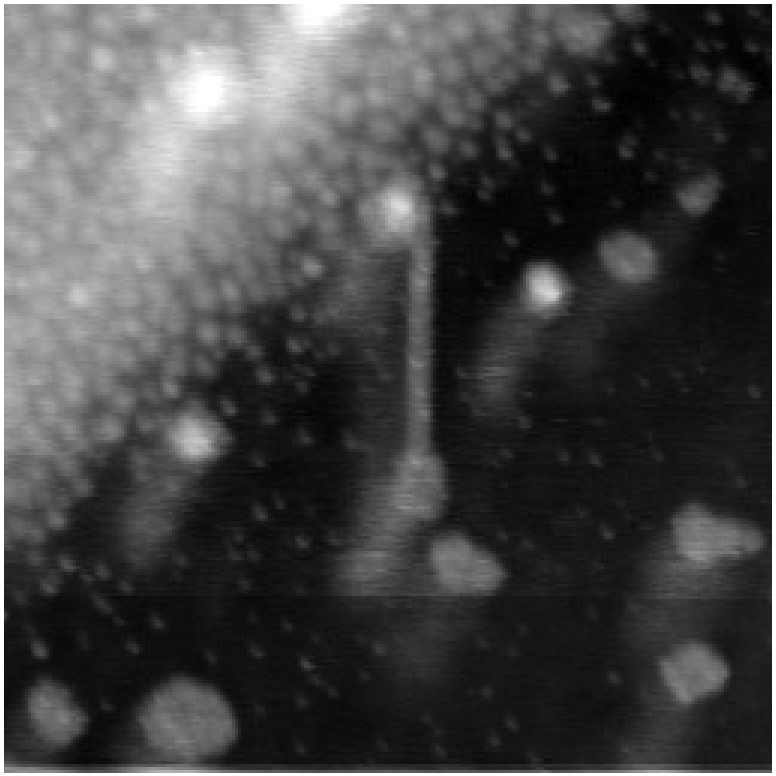
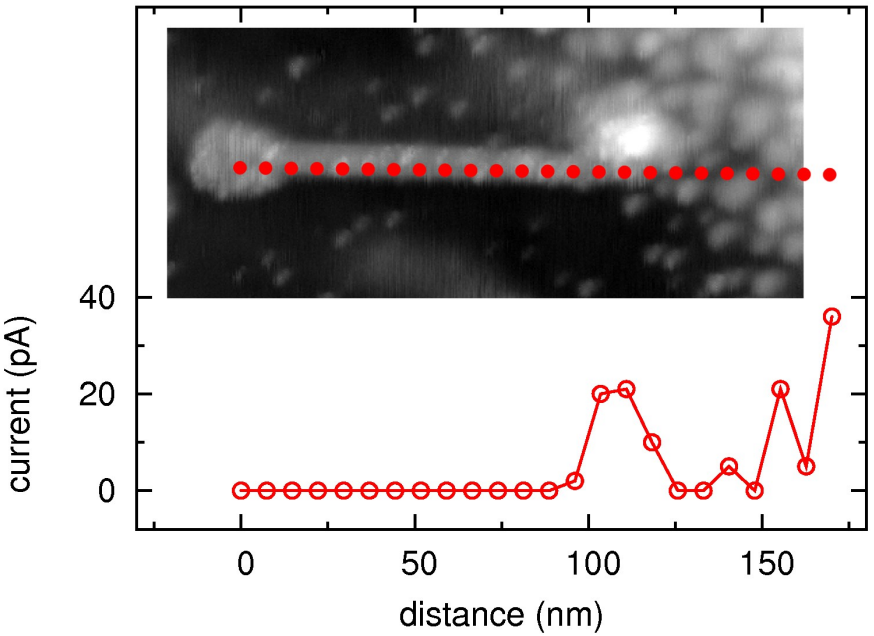


300x300nm^2



Vielen Dank
für Ihre
Aufmerksamkeit!

Thank you
for your attention!

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