

1000 Hot Tips on Nanorecording

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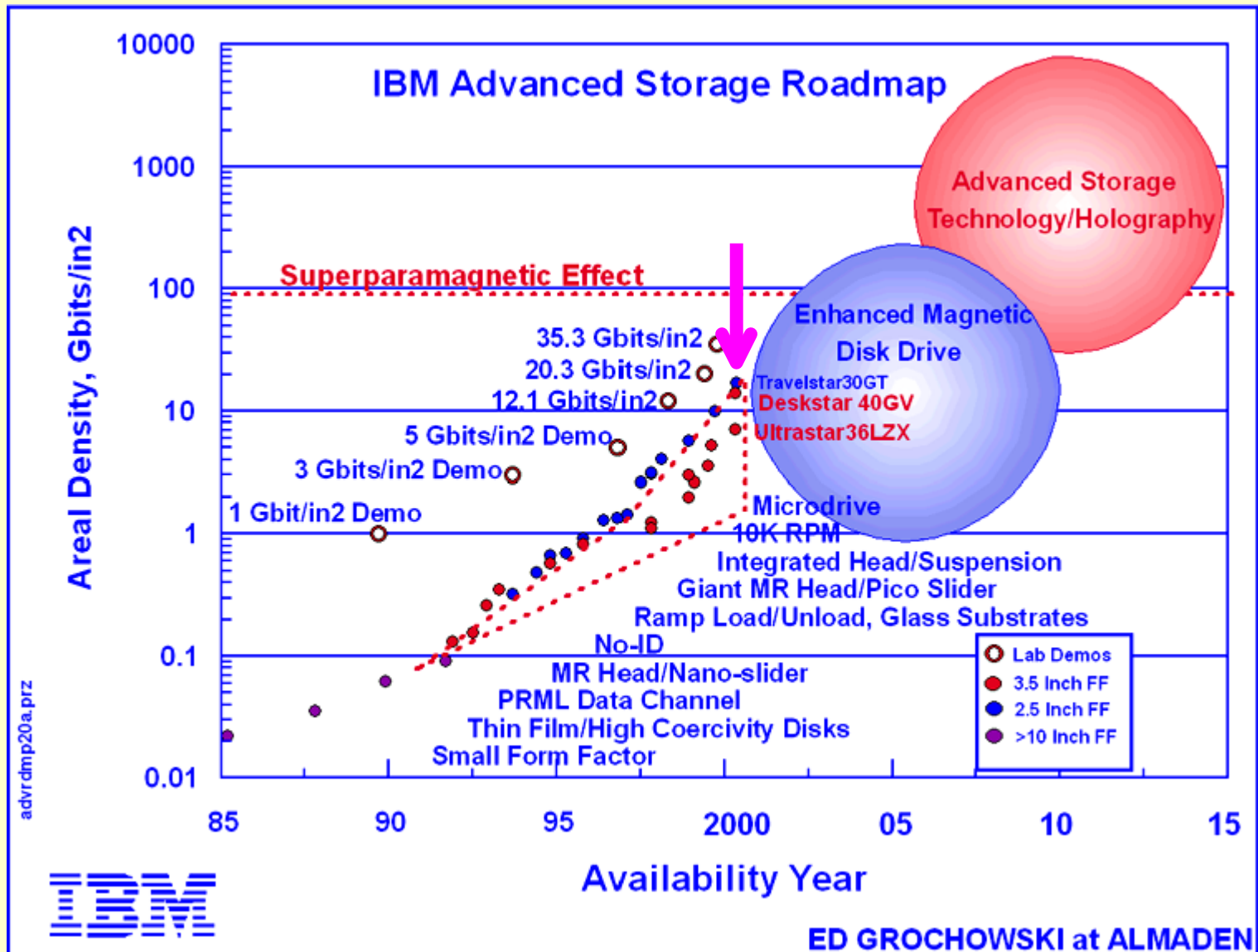
Outline

- Introduction
- Scanning Tunneling Microscopy (STM)
 - Tunneling
 - Operation
 - Atom Herding
- Atomic Force Microscopy (AFM)
- AFM-based Nanorecording
- Outlook

Introduction

- Information storage: 1's and 0's
- Magnetic recording:
 - \$50 billion a year
 - 150 million units shipped last year
- Current Speed: 50 Mb/second
- Current Density: 10 Gb/in²
 - ⇒ Bit size ~ 250 nm
 - ⇒ 200 bits ≡ 1 hair

Magnetic Storage Roadmap

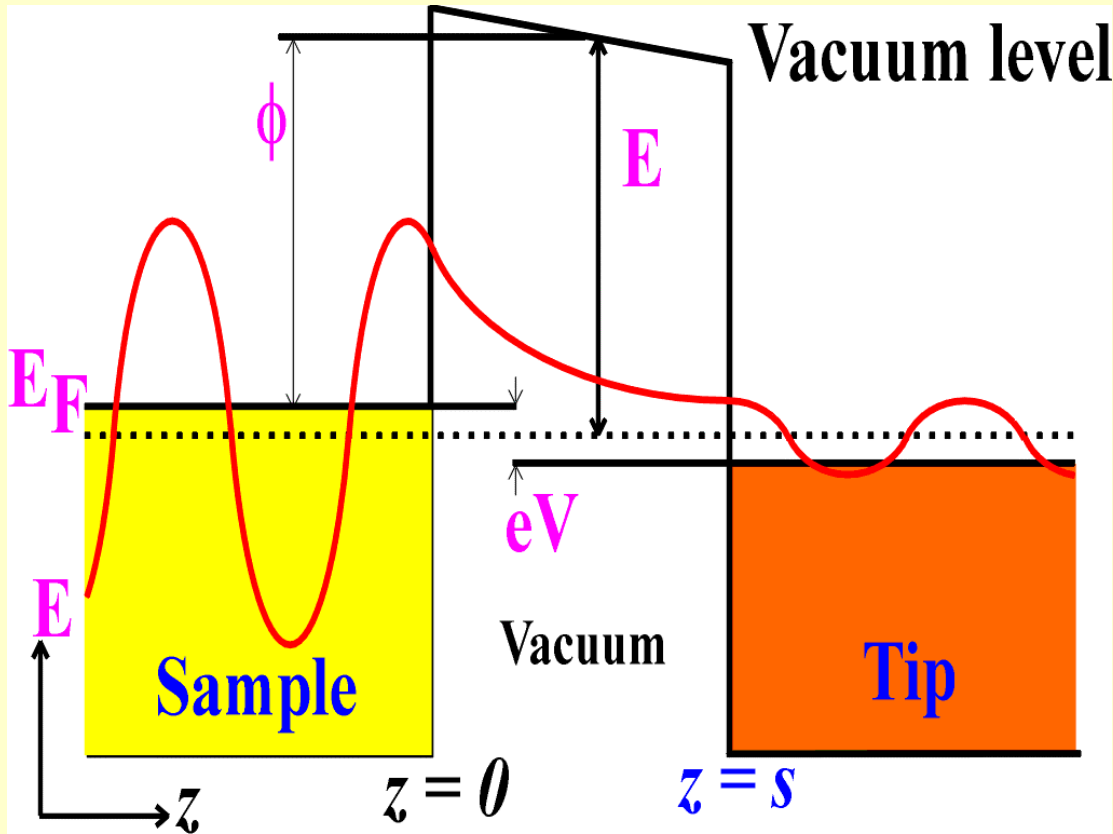


Introduction

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“There's plenty of room at the bottom”

Tunneling



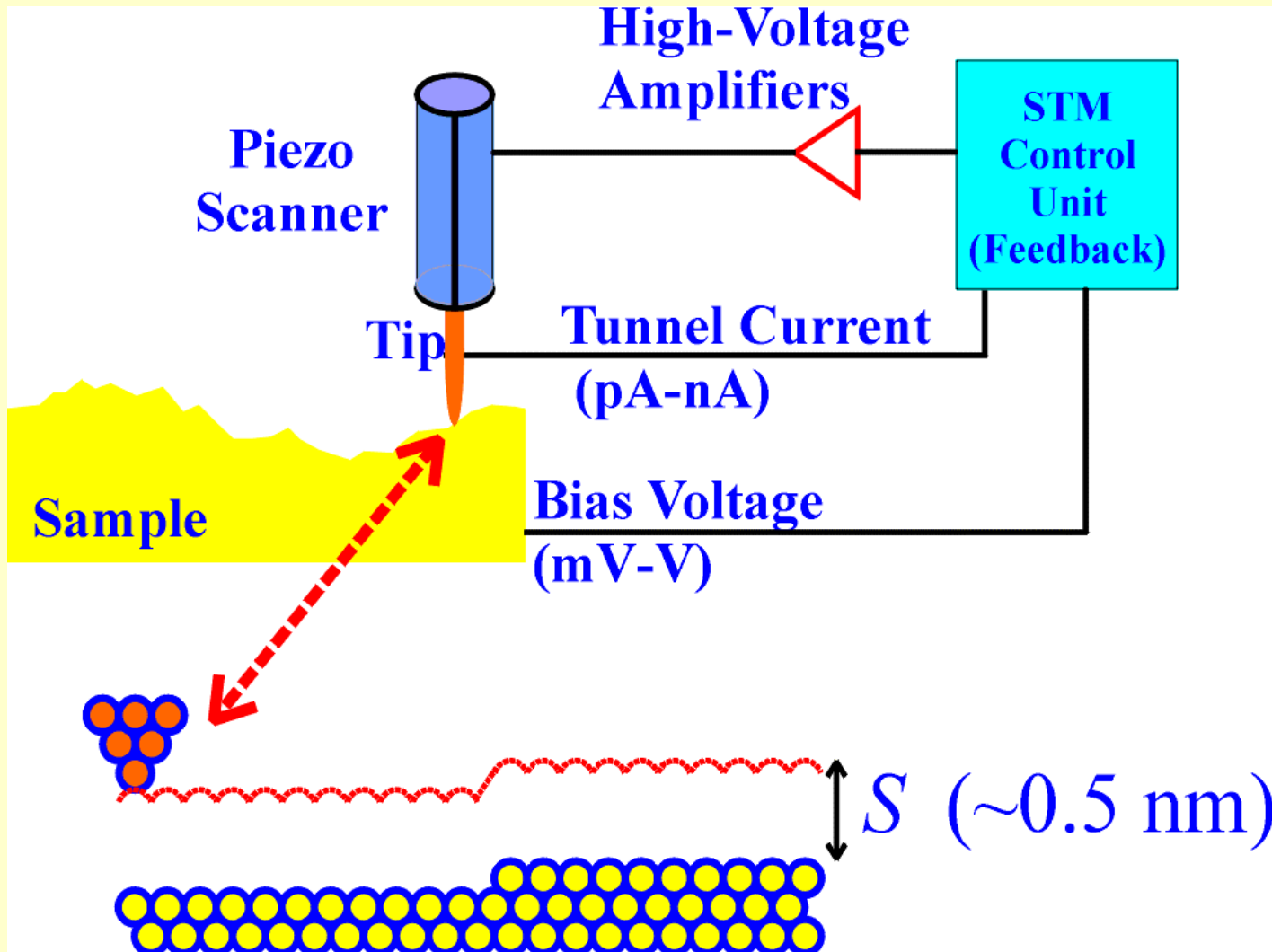
$$I \propto e^{-2\kappa s}$$

$$\kappa \propto \sqrt{\phi}$$

Reduce separation s
by 0.1 nm

$\Rightarrow I$ increases by 10

Scanning Tunneling Microscope (STM)



Binnig & Rohrer
1981

IBM Zurich

Nobel Prize 1986

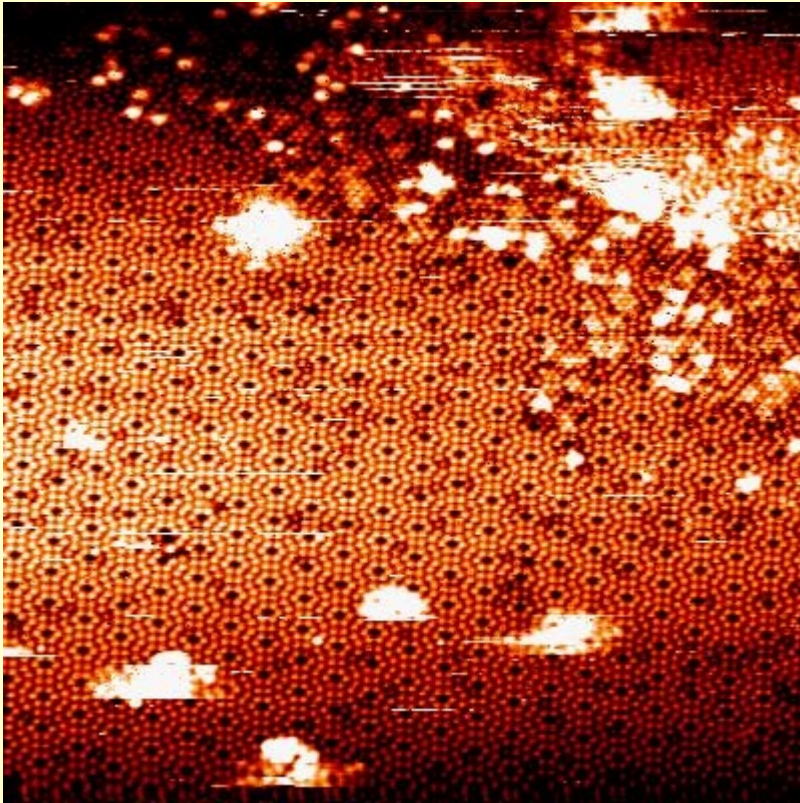
Atomic resolution
on (semi-)
conducting
samples

Resolution:

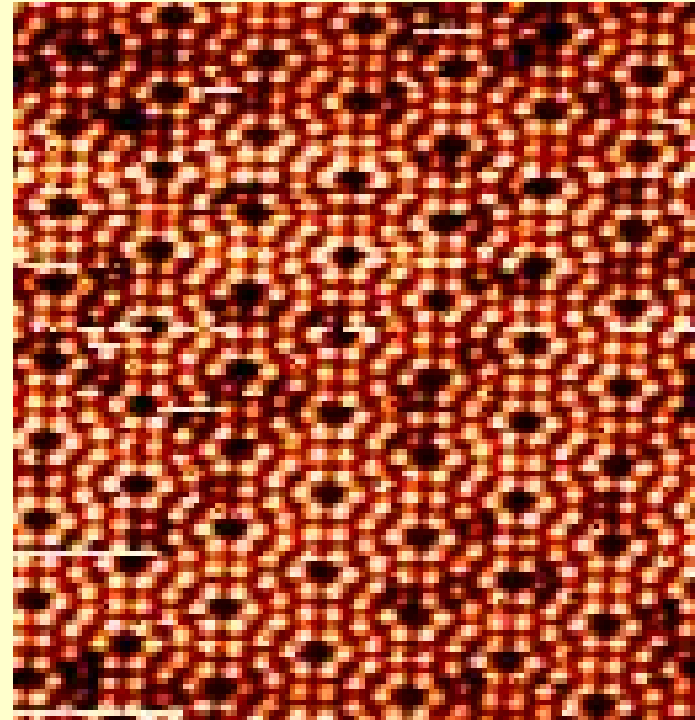
Vertical: 0.01 nm

Lateral: 0.2 nm

STM on Si(111) 7×7

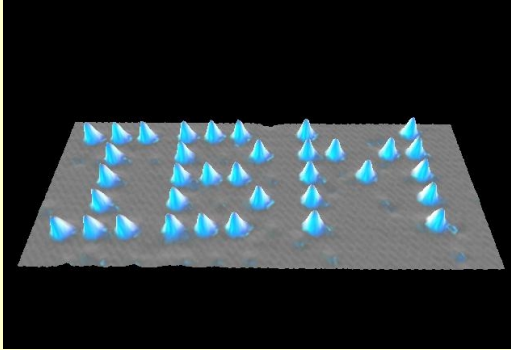


55 × 55 nm
Tunnel Current 0.2 nA
Bias: 1.5 V

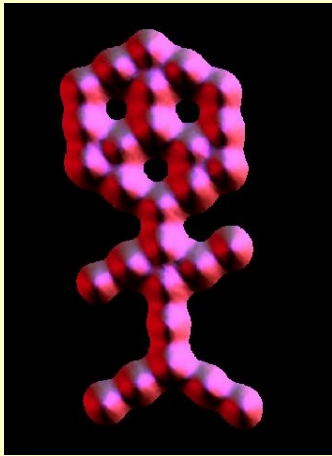


Exploded view

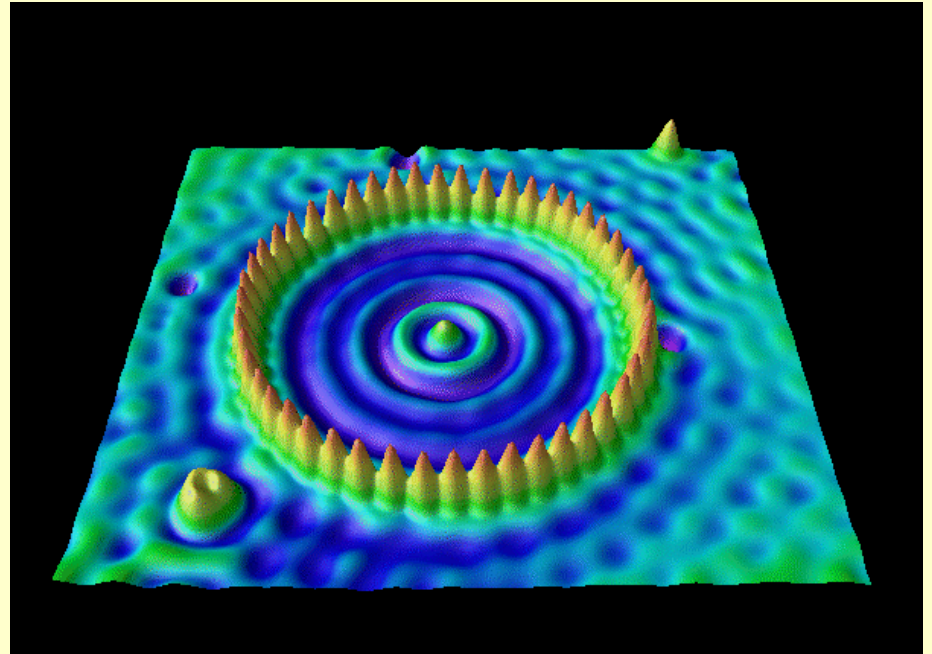
Atom Herding using STM



Xe/Ni(110)



CO/Pt(111)

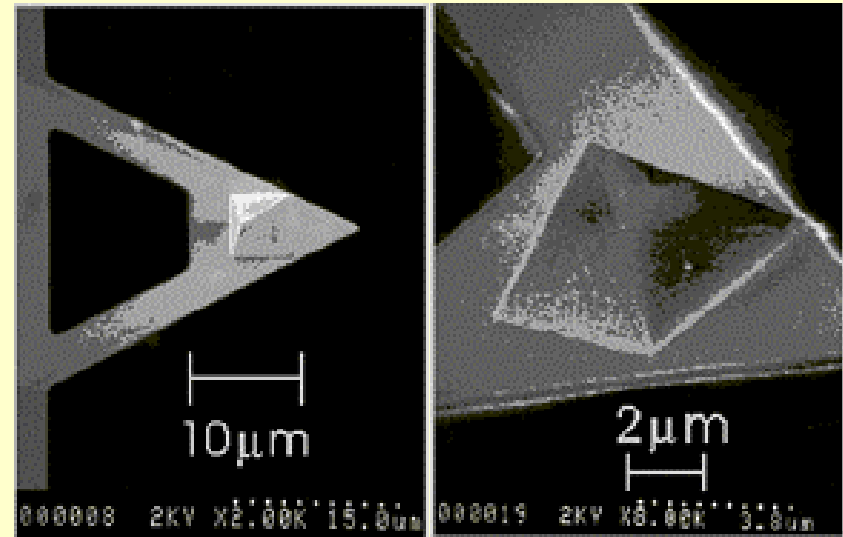
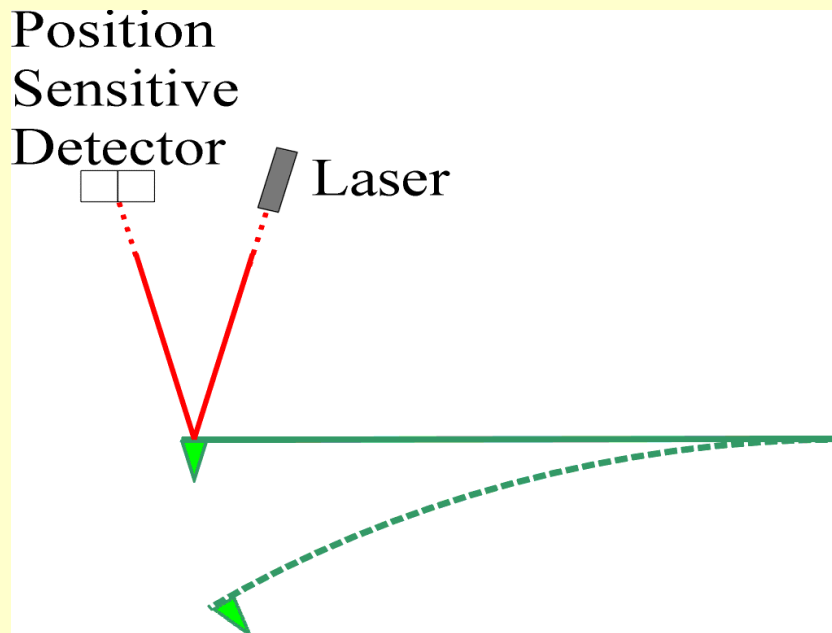


Quantum corral: Fe/Cu(111)

<http://www.almaden.ibm.com/vis/stm/gallery.html>

Atomic Force Microscopy (AFM)

'Replace' tunneling tip with cantilever



Batch fabricated Si cantilevers:

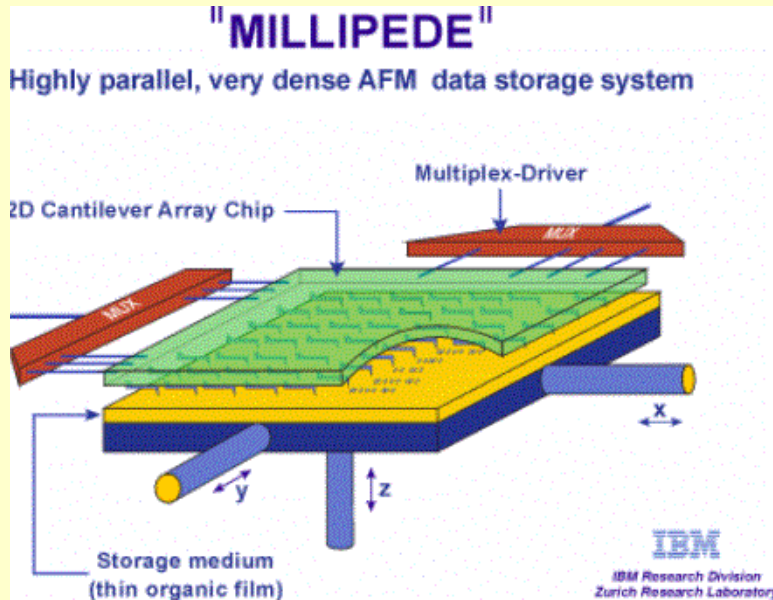
f_{res} : 100 kHz - 10 MHz

k : 0.1 - 100 N/m

$k_{at} \sim m_{at} \omega_{at}^2 \sim 10$ N/m

Applicable to insulators as well as conductors

AFM-based Nanorecording: The Millipede

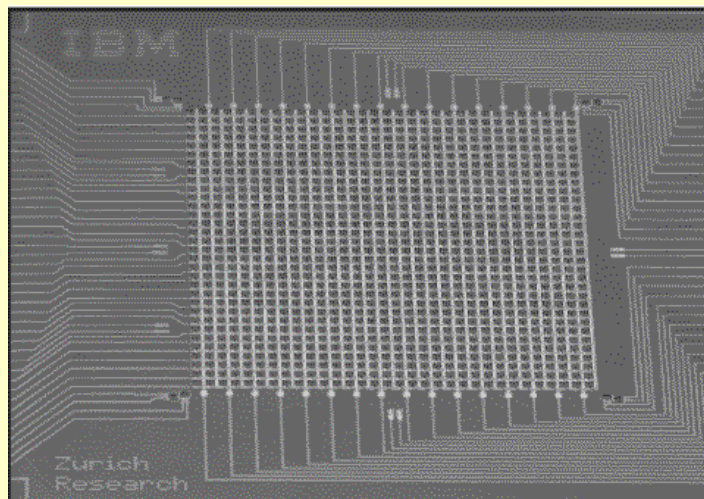
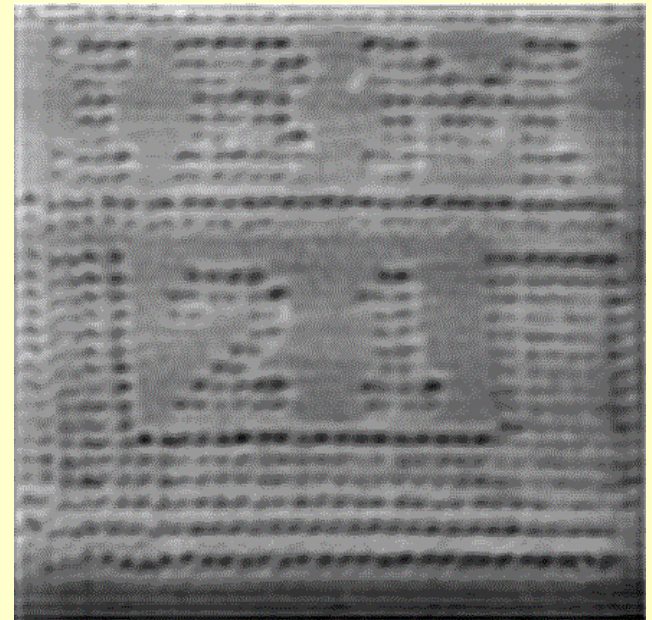


Demonstrator:

Read-Only: 60 Gb/in²

Read-Write: 30 Gb/in²

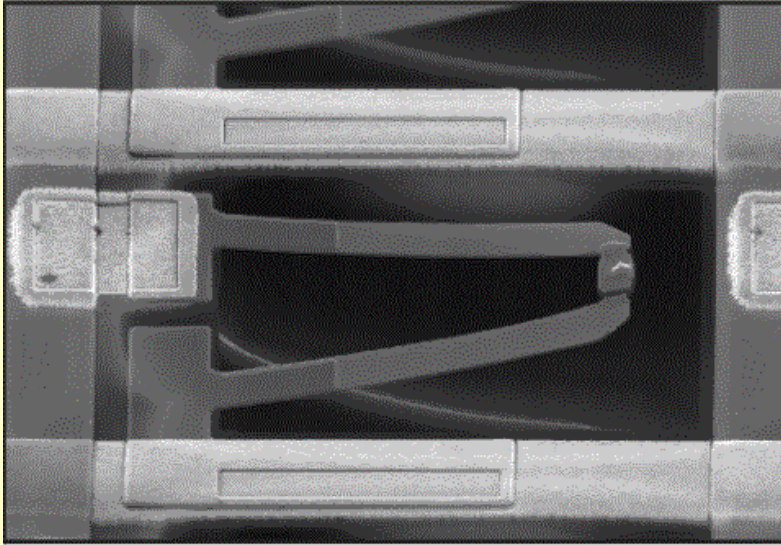
Read Speed: 10 Mb/s



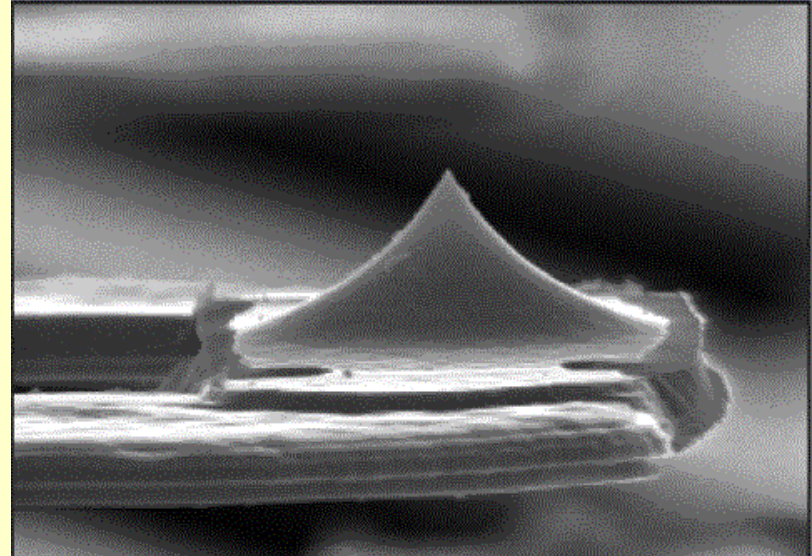
2D array of 32 × 32 cantilevers
on 3 mm × 3 mm area

<http://www.zurich.ibm.com/news/99/milliped.html>

AFM-based Nanorecording: The Millipede

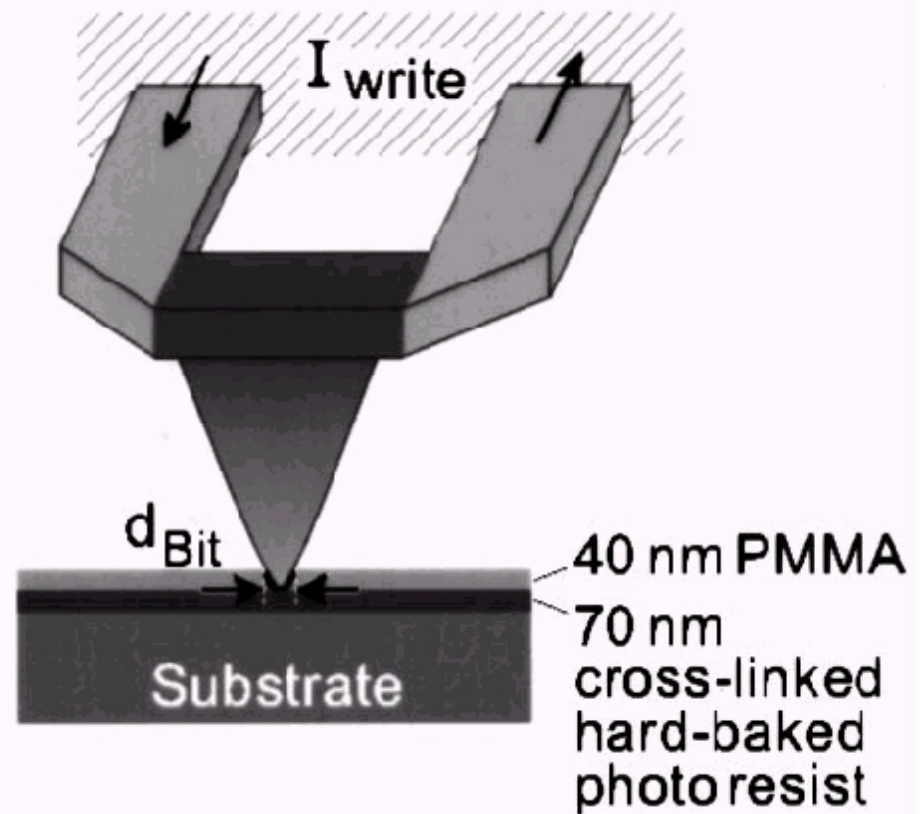
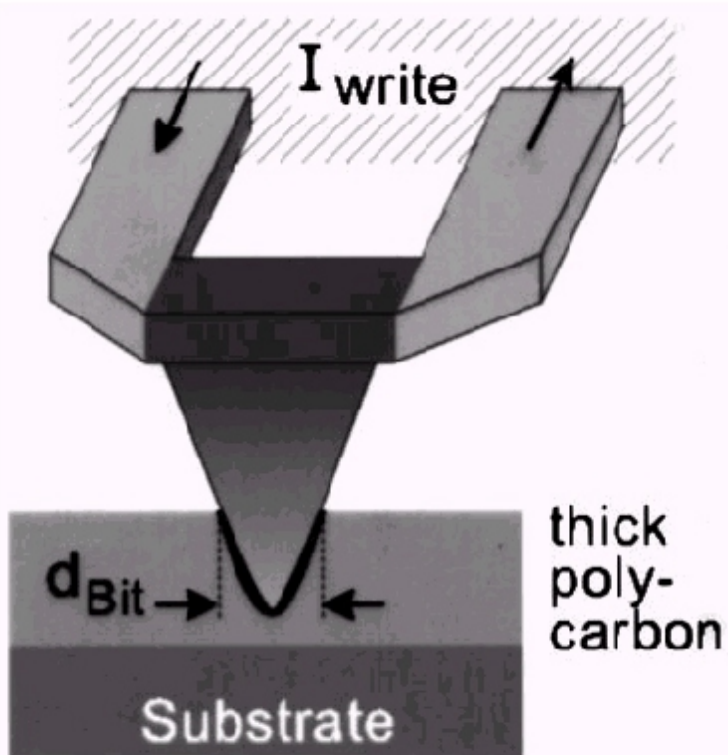


50 μm long

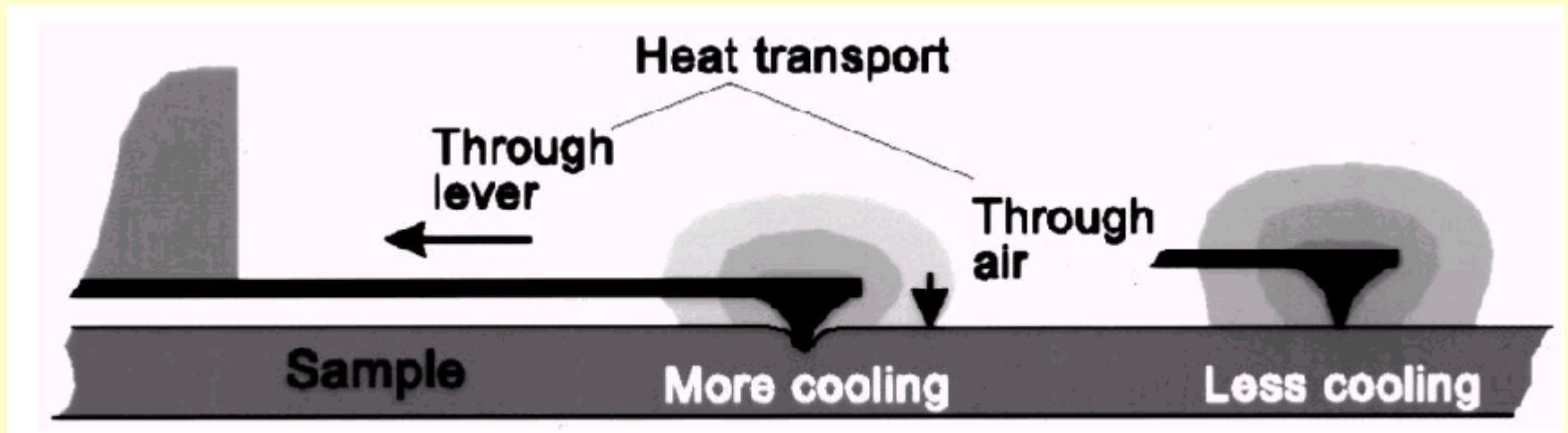


Tip 1.7 μm high

Thermomechanical Nanorecording



Thermomechanical Nanorecording



Pit acts as heat sink \Rightarrow Monitor change in R while scanning (10^{-3})

Outlook

- Innovative Technology from nanoscale science
- Nanorecording successfully demonstrated
- Still some issues remaining (wear, stability etc.)
- 300 Gb/in² ?