

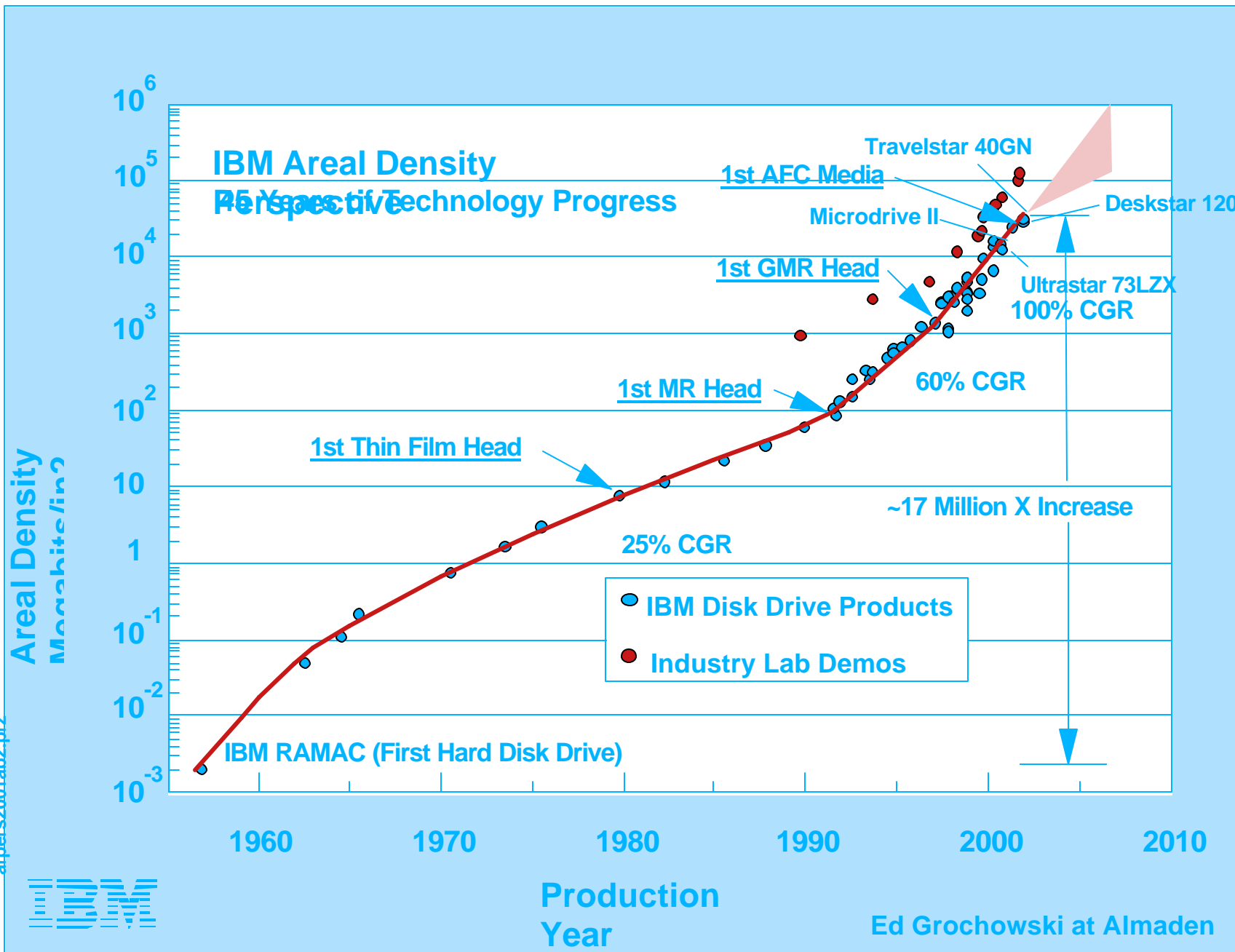
The Future of Data Storage

Principles, Potential and Problems

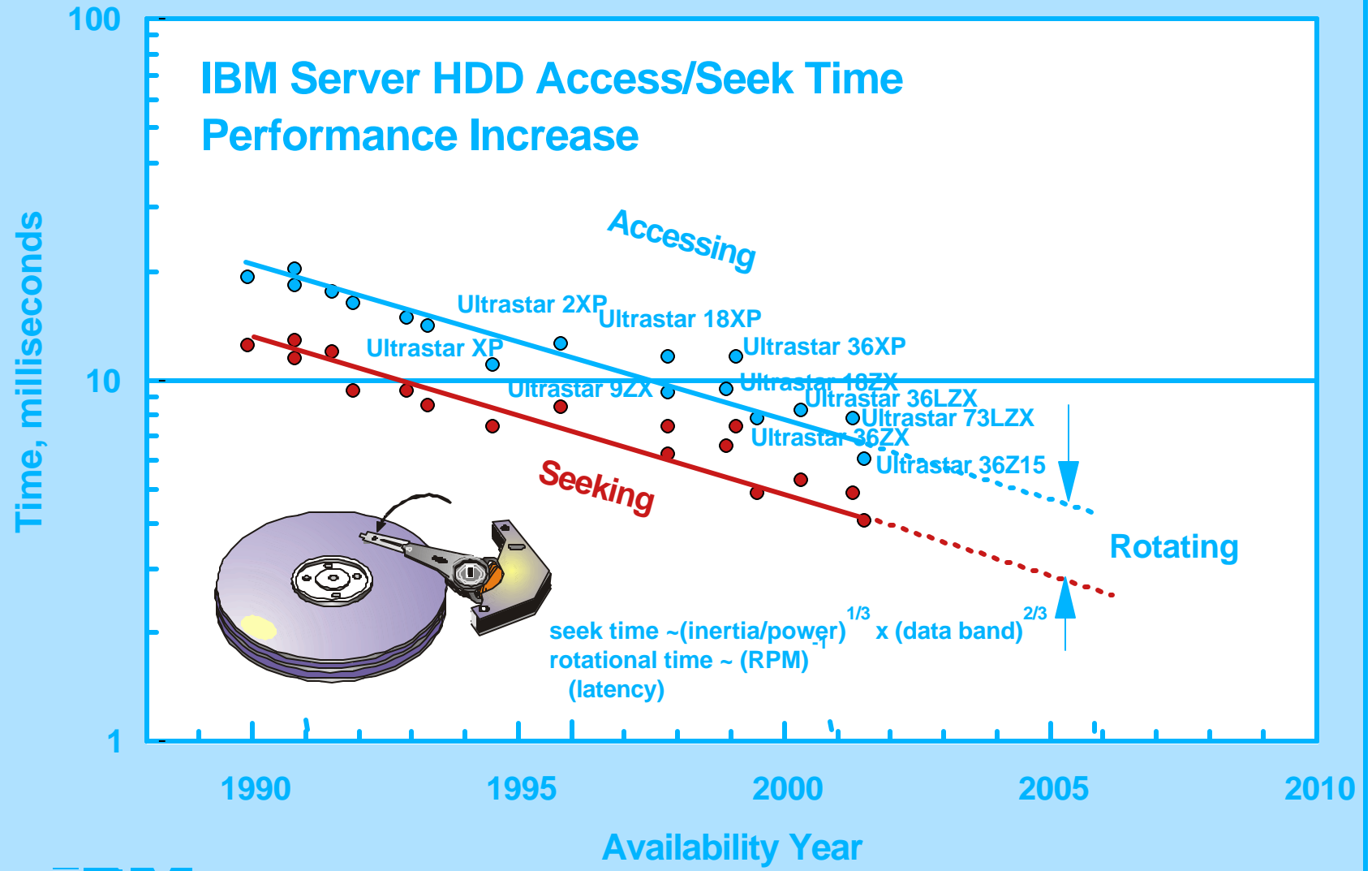
Hans Coufal



IBM Almaden Research
Center



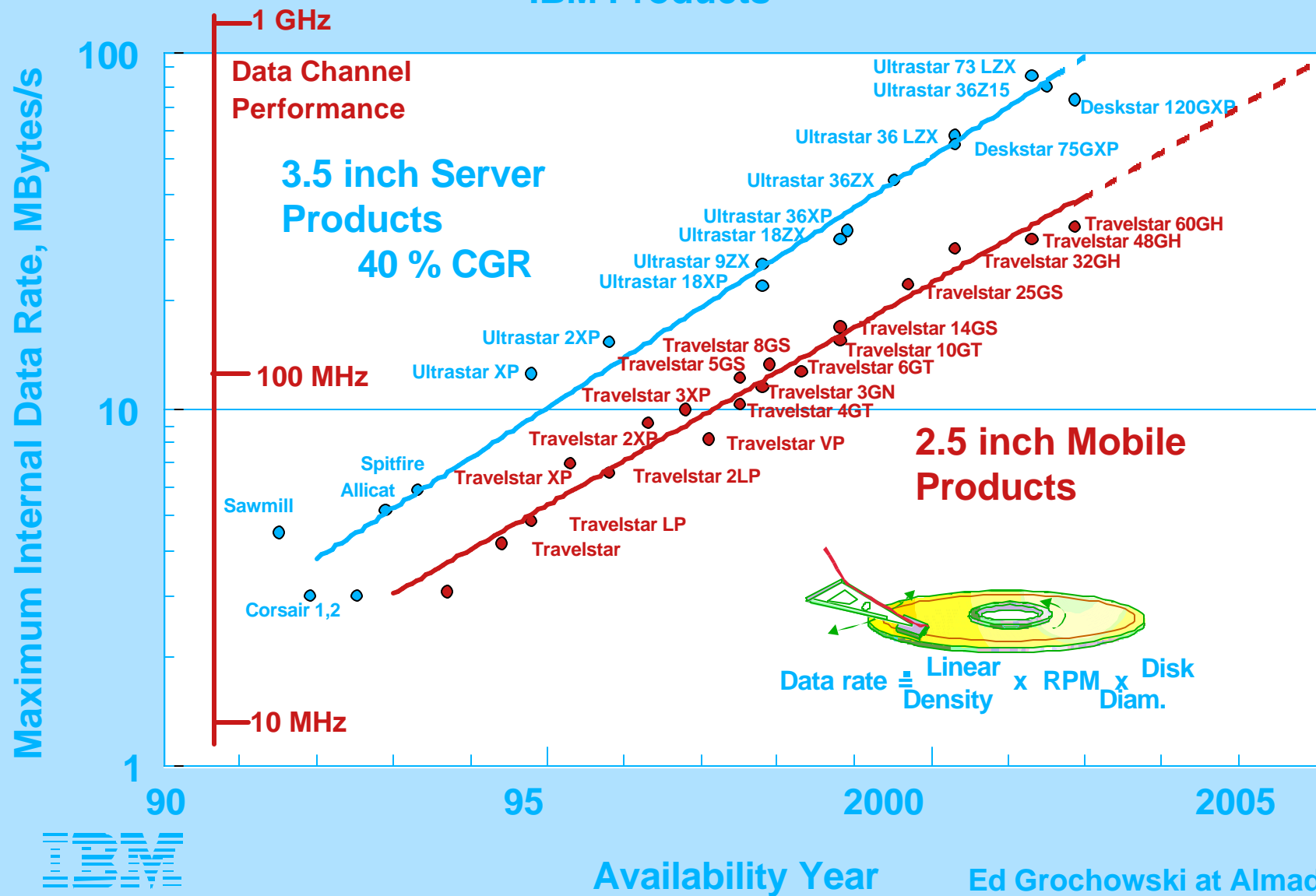
arpers2001ab2.prz



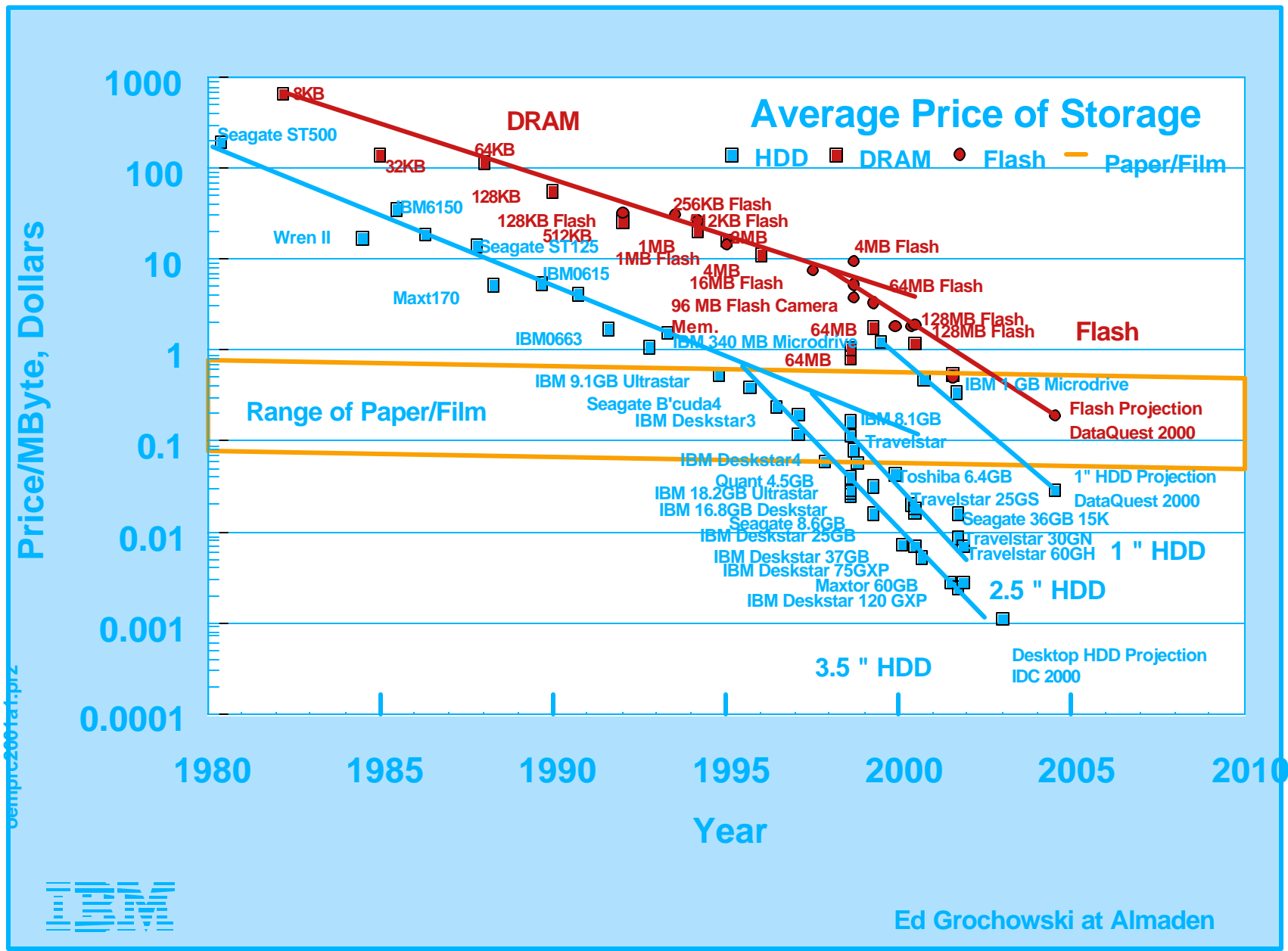
SEEK2001A.PRZ



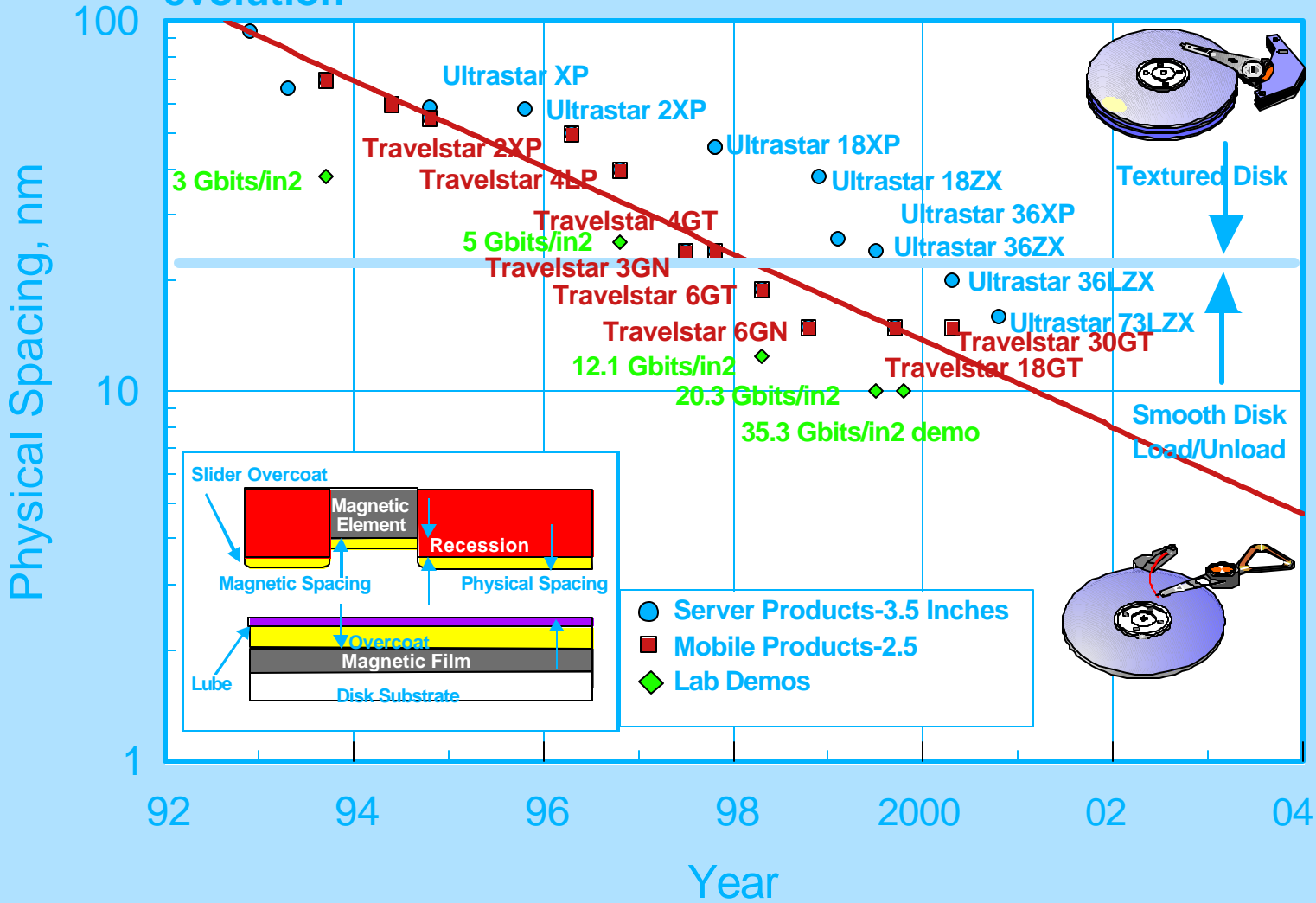
Magnetic Hard Disk Drive Internal Data Rate IBM Products



dtttrd004.vw.ppt



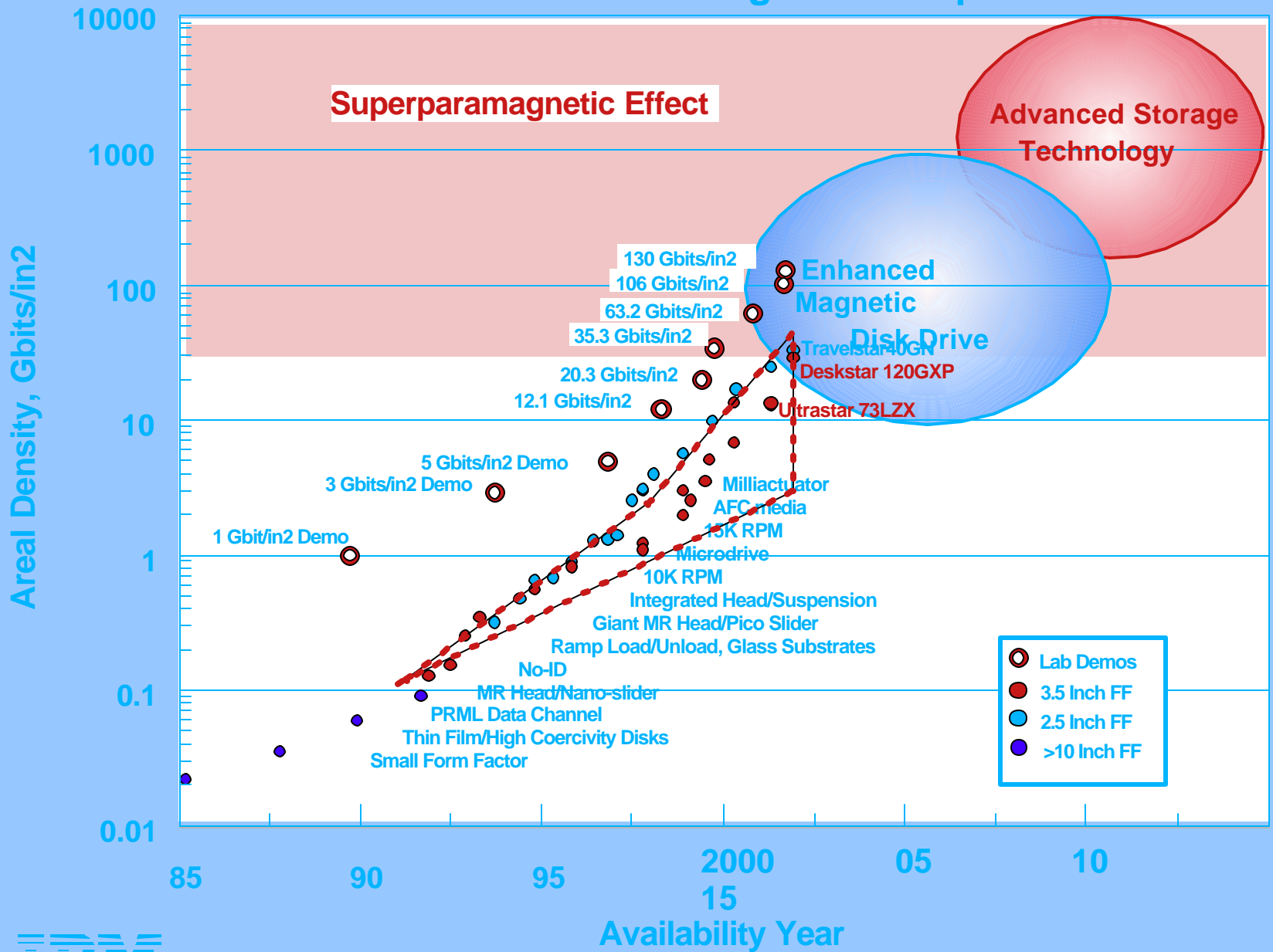
Physical spacing and disk surface evolution



spac2000f.prz



IBM Advanced Storage Roadmap

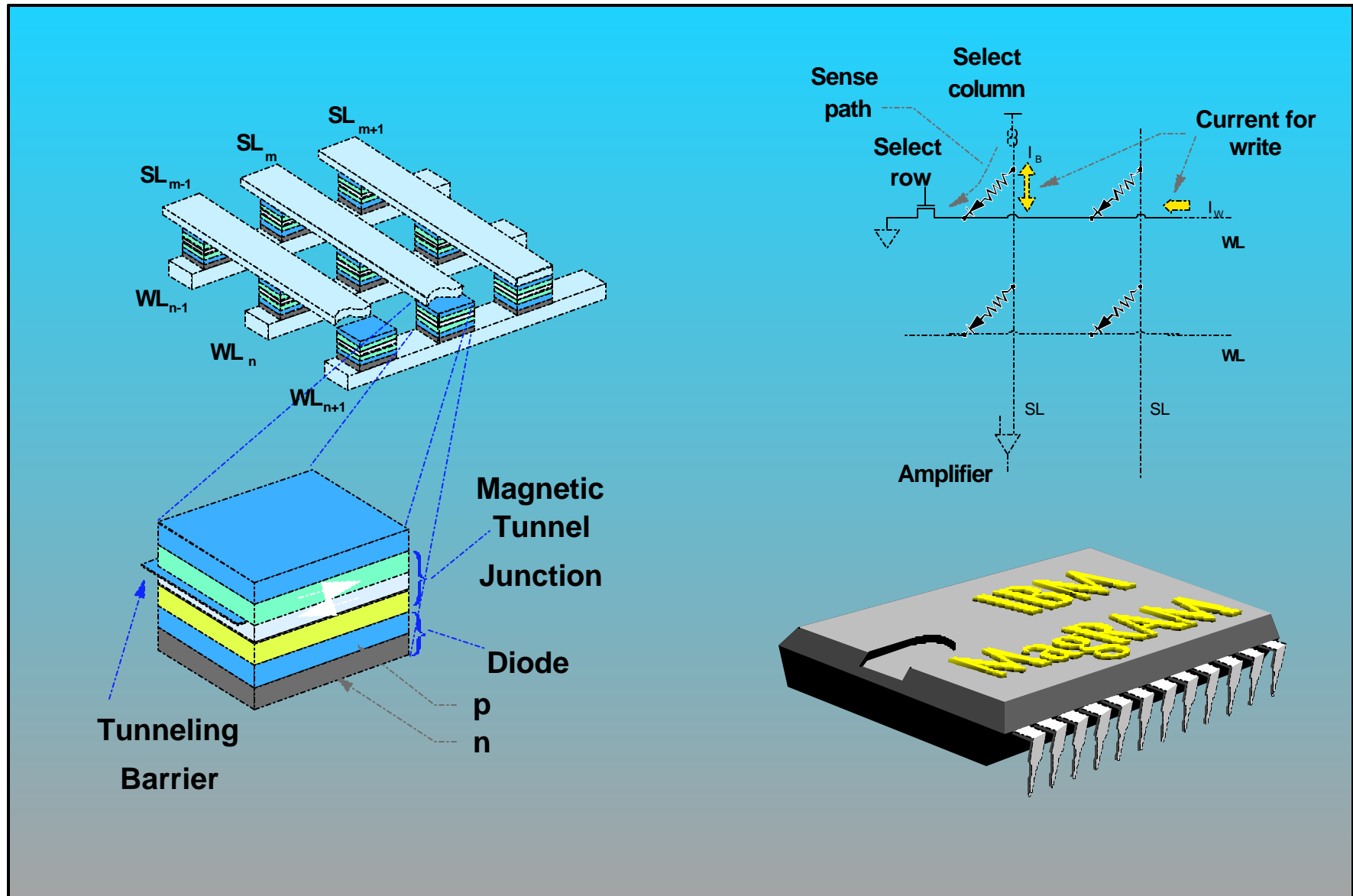


edgrodmp21a.pptz

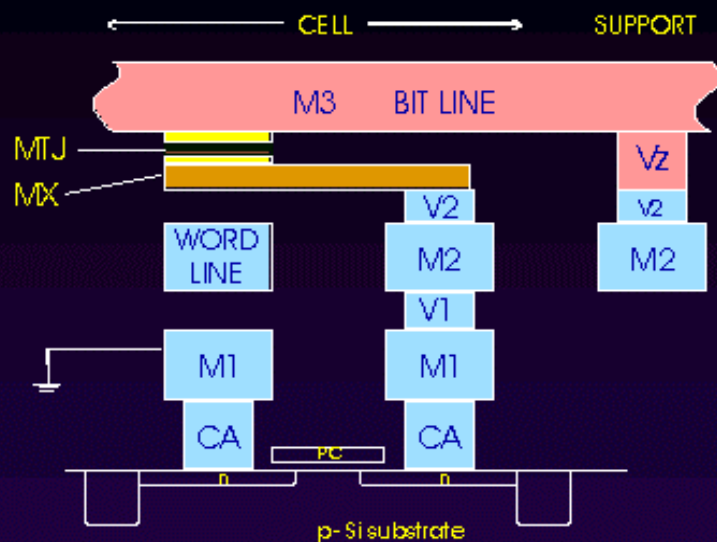


ED GROCHOWSKI at ALMADEN

Non-Volatile Magnetic Memory



MTJ MRAM Demonstration



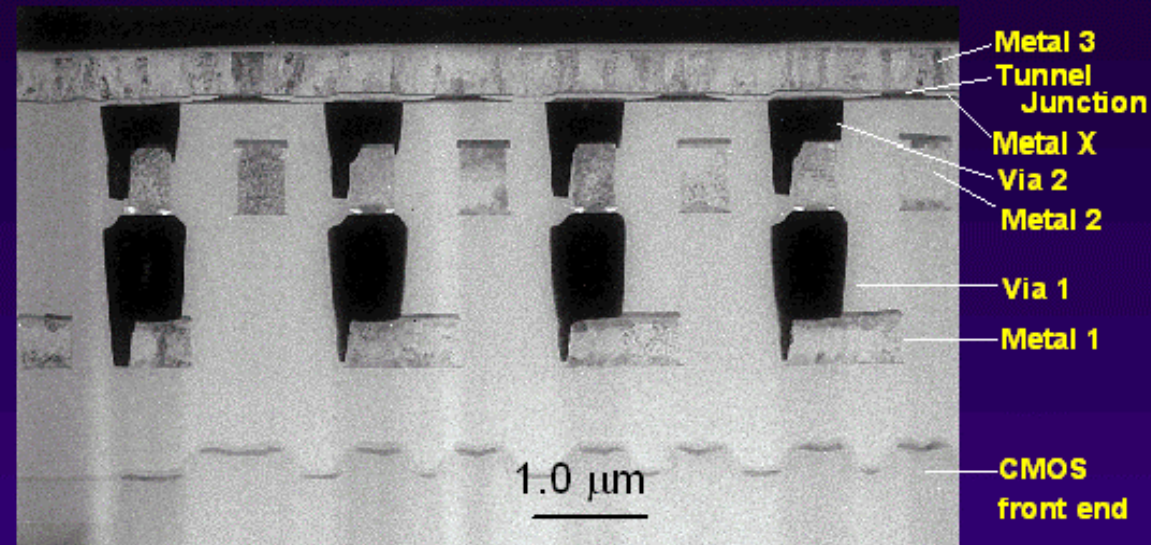
MTJ MRAM

As fast as SRAM, As dense as DRAM and
Non-volatile - no power needed to maintain memory

MRAM1 Characteristics

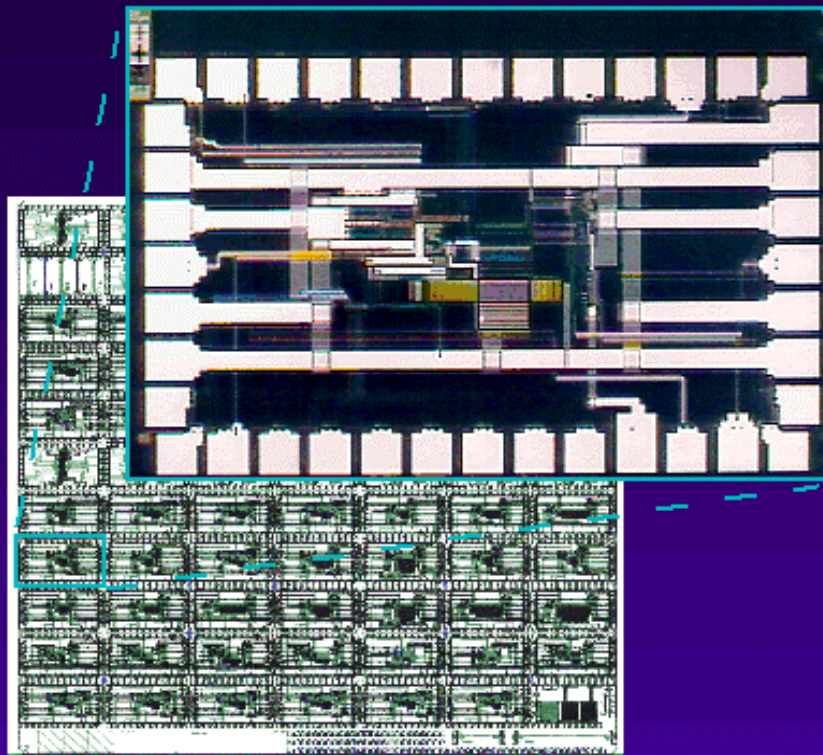
- 77 chiplets, 1 mm x 1.6 mm, 1K bit to 4K bit arrays
- Access time achieved: 2.25 ns
- Write time demonstrated: 2.3 ns
- Cycle time exercised: 10 ns (tester limited)

Via/ROM Cell 1 Cell 2 Cell 3

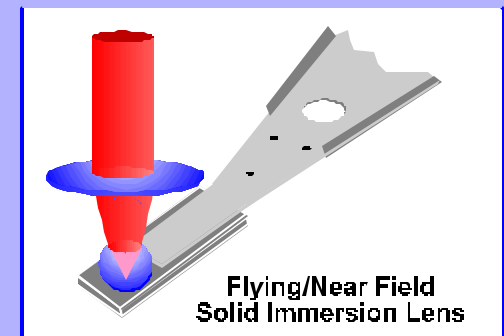
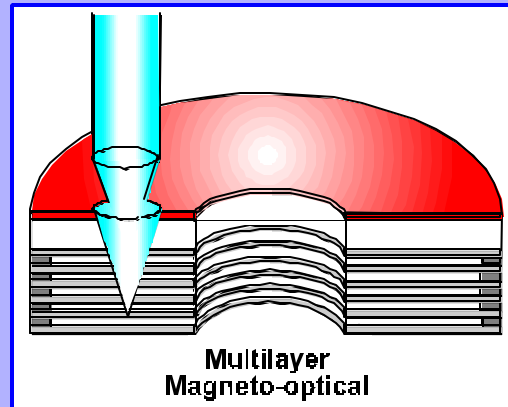
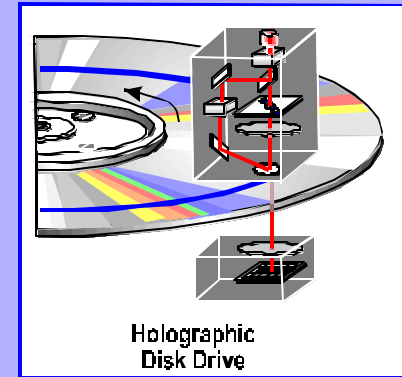
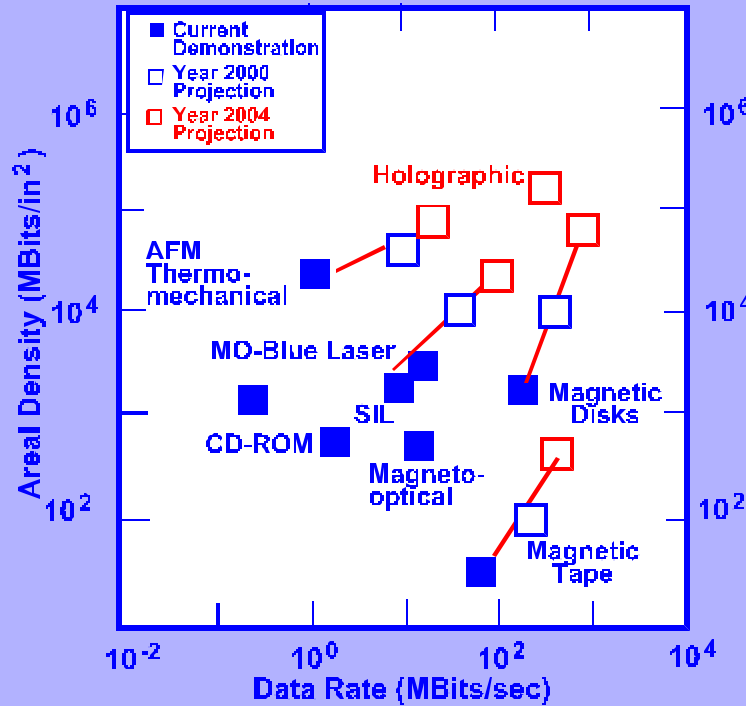
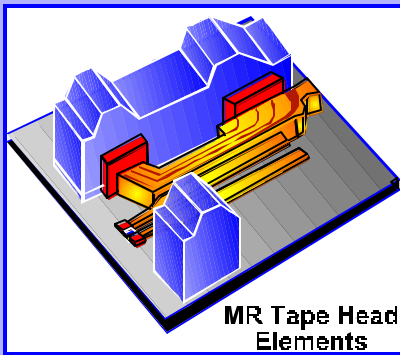
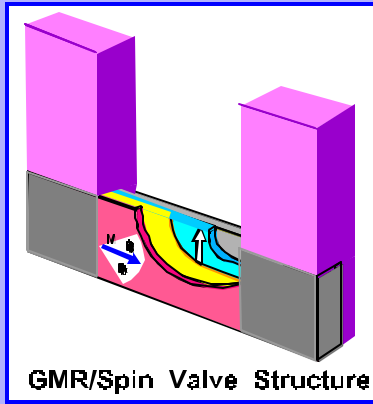


MRAM1 Processing

- CMOS 6SF fabricated in BTV on 200 mm Si, 3 special steps
- Wafers diced into 1" squares
- MTJ and MX materials (8 layers) deposited in Almaden
- MX, TJ, Vz, and M3 processed in Yorktown with e-beam lith

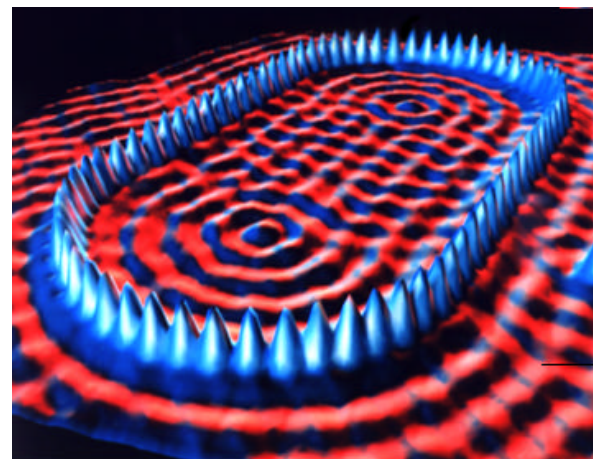
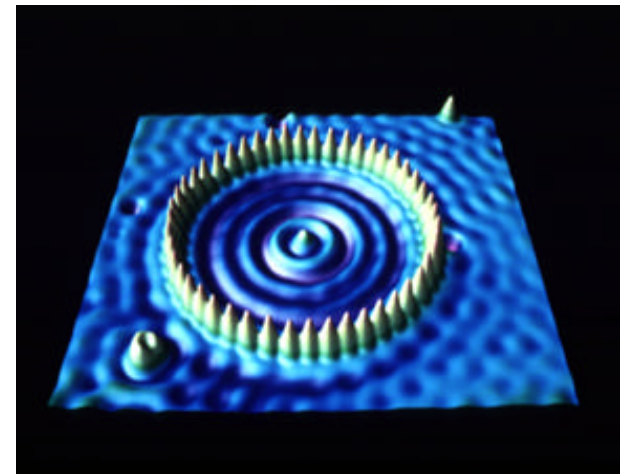
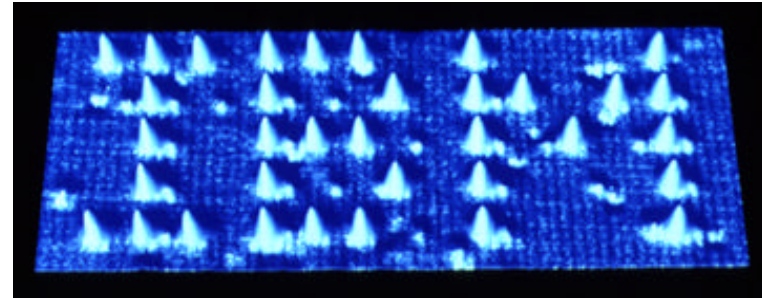


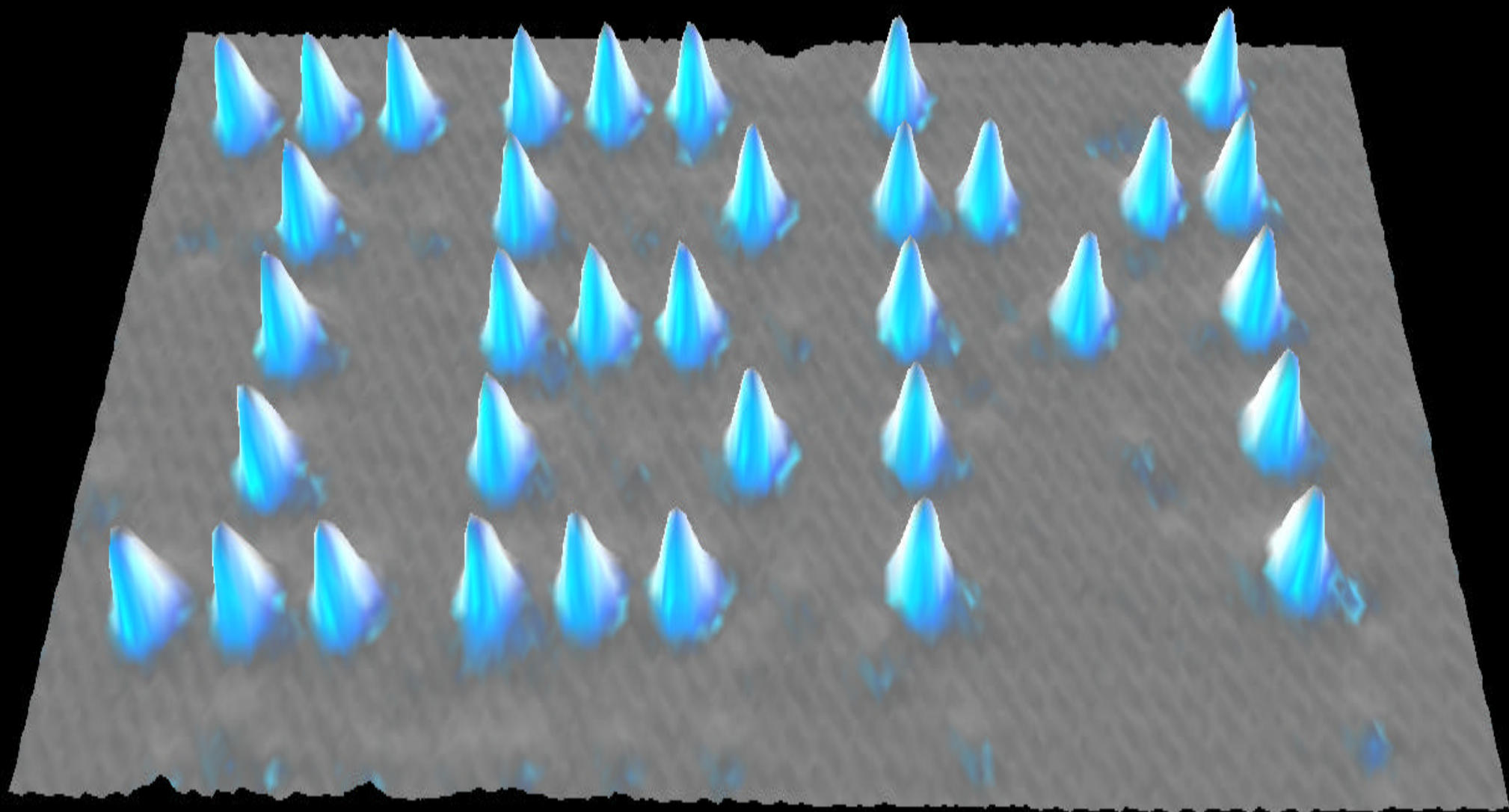
IBM's Exploration Of High Density Recording



IBM Advanced Technology

Moving Atoms





"Millipede" Nanoscale Mechanical Data Storage

Single Lever Write / Read
Principle

Nanoscience and Nanotechnology
IBM Zurich Research Laboratory

Nanoscale Mechanical Data Storage

Single Lever Write / Read Principle

Video Animation

"Millipede" **Nanoscale Mechanical Data Storage**

Single Lever Write / Read
Principle

[Video Animation](#)

"Millipede" Nanoscale Mechanical Data Storage

Highly Parallel
Recording

Nanoscience and Nanotechnology
IBM Zurich Research Laboratory

Nanoscale Mechanical
Data Storage

Highly Parallel Recording

Video Animation

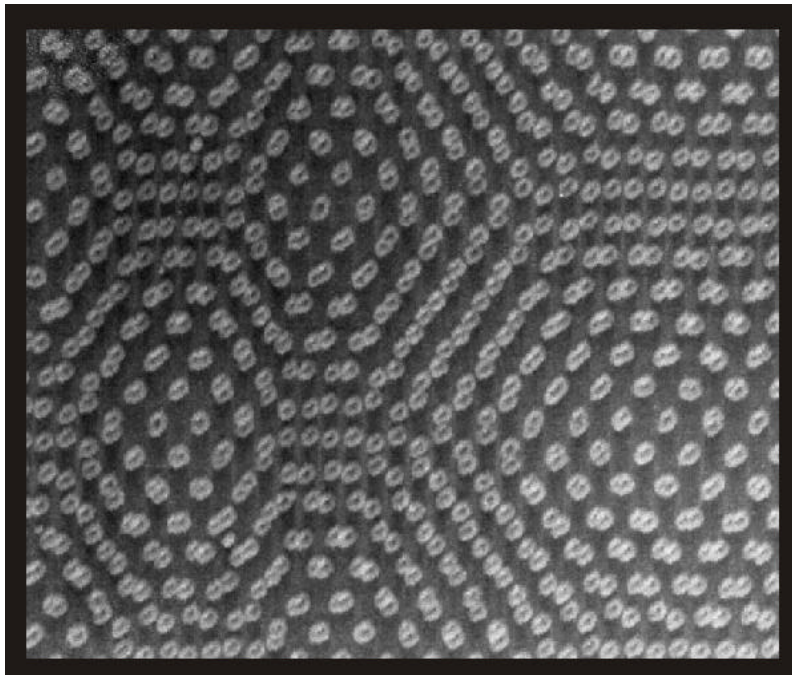
"Millipede" Nanoscale Mechanical Data Storage

Highly Parallel
Recording

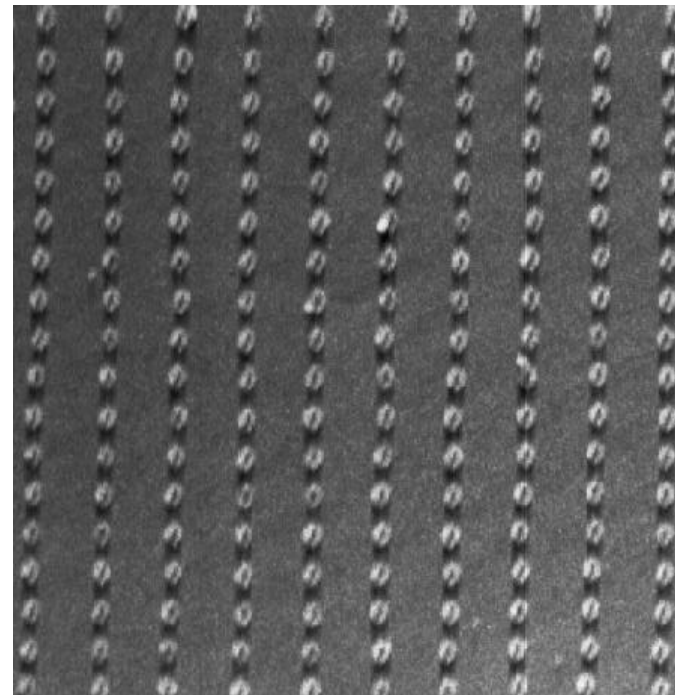
Video Animation

Thermomechanical read/write Results

40 nm bit size



400 Gbits/inch²

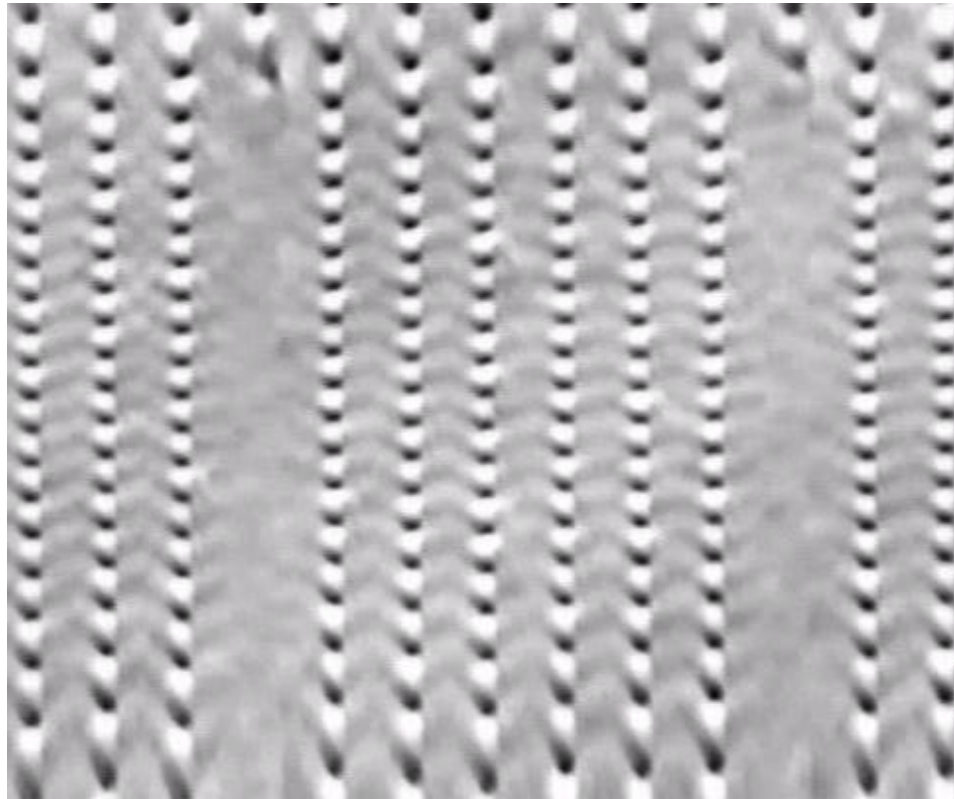


120 nm pitch

"Millipede" Nanoscale Mechanical Data Storage

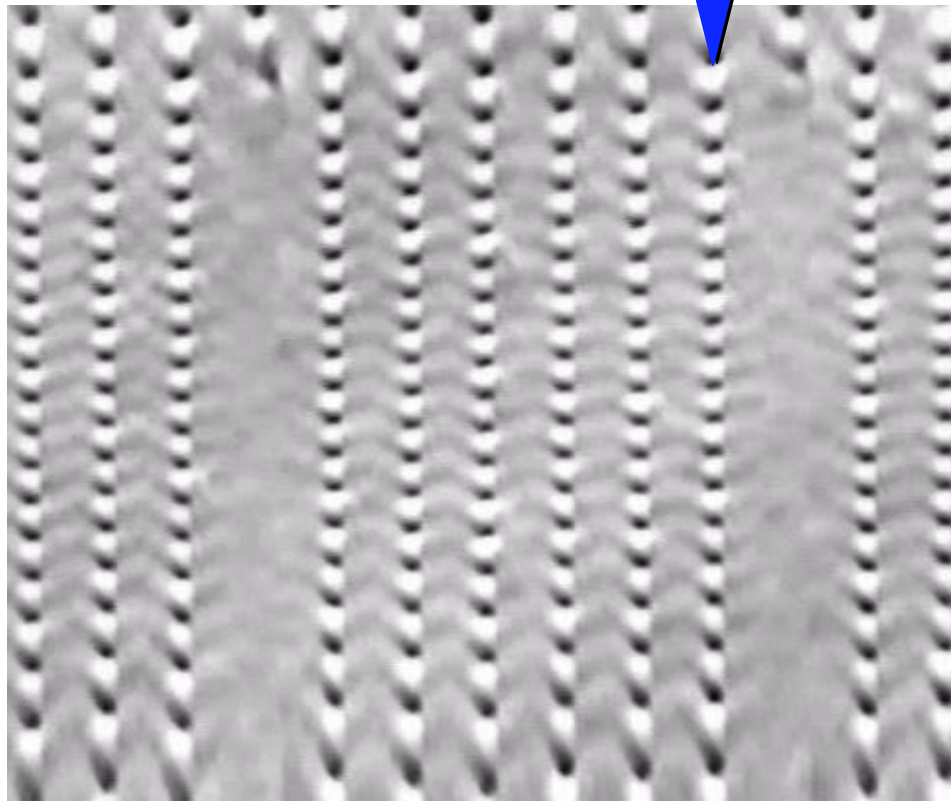
erasing two lines

"Millipede" Nanoscale Mechanical Data Storage



"Millipede" Nanoscale Mechanical Data Storage

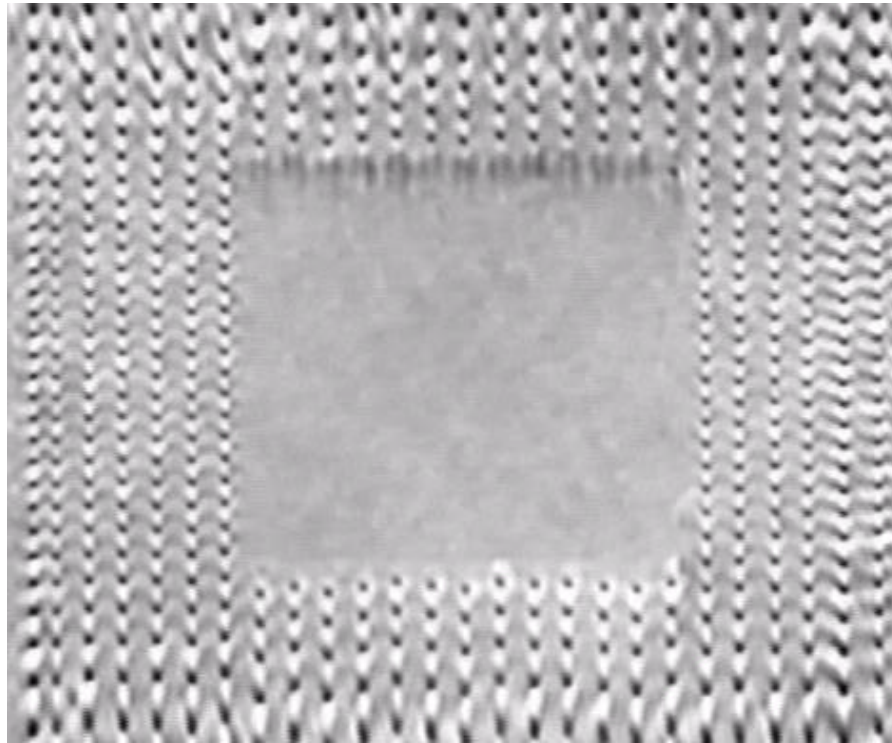
keeping one line



"Millipede" Nanoscale Mechanical Data Storage

erasing line but keeping one line

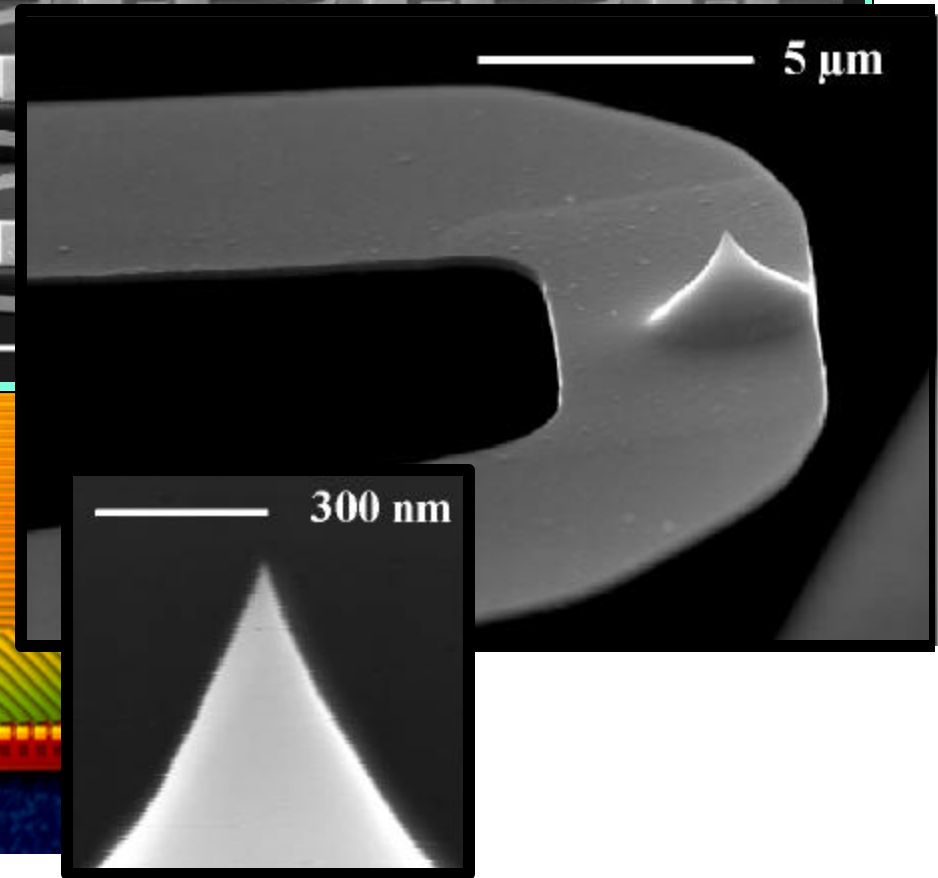
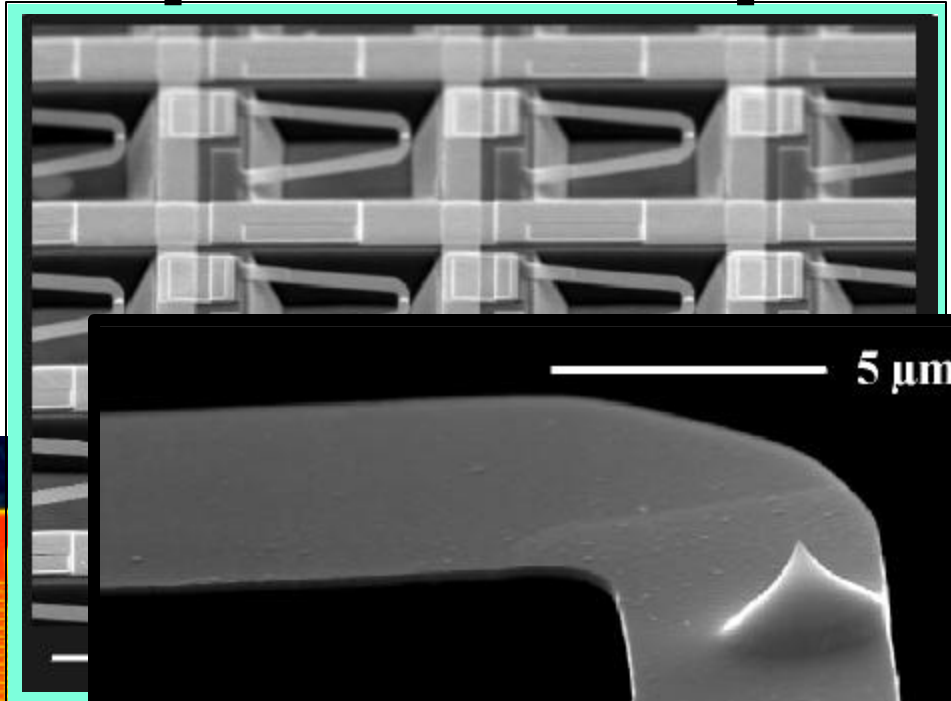
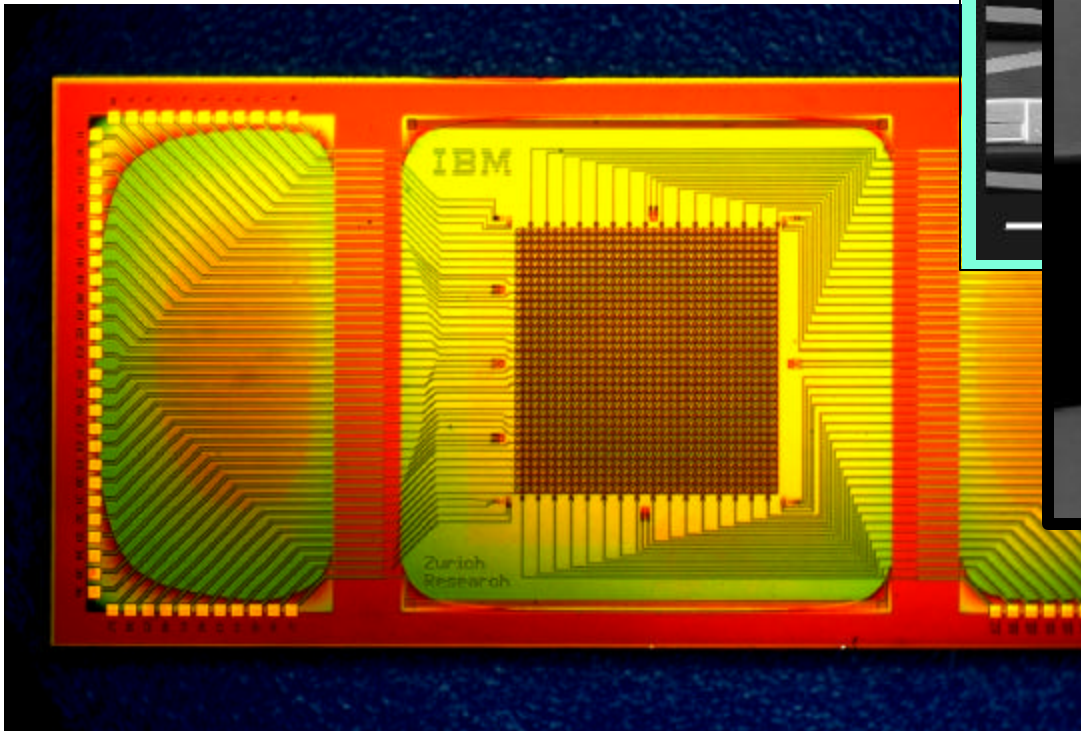
"Millipede" Nanoscale Mechanical Data Storage



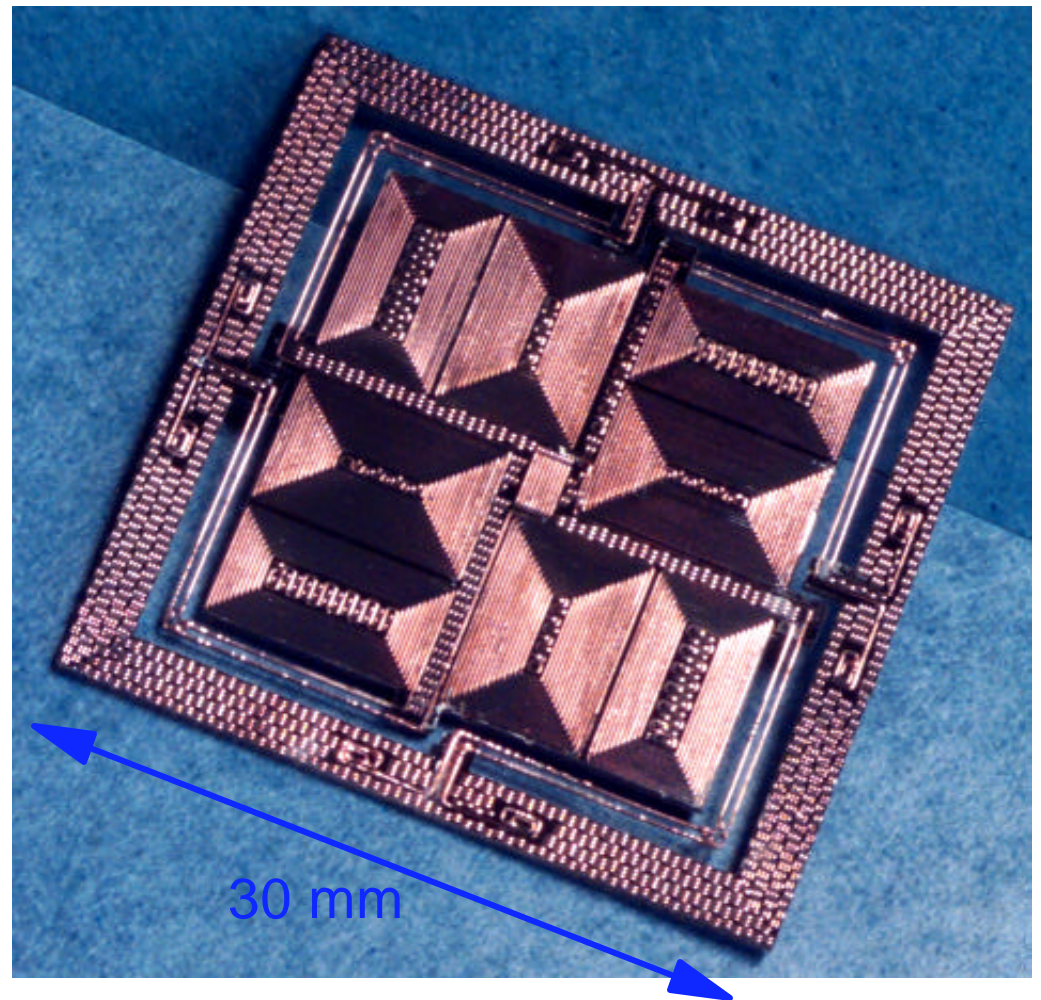
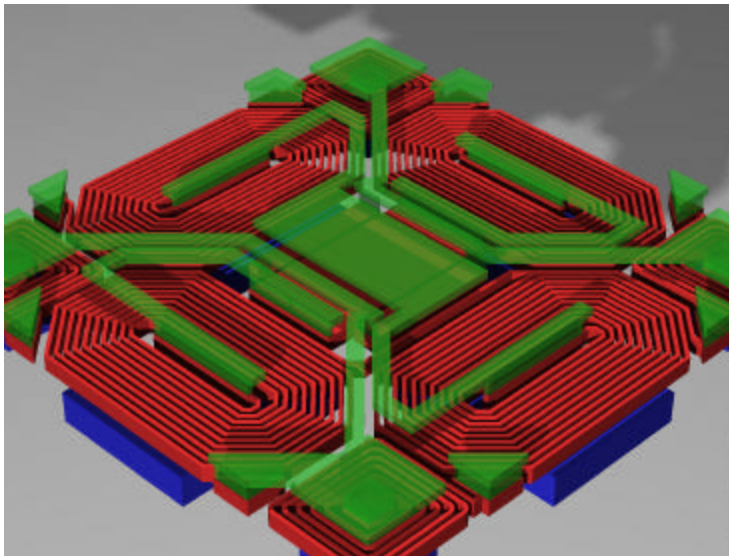
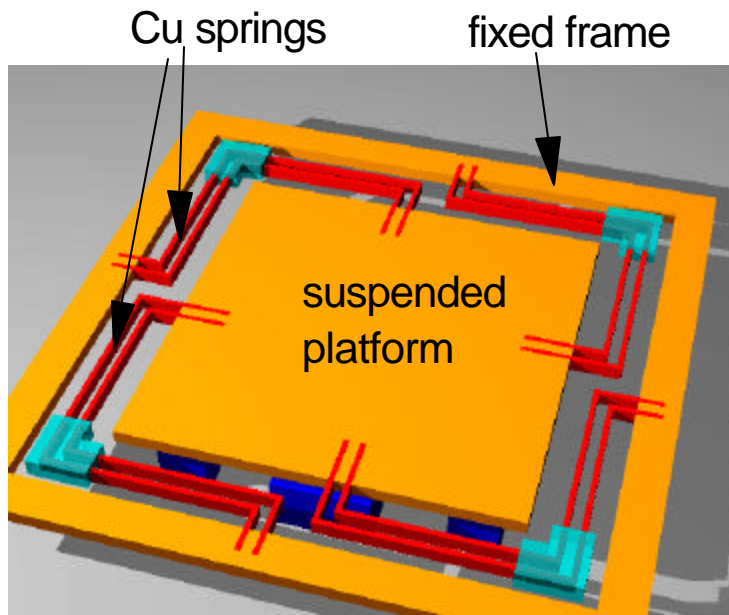
Fabricated "Millipede" Chip

Integration in a $7 \times 14 \text{ mm}^2$ chip size of:

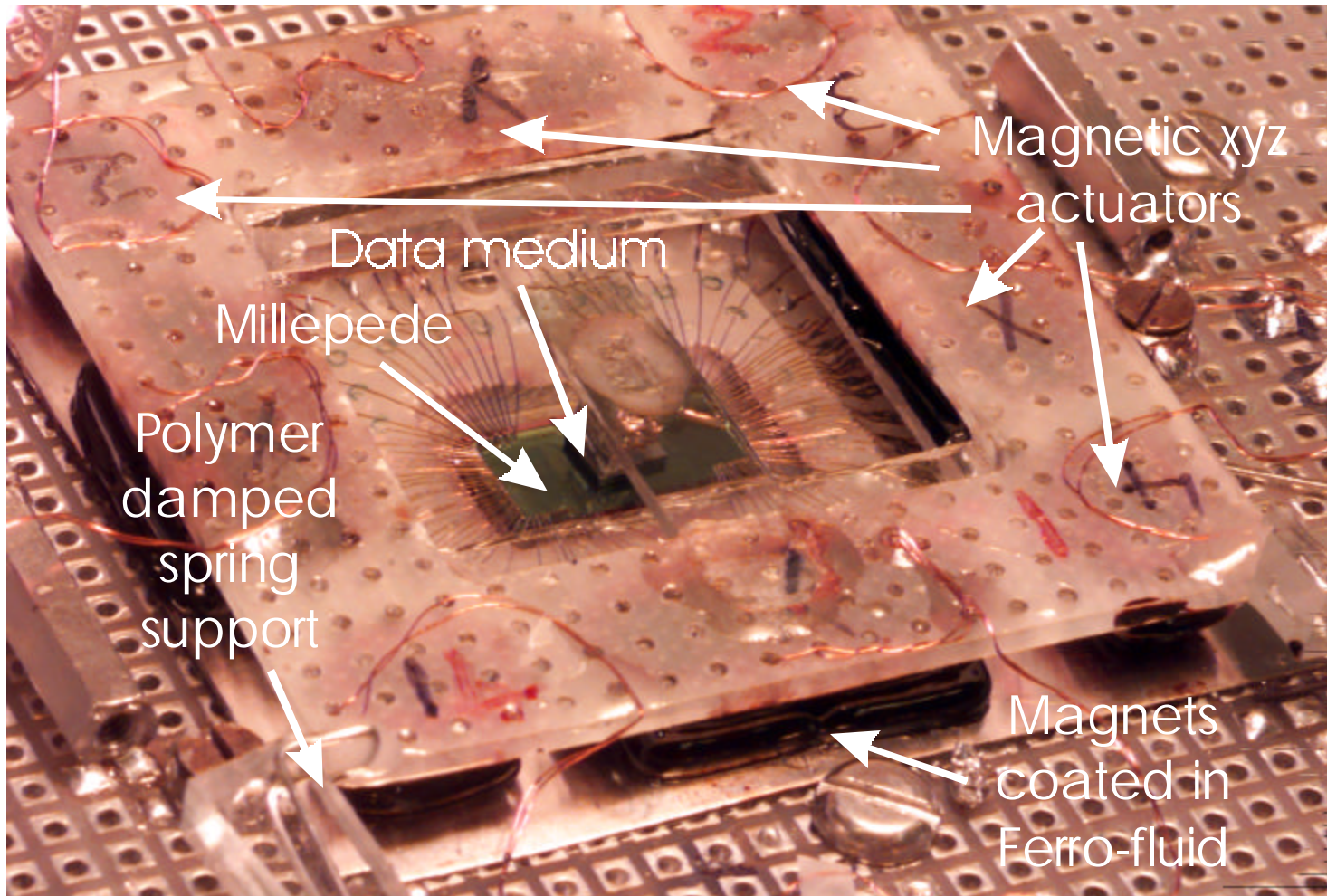
- An array of 32×32 (1024) Cantilever
- Approaching, leveling sensors (4)
- Thermal sensors (4)
- Heaters

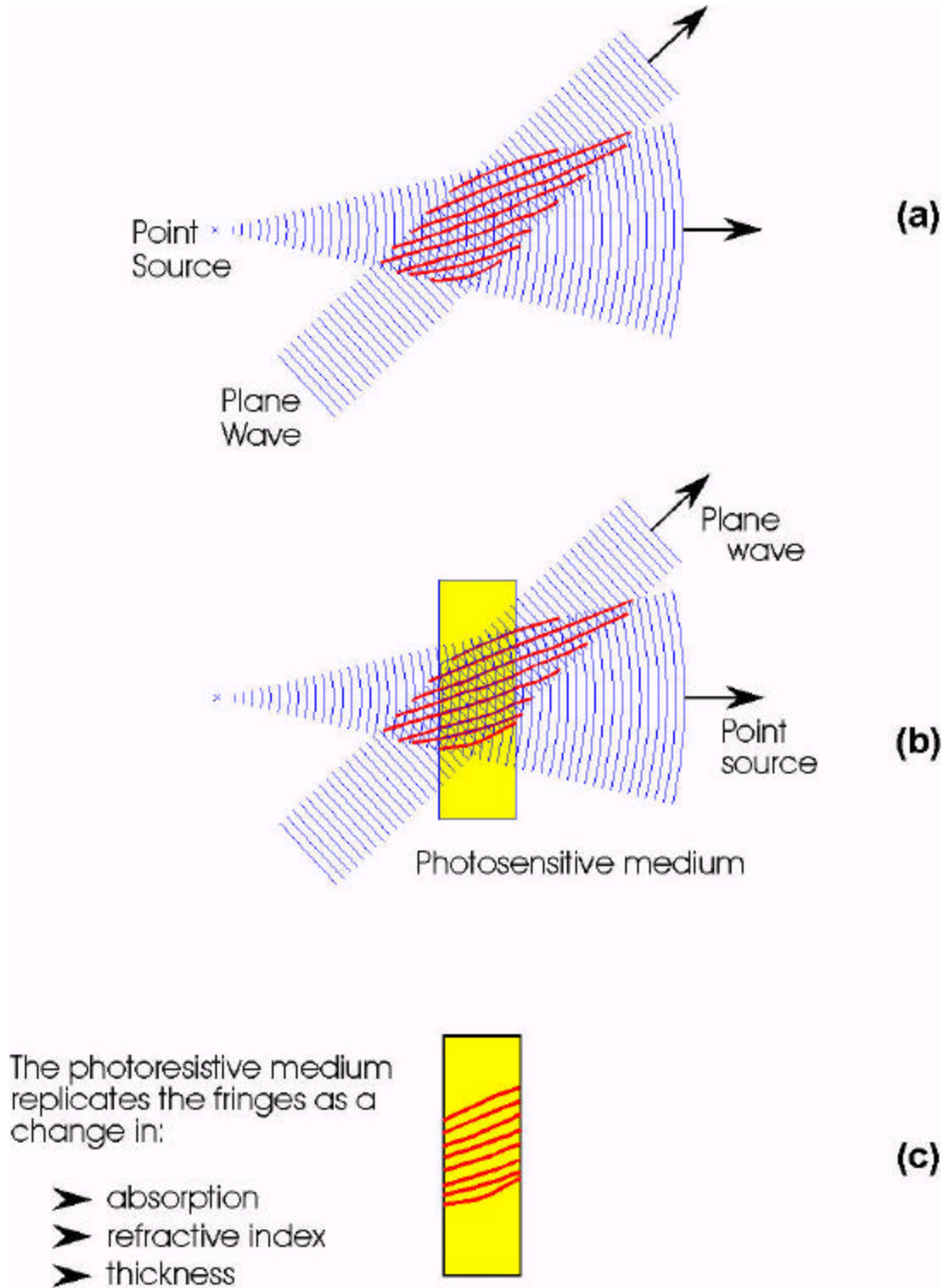


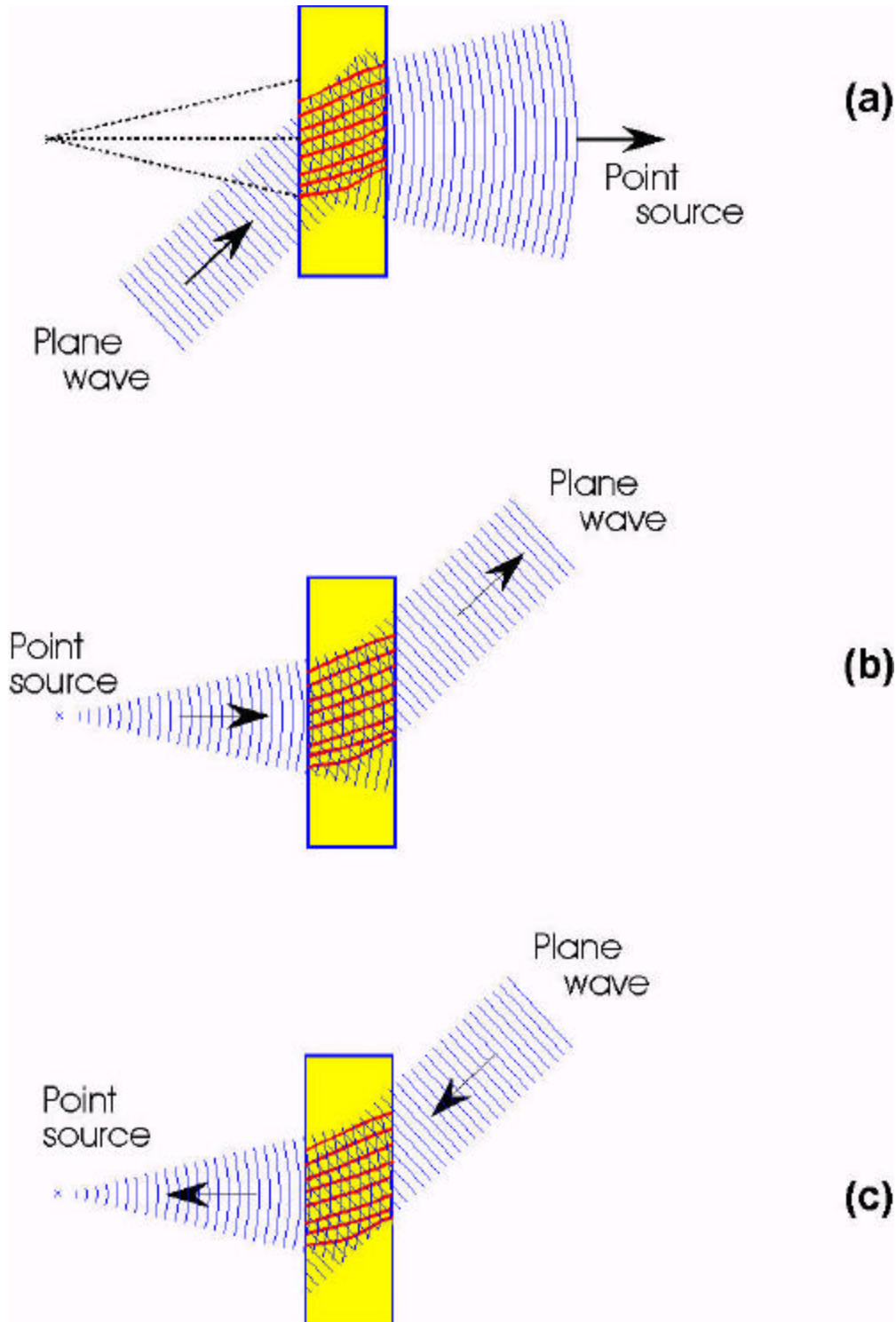
Microfabricated Si / Cu Scanner



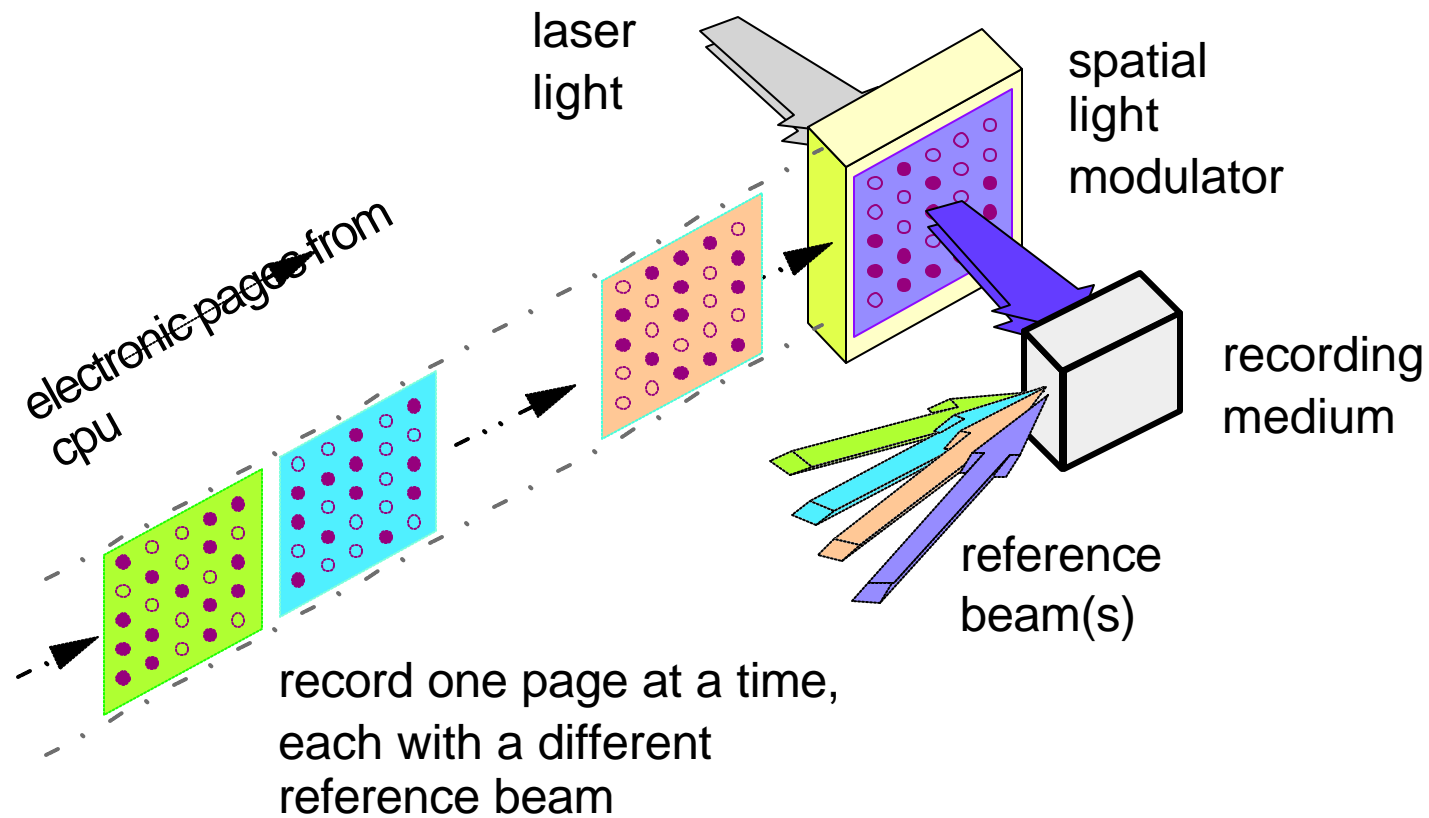
Experimental System



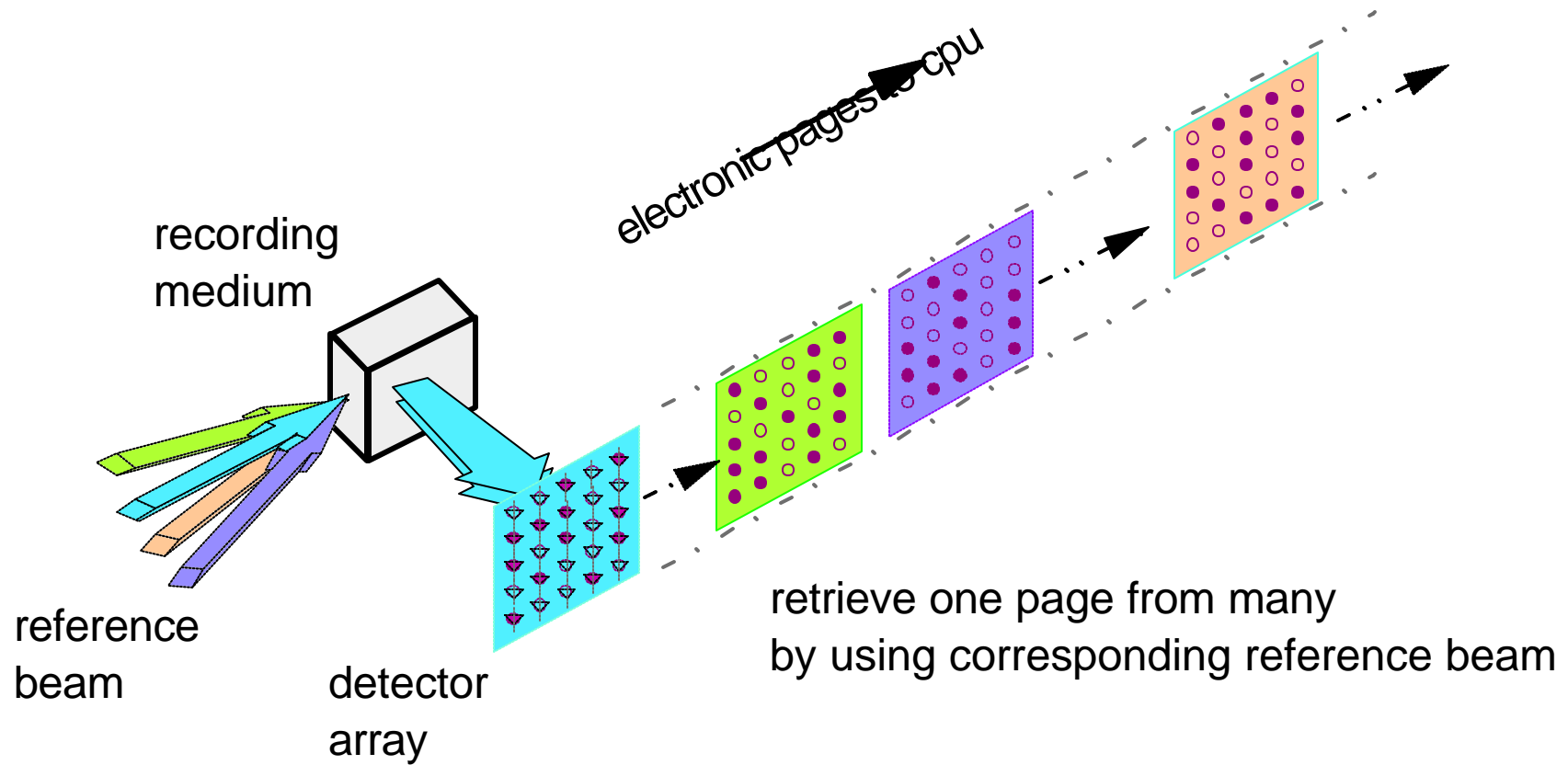




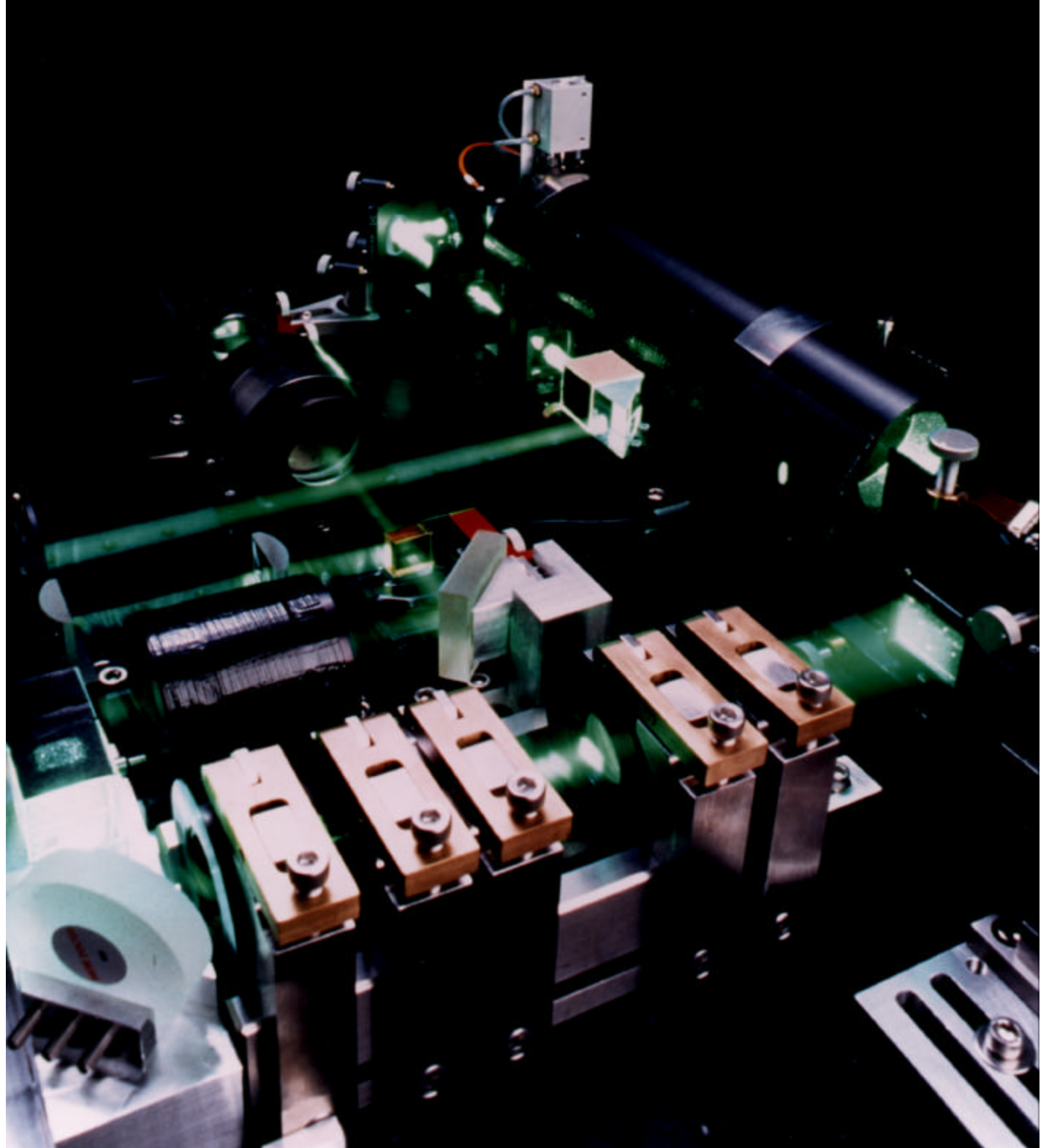
Holographic Storage - Recording Data



Holographic Storage - Retrieving Data



DEMON I



Holographic data storage at 250 Gbit/sq.in.



**Almaden
Research
Center**

Geoffrey Burr
Hans Coufal
John Hoffnagle

Mike Jefferson
Mark Jurich
Roger Macfarlane
Bob Shelby



**Holographic Data Storage
Systems Consortium**



Holographic Data Storage
Systems Consortium

Holographic
data storage at
250 Gbit/sq.in.



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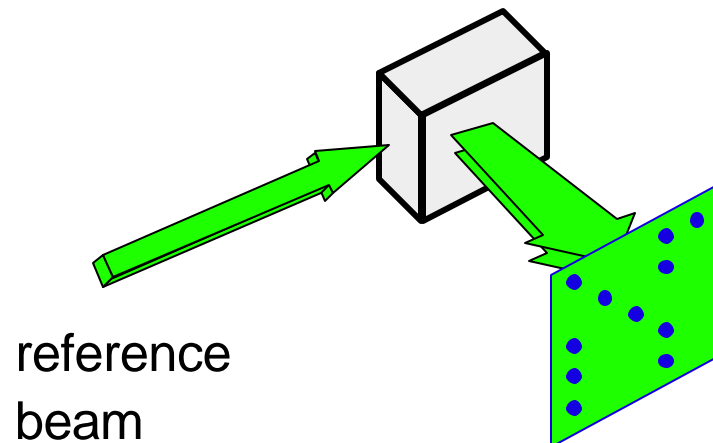
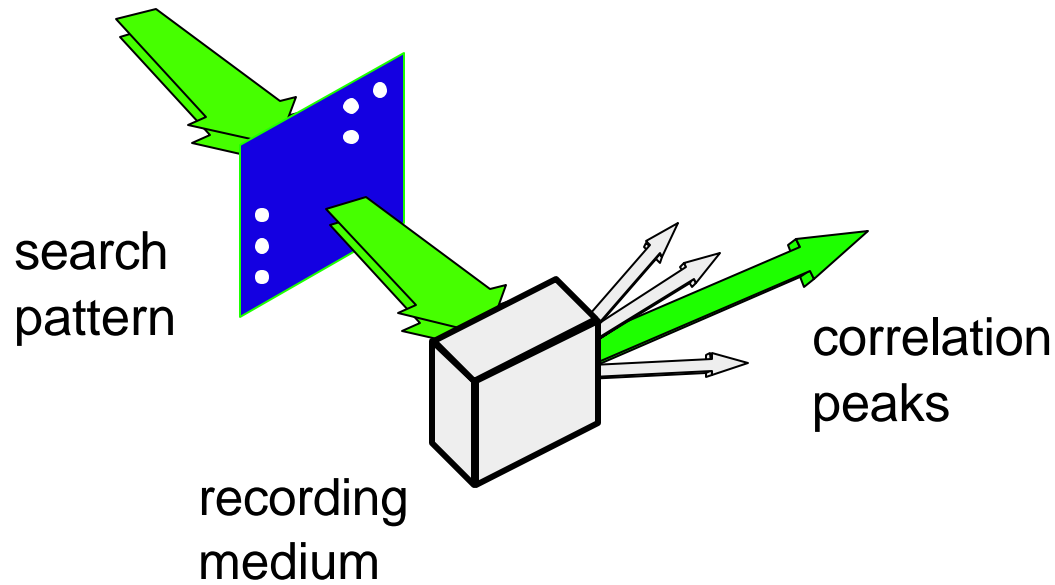
Almaden Research Center

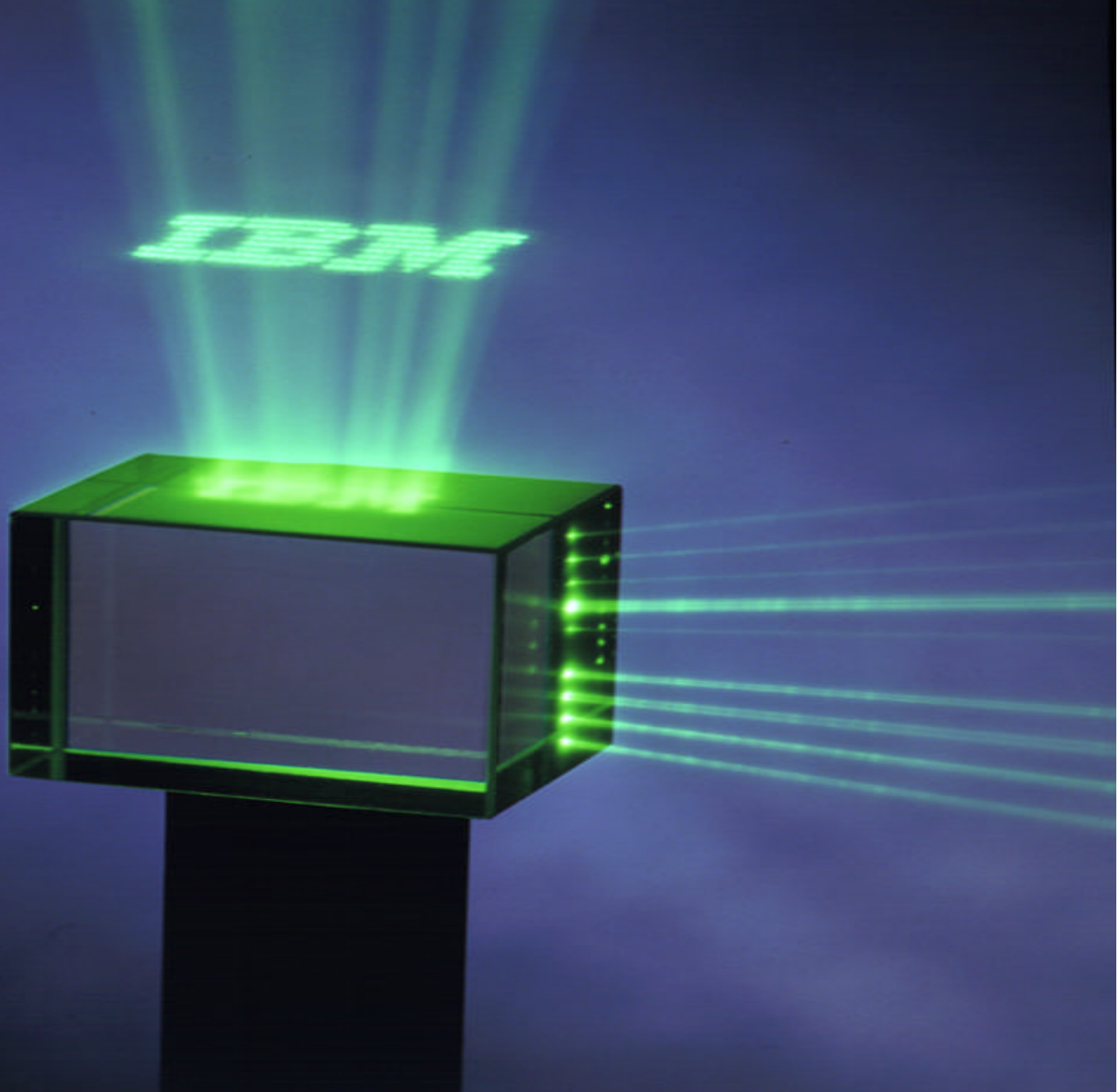
High density, high speed

Holographic data storage

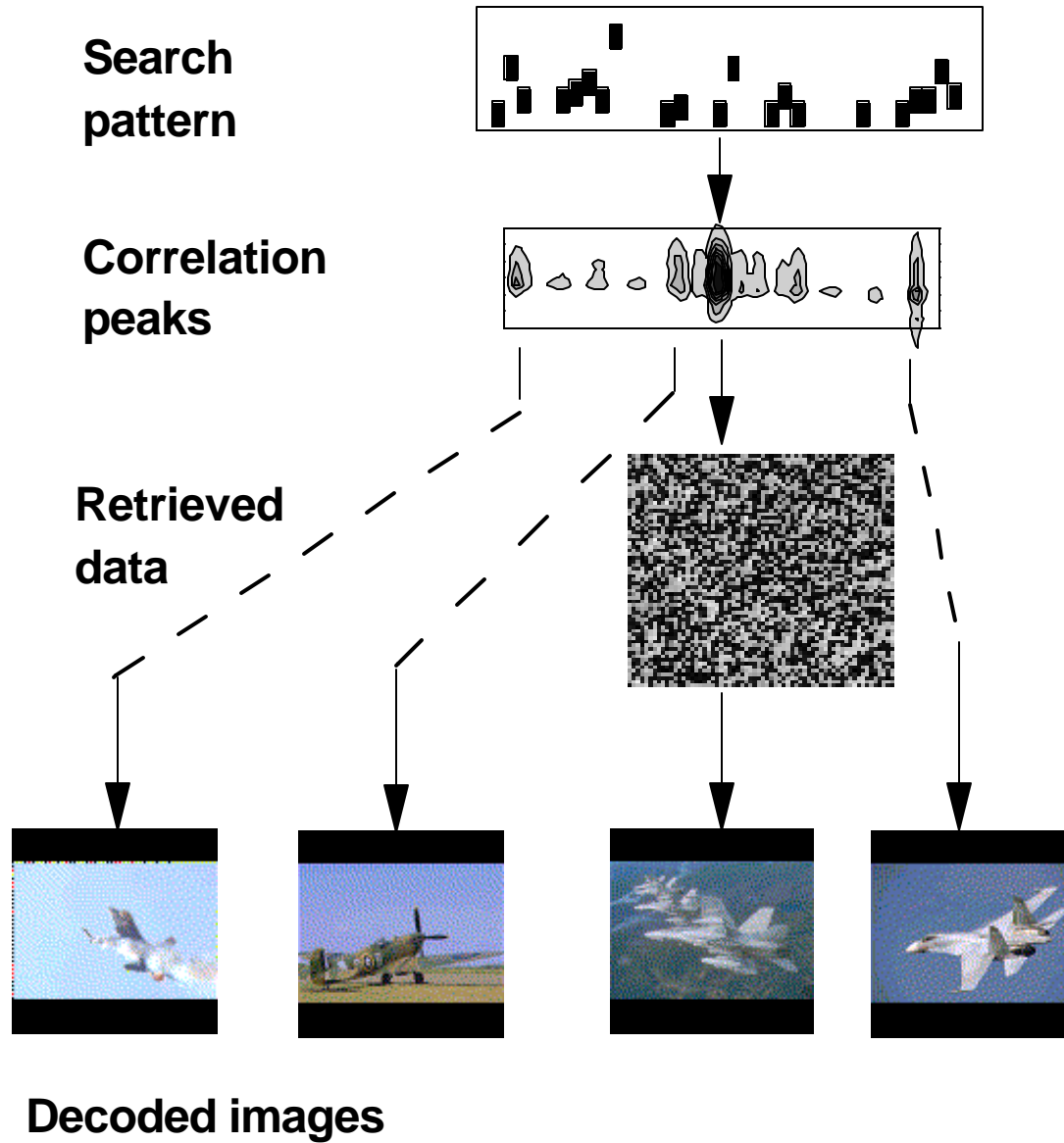
150 + 1
Gbit/sq.in. Gbit/sec

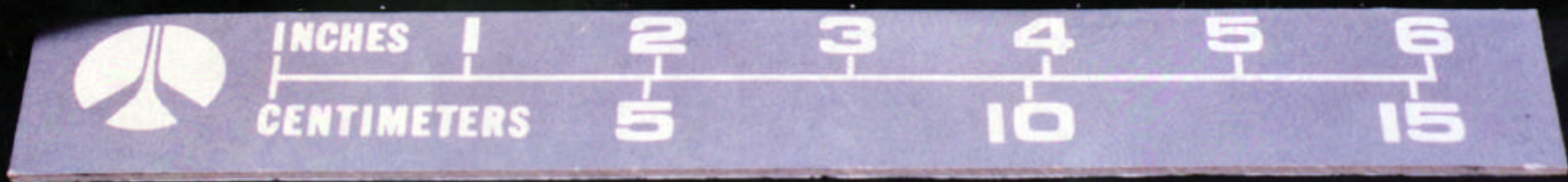
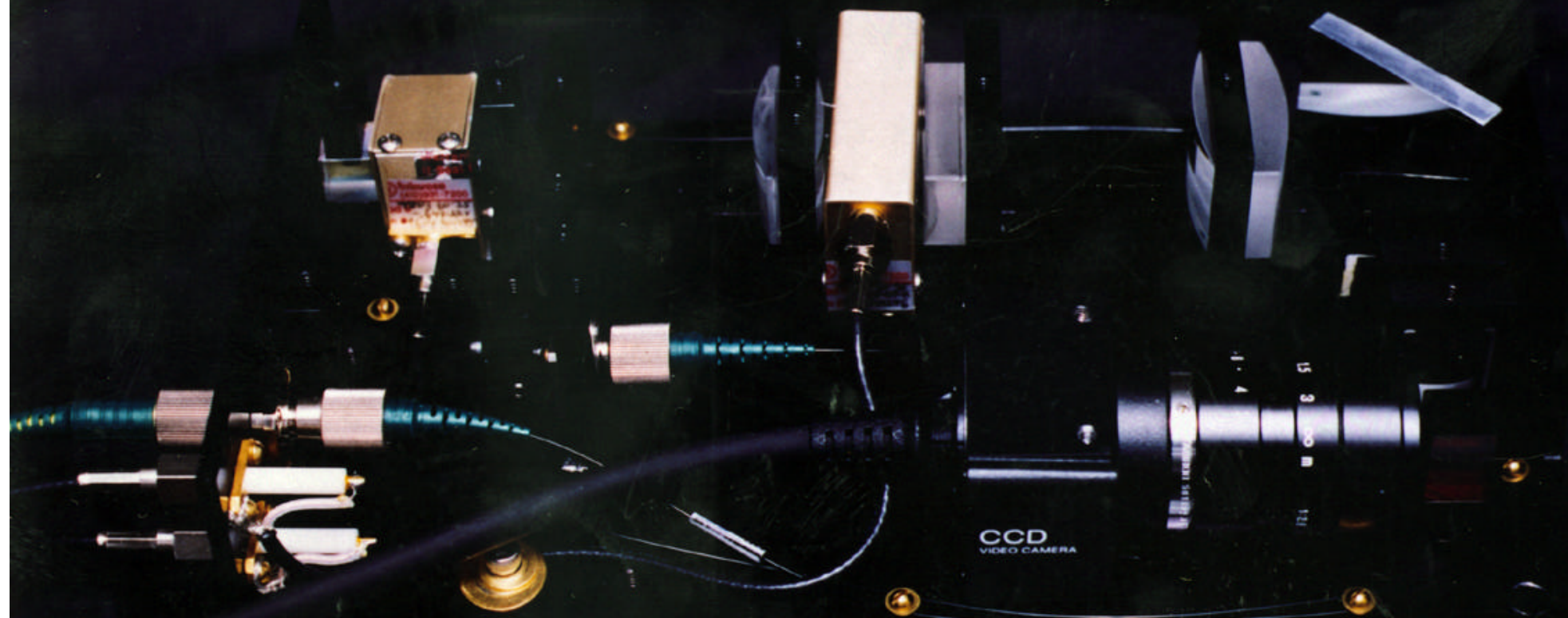
Retrieve by Content





Associative Retrieval





INCHES

CENTIMETERS

1

2

3

4

5

6

5

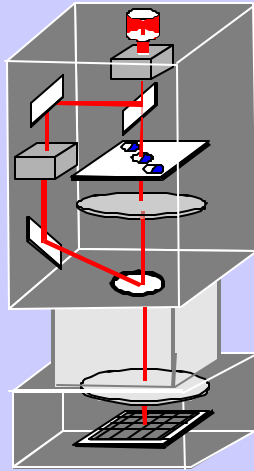
10

15

CCD
VIDEO CAMERA

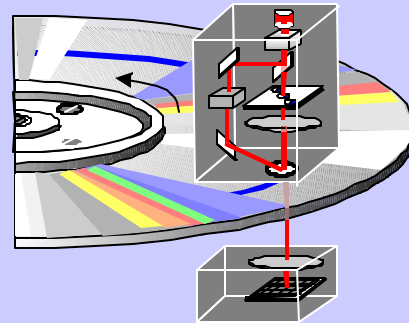
15 9 5
171

Holographic Storage 4 Product Scenarios



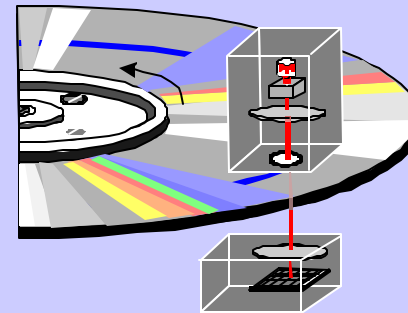
Extended DRAM Product

- Total Capacity: 25 GB
- Access Time: 10 μ s
- Non Volatile Cache



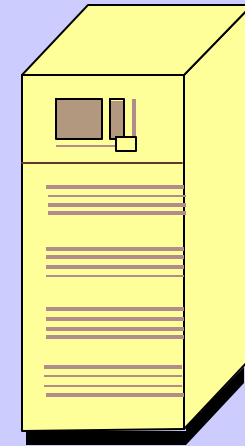
Hard Disk Drive (DASD) Product

- High Capacity: 1 TB
- Access Time: 10 ms
- High Reliability/Availability



Hard Disk Drive (CDROM-Type) Product

- High Capacity: 1 TB
- Access Time: 10 ms
- High Capacity/Low Cost



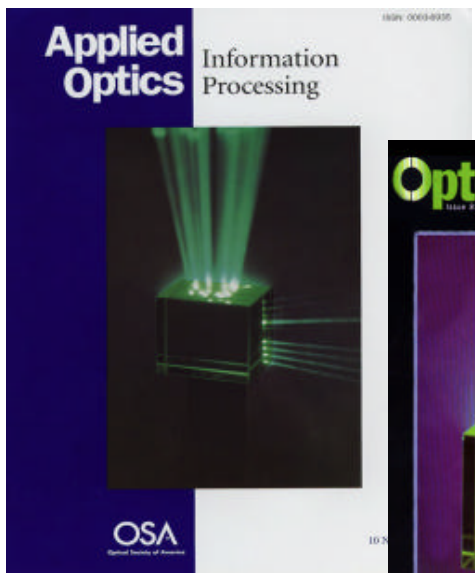
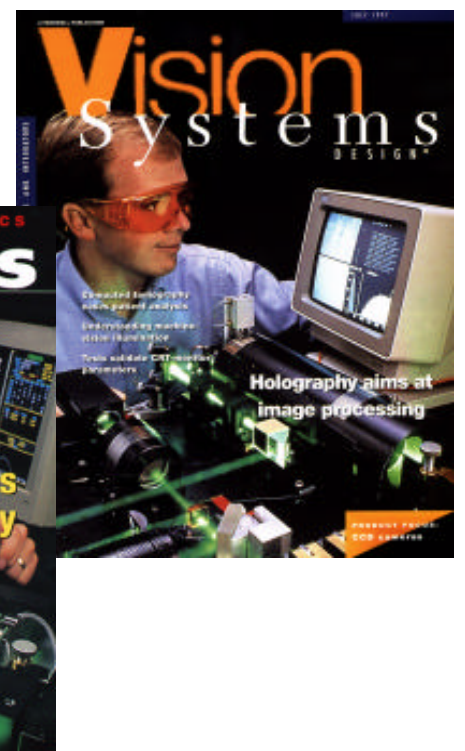
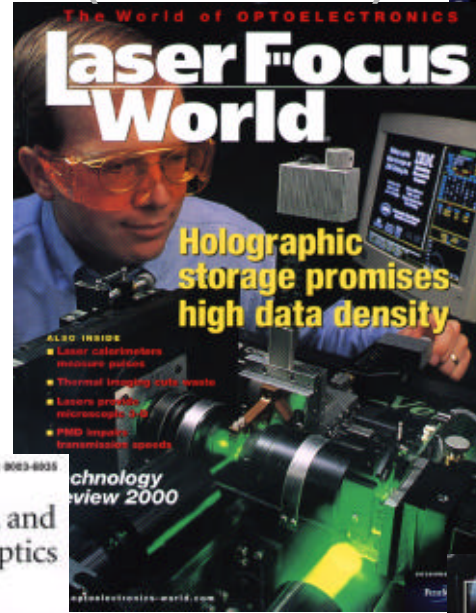
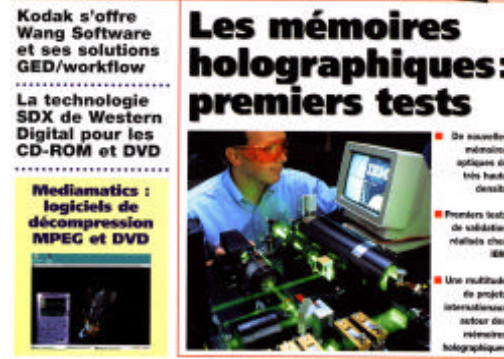
Rack Mounted Archive Product

- High Capacity: 1 PB
- Access Time: 10 s
- High Volumetric Density

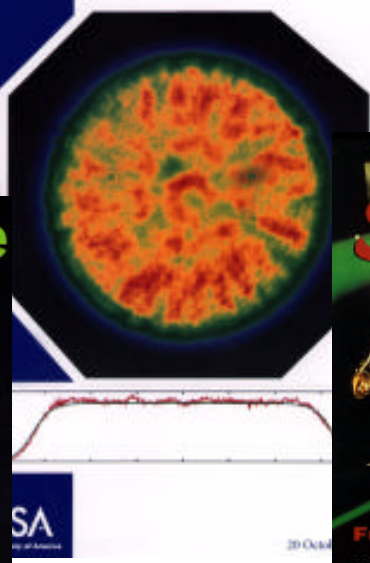




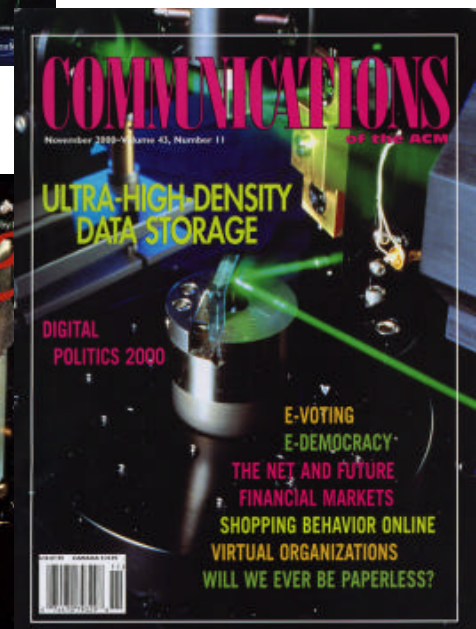
**Demon I
(first test bed)**



Associative Retrieval

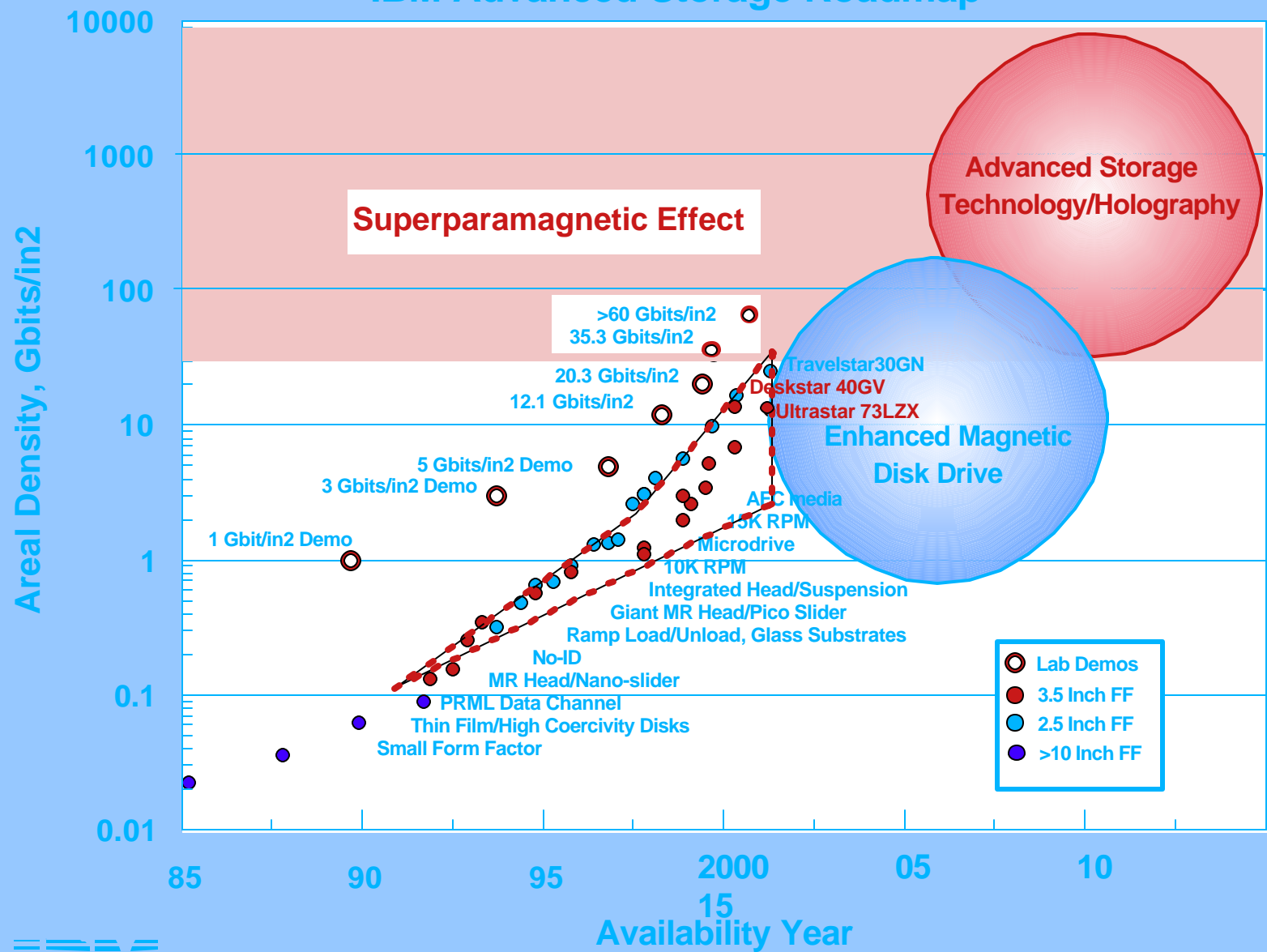


Optical Beam Apodizer



**Demon II
(second test bed)**

IBM Advanced Storage Roadmap



advrdmp21a.prz



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