Micro Electro Mechanical Systems (MEMS):

A selective overview

Andrew Berlin

Intel Corporation

Towards 'Proactive Computing'

- Computing everywhere and in everything
- Communications everywhere
- …and coming soon thanks to technologies such as MEMS:
- Sensing and Actuation everywhere
  - Embedded within materials
  - Coated on surfaces
  - On and in our bodies
  - Distributed throughout the environment

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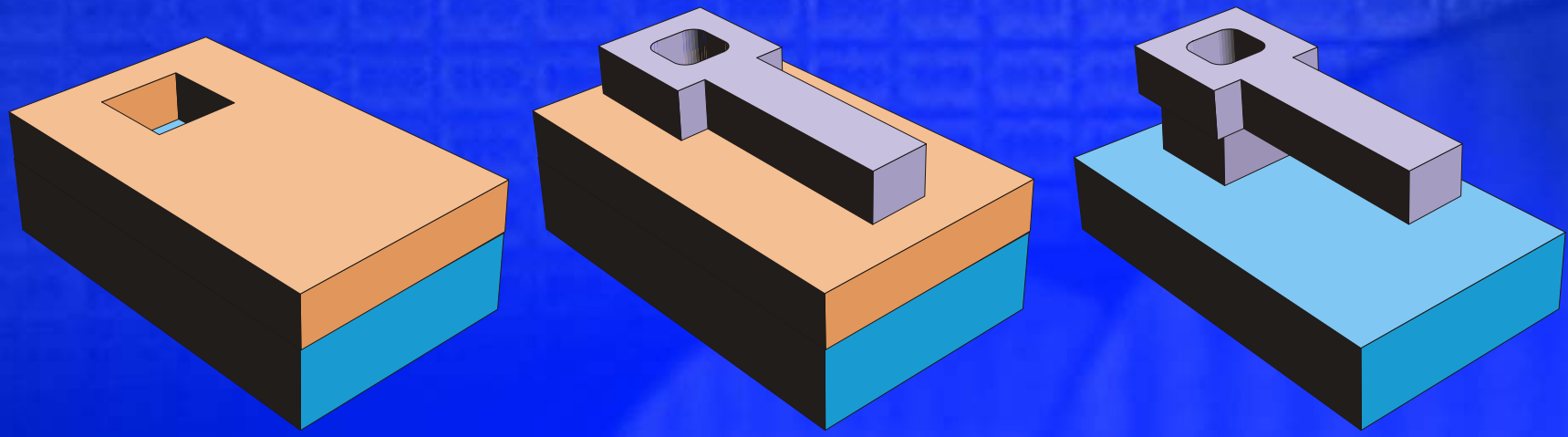
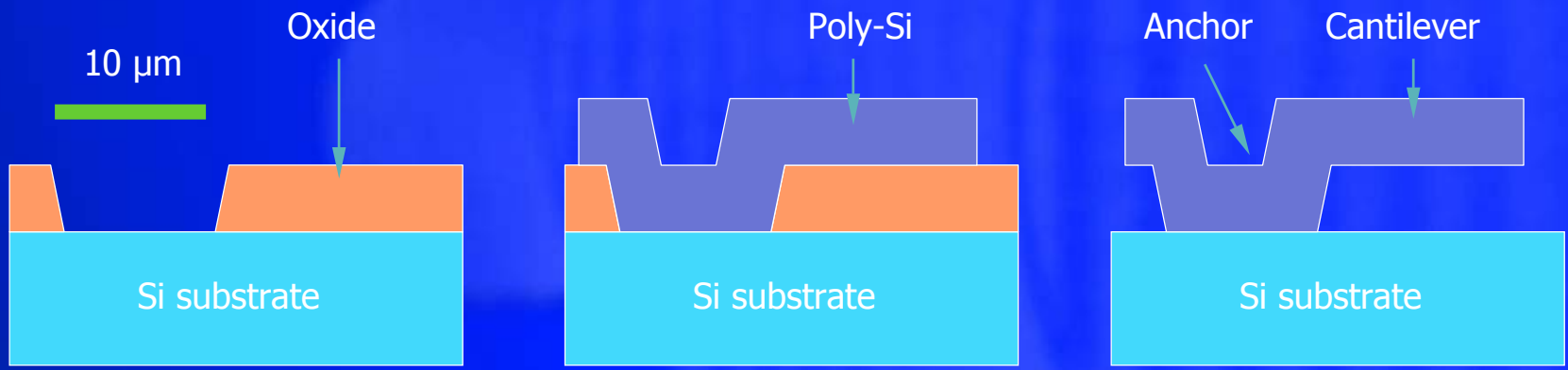
Surface Micromachining



Deposit & pattern oxide ***Deposit & pattern poly*** ***Sacrificial etch***



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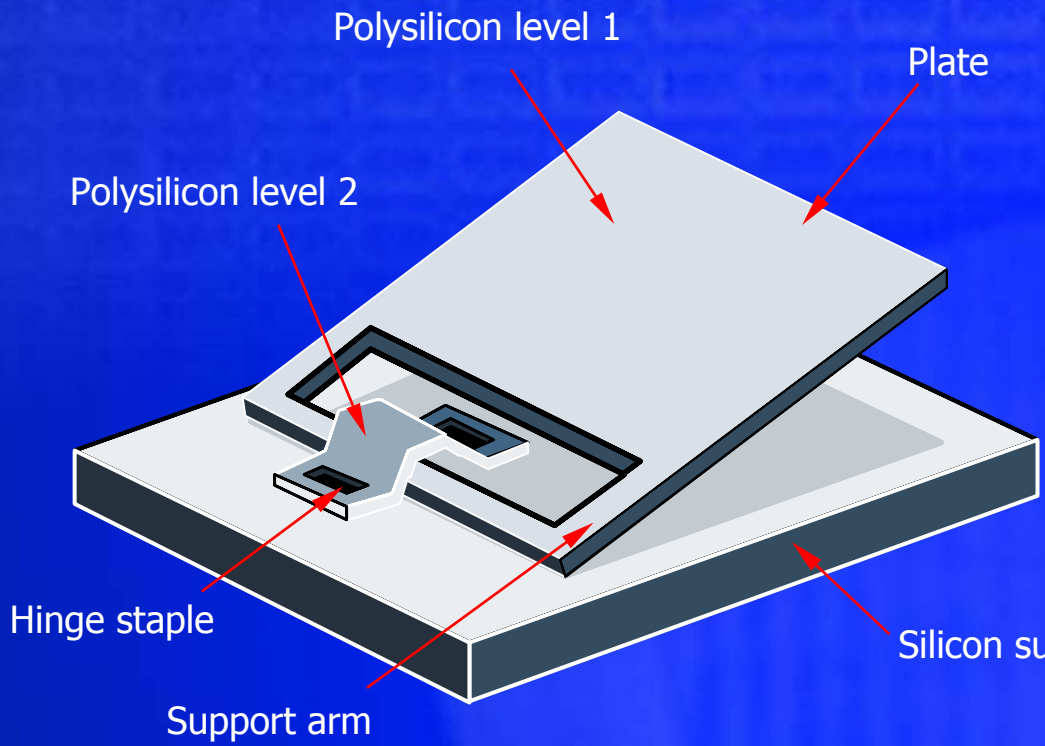
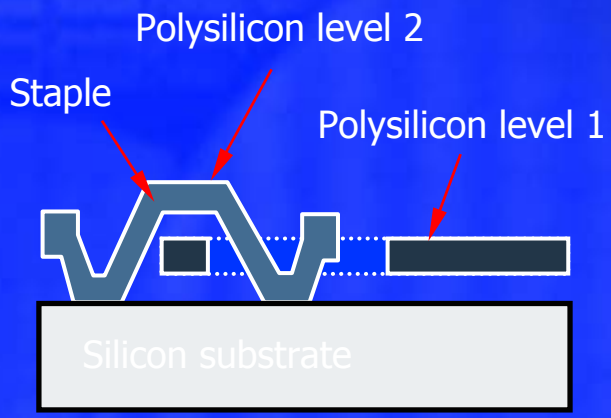
Surface Micromachined Hinge





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Major MEMS application areas

- Navigation
- Industrial
- Displays
- Optical communications
- RF (MEMS Radio)
- Microbiology meets Microtechnology
- MEMS power sources

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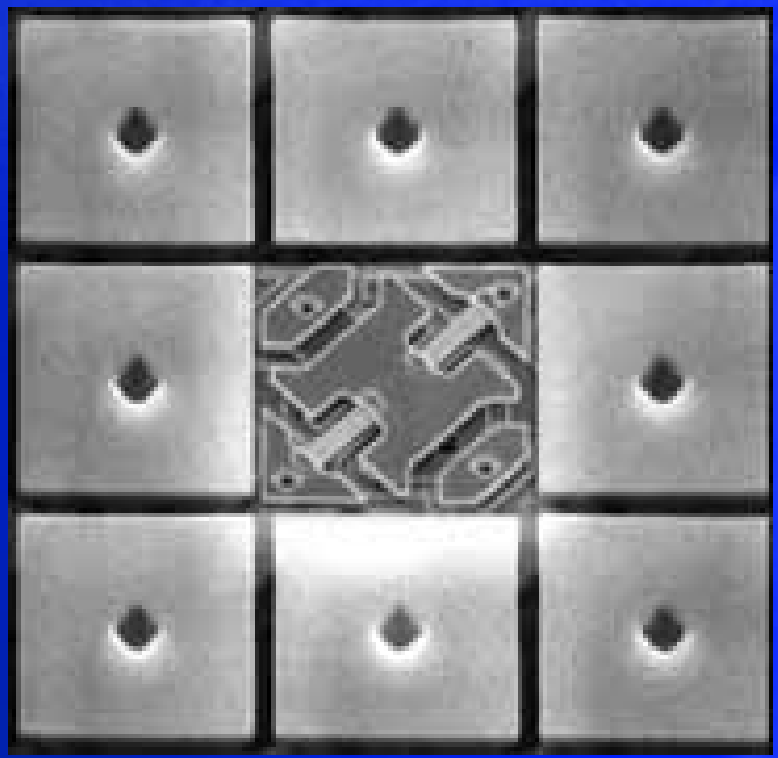
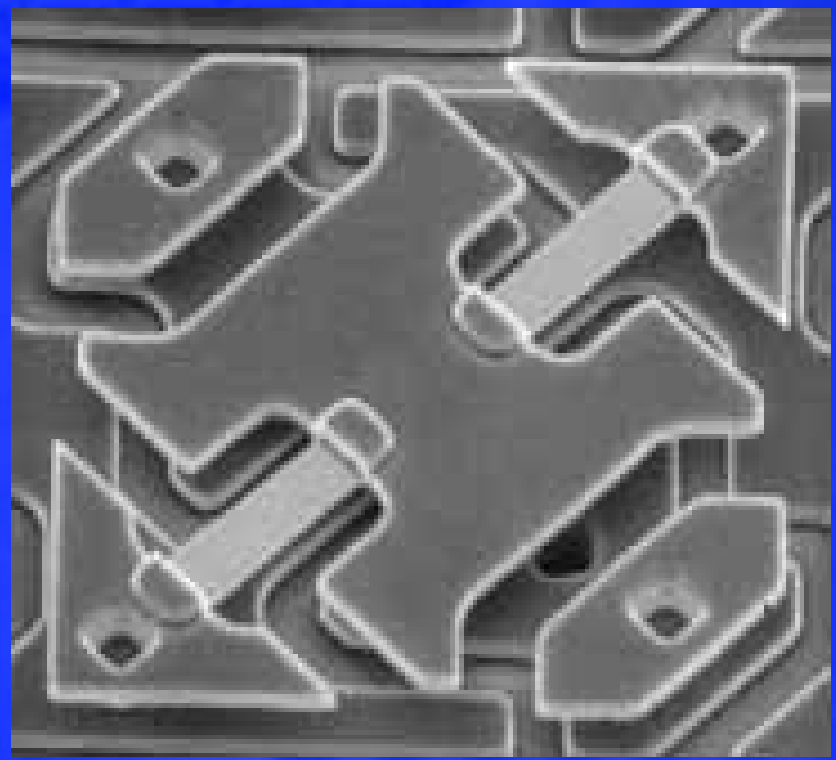
MEMS Projection Displays





Texas Instruments Digital Light Projector

TI Micro-Mirror
Display :
> 1M moving parts

Boeing 747 :
>50K moving parts

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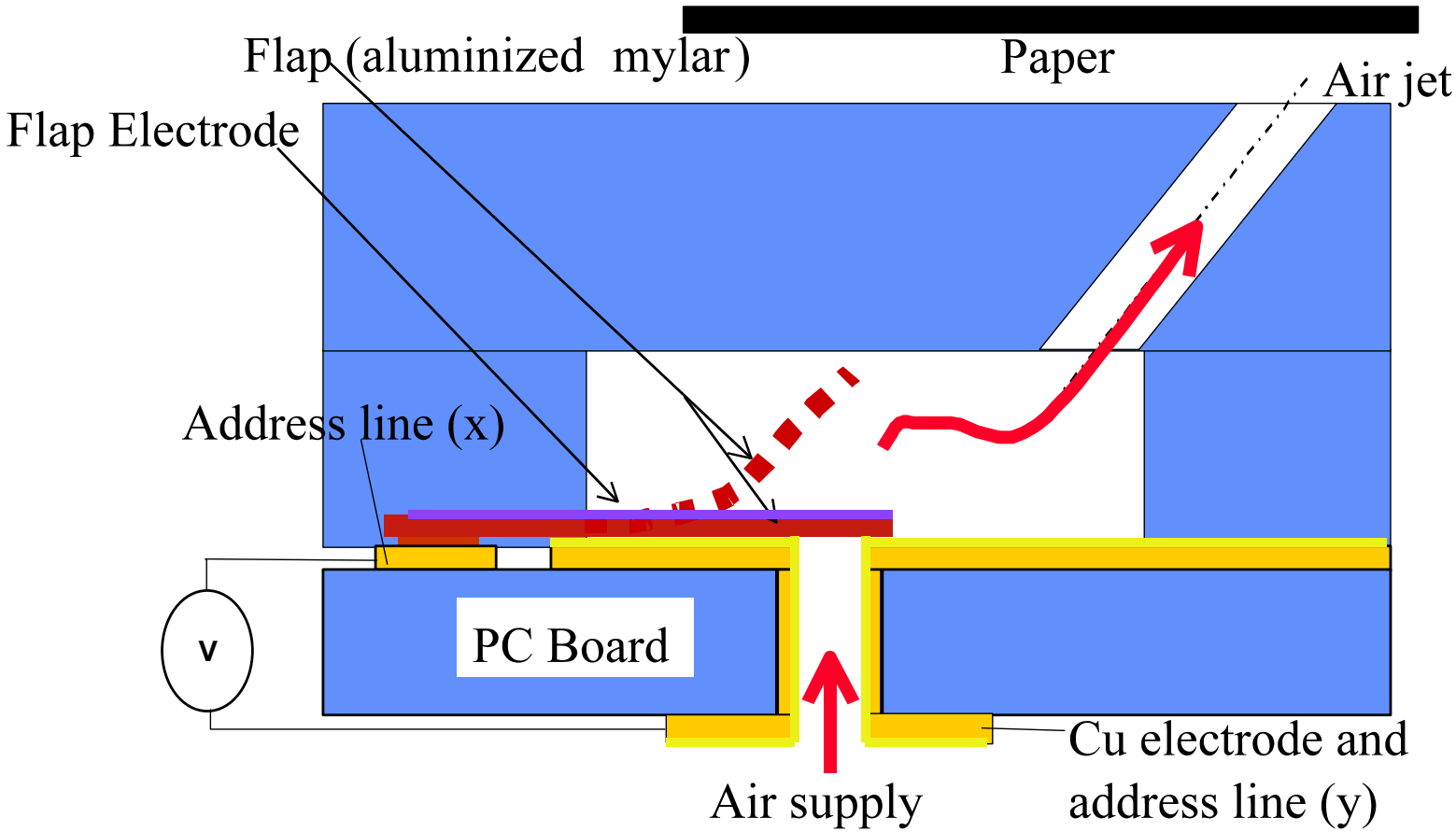
Cantilevered valve structure



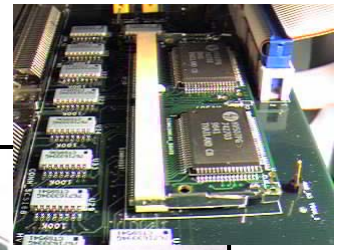
Levitating Media Transport

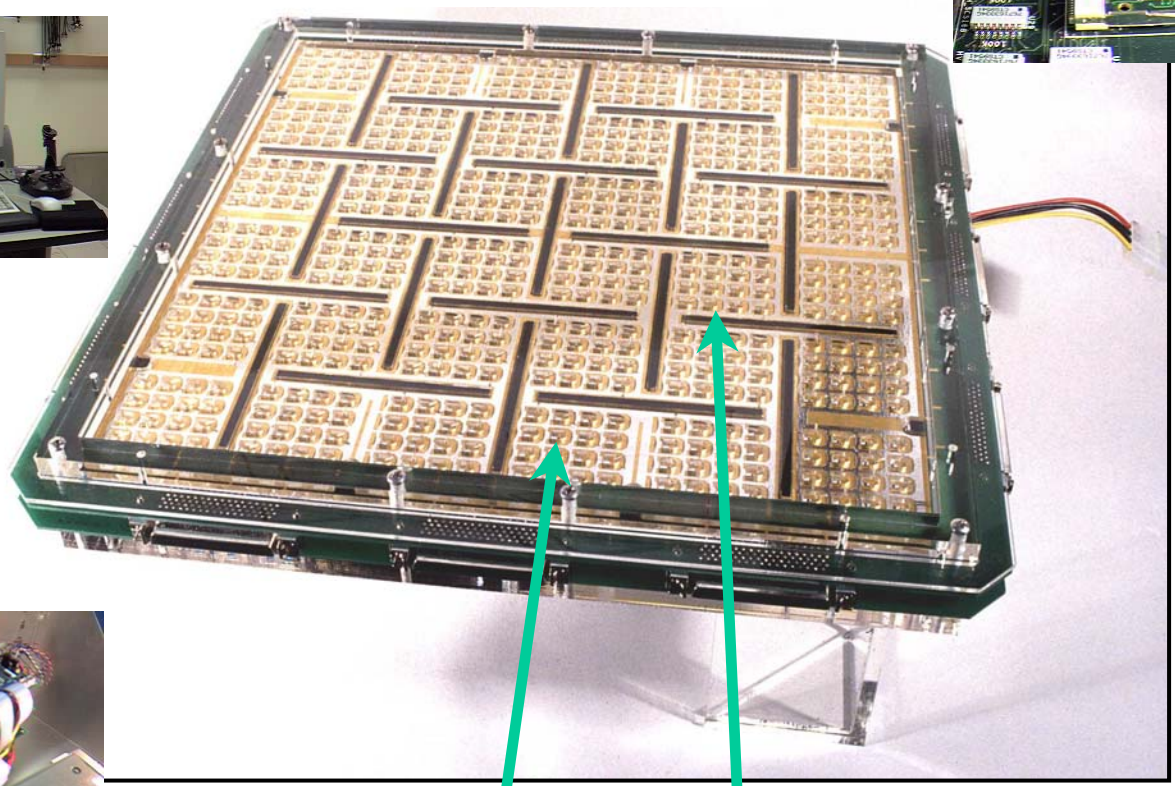
- Using large MEMS-like arrays to manipulate macro-scale objects
- Directed air jets as a ‘leverage point’
- 12”x12” array containing 576 individually valved jets and 32,000 photodiode sensors
- Precision motion control: ~50 microns

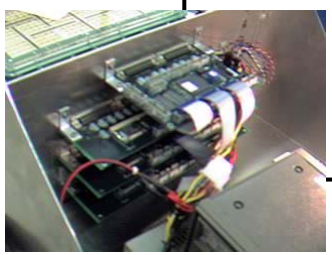
MEMS-based Active Surface

PC-hosted DSP
control @ 1 kHz

12x12” Board

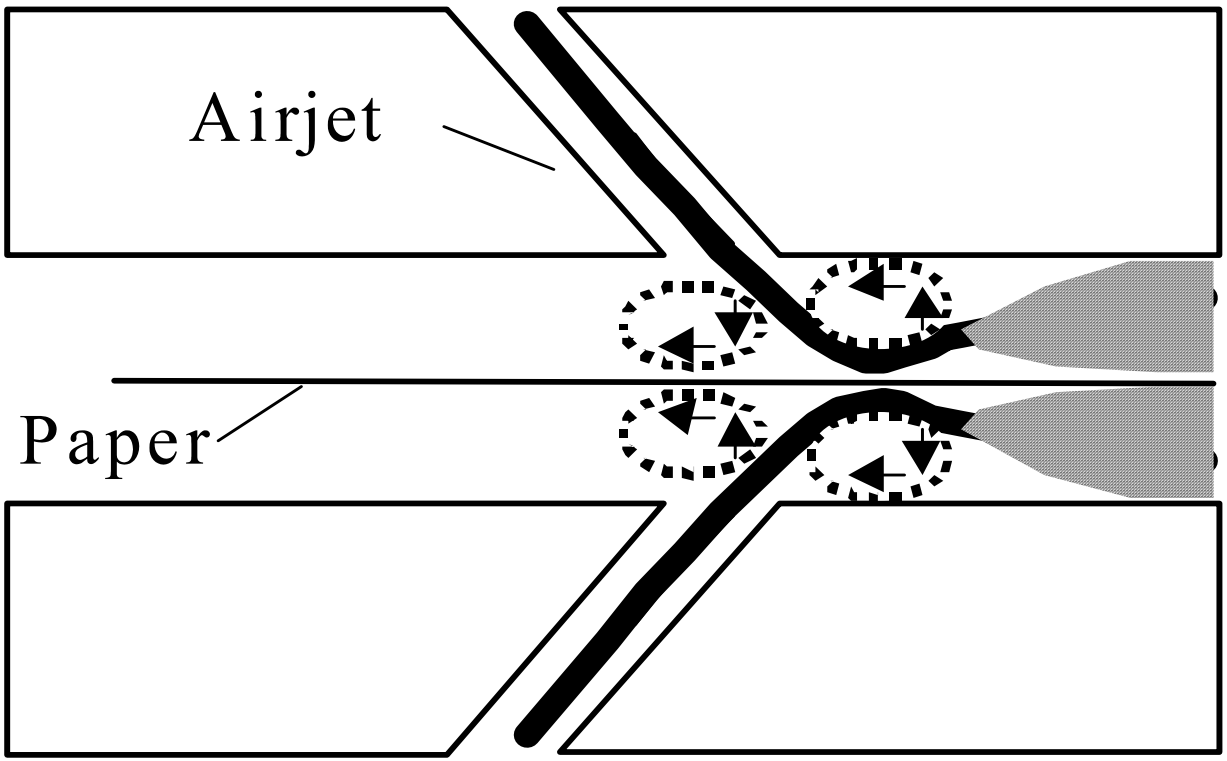






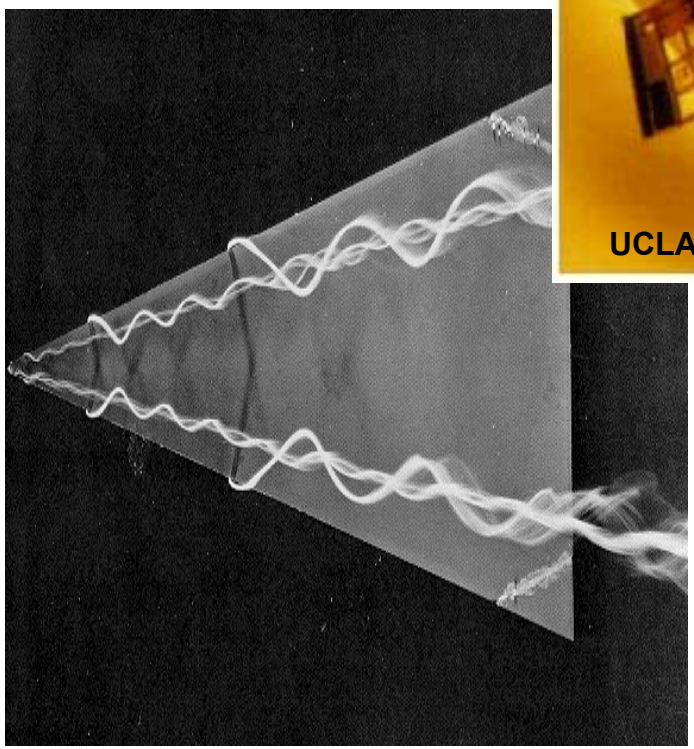
576 Valves
(144 per direction)

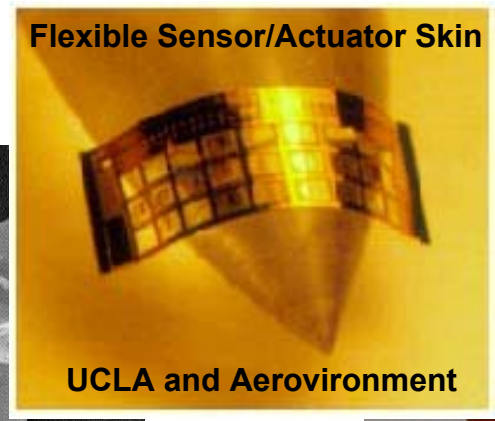
Air jet actuation



Airjet Paper Moving

MEMS Actuators for Aero Control





MEMS Actuator Array on the Leading Edge of Wing of 1/7 Scale Mirage III Fighter

UCLA and Aerovironment

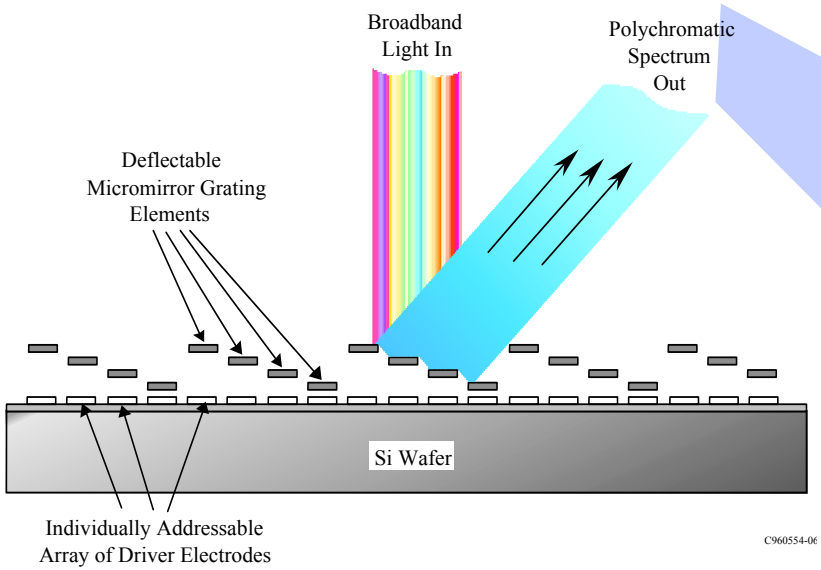
Aircraft Controlled by Micro Actuators

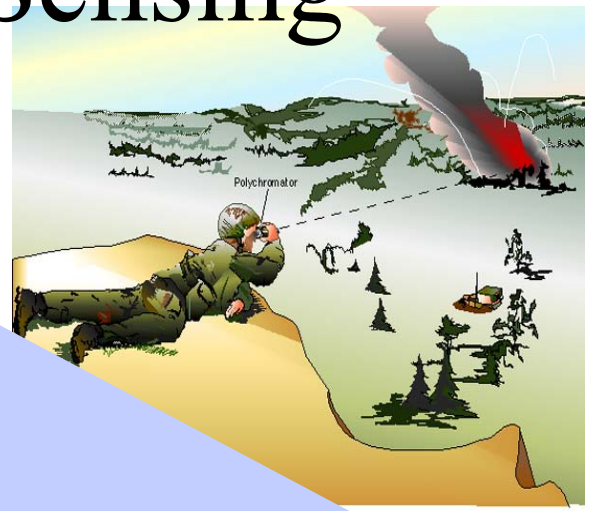
Gwo-Bin Lee & Chih-Ming Ho, UCLA

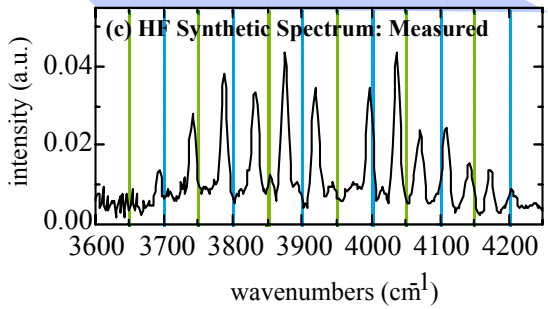
T. Tsao, F. Jiang & Y. C. Tai, Caltech

Standoff Chemical Sensing

MEMS Polychromator



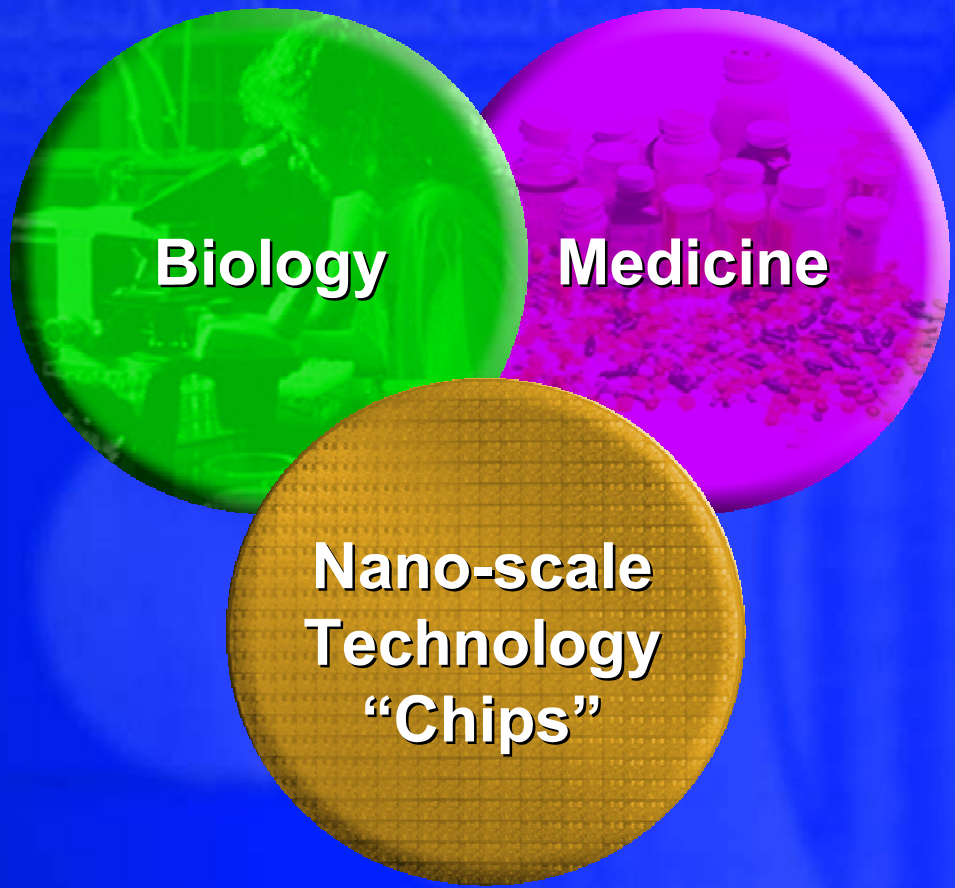




Honeywell Corp.

- **A new concept for a programmable, dark-field correlation spectrometer based on a MEMS diffraction grating.**
- **Leads to development of a miniature, programmable remote chemical detection system for field use.**

Converging Technologies: Silicon Meets Biology



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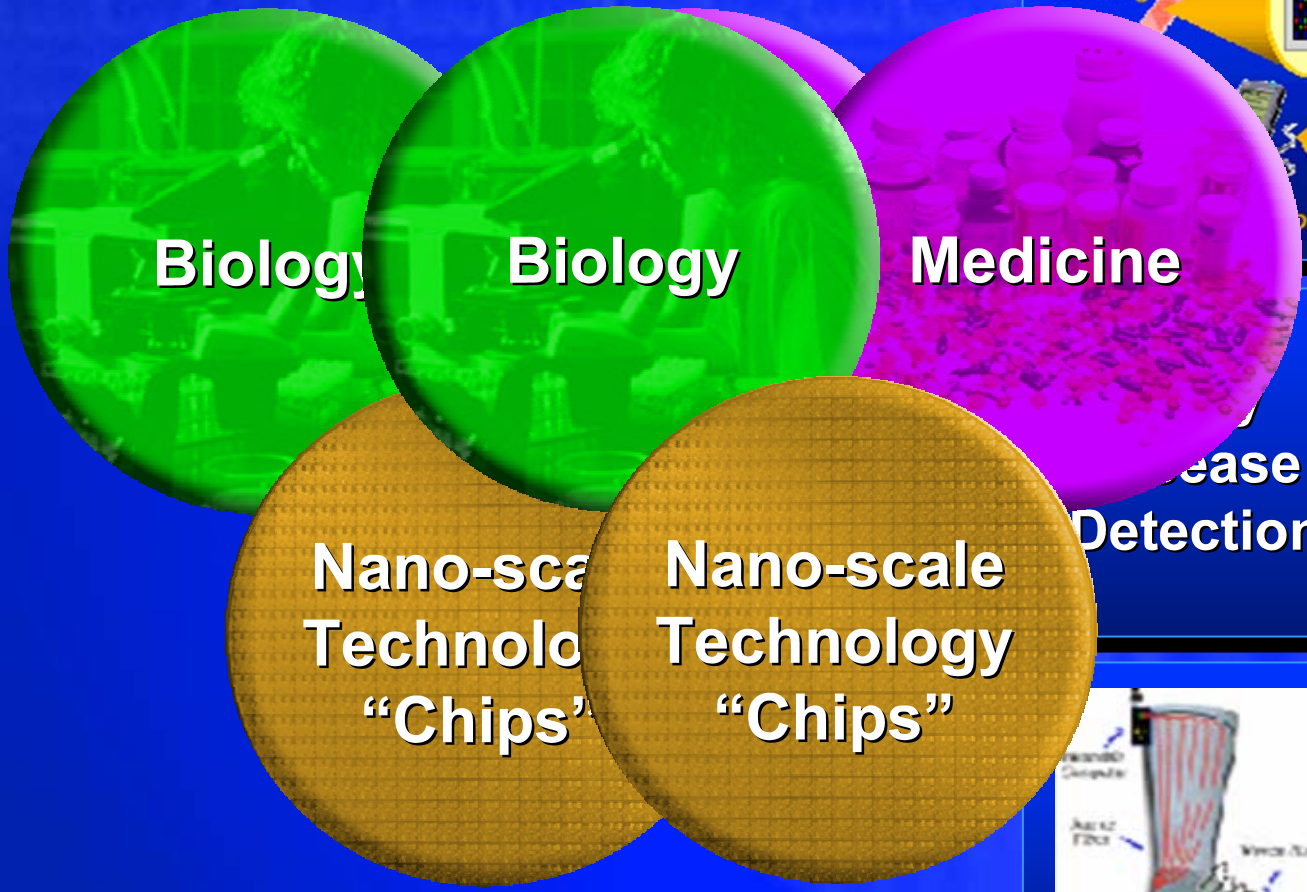
Converging Technologies: Silicon Meets Biology



Smart Band-aids

ease Detection

Health Monitoring

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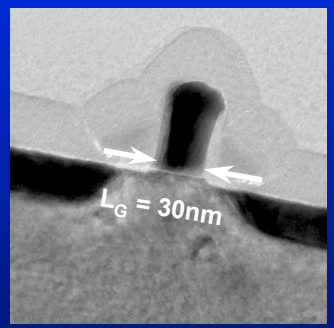
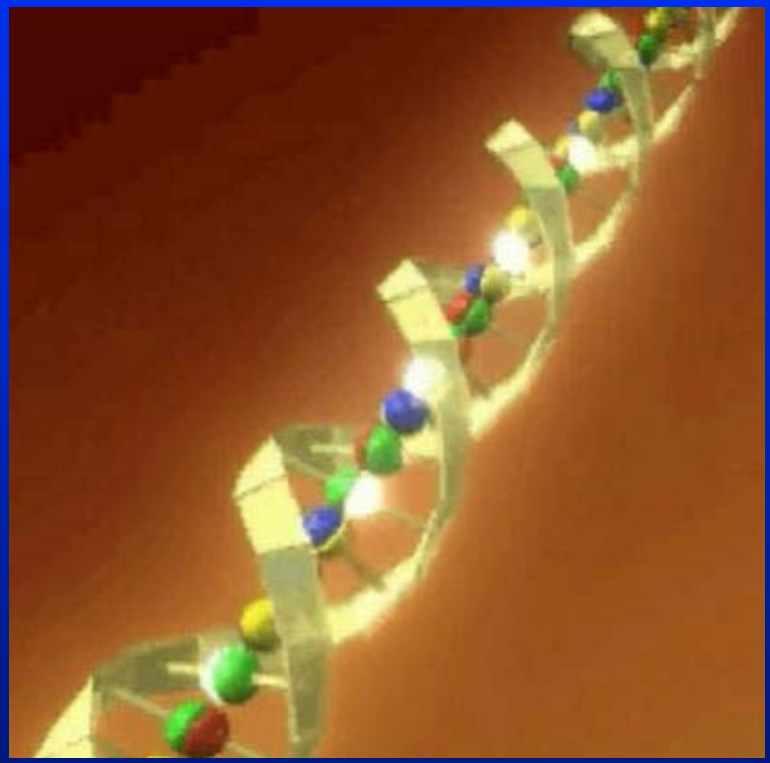
Operating At The Nano-scale

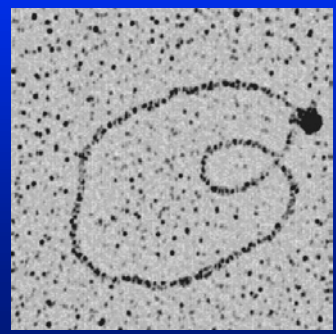
30 Nm Intel Research Transistor



Human DNA



10nm Gold Particle with DNA



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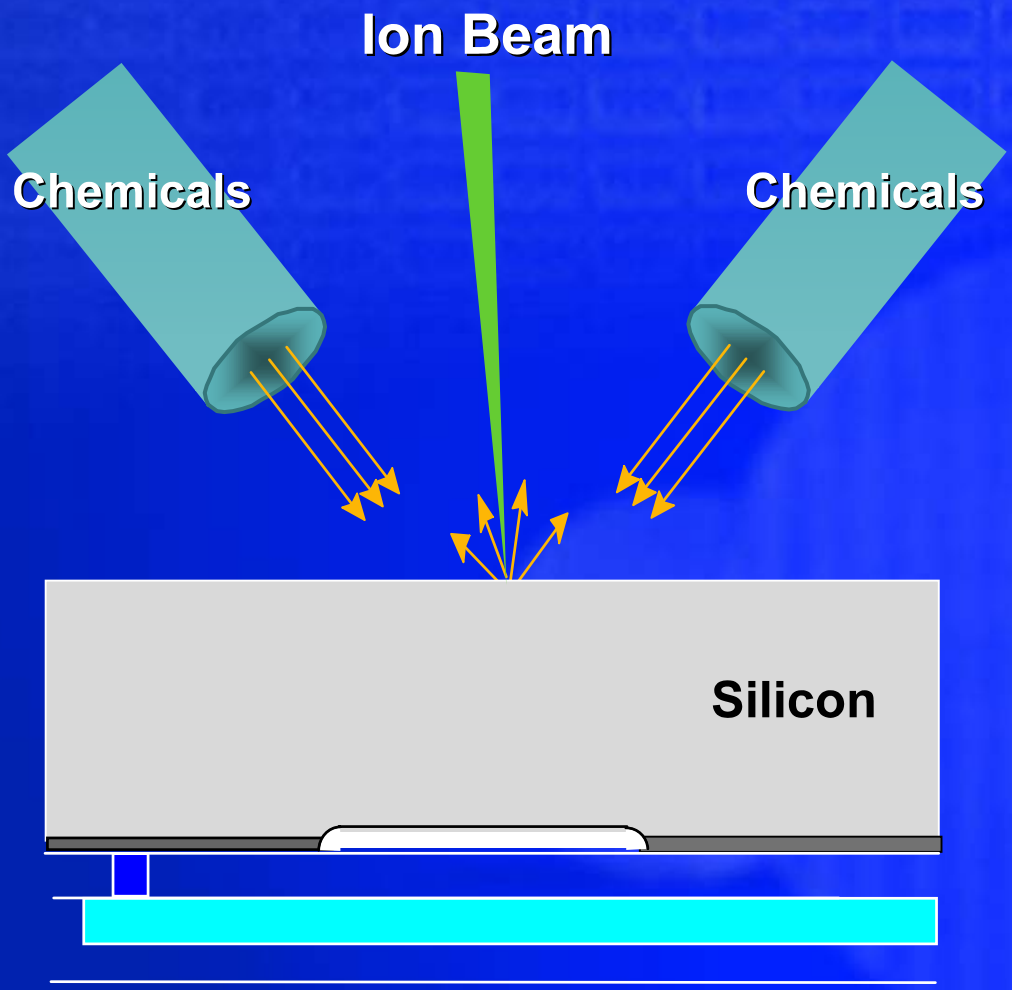
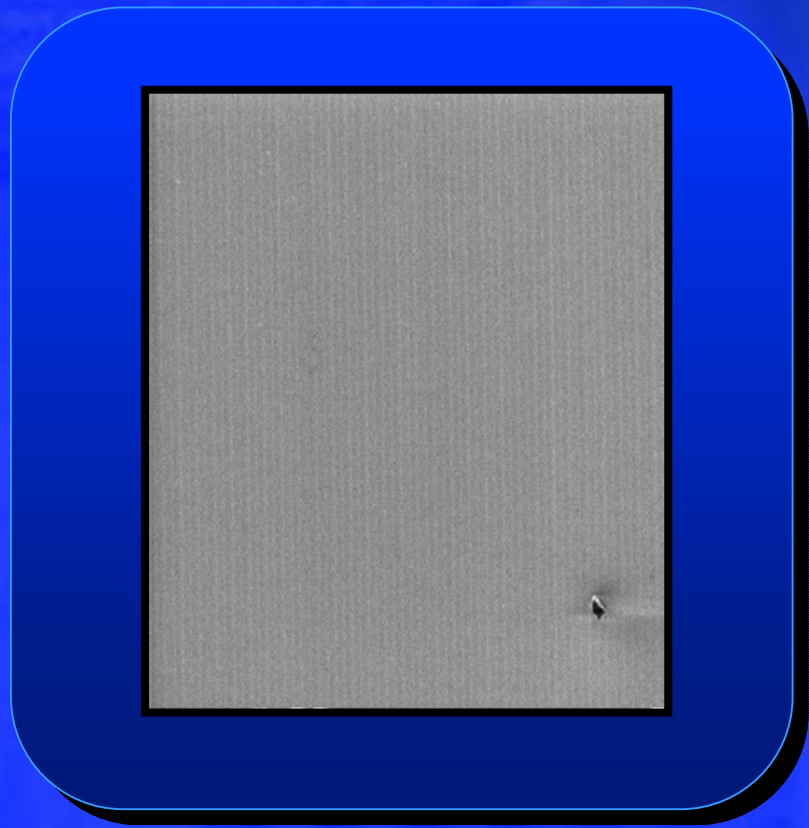
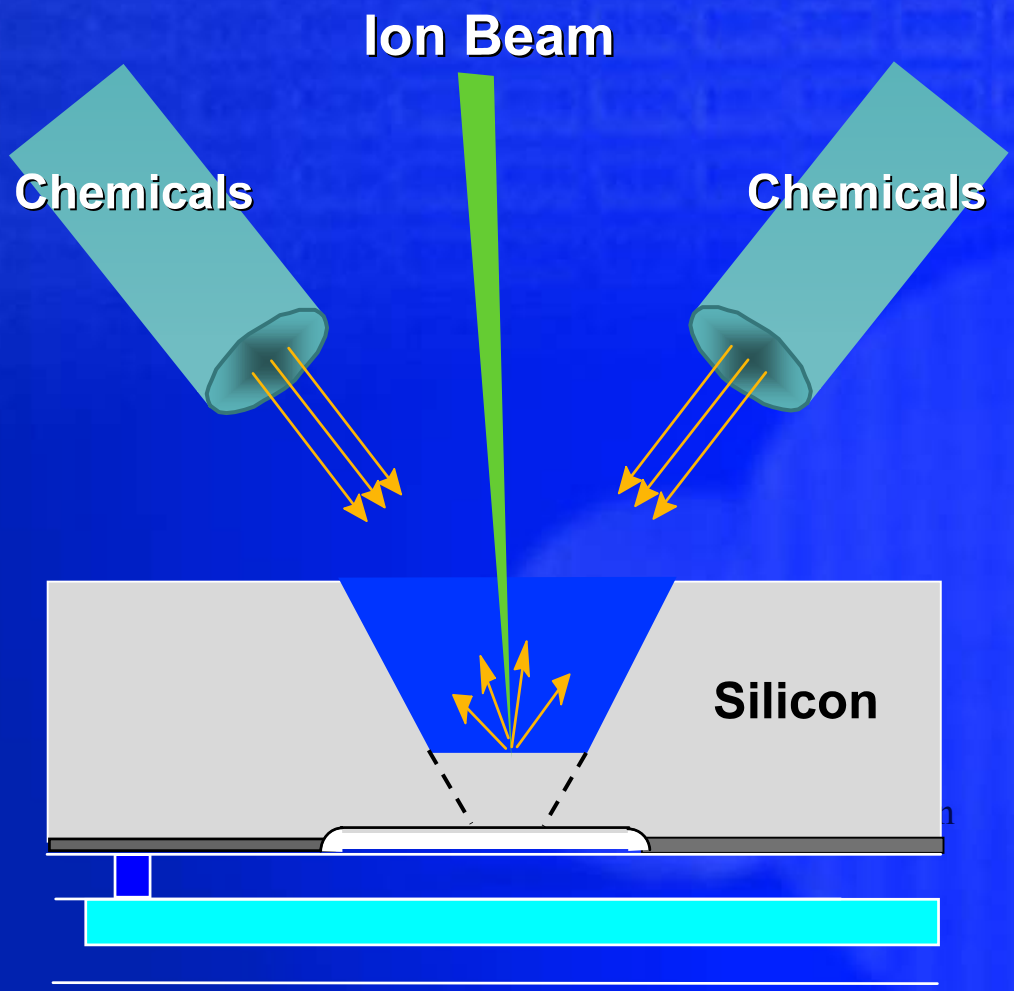
* attached to Z-DNA antibody John Jackson & Inman. Gene 1989 84 221-226.

Sculpting at the Nano-scale

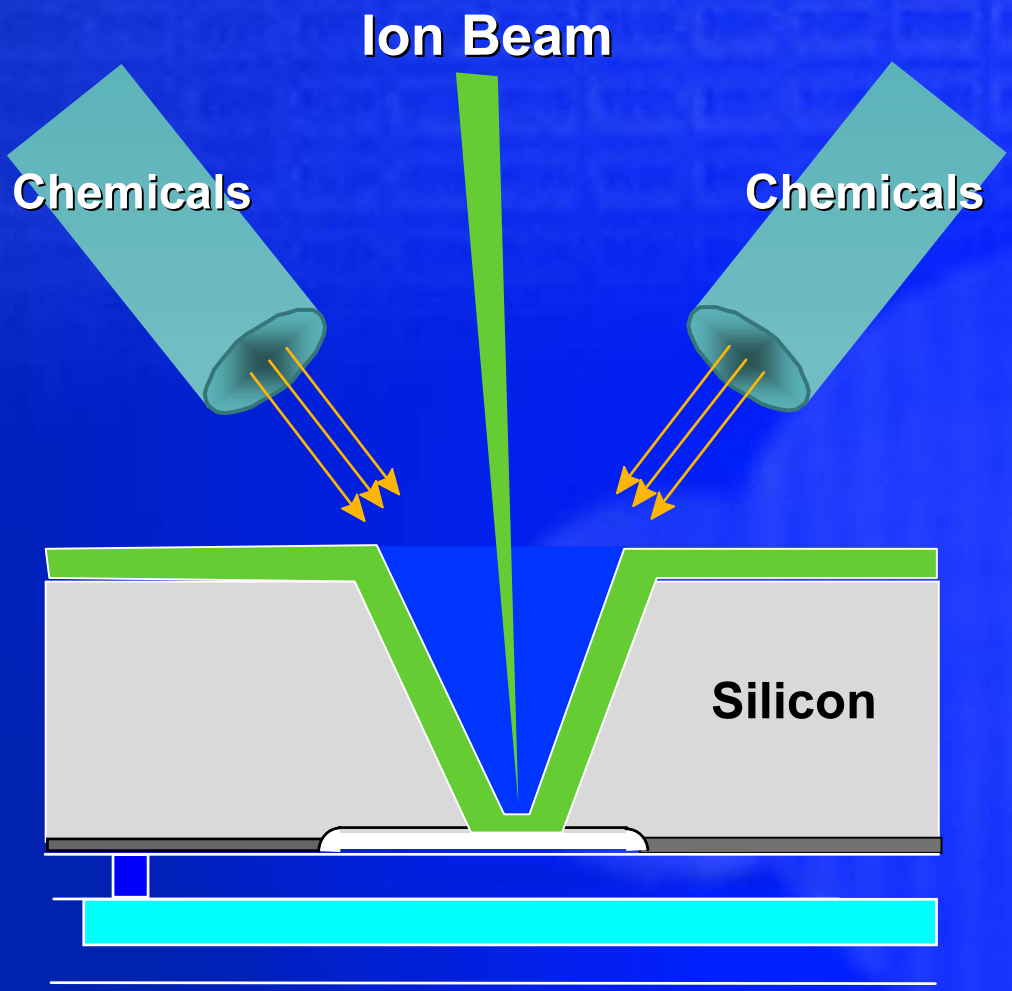




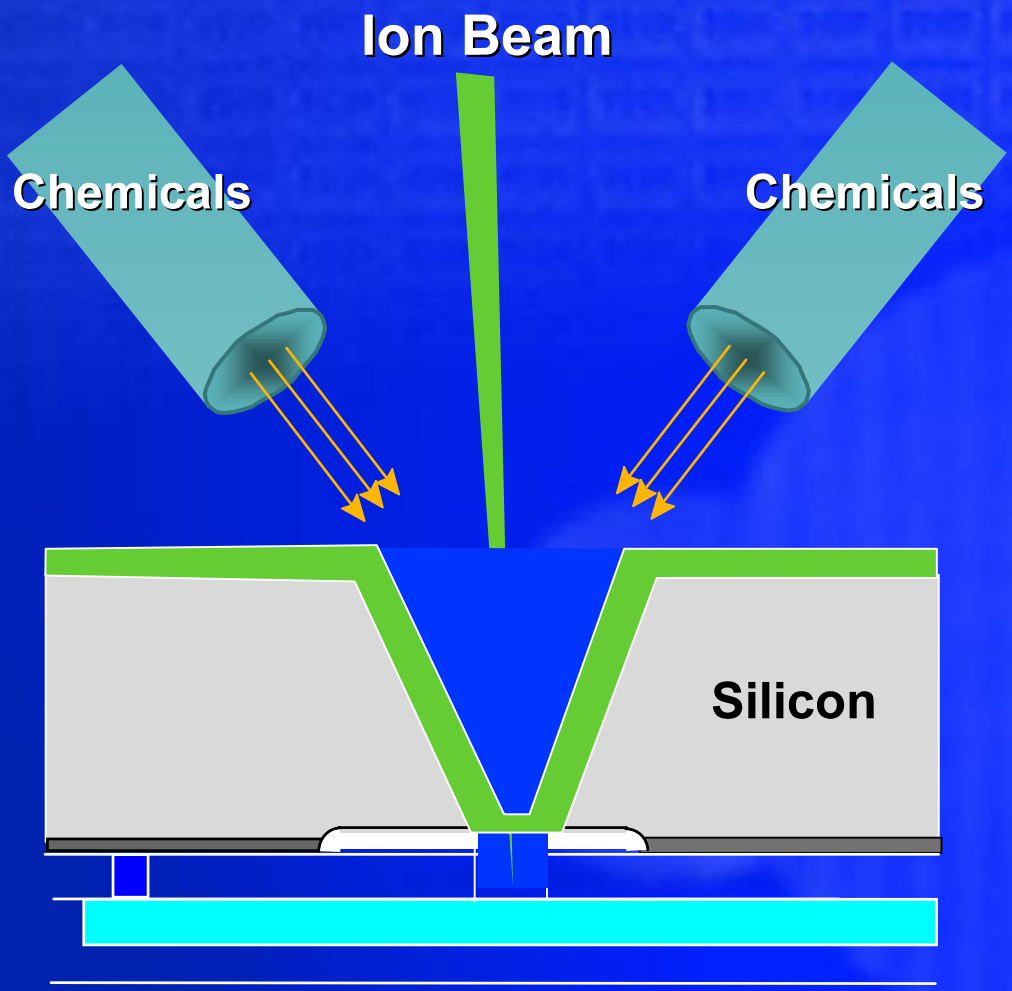
Sculpting at the Nano-scale



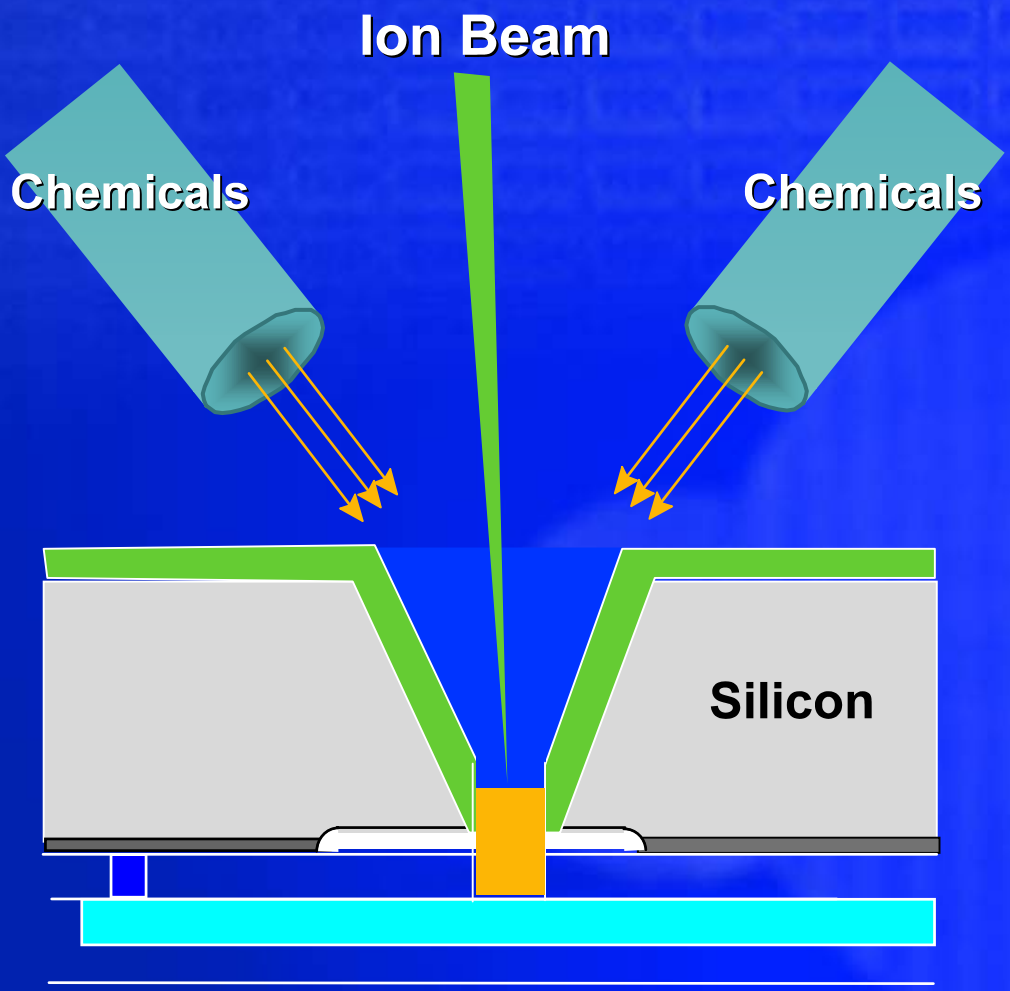
Sculpting at the Nano-scale



Sculpting at the Nano-scale

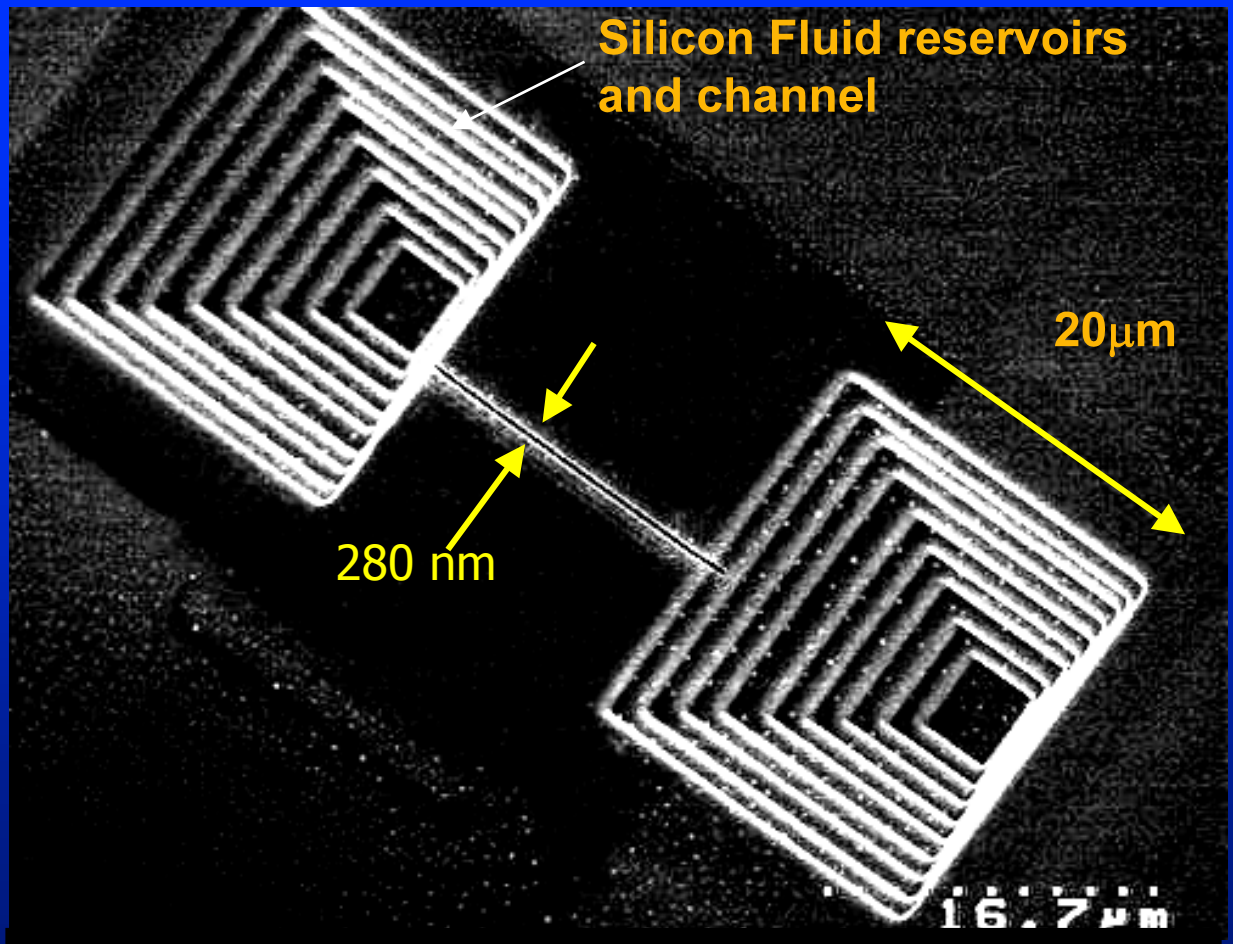


Sculpting at the Nano-scale



Research Results

Early Research: Micro-fluidics



Micro-fluidic channels

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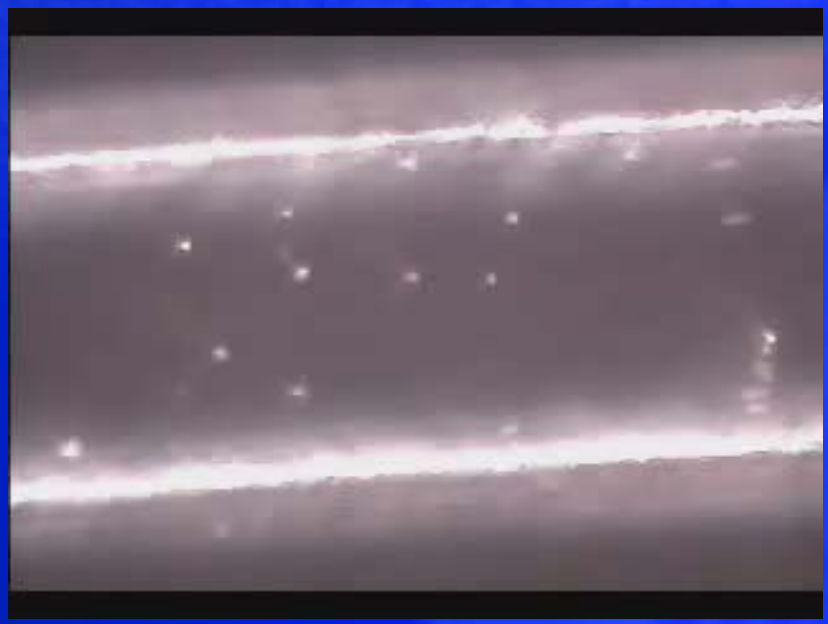
DNA Flow In Microchannel



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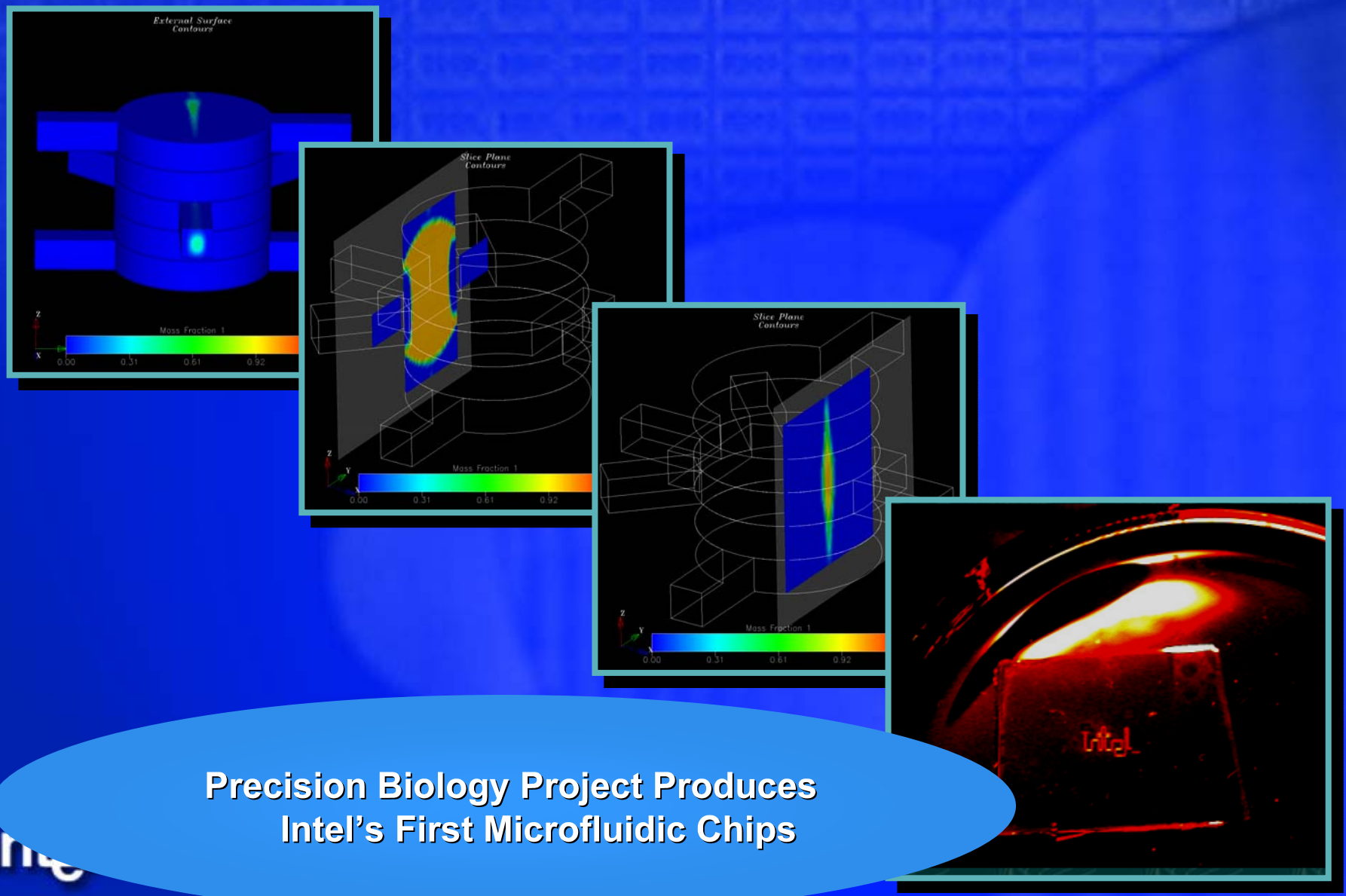
Intel Precision Biology



Precision Biology Project Produces Intel's First Microfluidic Chips

MEMS for wireless integration

Antennas

Color bi-stable display

Micro-switches

Tunable capacitors and inductors

Tunable filters

Directional microphone

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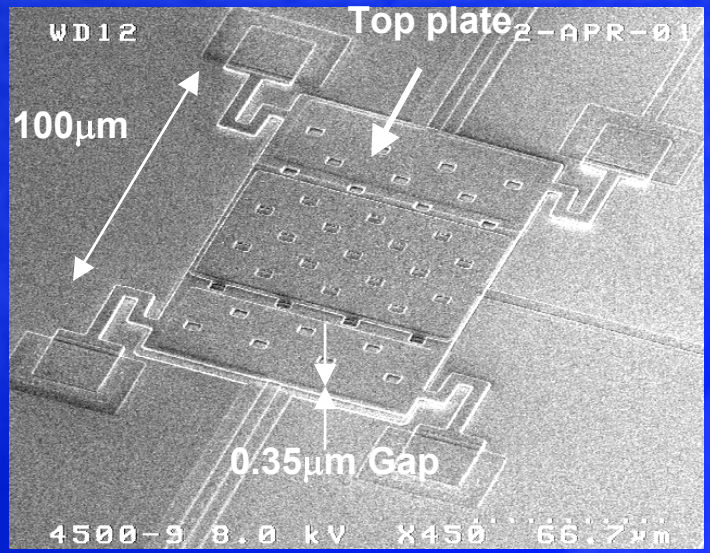
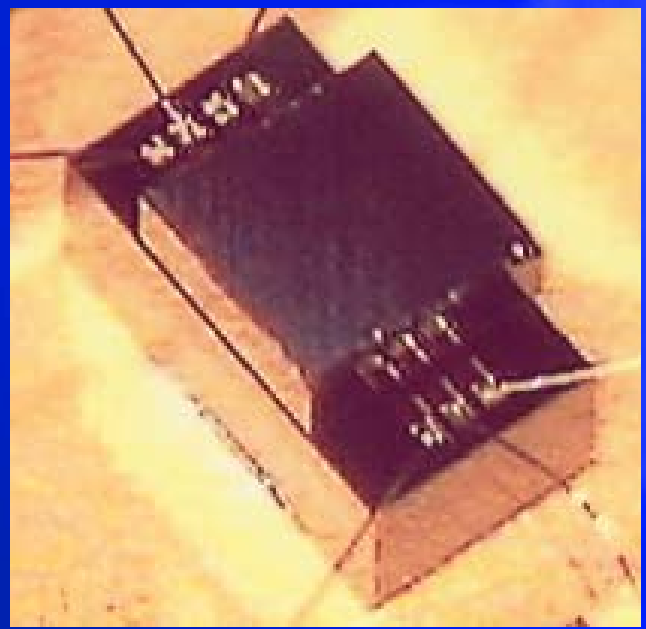
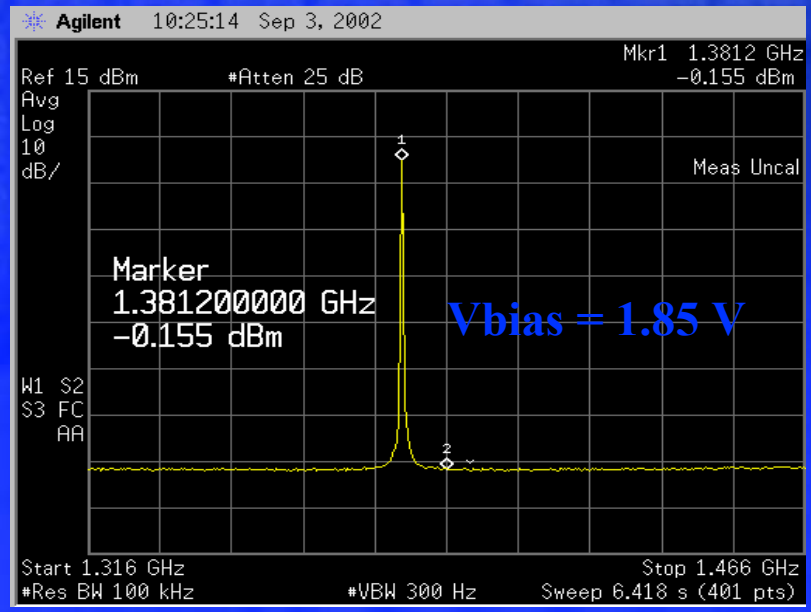
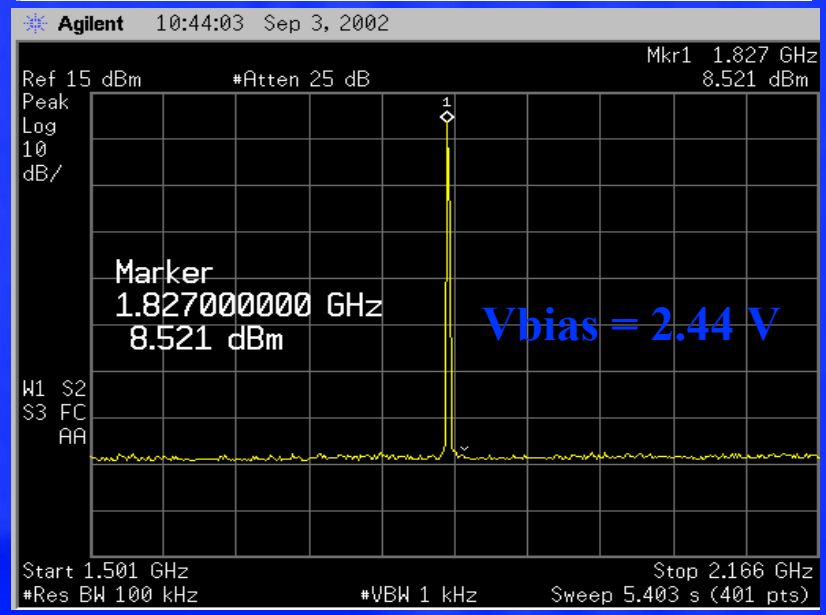
Aluminum plate varactor and VCO









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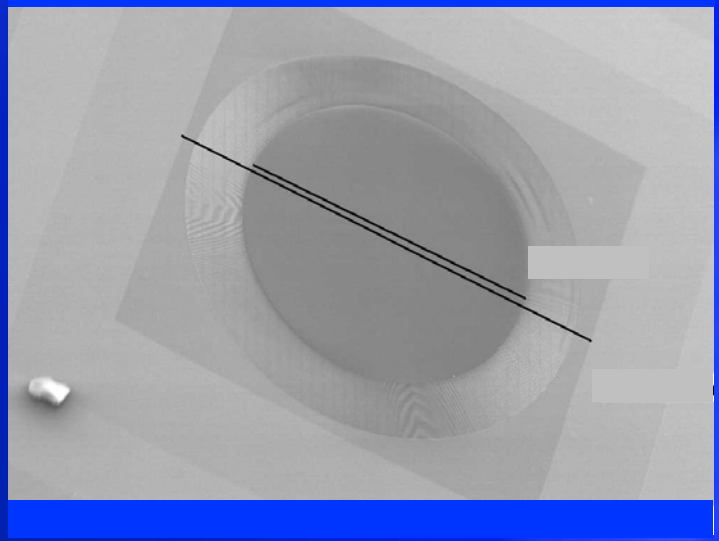
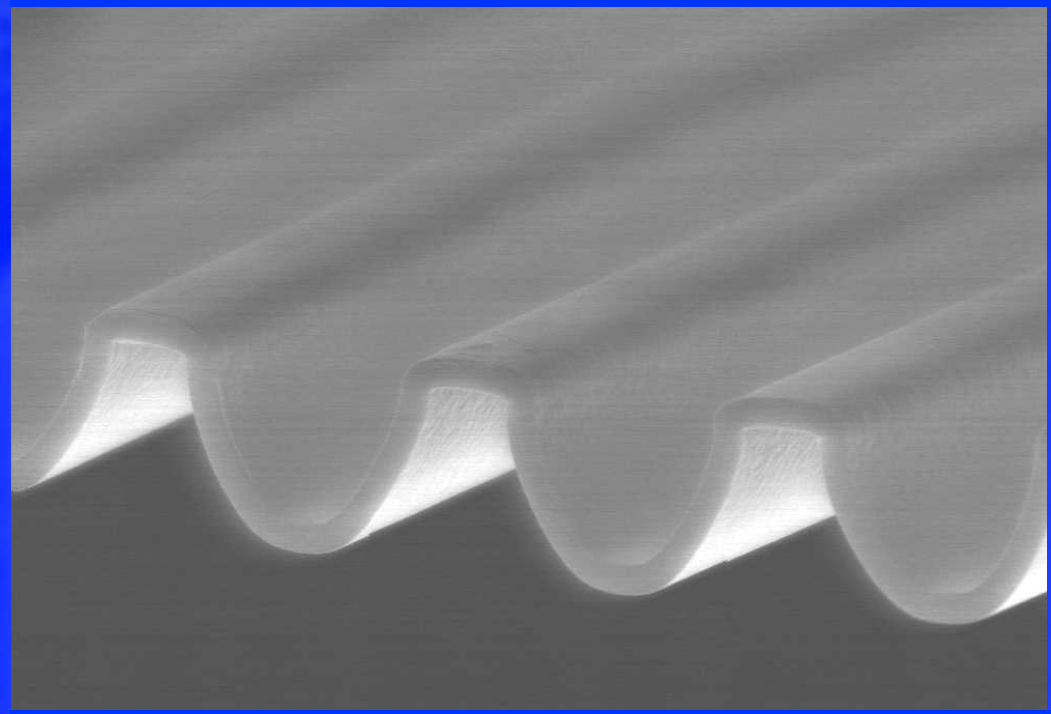
MEMS Microphone - Corrugated Silicon Nitride Membrane

Top view





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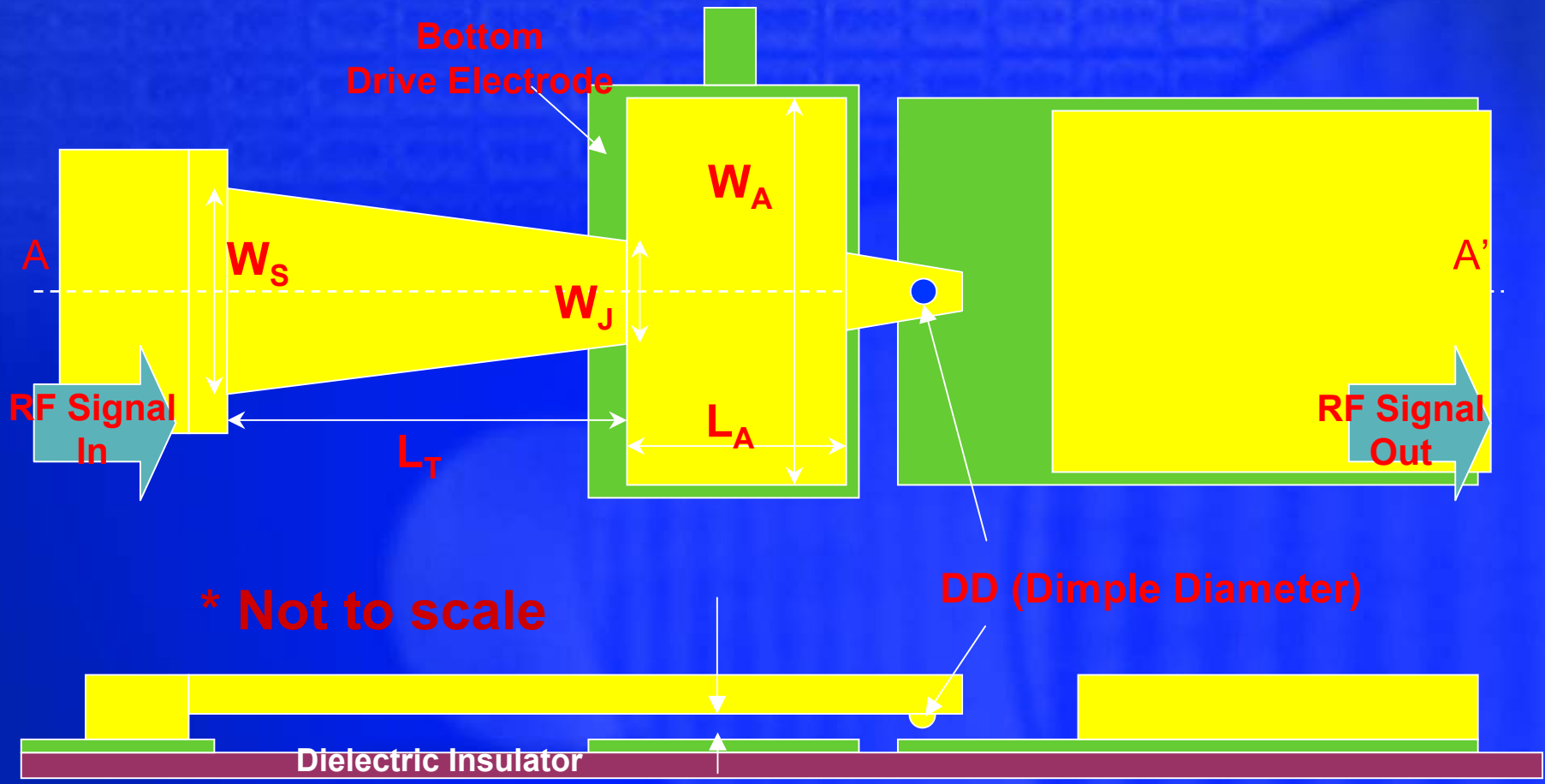
In-line resistive switch



Dimensions optimized using simulation

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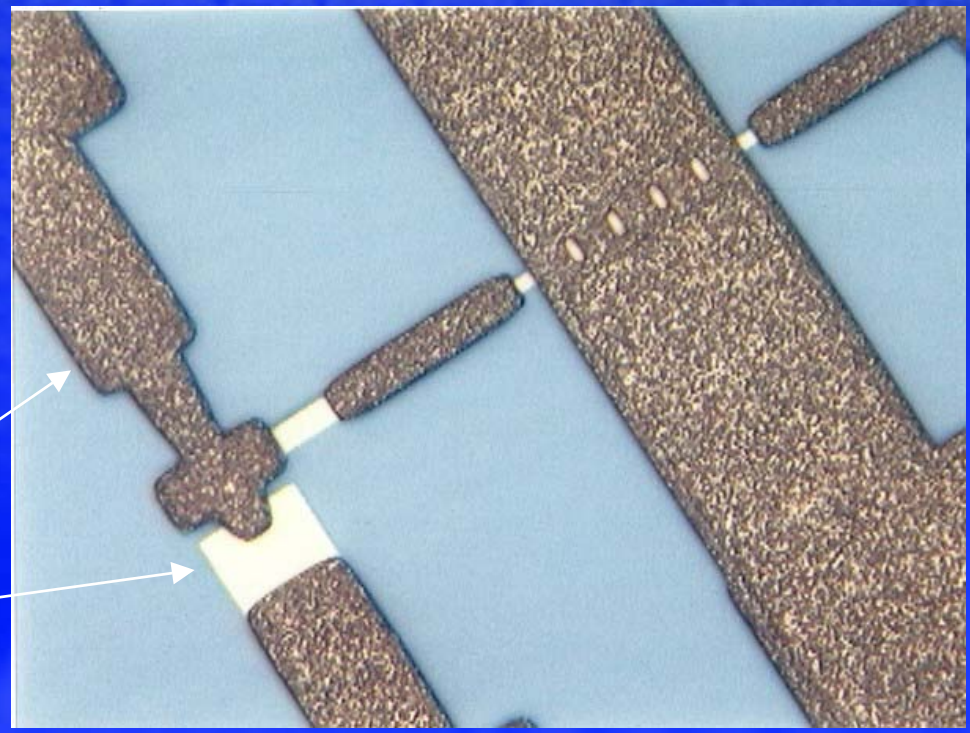
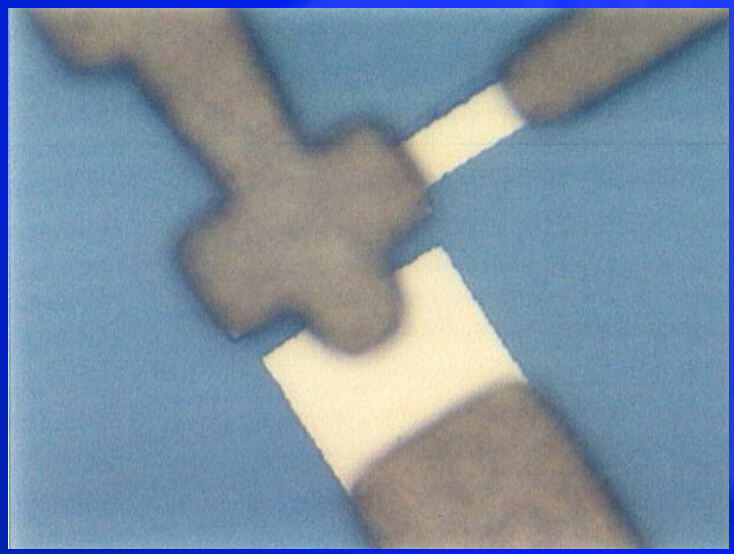
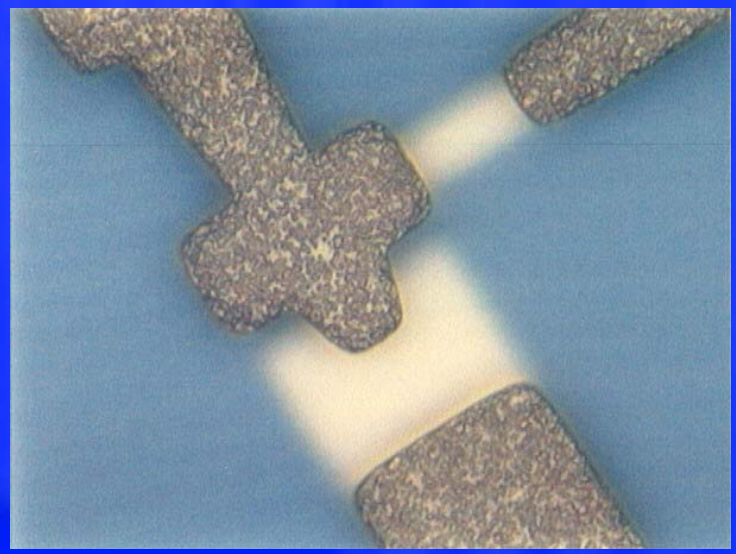
Released switch





Focus on bottom electrode



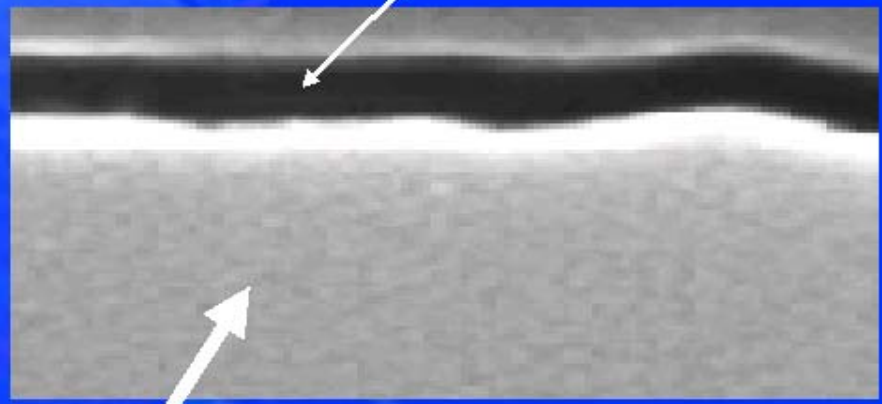
Focus on top electrode

Call to Action

- Optimize RF architectures to exploit the full capabilities that MEMS components can provide
- Deploy high value MEMS passive components in wireless handsets in the 3-4 year time frame
- Evolve tight integration of MEMS, Analog and RF functions in the longer term

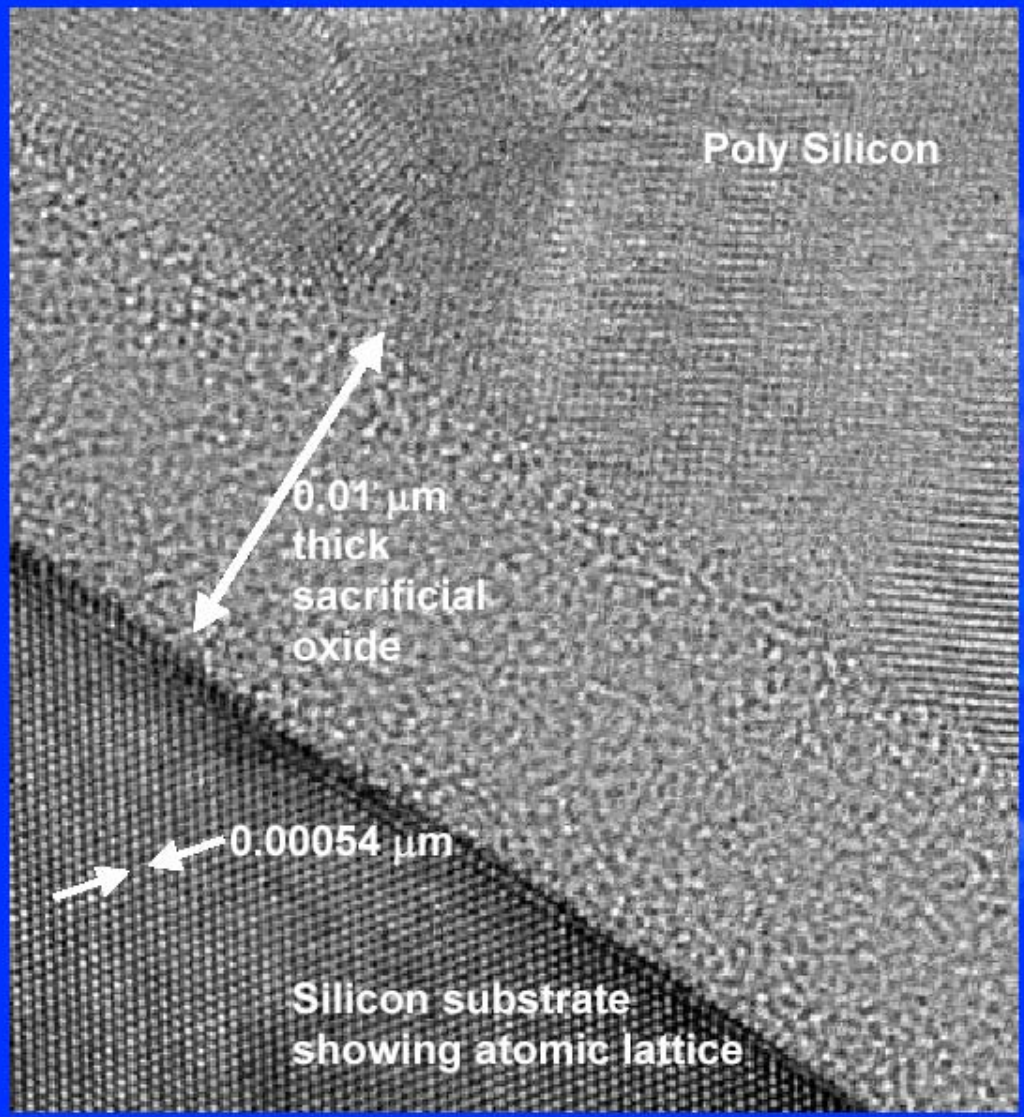
Beam Resonator with 0.014μm Gap

~0.014μm gap



Conformal step coverage

Analytical Capability



- Intel's Advanced analytical capability enables visualization of nano scale MEMS structures
  - We can see what we have built !
  - Atomic resolution !

Major MEMS application areas

- Navigation
- Industrial
- Displays
- Optical communications
- RF (MEMS Radio)
- Microbiology meets Microtechnology
- MEMS power sources

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MEMS for wireless integration

Antennas

Color bi-stable display

Micro-switches

Tunable capacitors and inductors

Tunable filters

Directional microphone

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Wearable Micro-display

How will all this tie together?

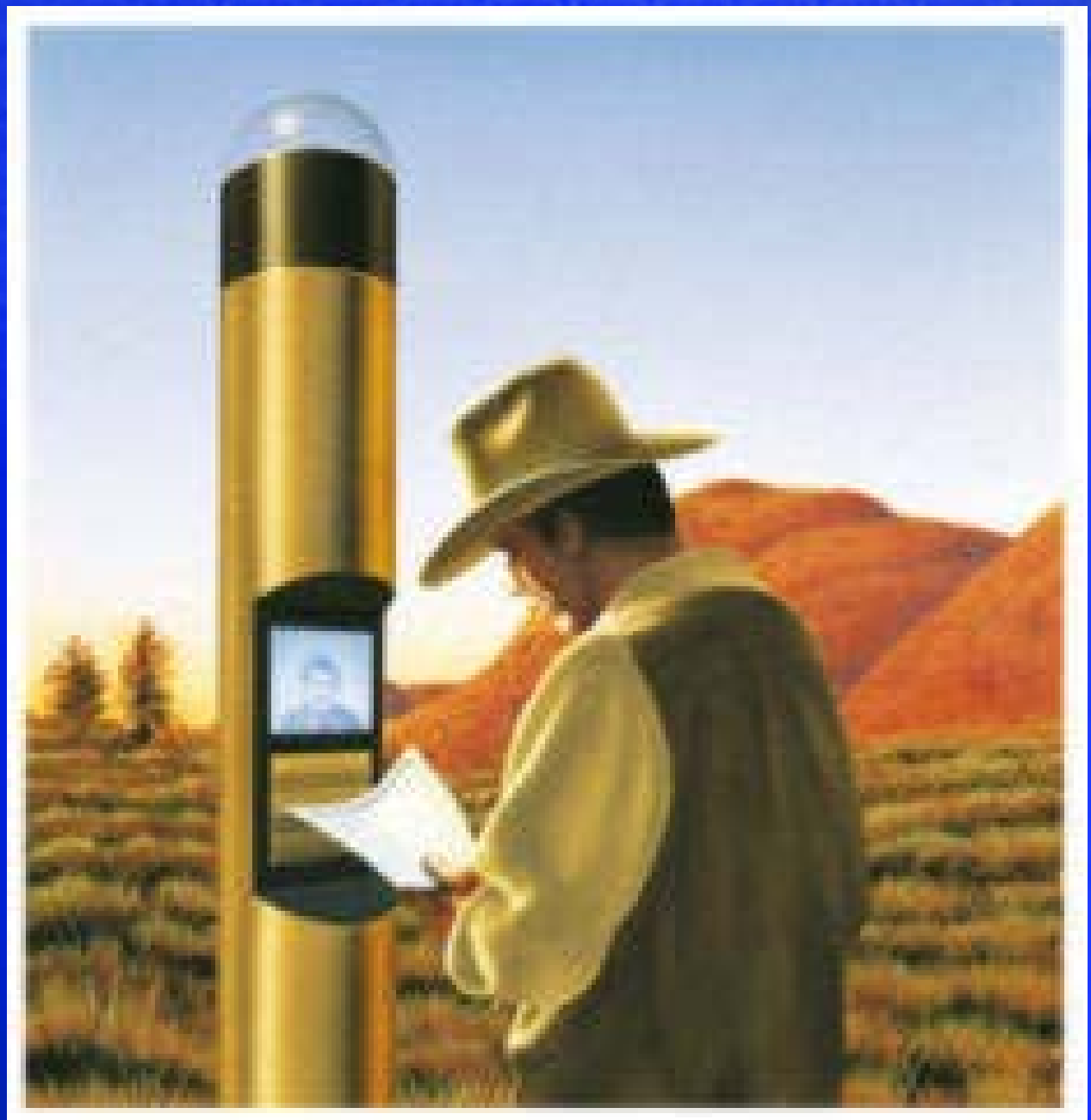

Photo credit:
Fuji Xerox web site

Technology and Society Co-Evolve

Telephone switching center, circa 1920

Photo credit: Telephone pioneers archive

Acknowledgments

This talk is based in part on original material from my Precision Biology lab at Intel, on material from the RF MEMS group at Intel, and in part on material drawn from a MEMS overview slide set prepared by Bill Tang at DARPA, as well as from material created and/or gathered by Kurt Petersen at Cepheid,. Many thanks to Bill and Kurt for providing this material.

Thanks also to Mark Miles at Iridigm, Chih-Ming Ho's group at UCLA, and the air jet paper mover team at the Xerox Palo Alto Research Center for providing slides and presentation material.

Some material is also drawn from a workshop on 'Lifescapes of the Future' that Gitti Jordan and I ran a couple of years ago.

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