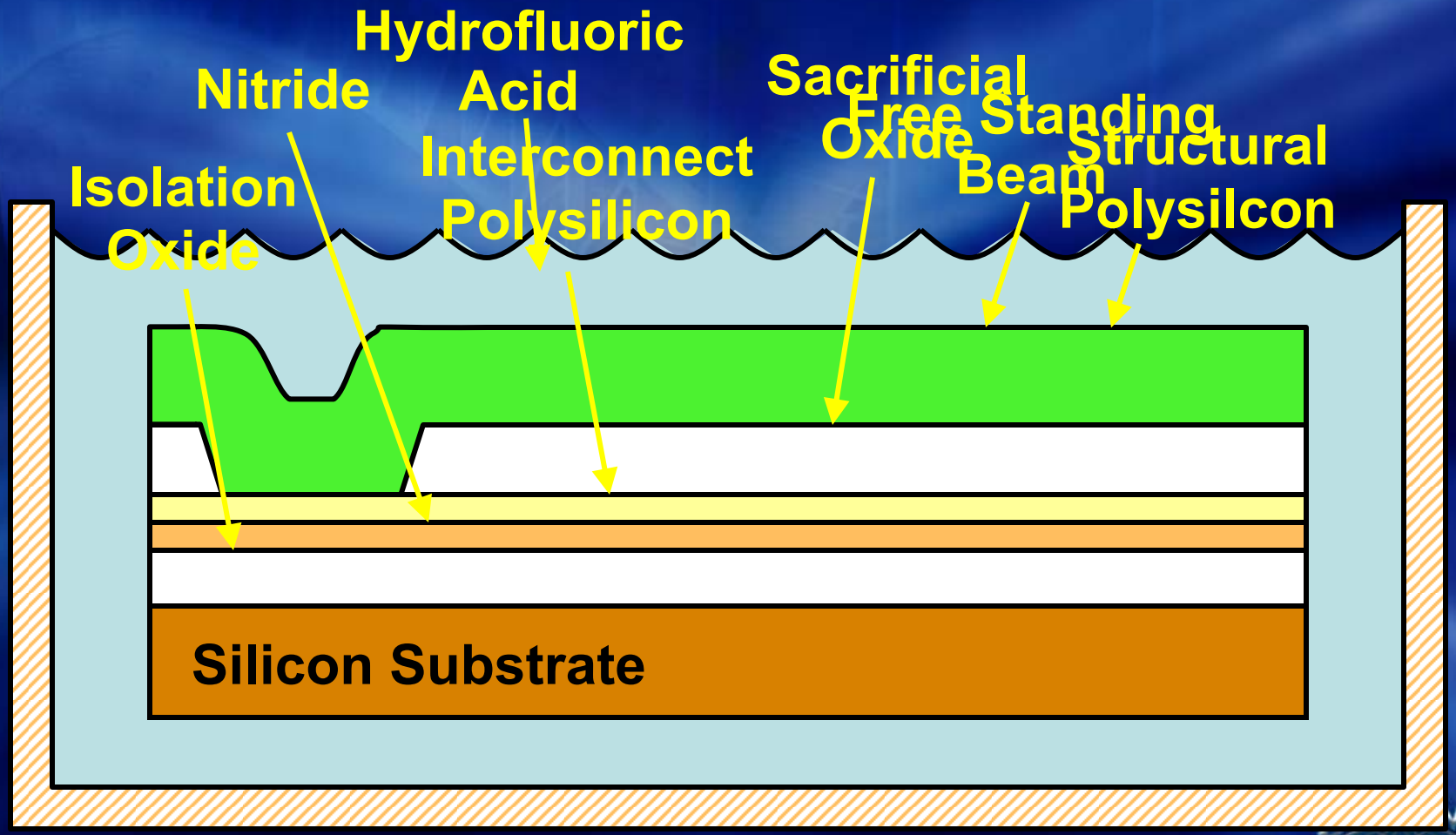
Micro Electro Mechanical Systems: Scaling Beyond the Electrical Domain

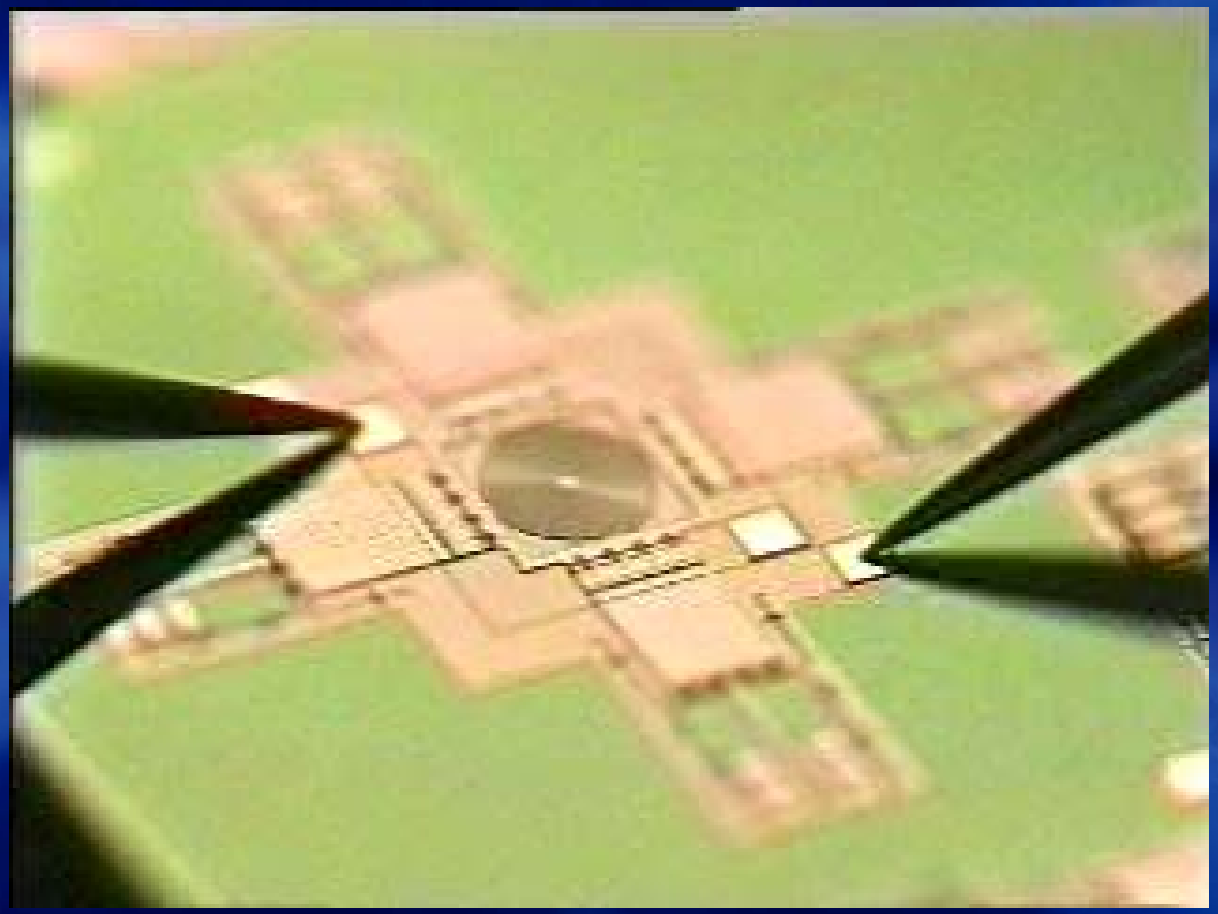
Clark T.-C. Nguyen

Smaller Is Better

Surface Micromachining



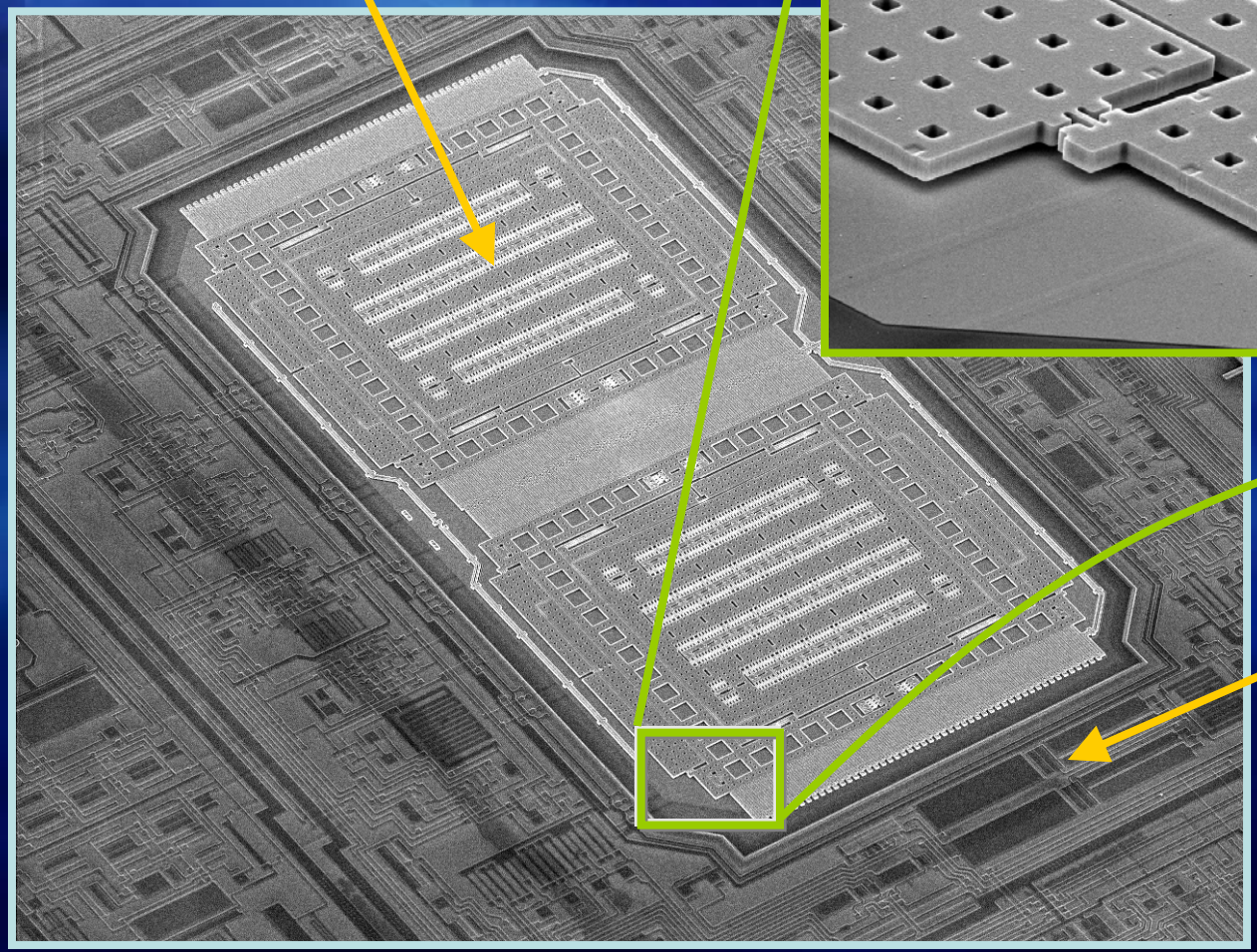
Surface Micromachining

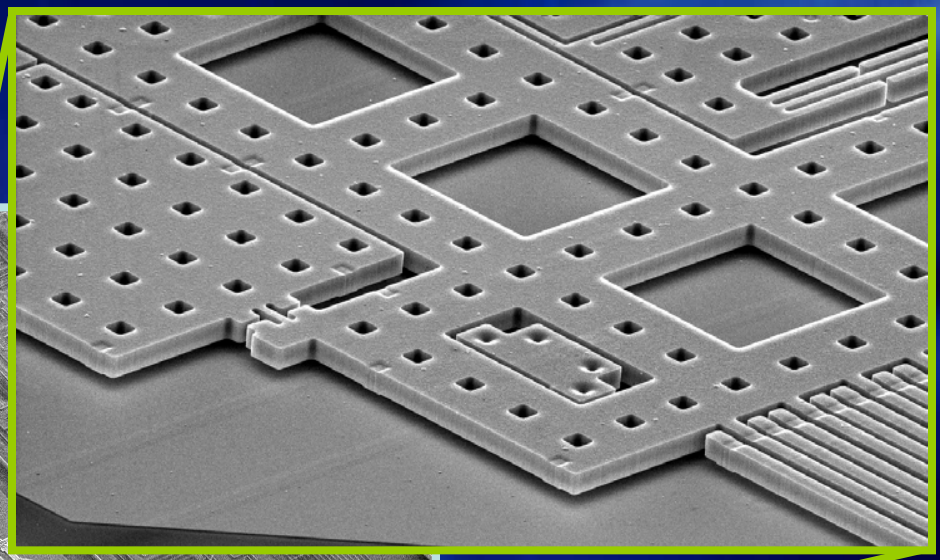


[UCLA]

Integrated CMOS/MEMS Device

Vibrating Mechanical Element



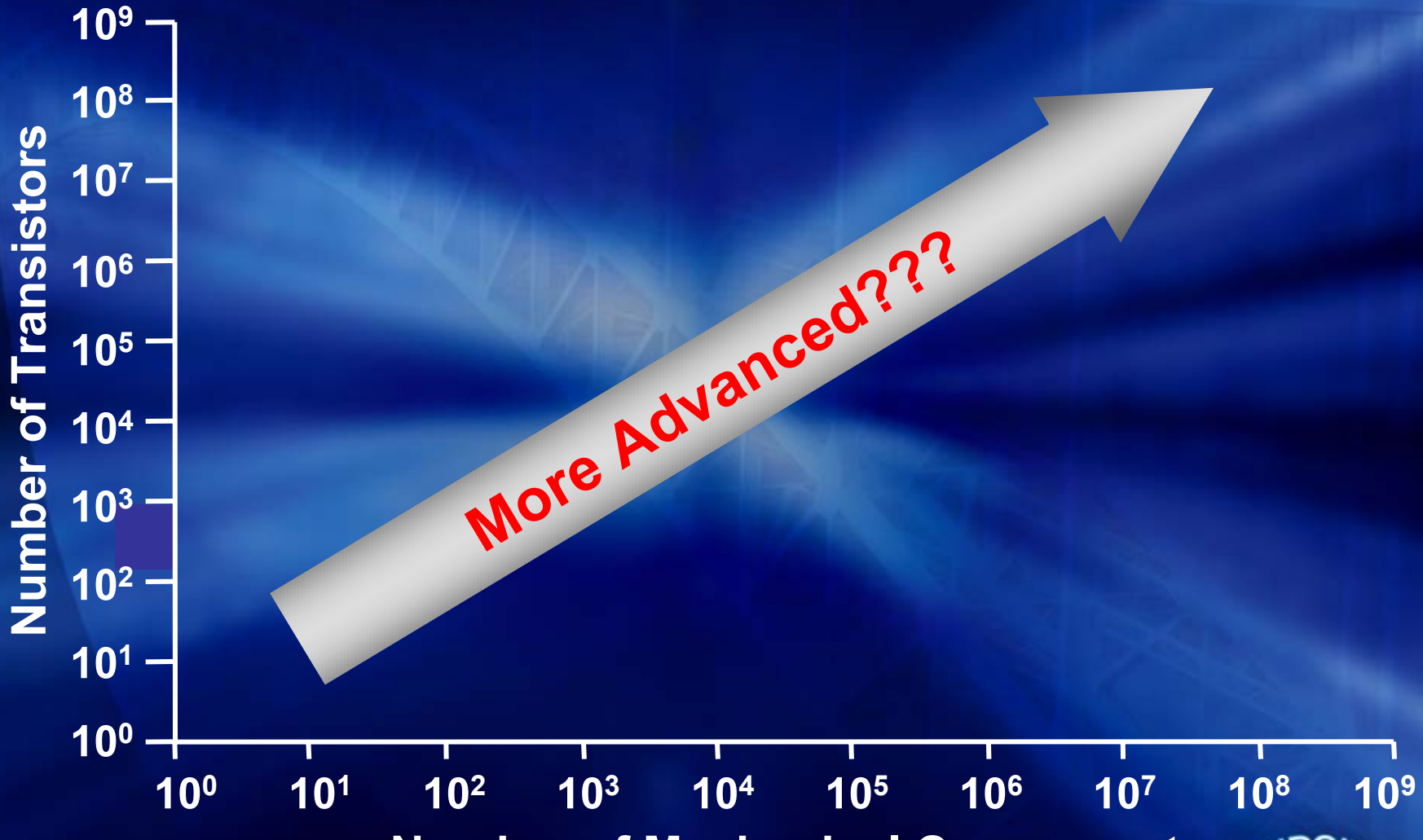


Integrated CMOS Electronics

BRIDGING DARPA THE GAP

[Analog Devices]

MEMS Technology Roadmap



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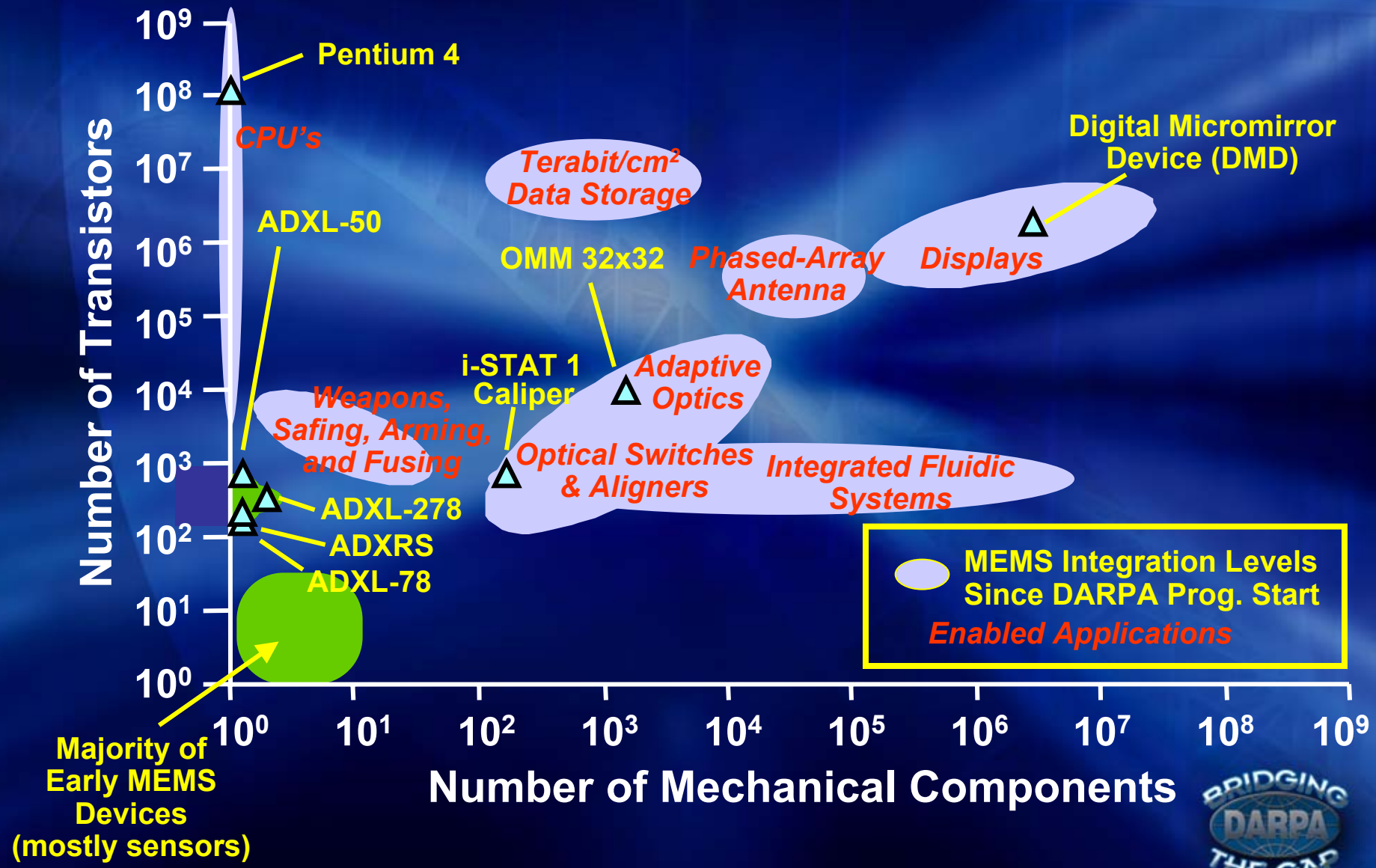
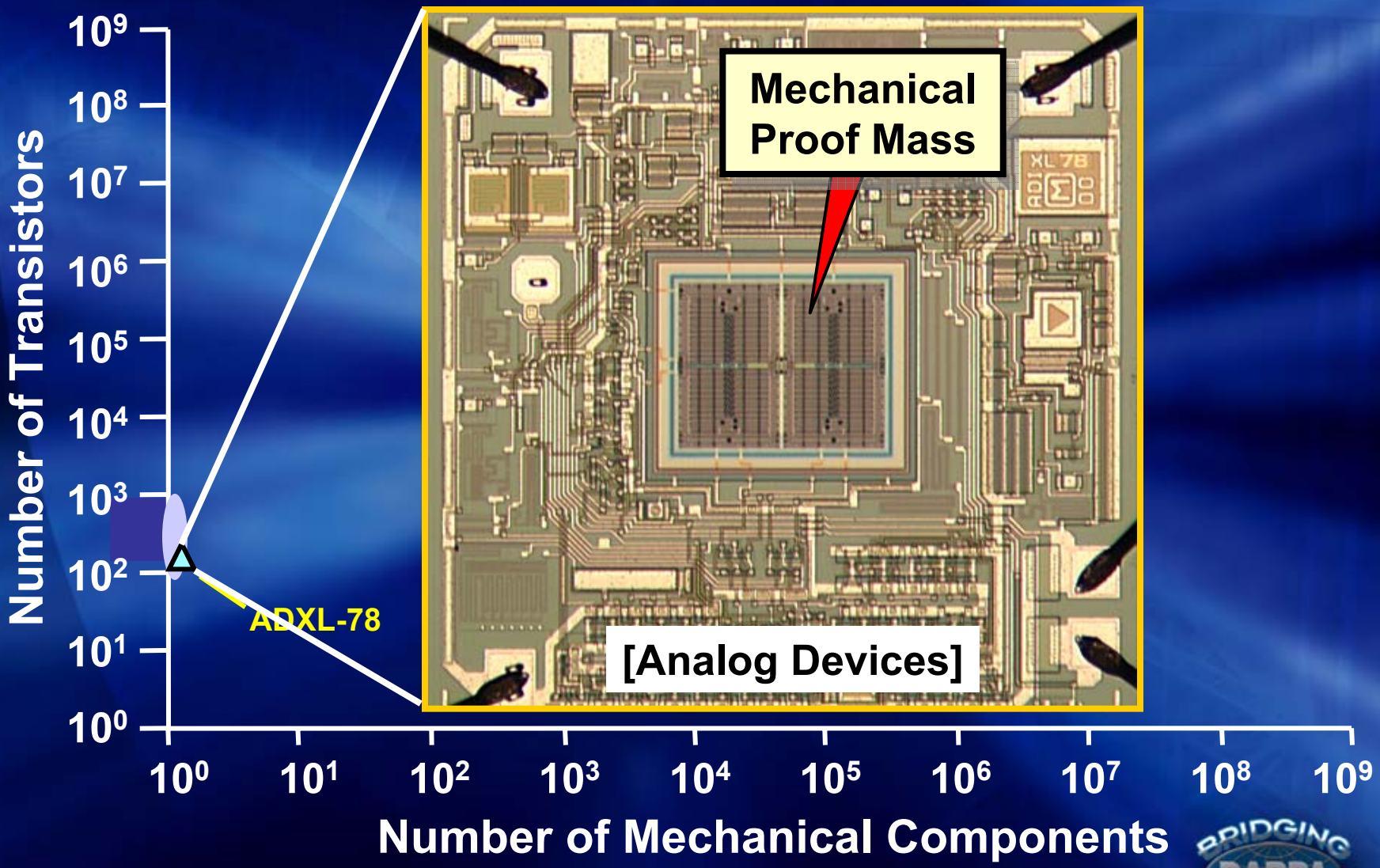
MEMS Technology Roadmap



Fully-Integrated Accelerometer



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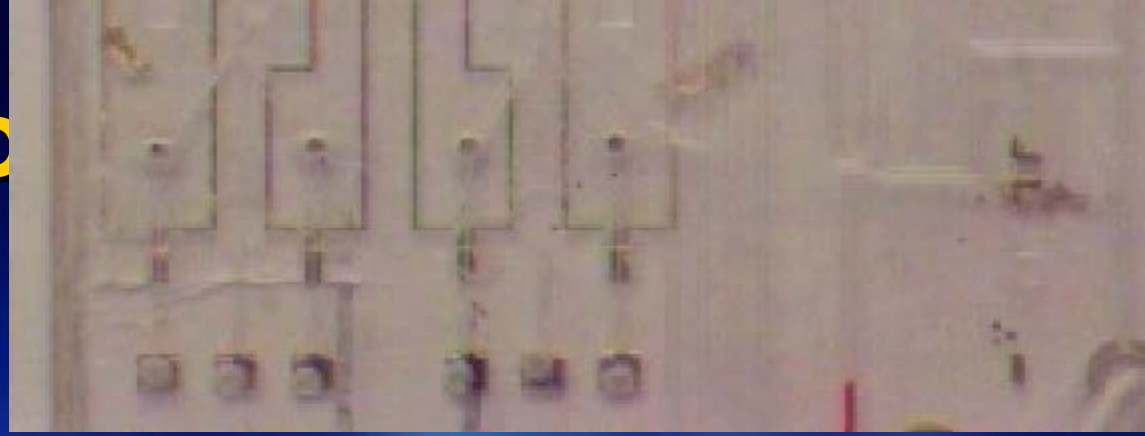
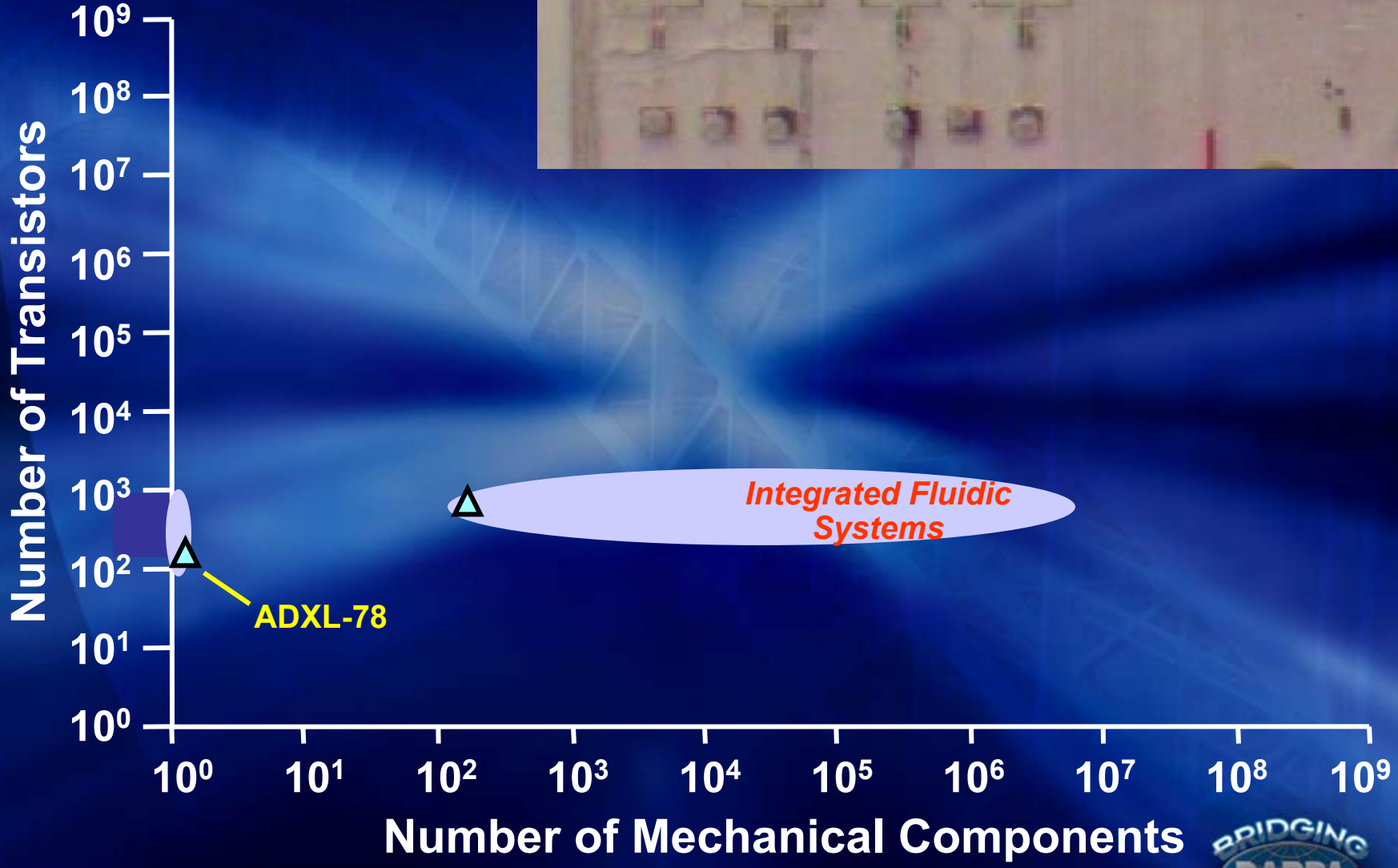
Micro





Probe-Based D

Number of Transistors

10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0

Terabit/cm² Data Storage

Integrated Fluidic Systems

ADXL-78

[IBM]

10^0 10^1 10^2 10^3 10^4 10^5 10^6 10^7 10^8 10^9

Number of Mechanical Components

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Optical MEMS

TI Digital Micromirror Device

Digital Micromirror Device (DMD)

Displays

Number of Tra

10^5

10^4

10^3

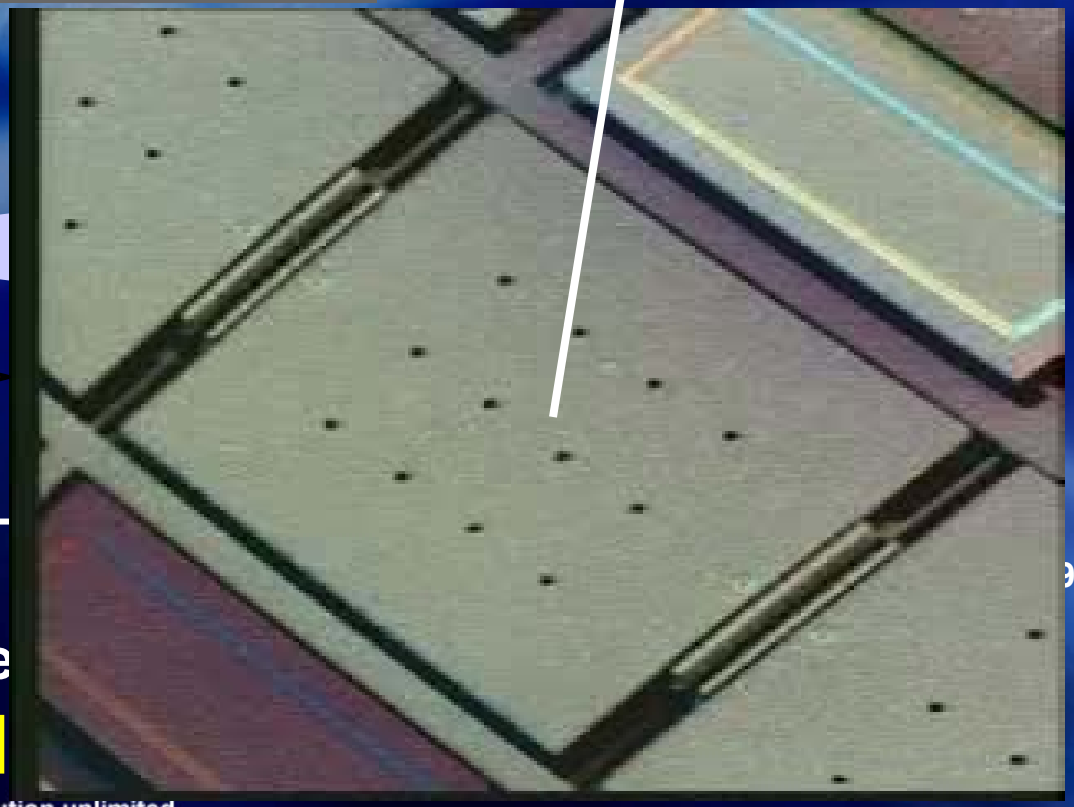
10^0

10^0 10^1 10^2

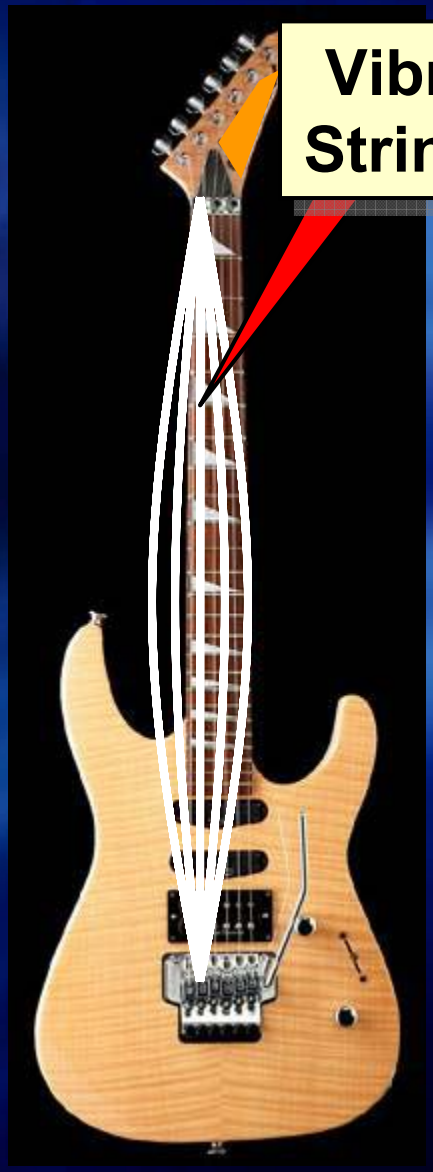
Numbe

Movable Micromirror

[UCLA]



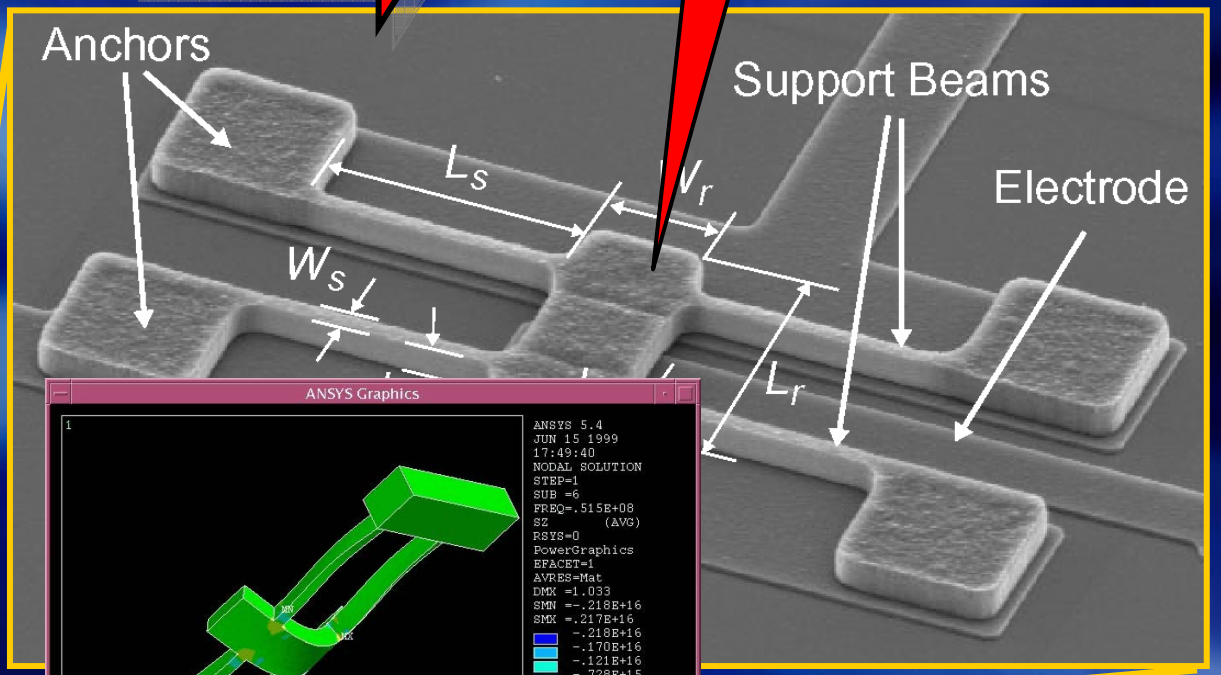
Scaling Guitar Strings



Vibrating "A" String (440 Hz)

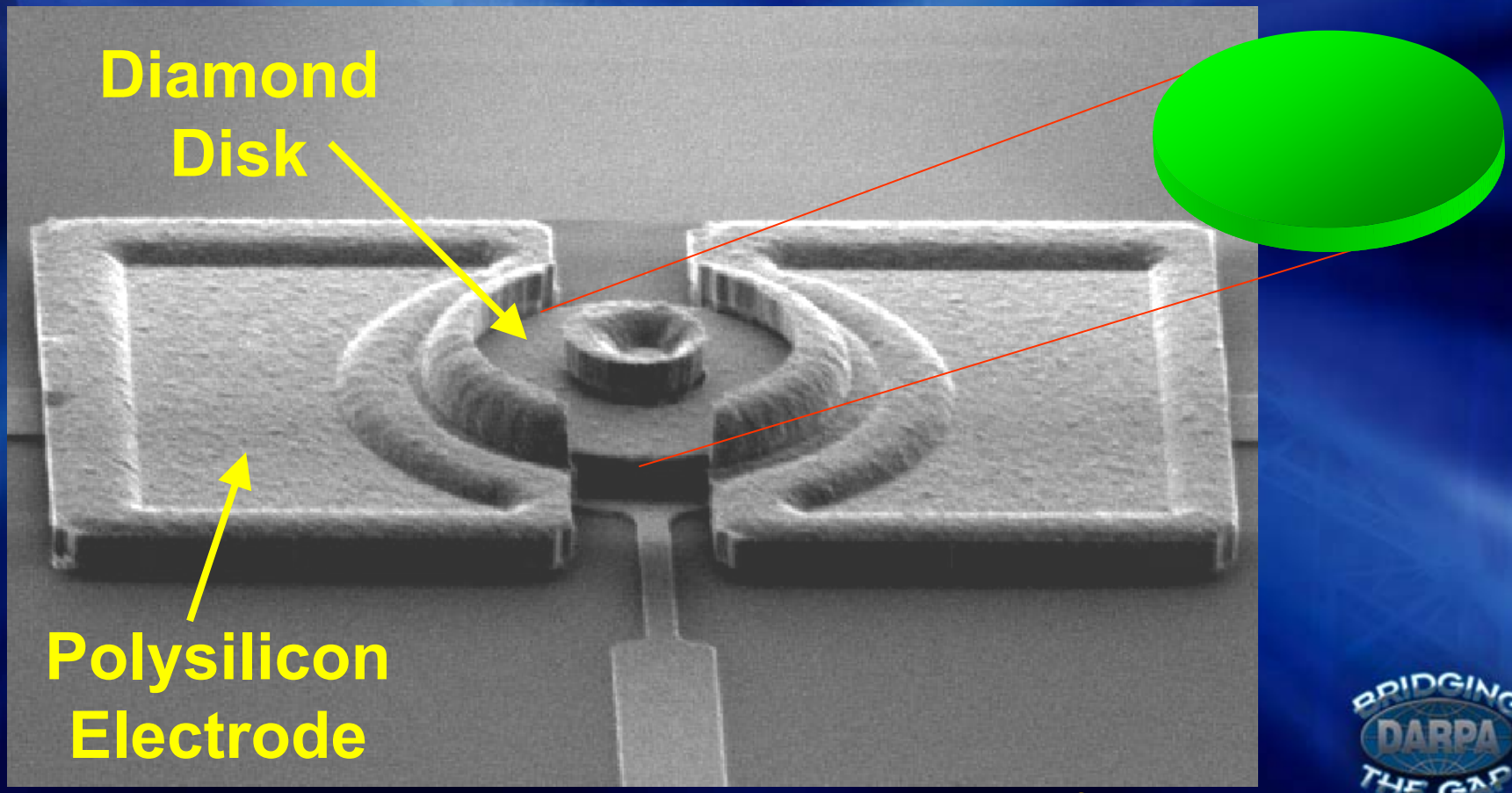
58,000X Size Reduction

Micromechanical Free-Free Beam (92 MHz)



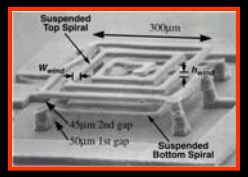
Diamond Micro-Disk Resonator

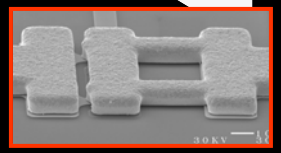
- Frequency = 1.5 GHz, Q = 11,555



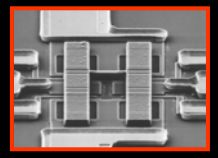
[Univ. of Michigan]

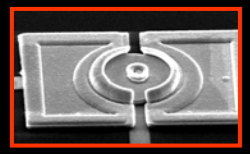
Change In Communication Architecture?





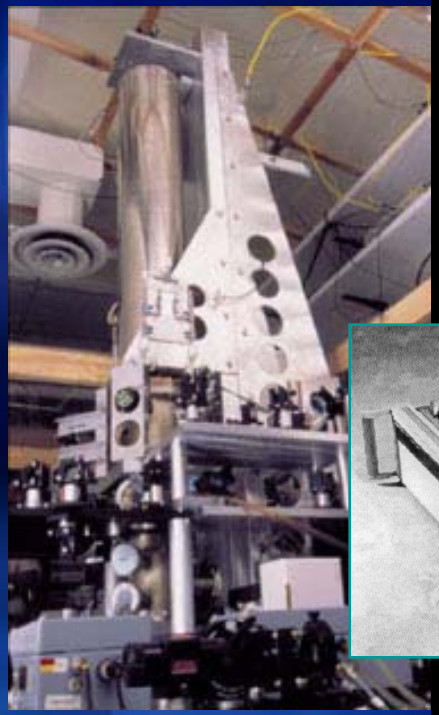
MEMS Technology





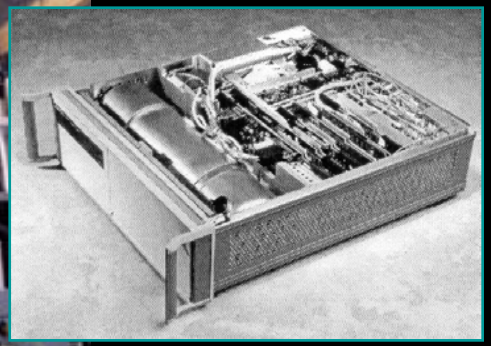
Single-Chip Transceiver

Chip-Scale Atomic Clock (CSAC)



NIST- F1

Vol: ~3.7 m^3
Power: ~500 W
Acc: 3.8×10^{-15}

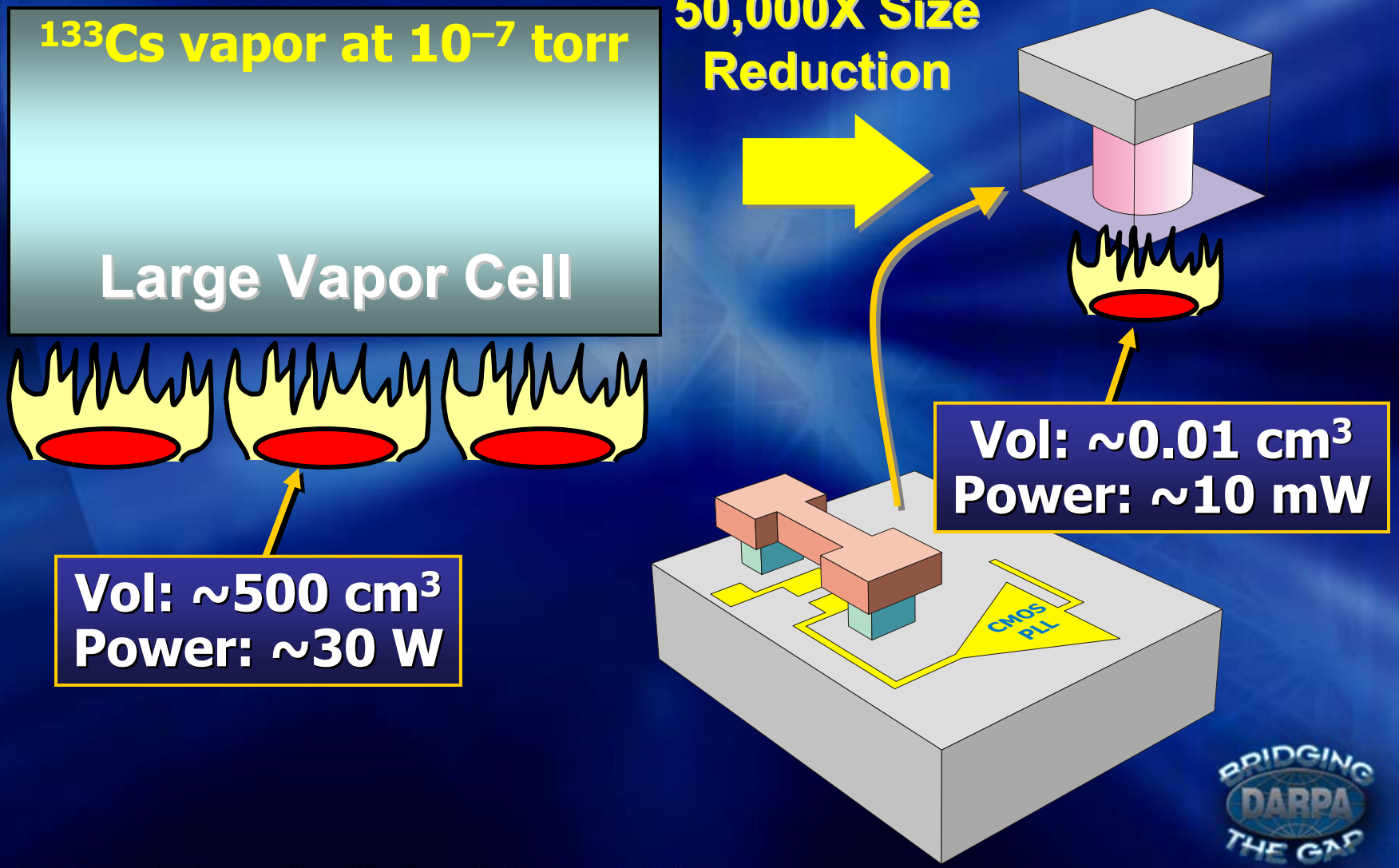


HP 5071A

CSAC

Vol: 1 cm^3
Power: 30 mW
Acc: 1×10^{-11}

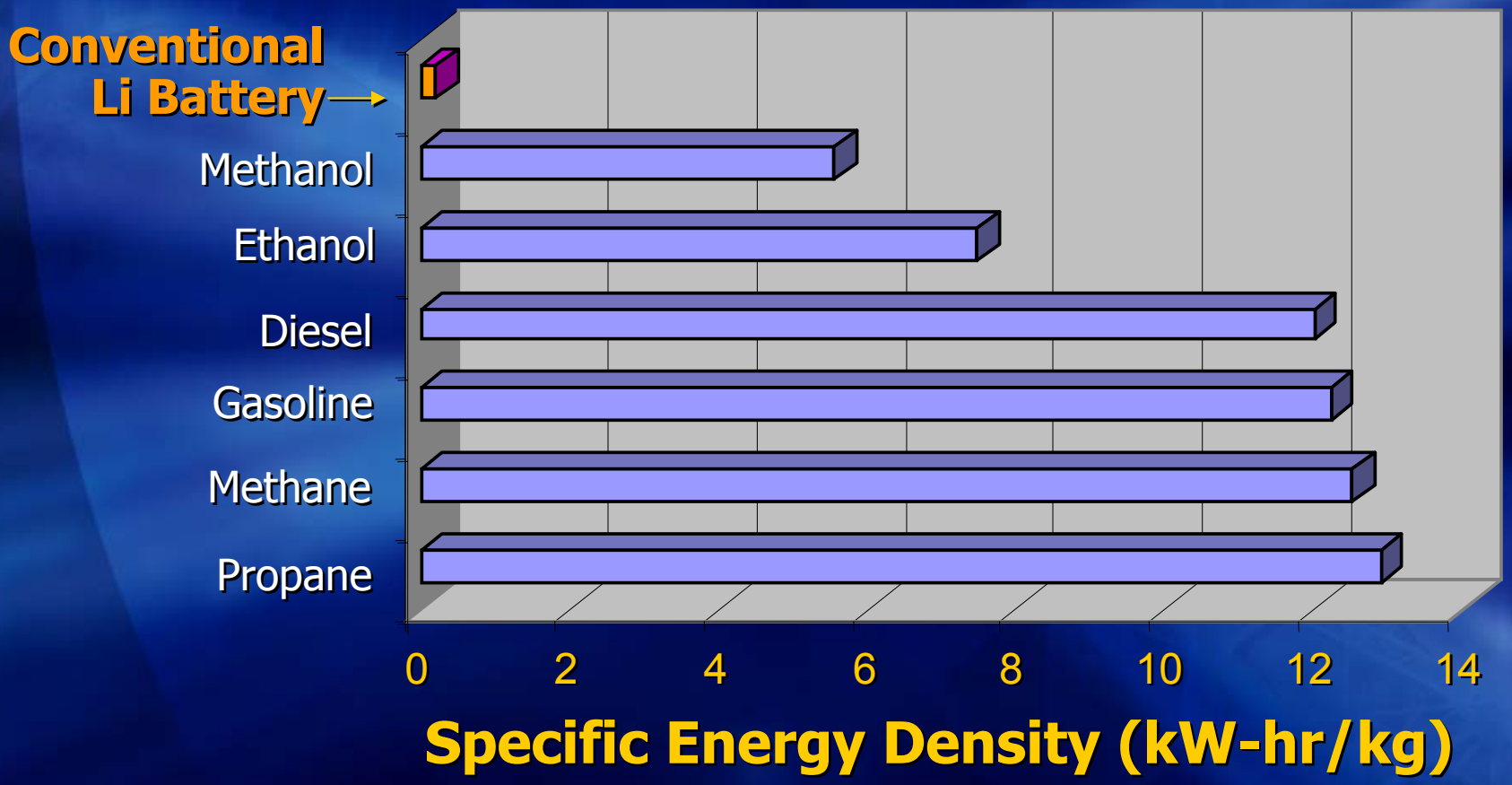
Size Versus Power



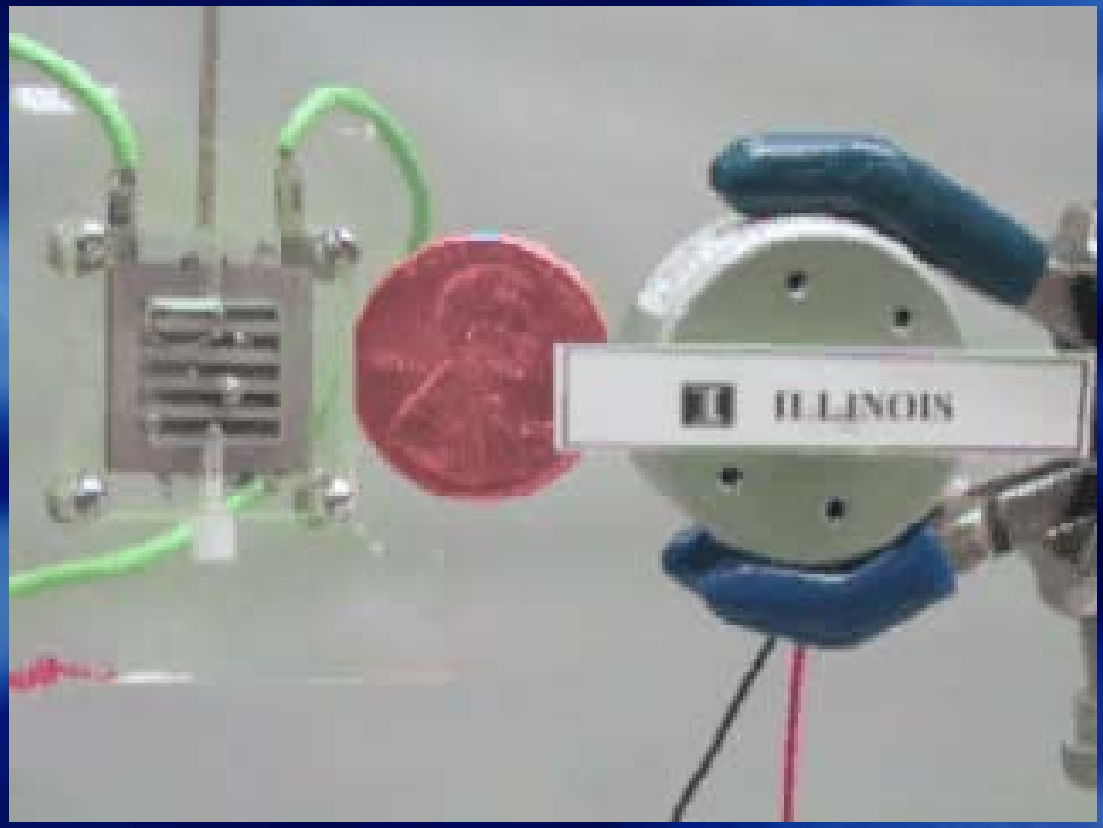
CSAC-Enabled Enhancements

GPS Free

Micro Power Generation



Formic Acid Fuel Cell →



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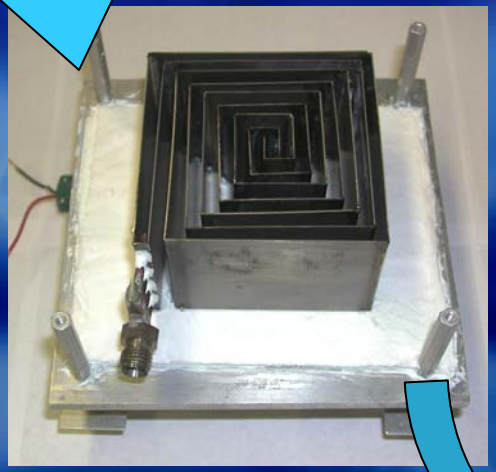
Solid Oxide Micro Fuel Cell

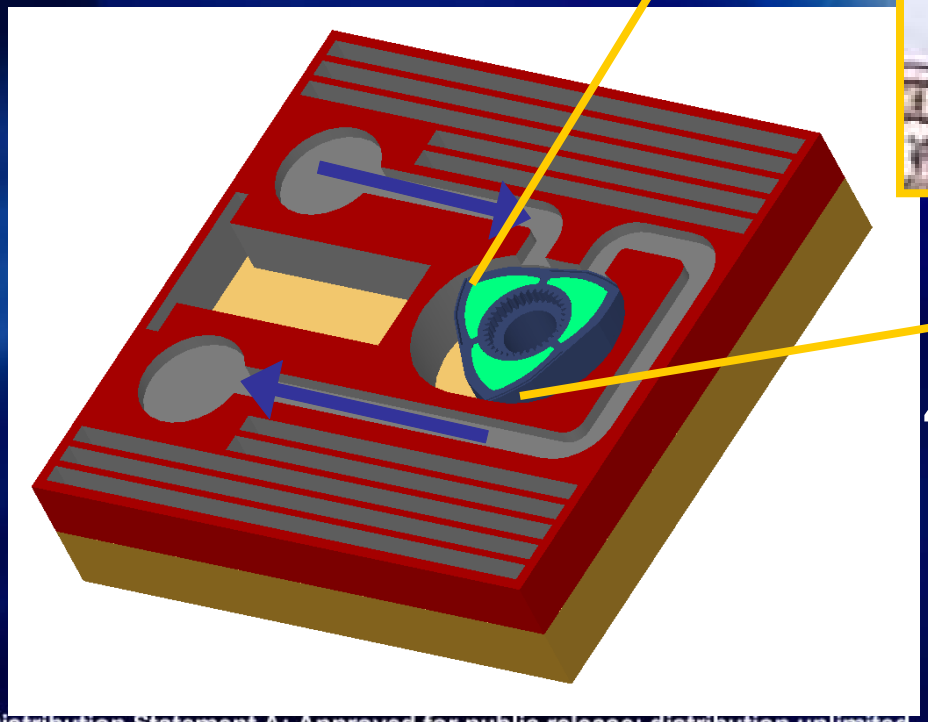
~ 1 cm



~ 8 cm

0.7 cm

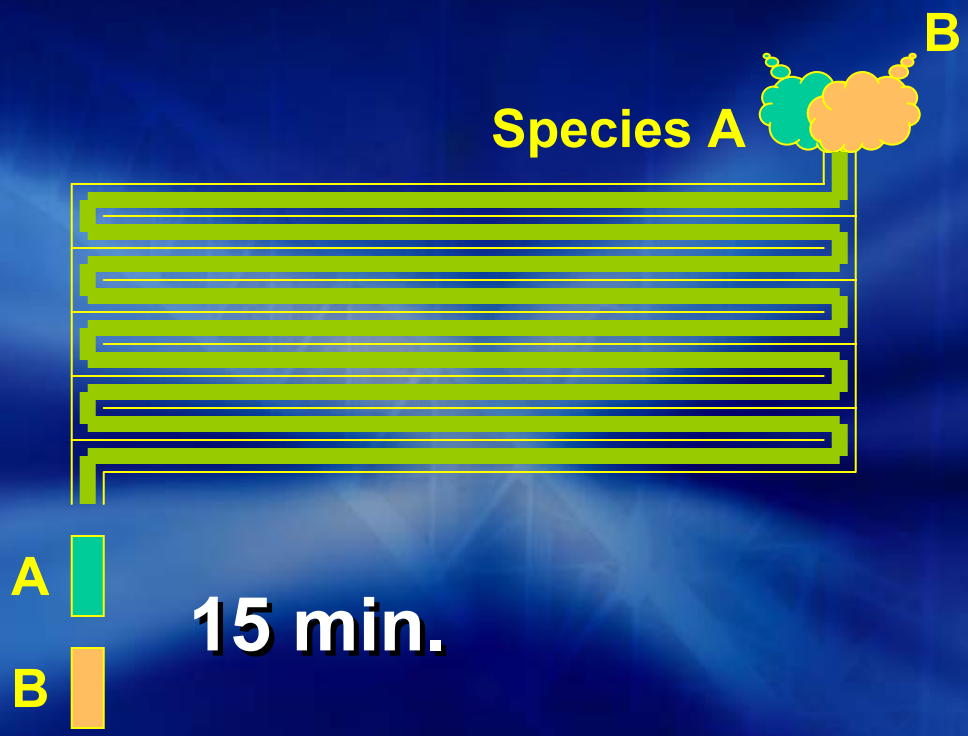
Miniature Wankel Engine



[UC Berkeley]

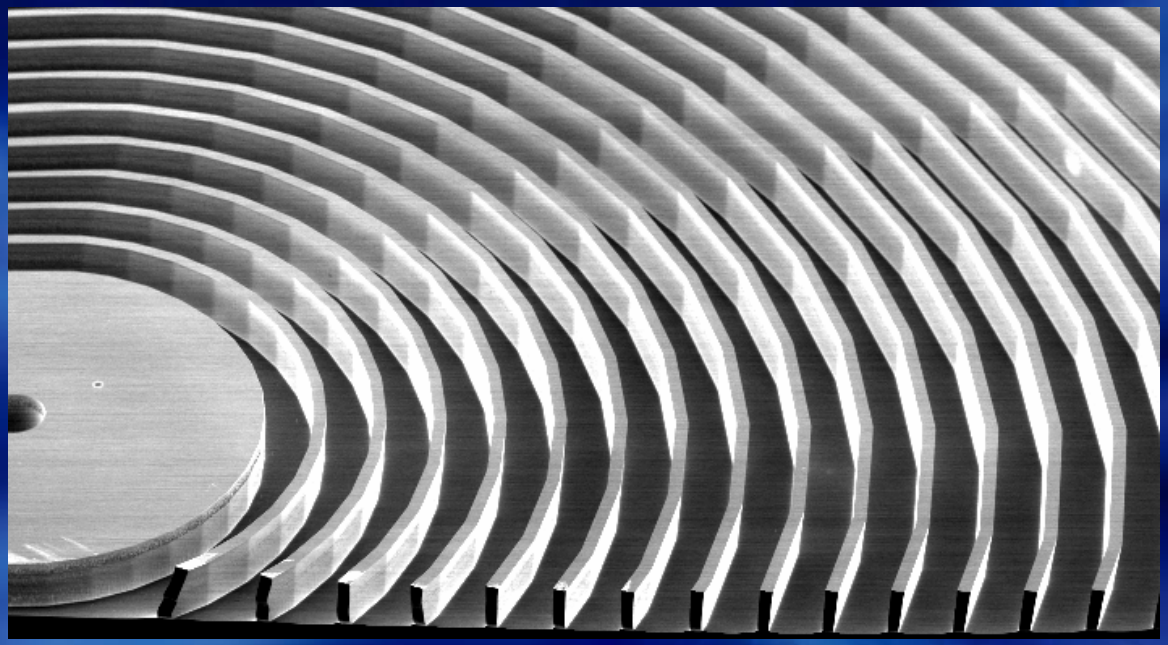
4 watts of power output

Micro Gas Analyzers



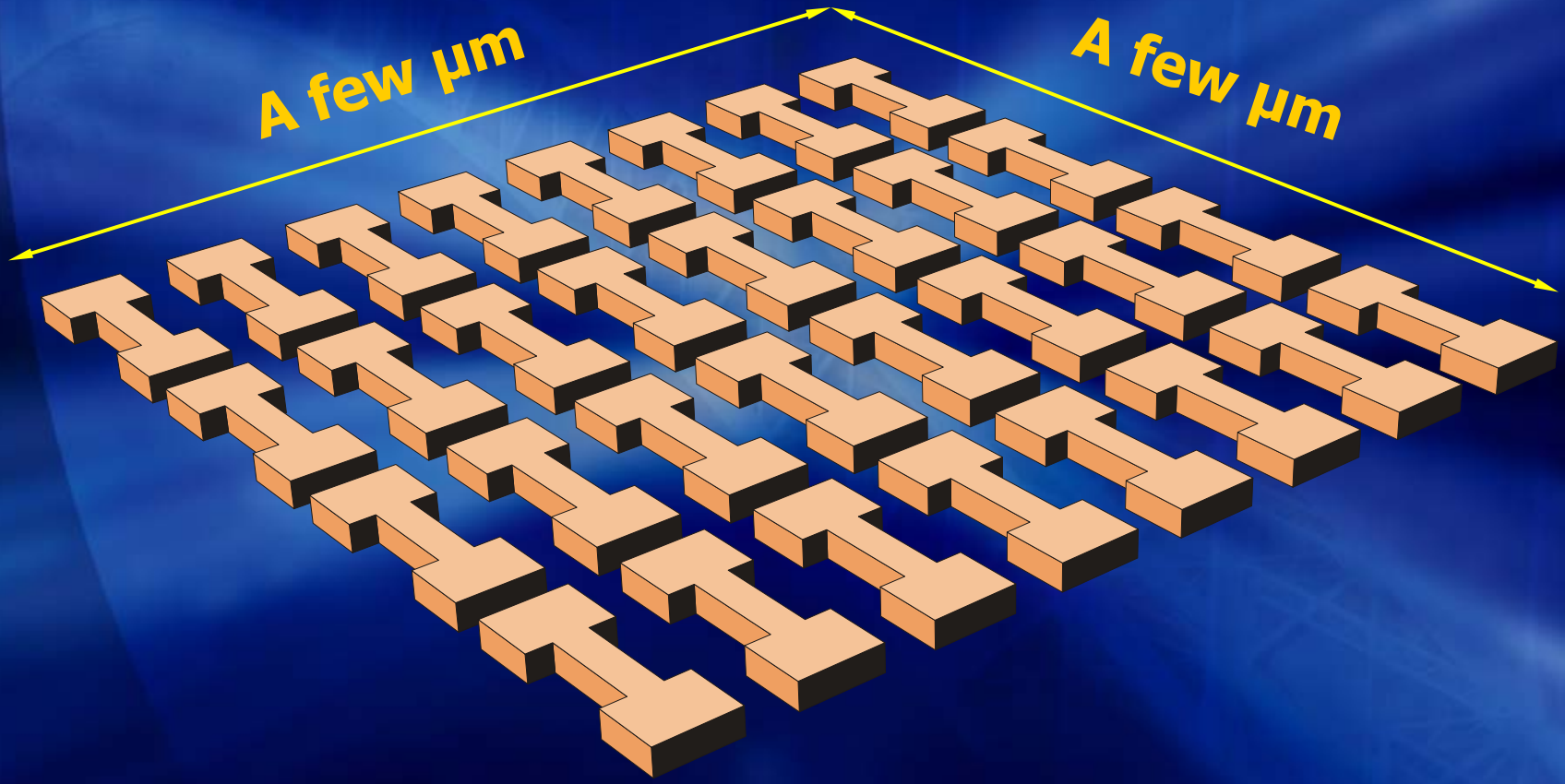
Separation Analyzer

Micro Gas Analyzers



separation time < 4 sec

Micromechanical Circuit



Nanomechanical Resonator

Frequency: 1.029 GHz