SAND2006-6801C

Sandia MEMS + Nano

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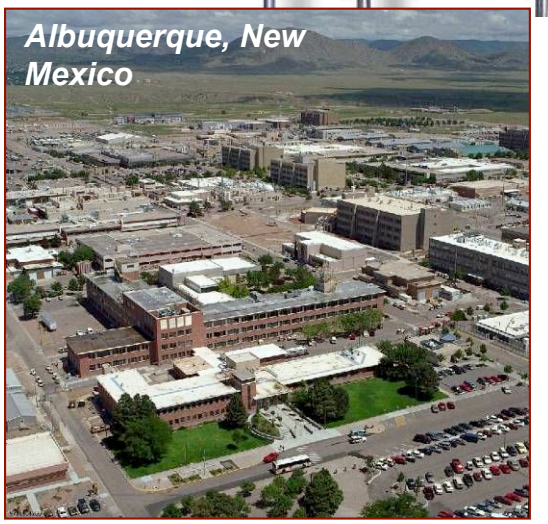
Albuquerque, NM 87185-1315

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy under contract DE-AC04-94AL85000.

Sandia
National
Laboratories

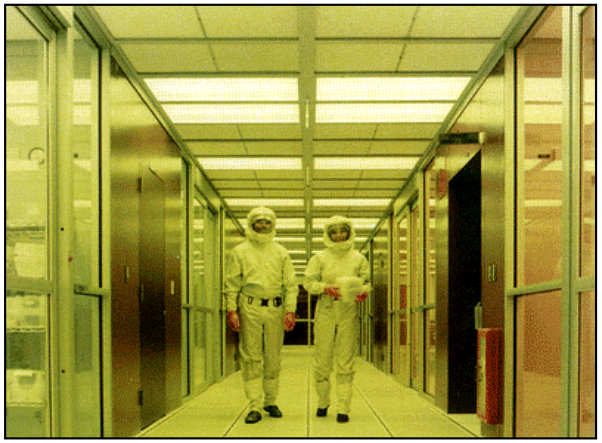
Sandia National Laboratories

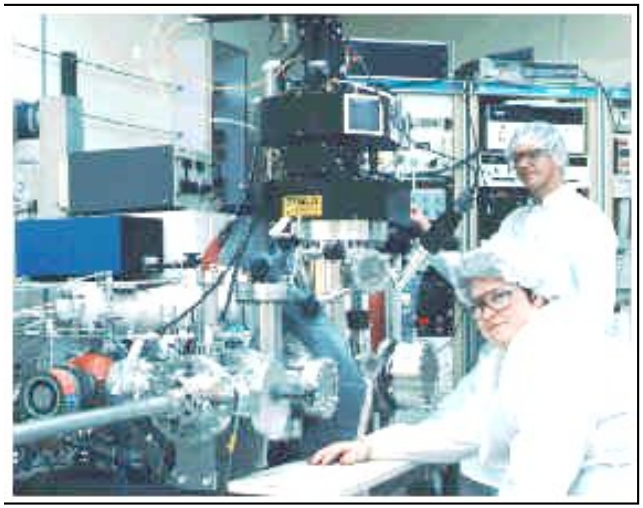

Albuquerque, New Mexico

- Founded in 1949
- Major sites: Albuquerque, NM & Livermore, CA
- 2.5 B$ Budget in 2005
- Managed by Lockheed Martin for US NNSA
- 8,500 Employees with 1,500 PhDs
- Missions
  - Nuclear Weapons
  - Defense Systems and Assessments
  - Energy, Resources and Nonproliferation
  - Homeland Security
  - Science, Technology & Engineering

Sandia National Laboratories

Sandia's Microsystems Activities





- Research-to-Development-to-Application in all areas of microsystems
- Major microelectronic & microsystem facilities
- Most advanced microelectronics and microsystems capability within the government
- Goal is to provide a differentiating strength to Sandia's national security business areas

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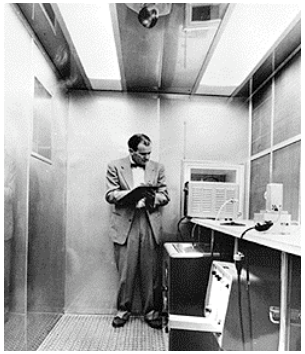
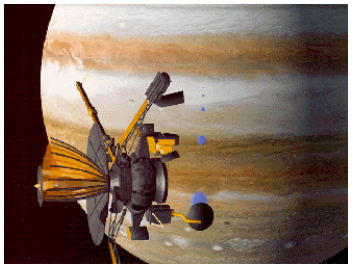
Sandia Has a Long History In Microelectronics and Microsystems

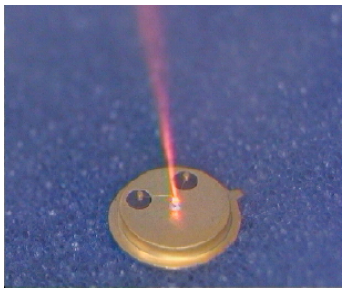
Laminar Flow Clean Room



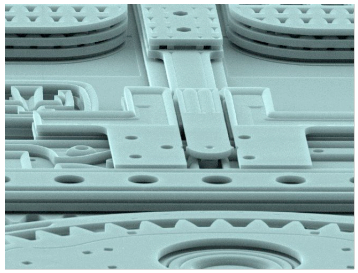
Design/Build Galileo ICs



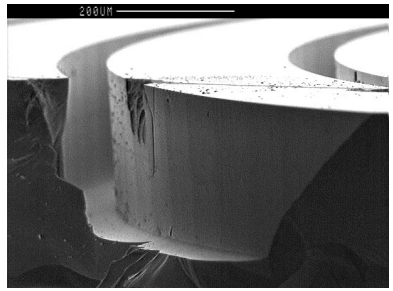
High Efficiency VCSEL

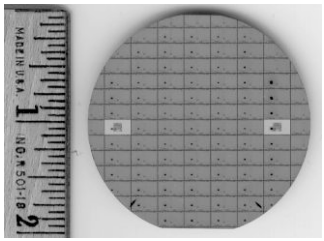


5-Level Surface Micromachining

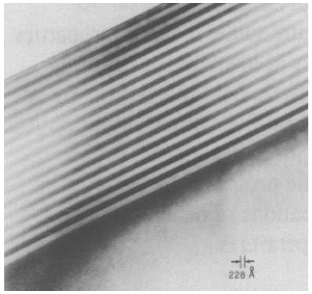


Chem Lab on a Chip

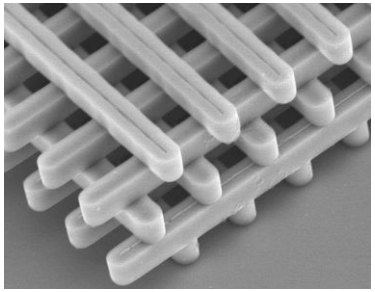




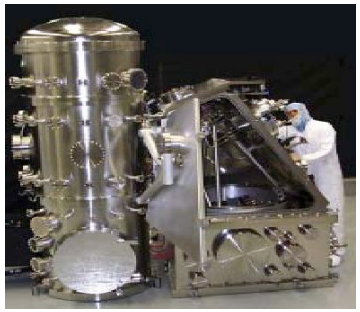
Radiation Hardened CMOS



Strained-layer Superlatices



Photonic Lattice



Extreme Ultra Violet Lithography

3-D Microsystems Integration

1960s **2000s**

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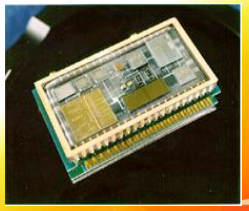
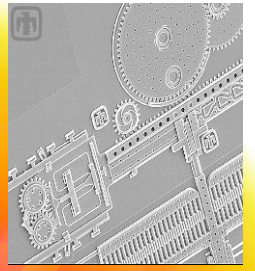
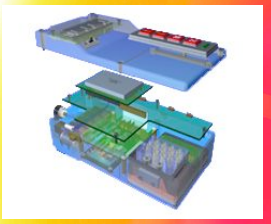
The Fusion of Microsystems and Engineering Science Spawns New Science, New Industry, New Tools for National Security



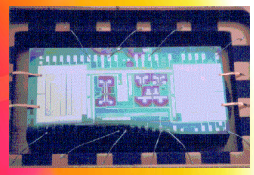
Micro-Navigator



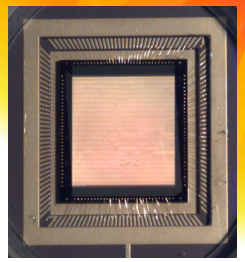
Micro-Lock



μChemLab

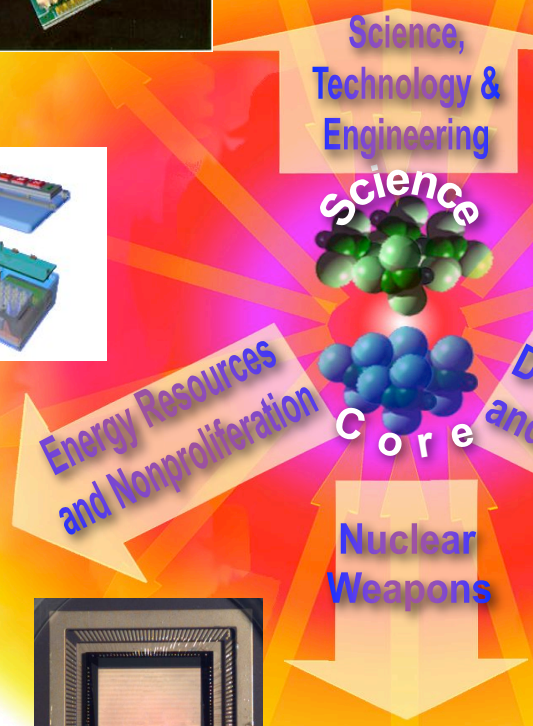


Integrated Chemical Sensor



Micromachined Diffraction Grating

Micro-Robot



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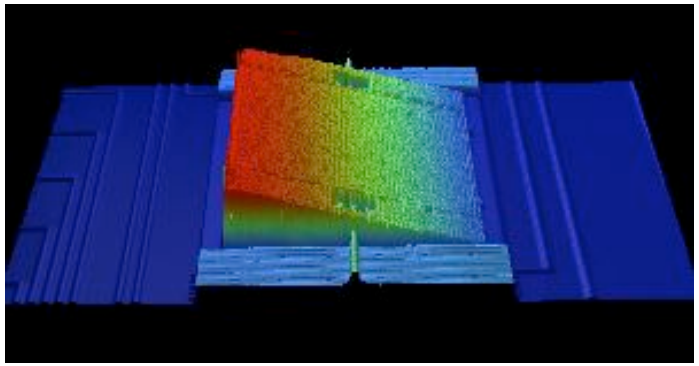
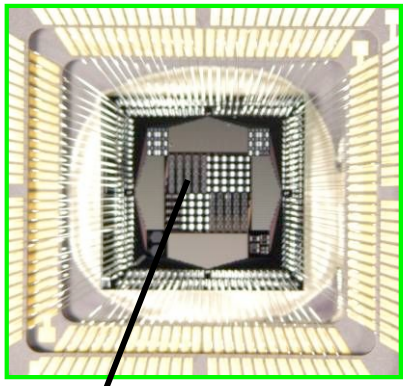
Sandia Beamformer Technologies

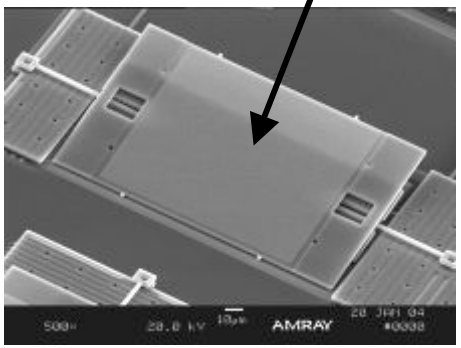
- MEMS enabled free space optical implementation of long delays offers highest payoff
  - Most hardware compressive
  - Optical paths share same volume
  - <6dB for 10-bit dc-20GHz, 0.3-30ns
- Demonstrated performance
  - ~ 20 ms switching
  - Tilt angle ±10°
  - 10^9 cycles without failure on packaged arrays





10x10 White Cell Mirror Array

SEM of Mirror Element



Delivered Hardware

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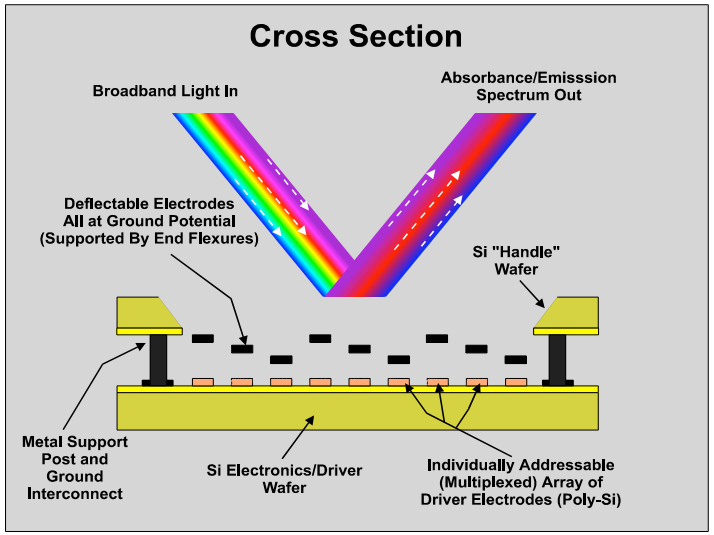
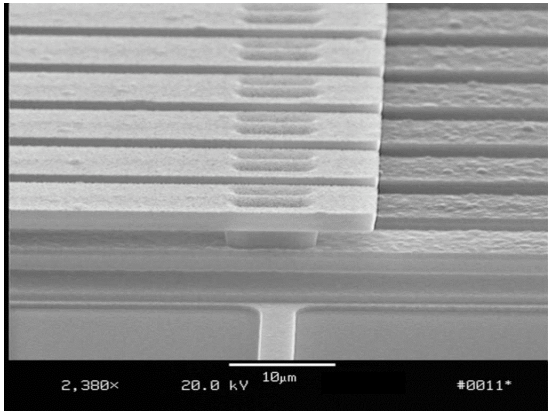
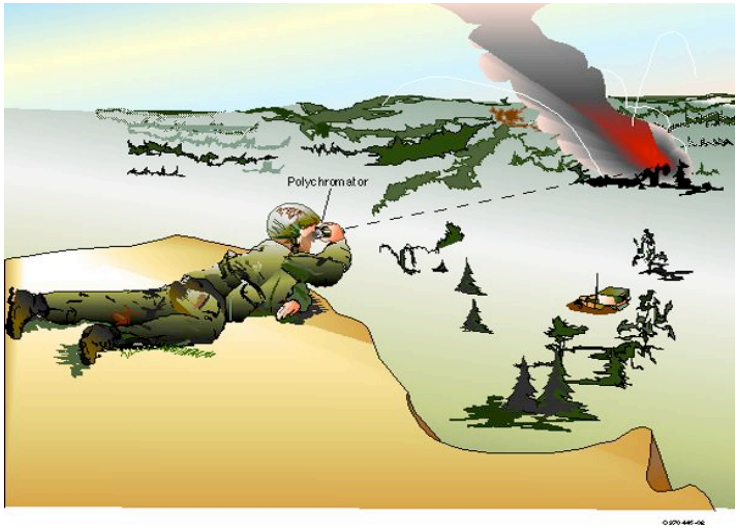
Polychromator for Remote Chemical Detection





Micromachined Diffraction Grating

- **Optical correlation spectrometer identifies spectral components**
- **Reference spectrum generated by an aperiodic diffraction grating**
- **Generate arbitrary reference spectra using electrically adjustable diffractors**



Our Vision: Remote Chemical Sensing in a Hand-Held Package

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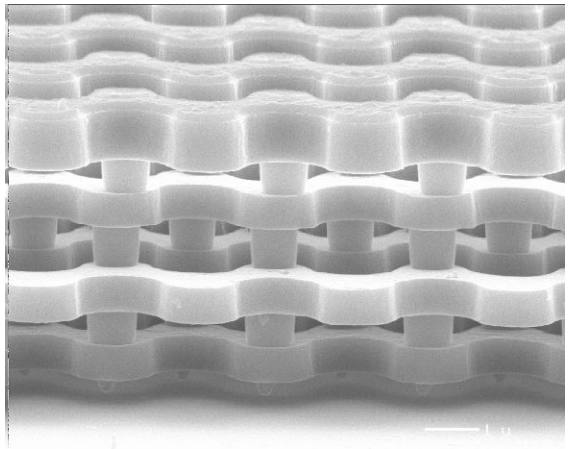
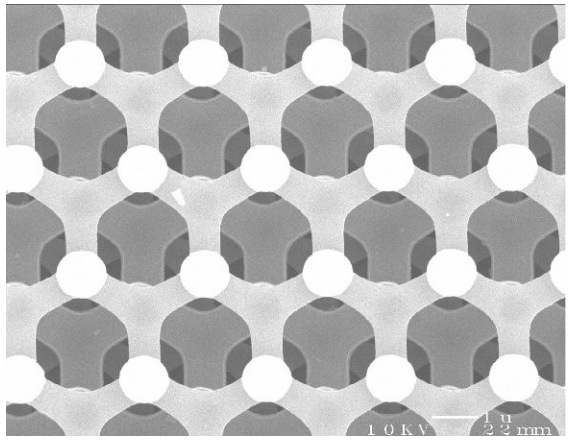
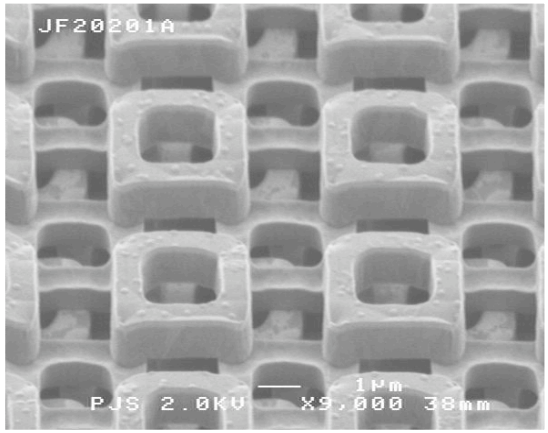
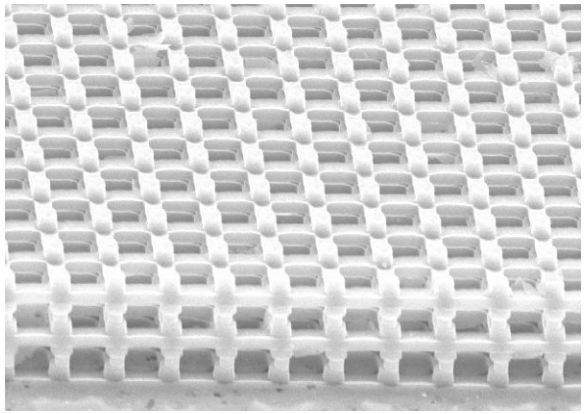
Sandia Photonic Lattice Structures

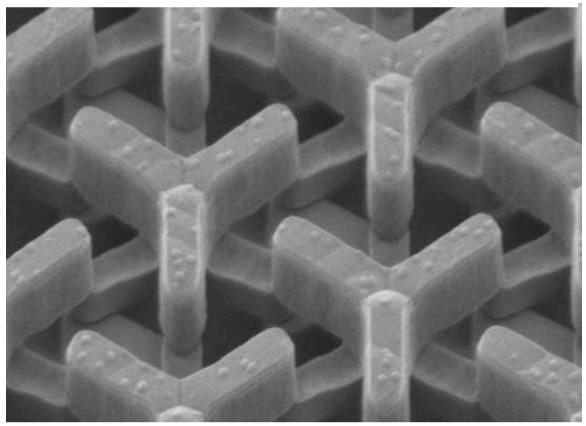
- **Sandia's unique silicon semiconductor based microsystem fabrication enables a wide range of photonic bandgap structures**

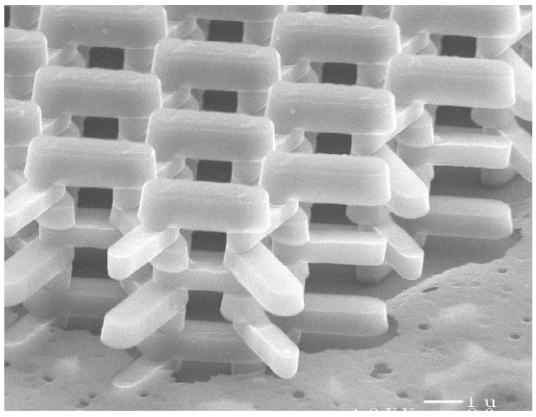












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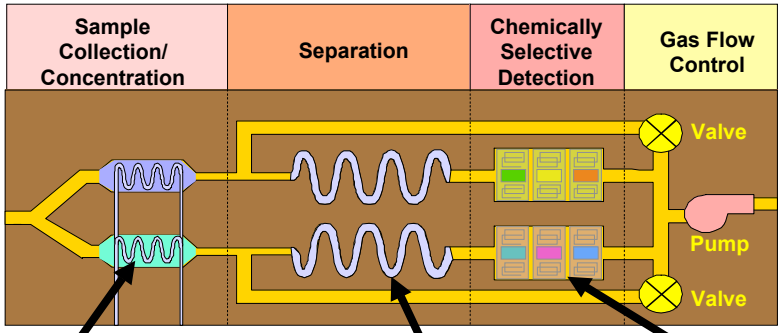
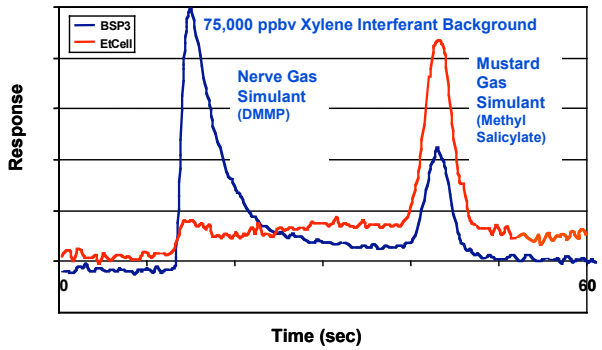
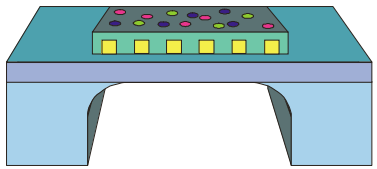
Gas-Phase *μChemLab*™

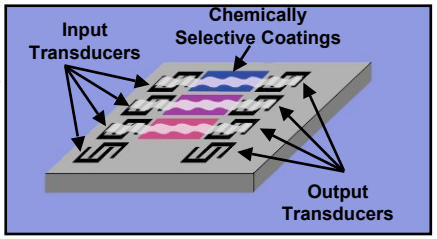
Hand-held chemical analysis system that uses three microfabricated stages.

- 8”x4”x2”
- 2 min. analysis
- 4W max. power

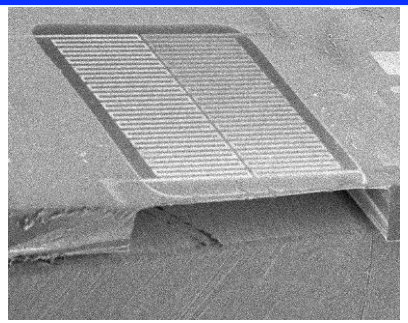




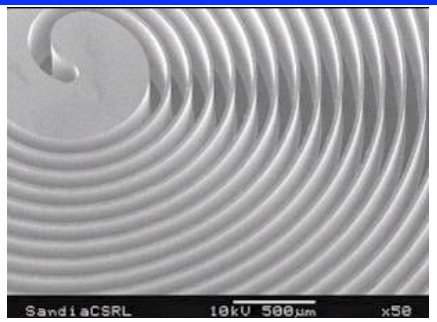




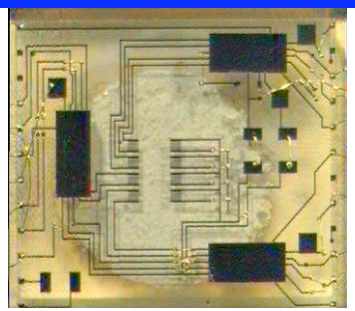
Preconcentrator accumulates species of interest



Gas Chromatograph separates species in time



Acoustic Sensors provide sensitive detection



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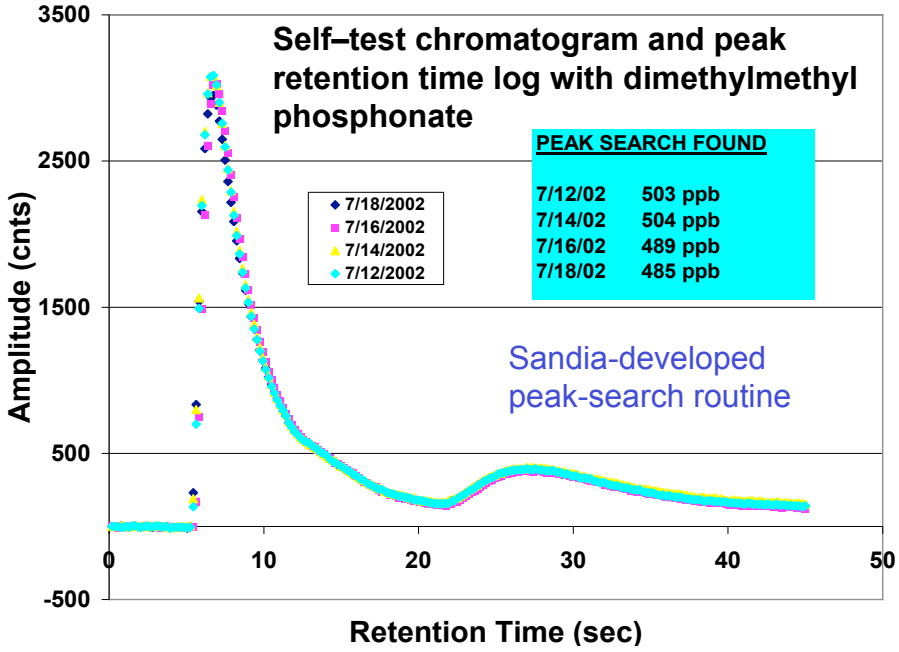
µChemLab™ Systems Installed In Test Beds – Airports & Subways

- Improved temperature control
- Durable pumps
- Gas chromatograph for false positive reduction
- Flexible method development
- Test results show analyses are very stable



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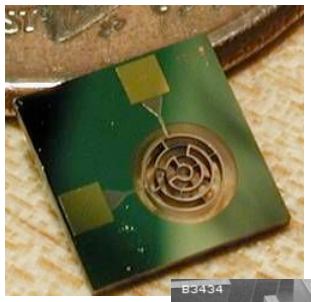
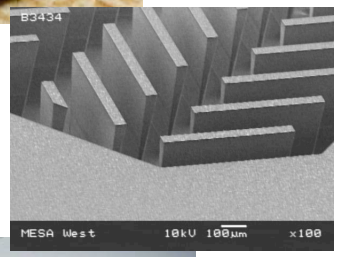
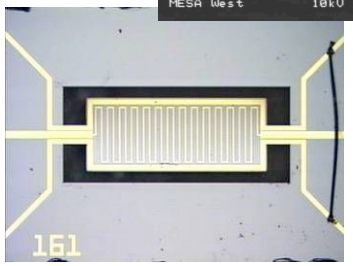
Next-Generation Systems

Preconcentration

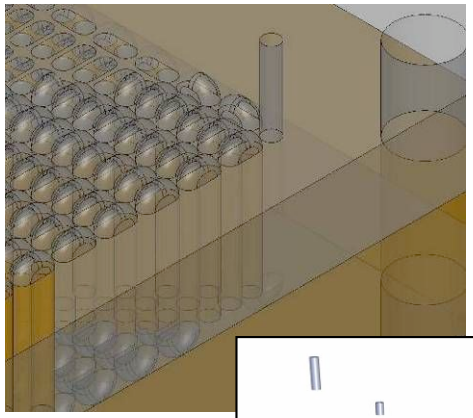


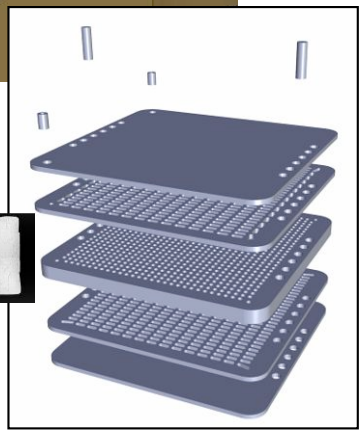




- New, higher surface area preconcentrators for more efficient collection
- "Smart" preconcentrator weighs sample collected

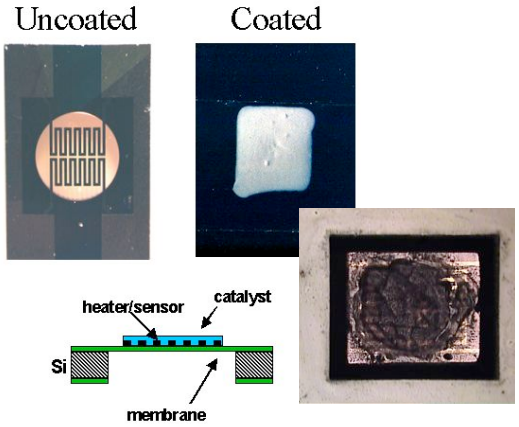
Separation

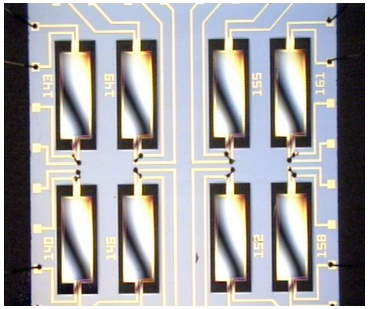




- New nickel chromatography columns formed using LIGA processing

Detection





- Micro nitrogen-phosphorous detector detects compounds with N and P with 1000X greater sensitivity over hydrocarbons

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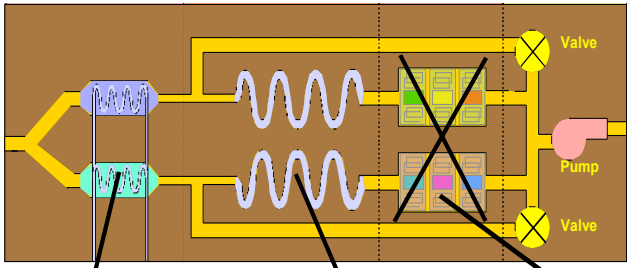
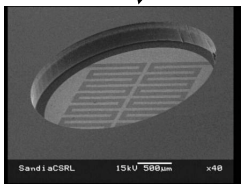
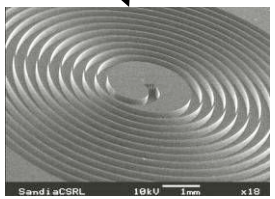
Towards a Micro-Gas Chromatograph & Micro-Mass Spectrometer System

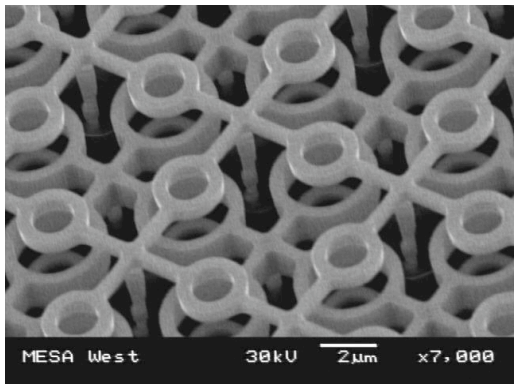




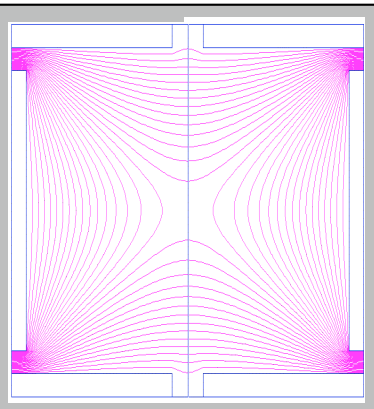
micro-hotplate preconcentrator



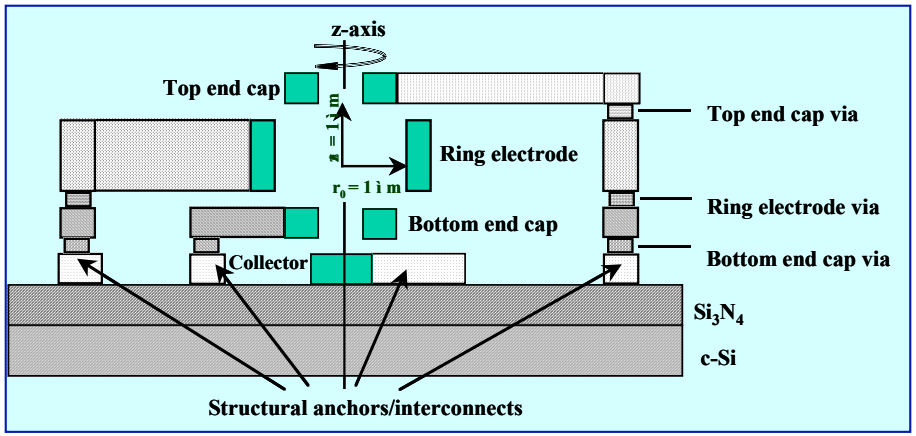
micro-gas chromatograph

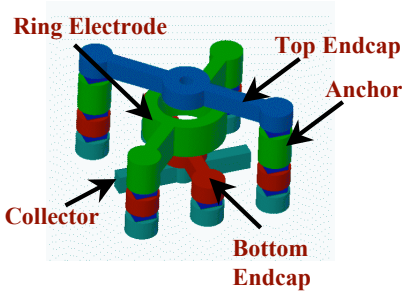


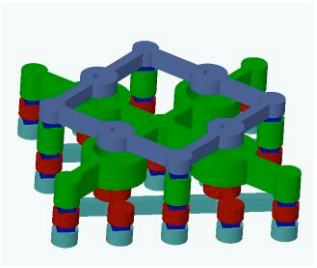
micro-cylindrical ion trap arrays



Equipotential contours in the cylindrical ion trap







Ion Trap Array

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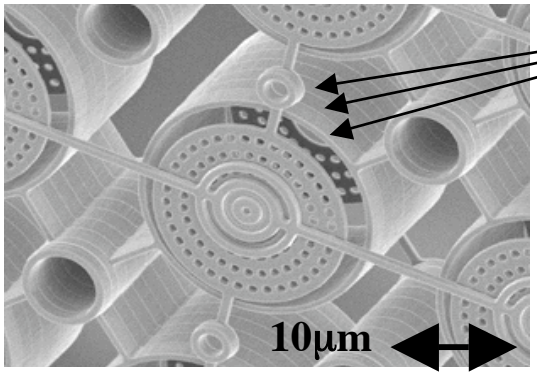
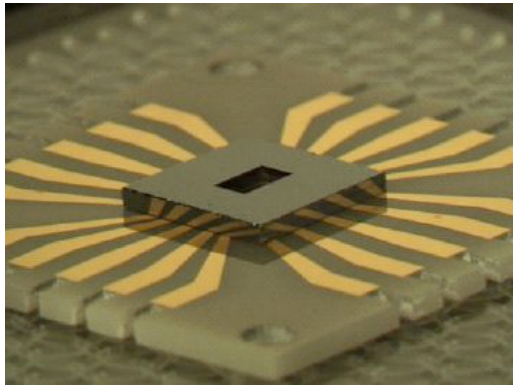
Ion Trap Chips for Quantum Computing

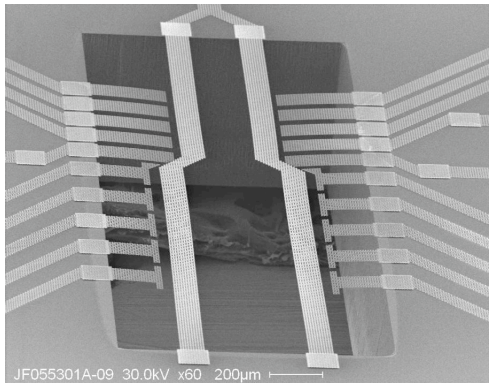


Portion of Array of 1,000,000 Cylindrical Ion Traps



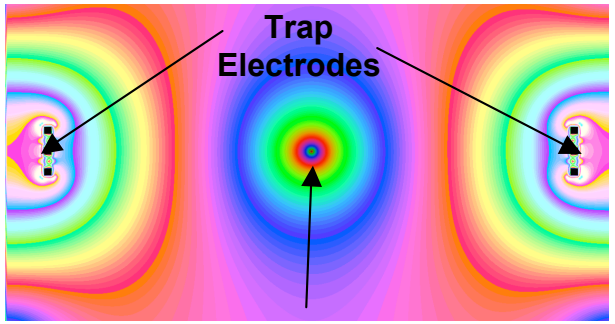
Ion Trap Chip Packaged with AIN Carrier

Differentiating Technology – All tungsten layer-by-layer processing developed at the MDL



Segmented Linear Traps of Two Sizes With Thru Chip Optical Access

Simulated Trap Performance



Enabling Capability – Multiphysics modeling of trap performance for design optimization.

Breakthrough Result – **Sandia has the only scalable, 3-D monolithic approach to fabricating an ion trap based quantum computer with a useful size**

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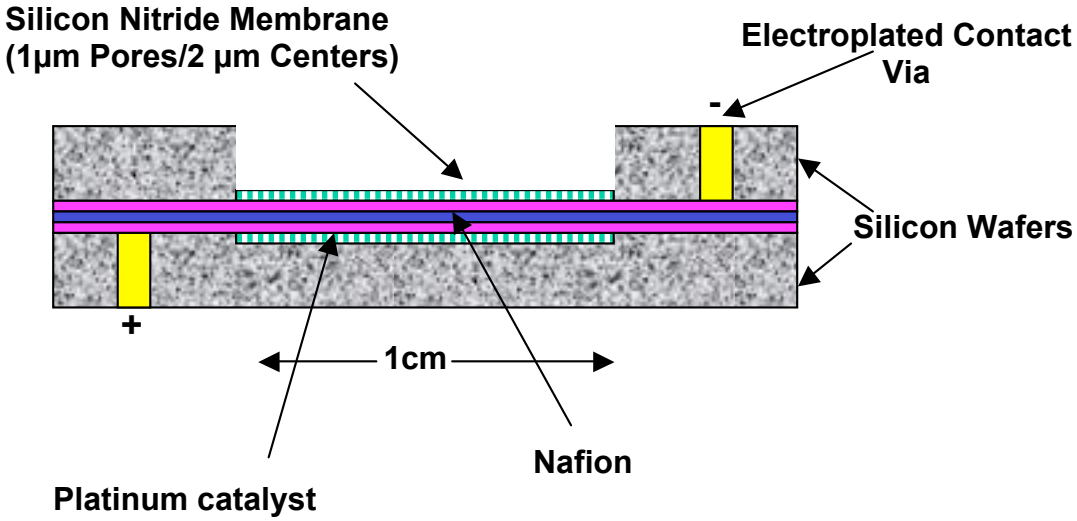
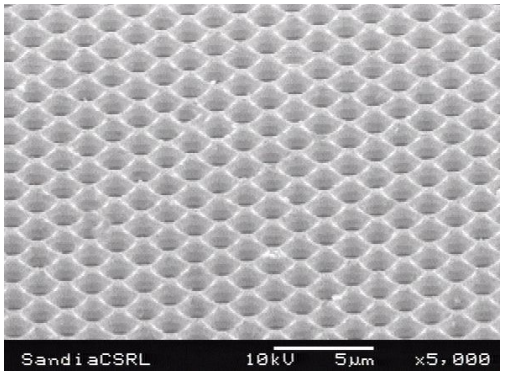
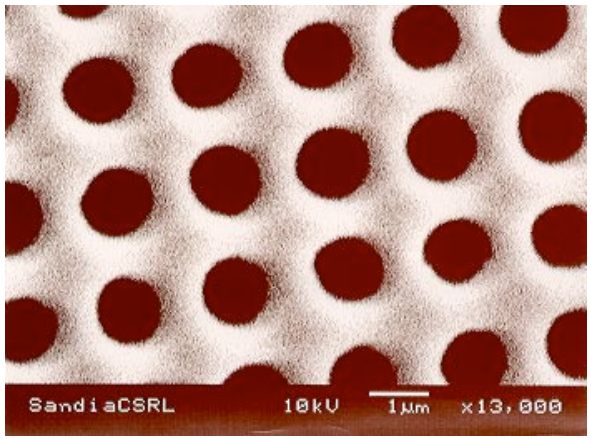
Micro Fuel Cell Technology



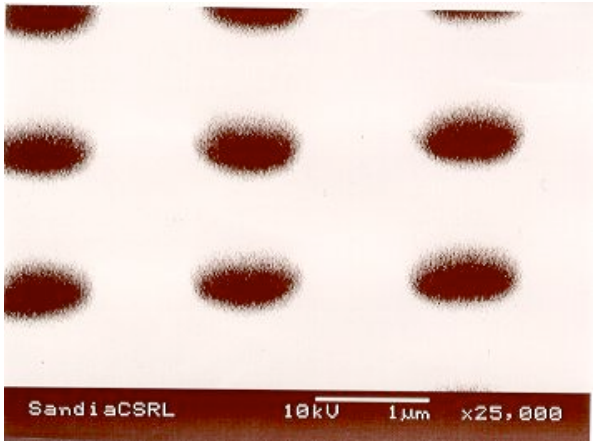
Silicon Nitride Membrane with 1 µm Pores and Gold Coating



Lithographically Defined 1 µm Pores on a 1µm Thick, 1cm² Silicon Nitride Membrane



Plan view of 1 µm pores



View of pores at approx. 45 deg angle

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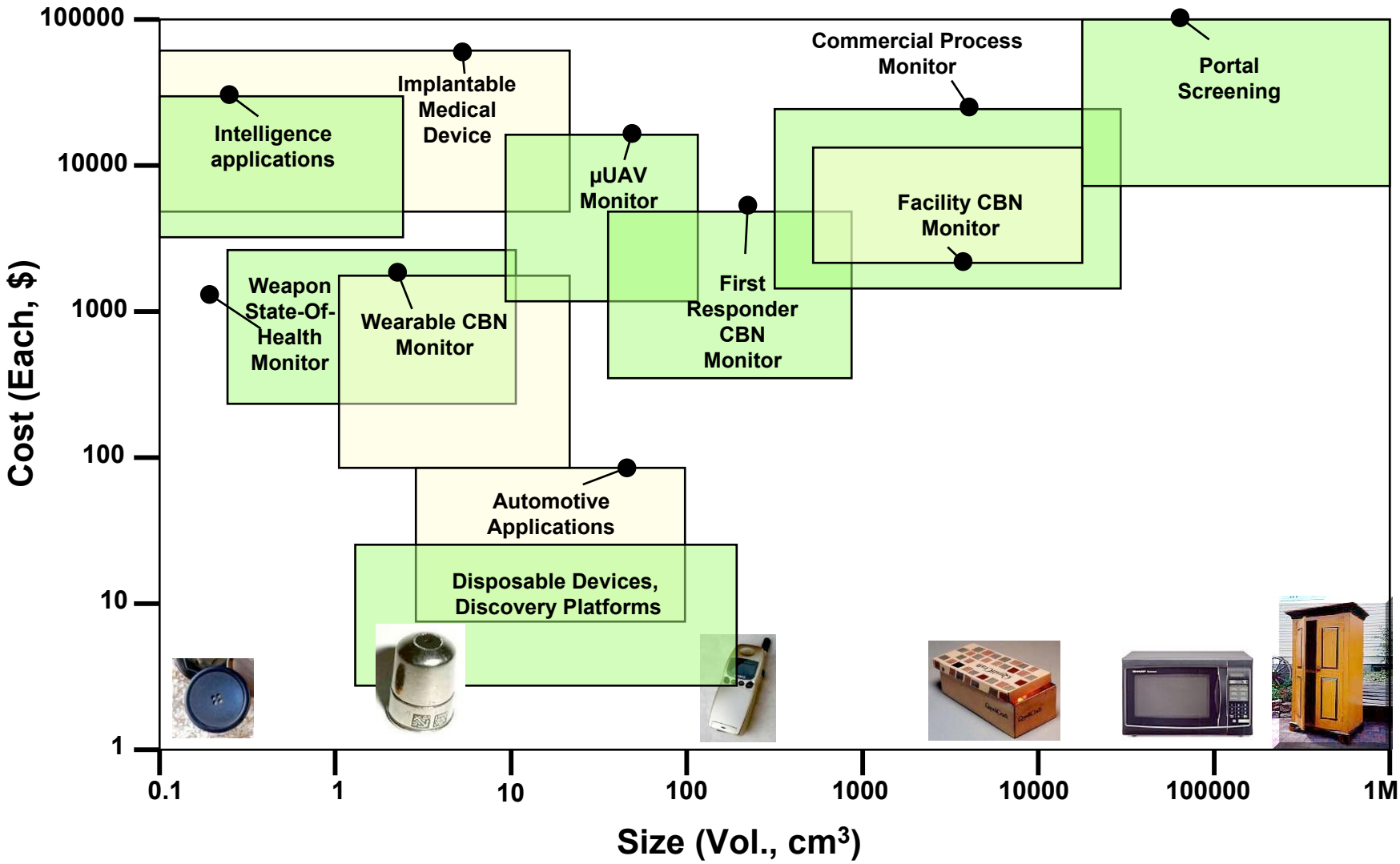
Opportunities for Microsystems

"There's plenty of room at the bottom"—R. Feynman



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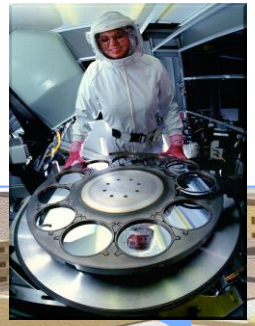
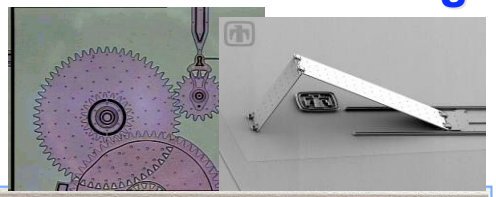
MESA Provides Top Facilities and Equipment For Microsystems Design, Fabrication and Test

$400M including > 50% equipment and cleanrooms

Microfabrication

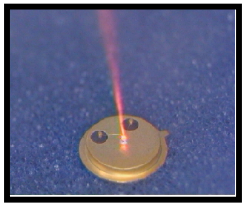


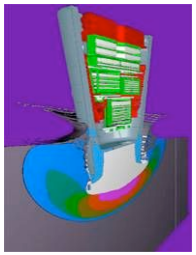
Si Micromachining



Photonics

III-V Semiconductors

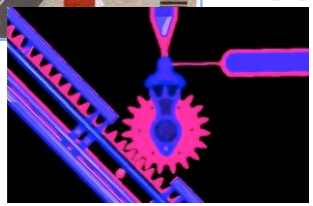




Adv. Computation

Nanotechnology

3-D design, modeling/simul



Packaging and Qualification

650 people
380,000 sq ft

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Partnering is essential to our success

- **Microsystems Center has been actively engaged with the external community**
- **R&D Partnerships**
- **MESA Institute**
- **Micro-Nano coupling with the DOE Center for Integrated Nanotechnologies (CINT)**
- **Samples Program**
  - Access to advanced surface micromachining
  - University licensing of MEMS course material and design tools

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