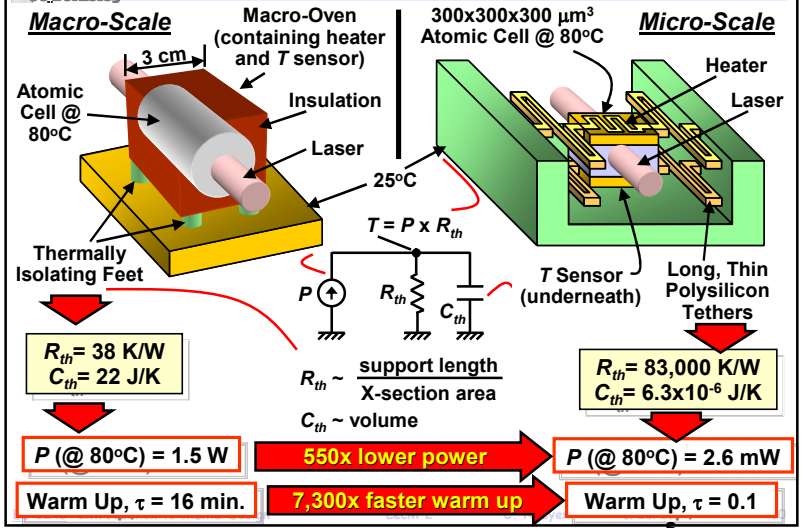
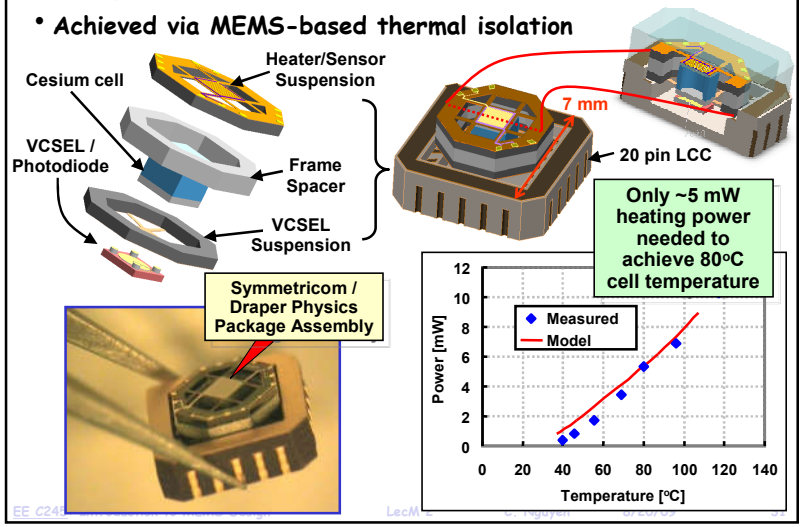
Micro-Scale Oven-Control Advantages



Physics Package Power Diss. < 10 mW

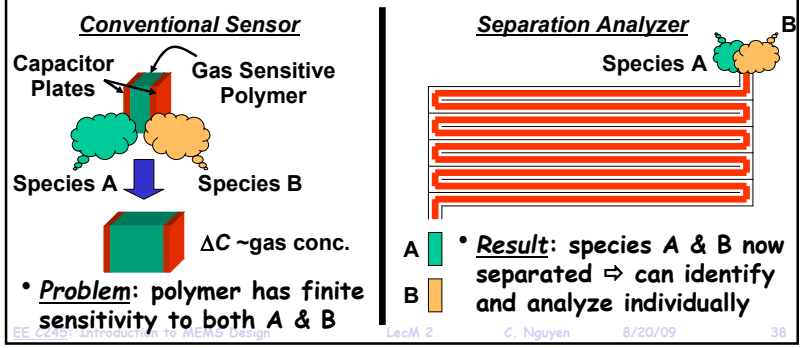
- Achieved via MEMS-based thermal isolation



Micro Gas Analyzers (MGA)

Micro Gas Analyzers

- *Objective*: enable remote detection of chemical agents via tiny, ultra-low power, fast, chip-scale gas analyzers that greatly reduce the incidence of false positives
- *Approach*: use micromachining technologies to implement separation-based analyzers (e.g., gas chromatographs, mass spectrometers) at the micro-scale to enhance gas selectivity



- *Problem*: polymer has finite sensitivity to both A & B
- *Result*: species A & B now separated ⇨ can identify and analyze individually

Advantages of Miniaturization

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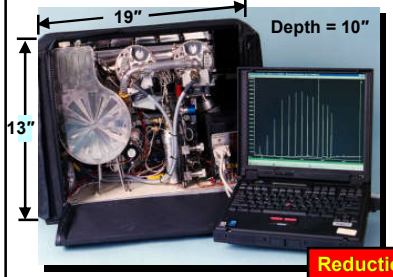
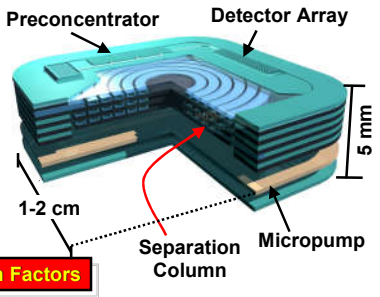
Portable Gas Chromatograph



Chip-Scale Gas Chromatograph



		Reduction Factors		
Size	40,500 cm^3	20,000X	Size	2 cm^3
Sensitivity	1 ppb	1,000X	Sensitivity	1 ppt
Analysis Time	15 min.	225X	Analysis Time	4 sec
Energy Per Analysis	10,000 J	10,000X	Energy Per Analysis	1 J

Basic Approach: Separation Analyzer

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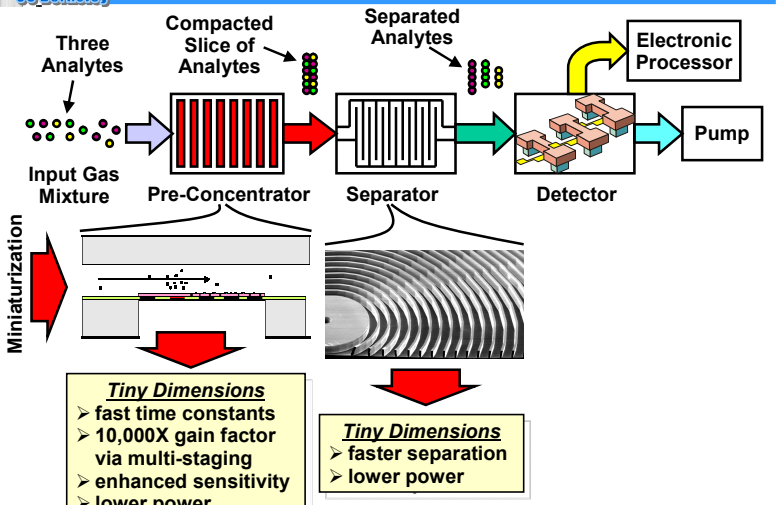

Tiny Dimensions
- fast time constants
- 10,000X gain factor via multi-staging
- enhanced sensitivity
- lower power

Tiny Dimensions
- faster separation
- lower power

Scaling Leads to Faster Separation

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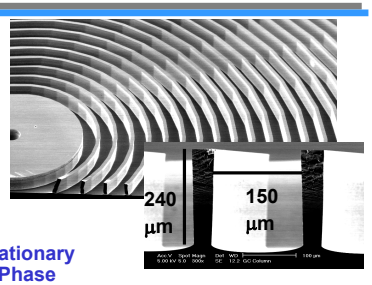
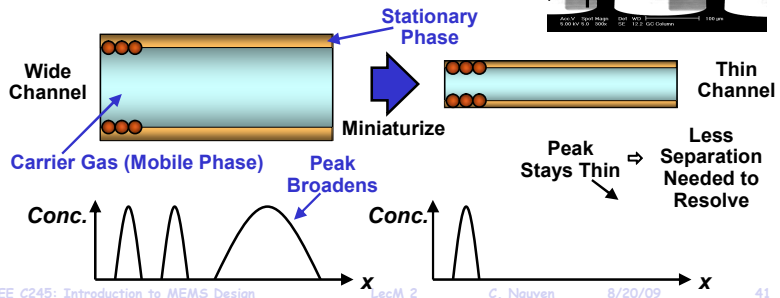
- *Example*: gas chromatograph separation column
  - unique analyte interactions with the column walls
  - different analyte velocities
  - *result*: separation after a finite distance





Scaling Leads to Faster Separation

UC Berkeley

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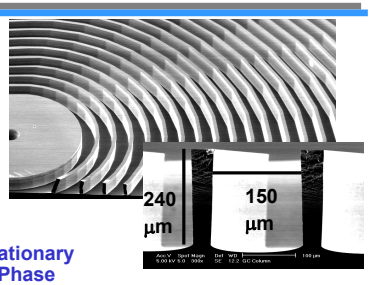

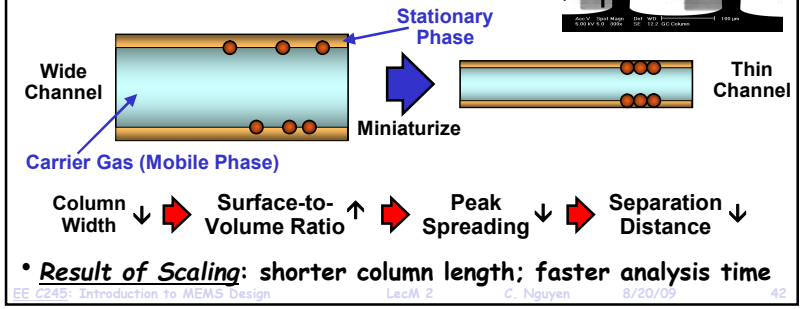

Column Width ↓ ⇒ Surface-to-Volume Ratio ↑ ⇒ Peak Spreading ↓ ⇒ Separation Distance ↓

- *Result of Scaling*: shorter column length; faster analysis time

Gas Chromatography in Less Than 4s!

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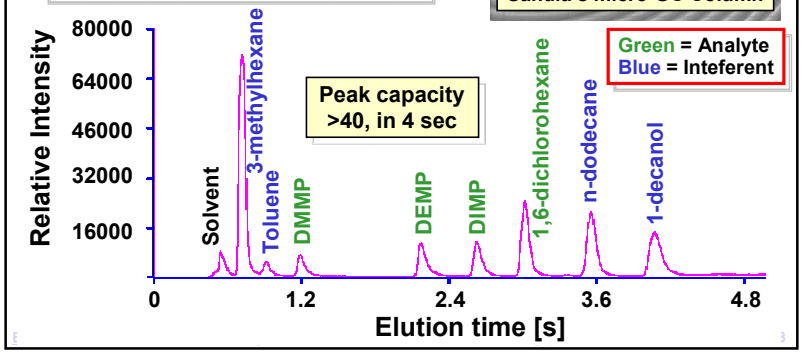
Design/Measurement Data:
0.75m x 100 μ column
0.1 μ DB-5 stationary phase
Heart-cut 275 msec peak injection
Temperature: ~30 deg C/sec
H_2 carrier: 35-39 psi at 1 psi/sec



Basic Approach: Separation Analyzer

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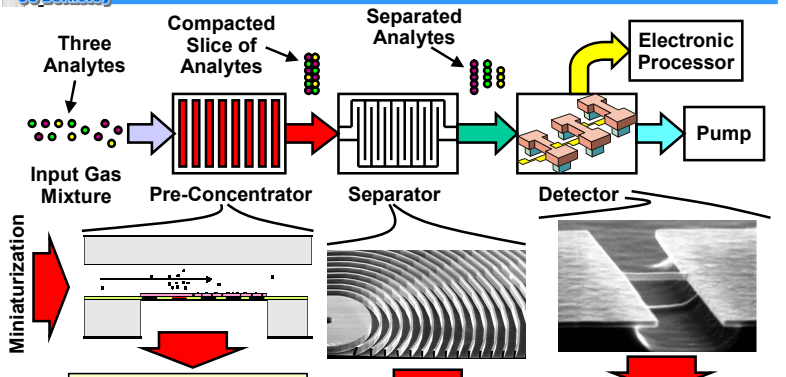

Tiny Dimensions
- fast time constants
- 10,000X gain factor via multi-staging
- enhanced sensitivity
- lower power

Tiny Dimensions
- faster separation
- lower power

Tiny Dimensions
- higher sensitivity
- faster refresh rate
- lower power
- arrays for specificity

Zeptogram Mass Sensors

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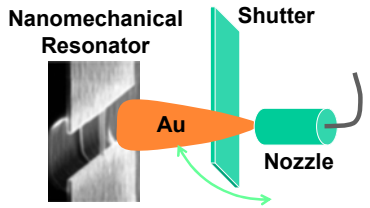
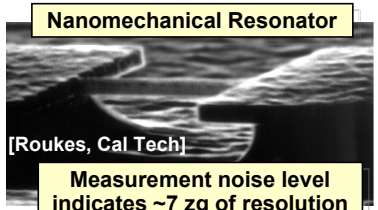
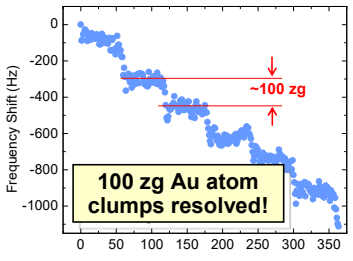
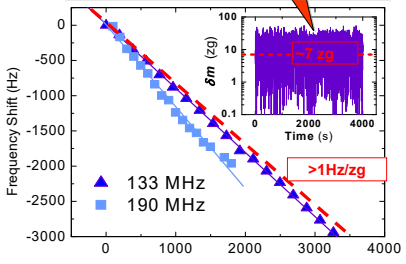




Measurement noise level indicates ~7 zg of resolution





Gas Analyzer Technology Progression

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Agilent 6852A
Vol: 60,000 cm³
Power: 20 W
Energy/Analysis: 18 kJ
Analysis Time: 15 min.

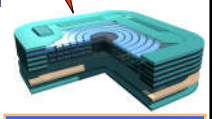
Gas Chromatograph/Mass Spectrometer (GC/MS) is a "gold standard" in chemical gas detection with excellent immunity to false alarms

Problems: too big, too slow, power hungry

LLNL
Vol: 40,500 cm³
Power: 11.5 W
Energy/Analysis: 10 kJ
Analysis Time: 15 min.

Sandia μChem Lab
Vol: 1,050 cm³
Power: 4.5 W
Energy/Analysis: 540 J
Analysis Time: 2 min.

- small enough for projectile delivery
- 1 ppt det. limit
- very fast
- battery operable



Solution: use MEMS technology to miniaturize the GC/MS, which in turn makes it faster and more energy efficient

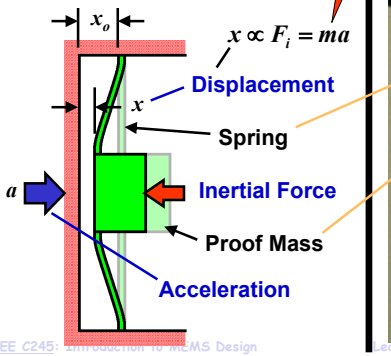
MGA Objective
Vol: 2 cm³
Power: <200 mW
Energy/Analysis: 1 J
Analysis Time: 4 s

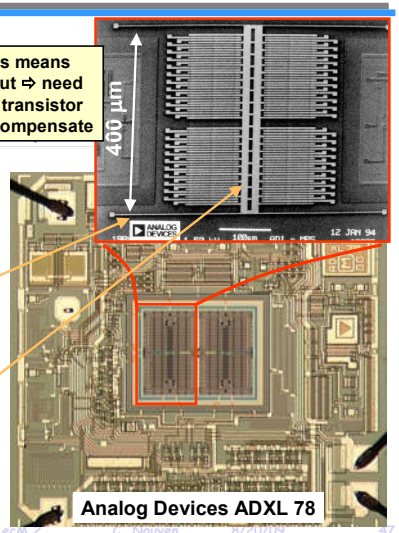
Example: Micromechanical Accelerometer

- *The MEMS Advantage:*
  - >30X size reductio
    accelerometer mec
  - allows integration

Tiny mass means small output ⇨ need integrated transistor circuits to compensate

Basic Operation Principle





Messages Going Forward …

- MEMS are micro-scale or smaller devices/systems that operate mainly via a mechanical or electromechanical means
- MEMS ⇨ NEMS offer the same scaling advantages that IC technology offers (e.g., speed, low power, complexity, cost), but they do so for domains beyond electronics:

Size ↓ ⇨
- resonant frequency ↑ (faster speed)
- actuation force ↓ (lower power)
- # mechanical elements ↑ (higher complexity)
- integration level ↑ (lower cost)

- Micro … nano … *it's all good*
- Just as important: MEMS or NEMS have brought together people from diverse disciplines ⇨ this is the key to growth!
- What's next? ⇨ Nano-nuclear fusion? Chip-scale atomic sensors?

… limitless possibilities …