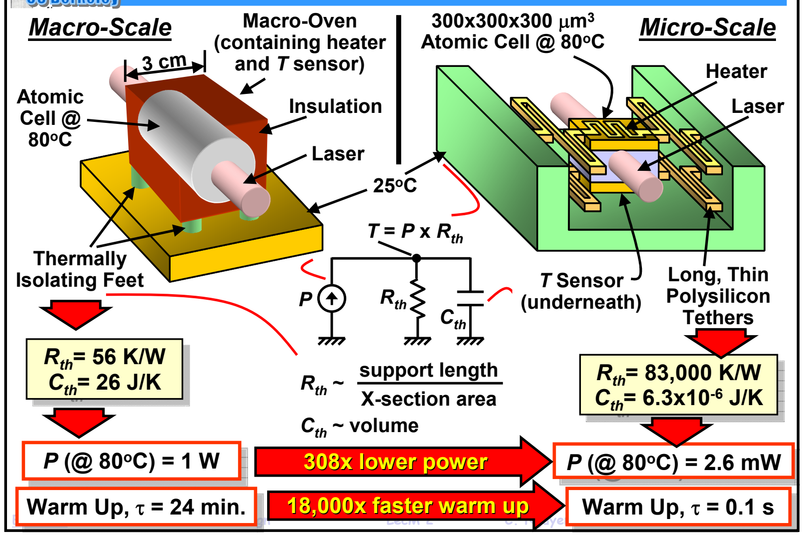
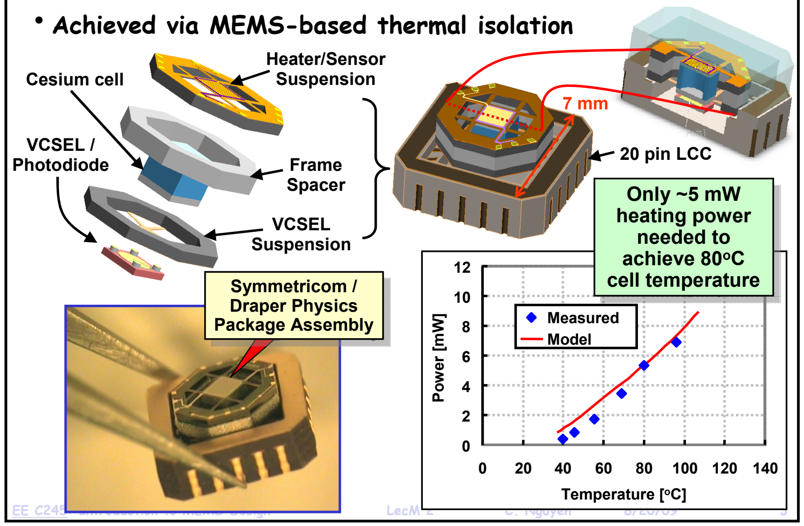
Micro-Scale Oven-Control Advantages



Physics Package Power Diss. < 10 mW

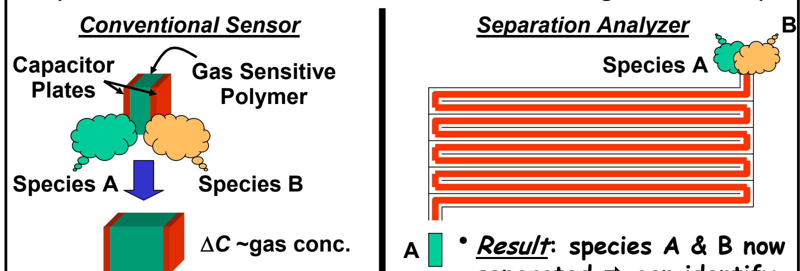
- Achieved via MEMS-based thermal isolation



Micro Gas Analyzers (MGA)

Micro Gas Analyzers

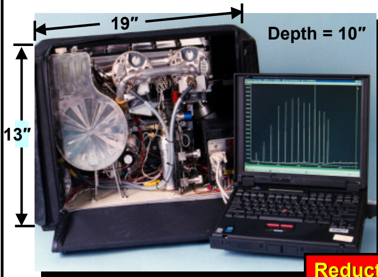
- ***Objective***: enable remote detection of chemical agents via tiny, ultra-low power, fast, chip-scale gas analyzers that greatly reduce the incidence of false positives
- ***Approach***: use micromachining technologies to implement separation-based analyzers (e.g., gas chromatographs, mass spectrometers)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



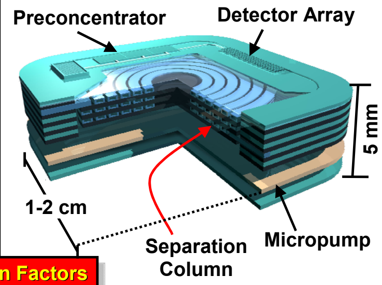
- ***Problem***: polymer has finite sensitivity to both A & B
- ***Result***: species A & B now separated ⇨ can identify and analyze individually

Advantages of Miniaturization

Portable Gas Chromatograph

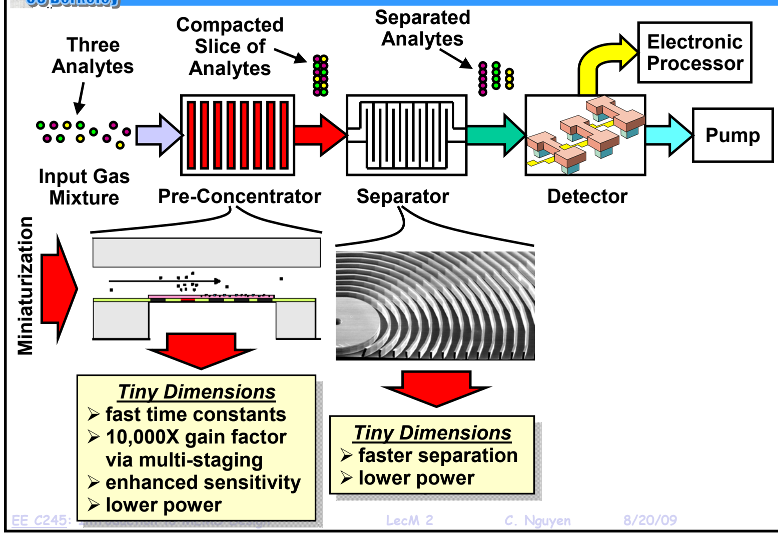


Chip-Scale Gas Chromatograph



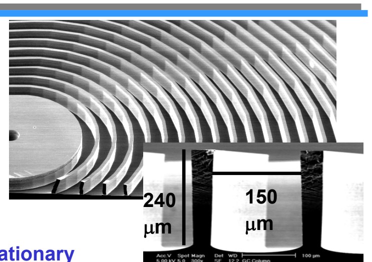
	Portable	Reduction Factors		Chip-Scale
Size	40,500 cm^3	20,000X	Size	2 cm^3
Sensitivity	1 ppb	1,000X	Sensitivity	1 ppt
Analysis Time	15 min.	225X	Analysis Time	4 sec
Energy Per Analysis	10,000 J	10,000X	Energy Per Analysis	1 J

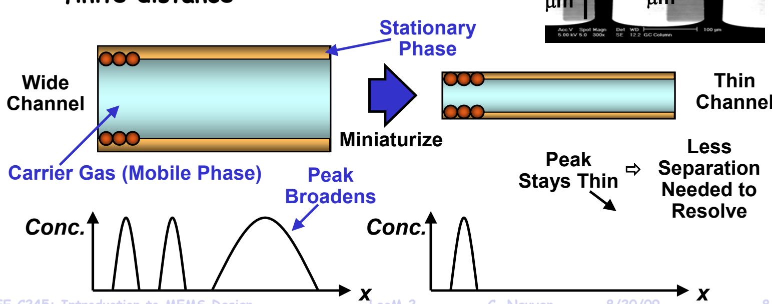
Basic Approach: Separation Analyzer



Scaling Leads to Faster Separation

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





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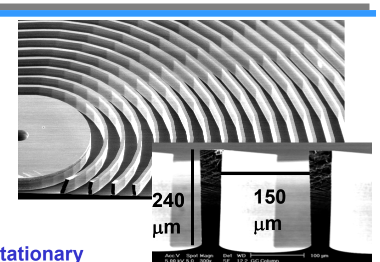
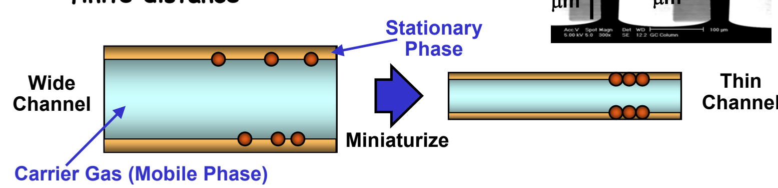
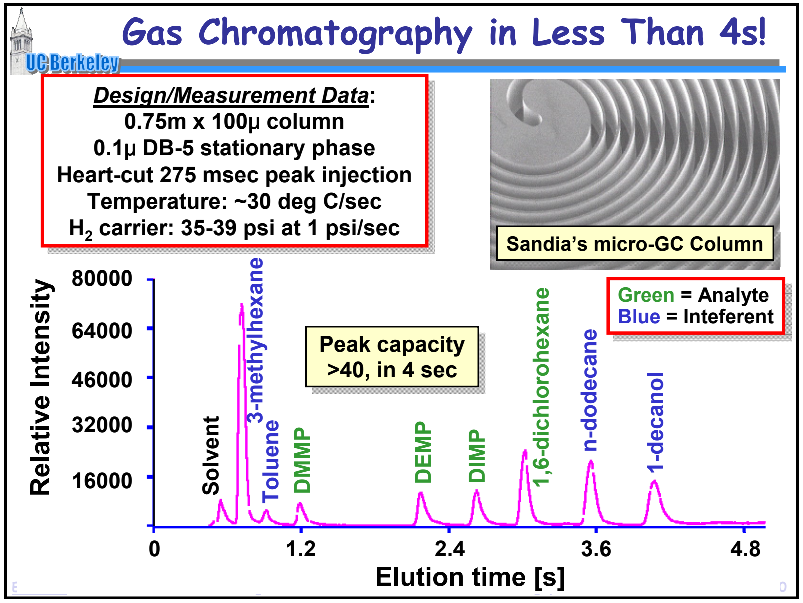
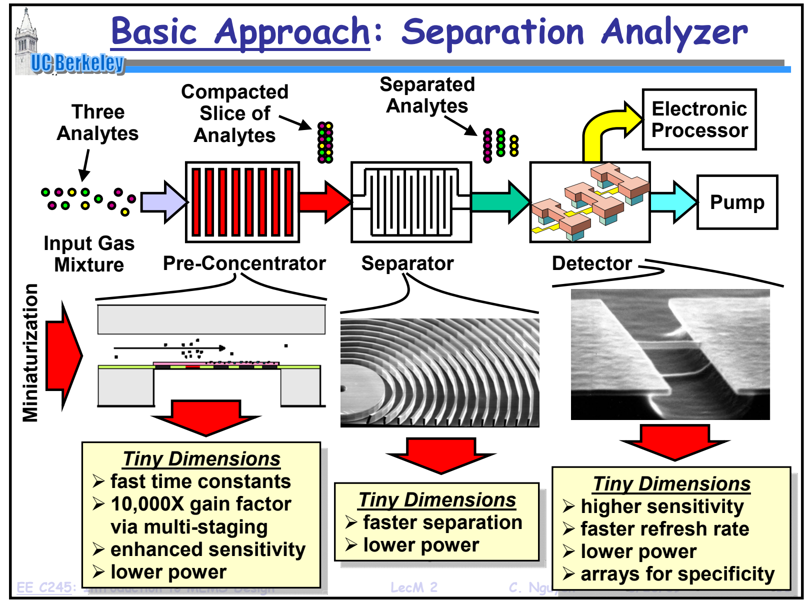


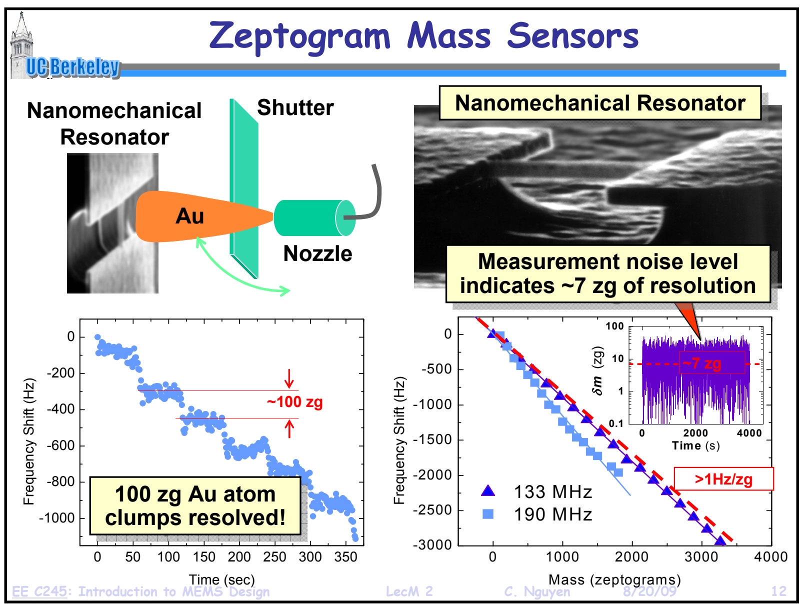


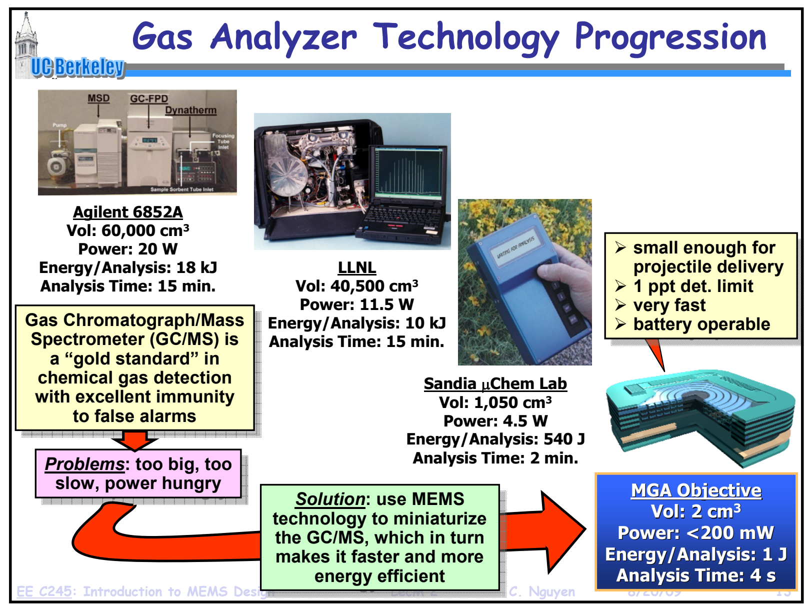
Column Width ↓ ➡ Surface-to-Volume Ratio ↑ ➡ Peak Spreading ↓ ➡ Separation Distance ↓

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


Gas Chromatography in Less Than 4s!
UC Berkeley
Design/Measurement Data:
0.75m x 100μ column
0.1μ DB-5 stationary phase
Heart-cut 275 msec peak injection
Temperature: ~30 deg C/sec
H2 carrier: 35-39 psi at 1 psi/sec
Sandia's micro-GC Column
Green = Analyte
Blue = Inteferent
Peak capacity >40, in 4 sec
Relative Intensity
80000
64000
46000
32000
16000
Solvent
3-methylhexane
Toluene
DMMP
DEMP
DIMP
1,6-dichlorohexane
n-dodecane
1-decanol
0
1.2
2.4
3.6
4.8
Elution time [s]


Basic Approach: Separation Analyzer
UC Berkeley
Three Analytes
Compacted Slice of Analytes
Separated Analytes
Electronic Processor
Pump
Input Gas Mixture
Pre-Concentrator
Separator
Detector
Miniaturization
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
UC Berkeley
Nanomechanical Resonator
Shutter
Au
Nozzle
Nanomechanical Resonator
Measurement noise level indicates ~7 zg of resolution
~100 zg
100 zg Au atom clumps resolved!
Frequency Shift (Hz)
Time (sec)
~7 zg
>1Hz/zg
133 MHz
190 MHz
Mass (zeptograms)
Time (s)

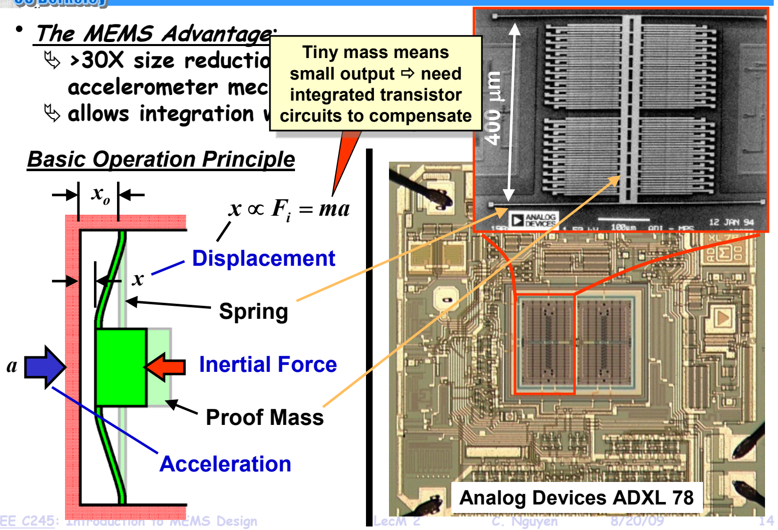

Gas Analyzer Technology Progression
UC Berkeley
Agilent 6852A
Vol: 60,000 cm³
Power: 20 W
Energy/Analysis: 18 kJ
Analysis Time: 15 min.
LLNL
Vol: 40,500 cm³
Power: 11.5 W
Energy/Analysis: 10 kJ
Analysis Time: 15 min.
Sandia μChem Lab
Vol: 1,050 cm³
Power: 4.5 W
Energy/Analysis: 540 J
Analysis Time: 2 min.
small enough for projectile delivery
1 ppt det. limit
very fast
battery operable
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
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[n] accelerometer mec[hanical]
  - allows integration w[ith]

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? ⇨ Chip-scale atomic sensors? Pico-Satellites?

… limitless possibilities …