EE C245 – ME C218
Introduction to MEMS Design
Fall 2011

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Lecture Module 2: Benefits of Scaling

Lecture Outline

- Reading: Senturia, Chapter 1
- Lecture Topics:
  - Benefits of Miniaturization
  - Examples
    - GHz micromechanical resonators
    - Chip-scale atomic clock
    - Micro gas chromatograph

Benefits of Size Reduction: MEMS

- Benefits of size reduction clear for IC's in elect. domain
  - size reduction ⇨ speed, low power, complexity, economy
- MEMS: enables a similar concept, but …

MEMS extends the benefits of size reduction *beyond* the electrical domain

Performance enhancements for application domains beyond those satisfied by electronics in the same general categories

Speed ➡	Frequency ↑ , Thermal Time Const. ↓
Power Consumption ➡	Actuation Energy ↓ , Heating Power ↓
Complexity ➡	Integration Density ↑ , Functionality ↑
Economy ➡	Batch Fab. Pot. ↑ (esp. for packaging)
Robustness ➡	g-Force Resilience ↑

Vibrating RF MEMS

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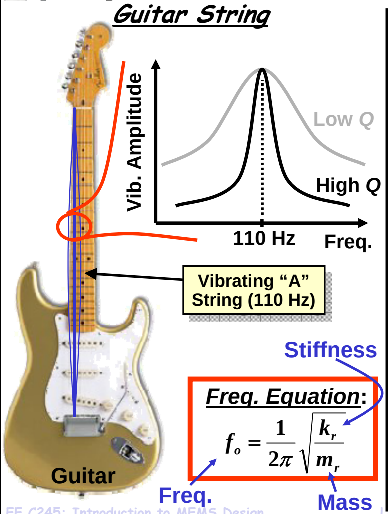
Basic Concept: Scaling Guitar Strings

Guitar String

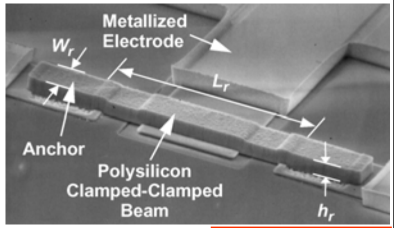


Freq. Equation:

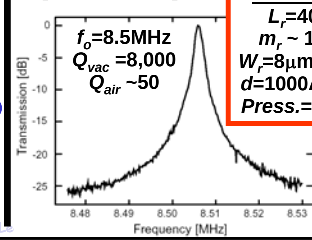
$$f_o = \frac{1}{2\pi}\sqrt{\frac{k_r}{m_r}}$$

Stiffness — Freq. — Mass

μMechanical Resonator



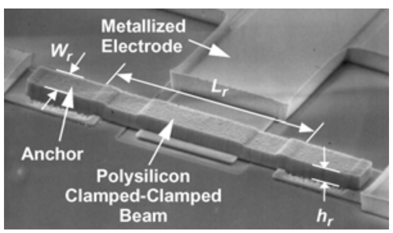
[Bannon 1996]



Performance:
L_r=40.8μm
m_r ~ 10^{-13} kg
W_r=8μm, h_r=2μm
d=1000Å, V_P=5V
Press.=70mTorr

Frequency of a Stretched Wire

Frequency of a Clamped-Clamped Beam



Frequency of a Clamped-Clamped Beam

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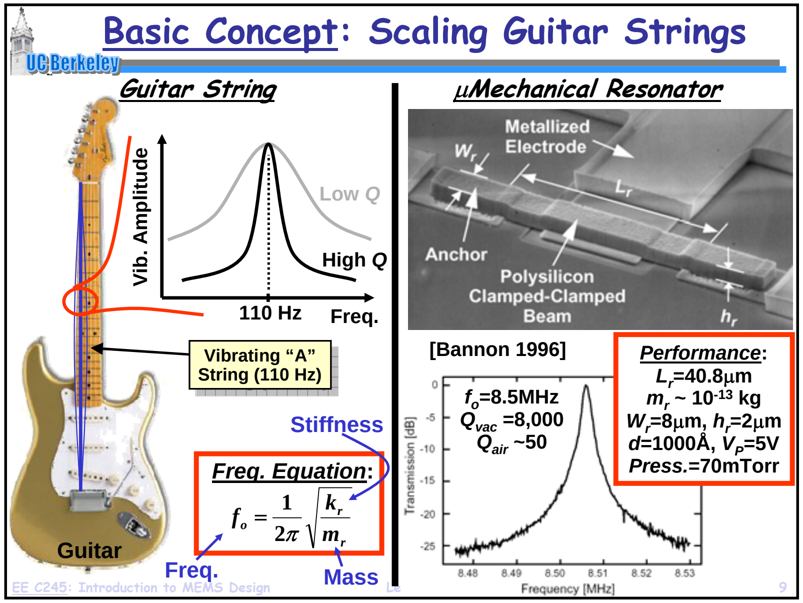

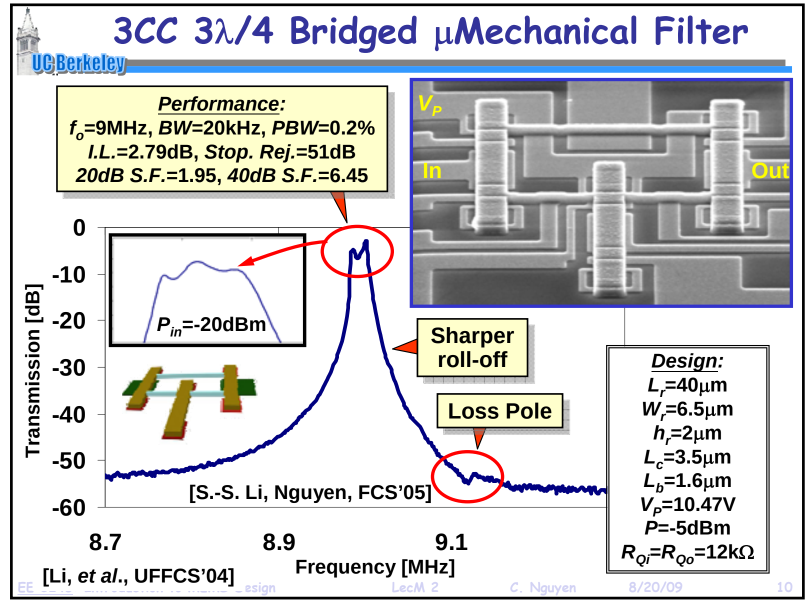

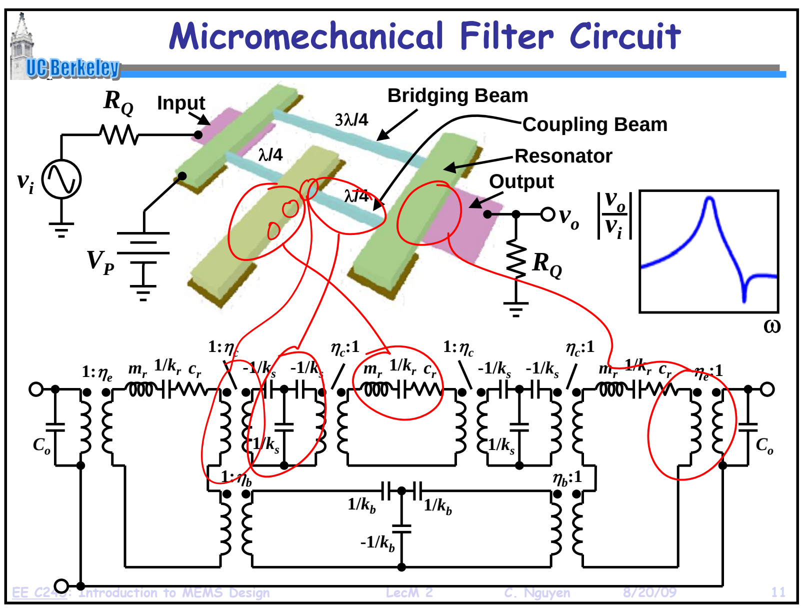

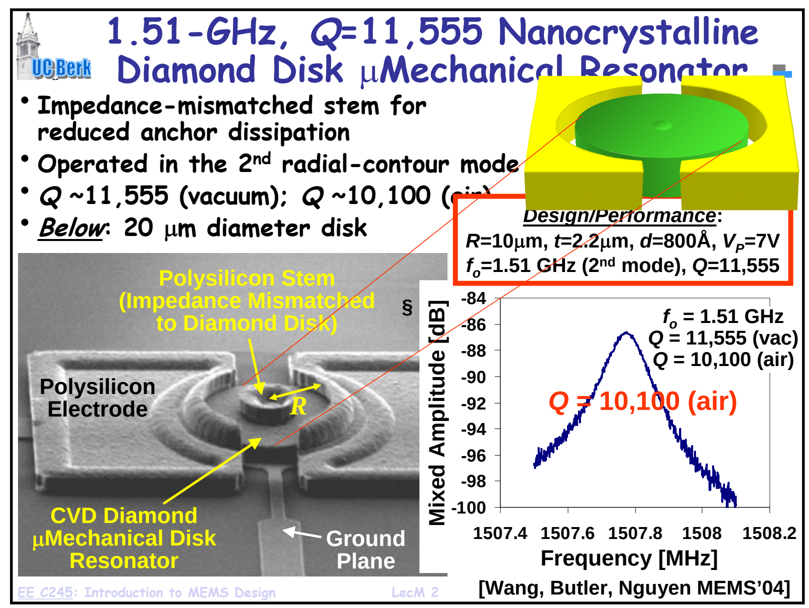

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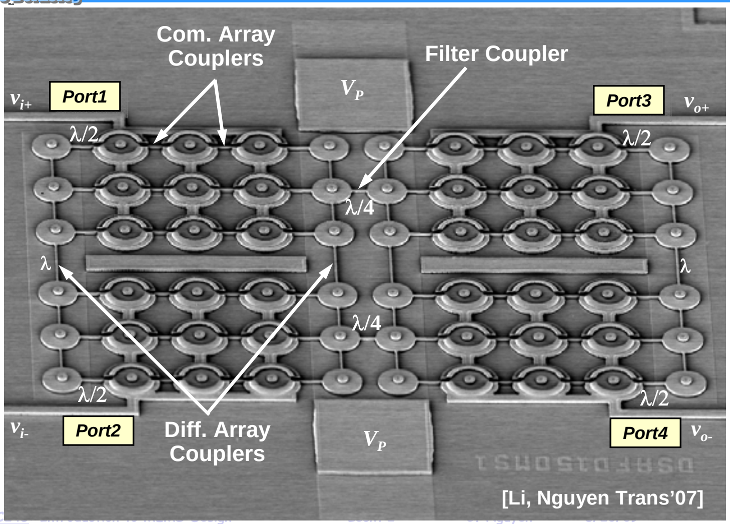
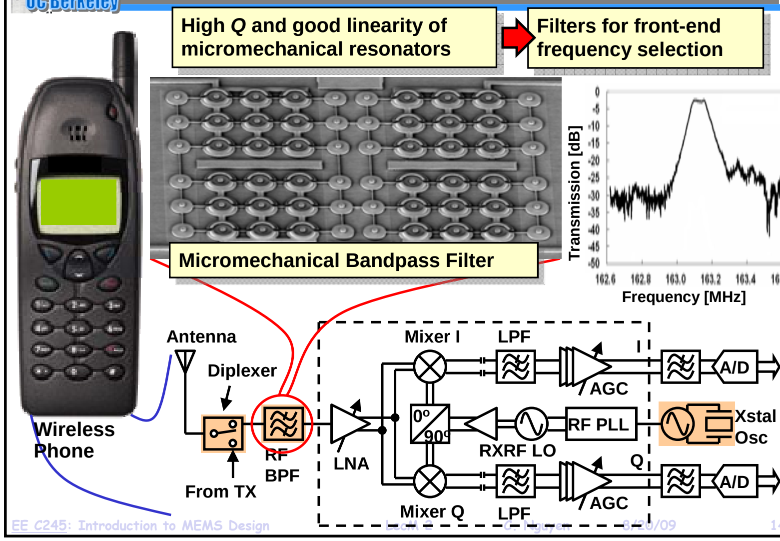
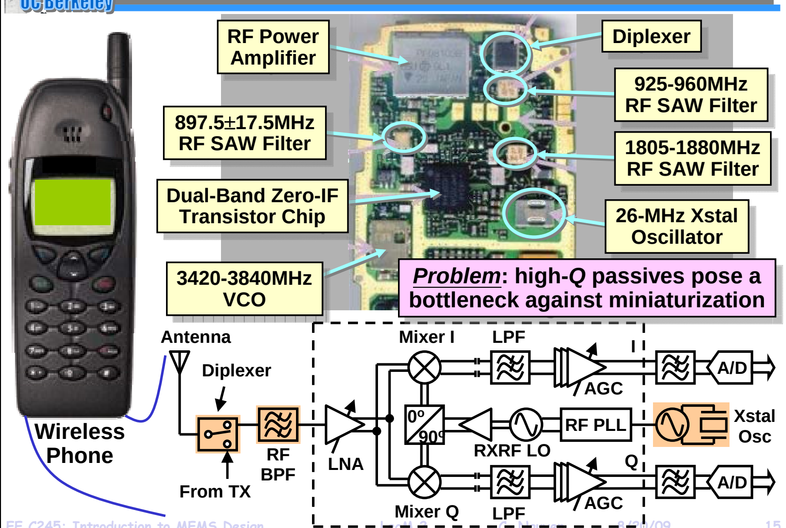
163-MHz Differential Disk-Array Filter



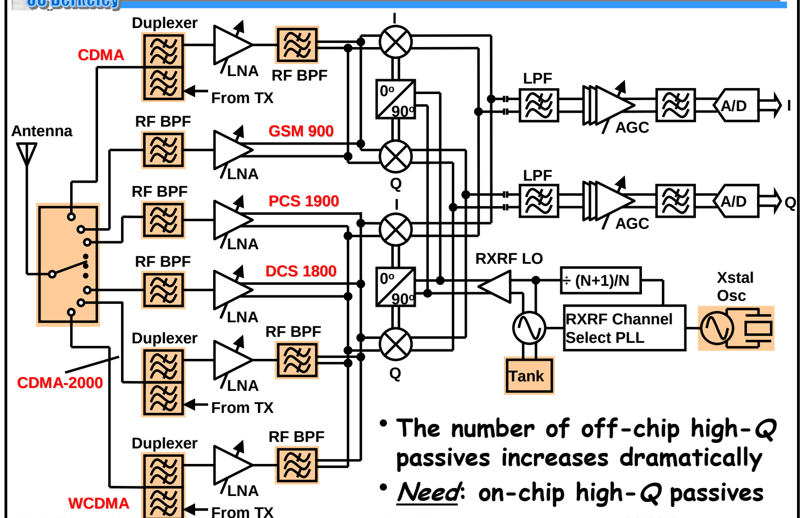
Linear MEMS in Wireless Comms



Miniaturization of RF Front Ends



Multi-Band Wireless Handsets



- The number of off-chip high-*Q* passives increases dramatically
- ***Need***: on-chip high-*Q* passives

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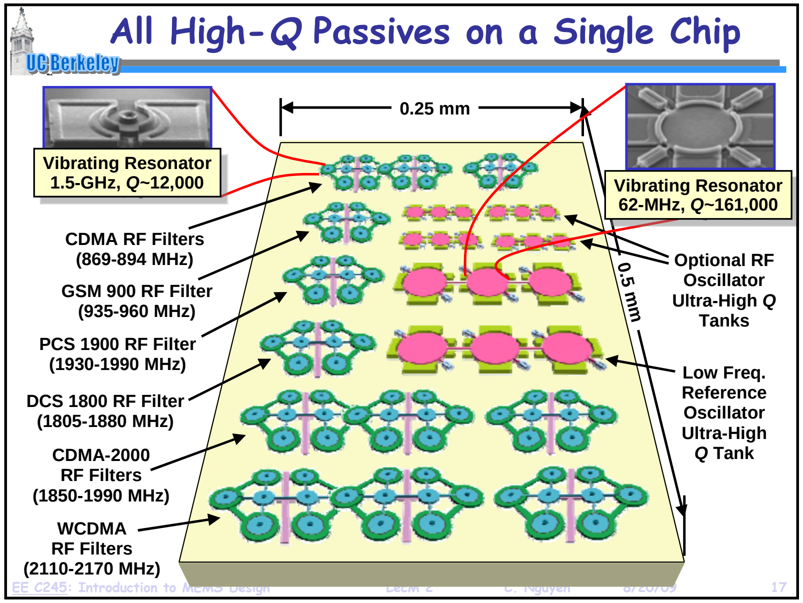
All High-Q Passives on a Single Chip
UC Berkeley
0.25 mm
0.5 mm
Vibrating Resonator
1.5-GHz, Q~12,000
Vibrating Resonator
62-MHz, Q~161,000
CDMA RF Filters
(869-894 MHz)
GSM 900 RF Filter
(935-960 MHz)
PCS 1900 RF Filter
(1930-1990 MHz)
DCS 1800 RF Filter
(1805-1880 MHz)
CDMA-2000
RF Filters
(1850-1990 MHz)
WCDMA
RF Filters
(2110-2170 MHz)
Optional RF
Oscillator
Ultra-High Q
Tanks
Low Freq.
Reference
Oscillator
Ultra-High
Q Tank