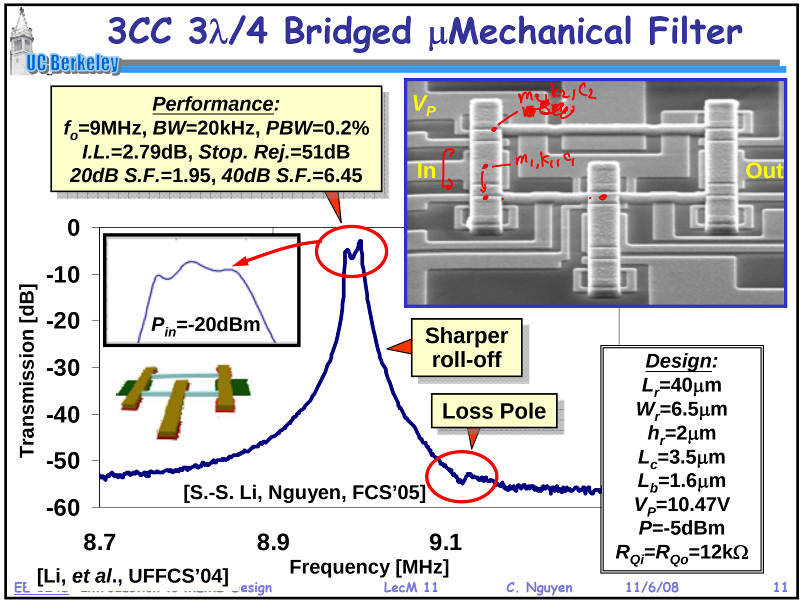
3CC 3λ/4 Bridged μMechanical Filter
UC Berkeley
Performance:
f_o=9MHz, BW=20kHz, PBW=0.2%
I.L.=2.79dB, Stop. Rej.=51dB
20dB S.F.=1.95, 40dB S.F.=6.45
V_P
In
Out
P_{in}=-20dBm
Sharper roll-off
Loss Pole
Design:
L_r=40μm
W_r=6.5μm
h_r=2μm
L_c=3.5μm
L_b=1.6μm
V_P=10.47V
P=-5dBm
R_{Qi}=R_{Qo}=12kΩ
Transmission [dB]
0
-10
-20
-30
-40
-50
-60
8.7
8.9
9.1
Frequency [MHz]
[S.-S. Li, Nguyen, FCS'05]
[Li, et al., UFFCS'04]
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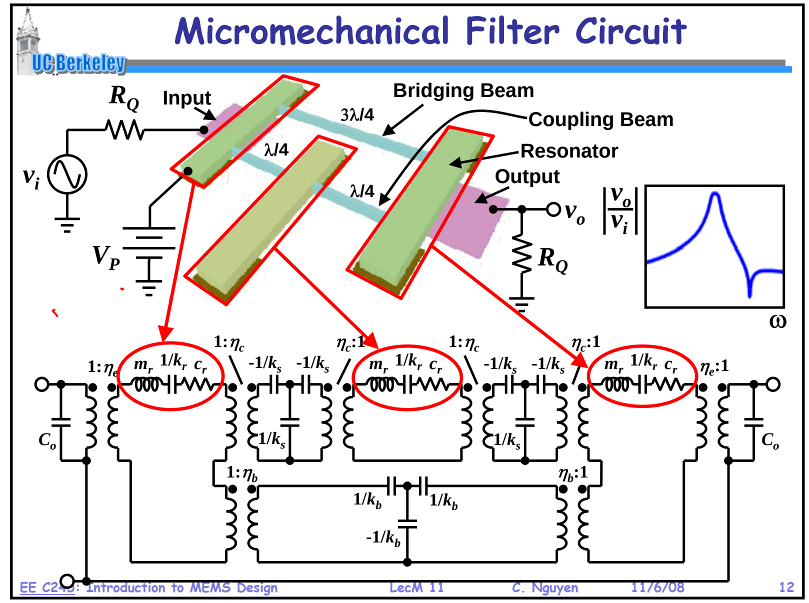
Micromechanical Filter Circuit
UC Berkeley
R_Q
Input
Bridging Beam
3λ/4
Coupling Beam
λ/4
Resonator
λ/4
Output
v_i
v_o
$|v_o/v_i|$
V_P
R_Q
ω
1:η_e
m_r 1/k_r c_r
1:η_c
-1/k_s -1/k_s
η_c:1
1/k_s
η_e:1
C_o
1:η_b
η_b:1
1/k_b
-1/k_b
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LecM 11
C. Nguyen
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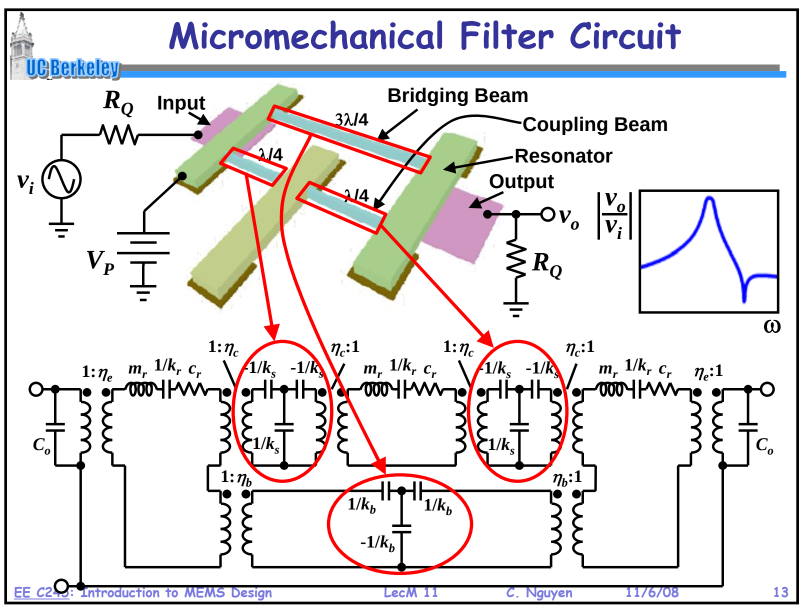
Micromechanical Filter Circuit
UC Berkeley
R_Q
Input
Bridging Beam
3λ/4
Coupling Beam
λ/4
Resonator
λ/4
Output
v_i
v_o
$|v_o/v_i|$
V_P
R_Q
ω
1:η_e
m_r 1/k_r c_r
1:η_c
-1/k_s -1/k_s
η_c:1
1/k_s
η_e:1
C_o
1:η_b
η_b:1
1/k_b
-1/k_b
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LecM 11
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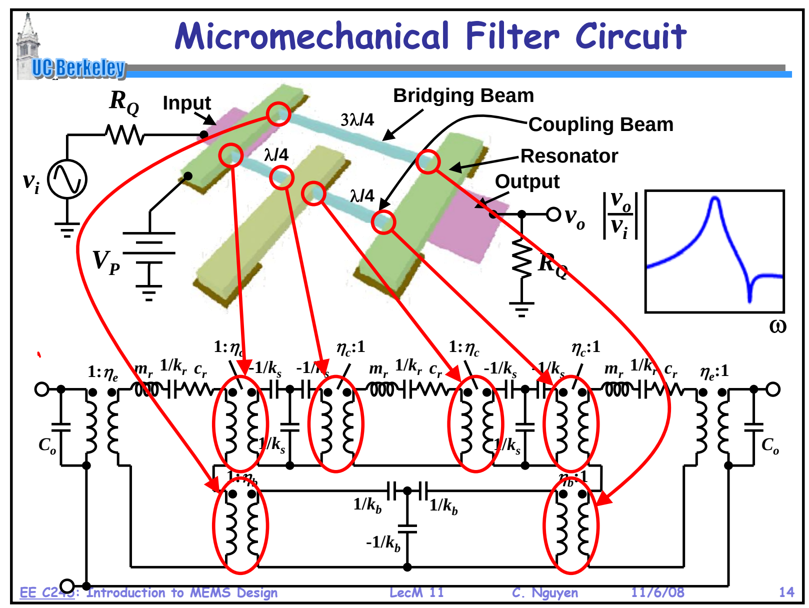
Micromechanical Filter Circuit
UC Berkeley
R_Q
Input
Bridging Beam
3λ/4
Coupling Beam
λ/4
Resonator
λ/4
Output
v_i
v_o
$|v_o/v_i|$
V_P
R_Q
ω
1:η_e
m_r 1/k_r c_r
1:η_c
-1/k_s
η_c:1
1/k_s
η_e:1
C_o
1/k_b
-1/k_b
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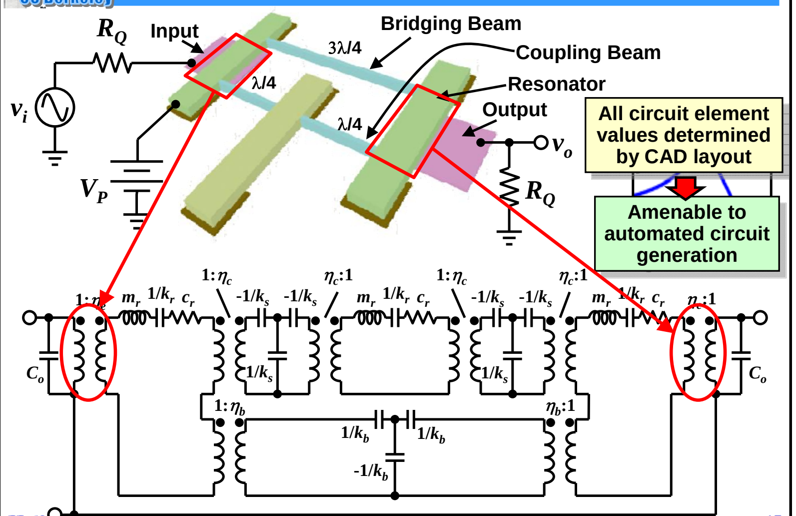
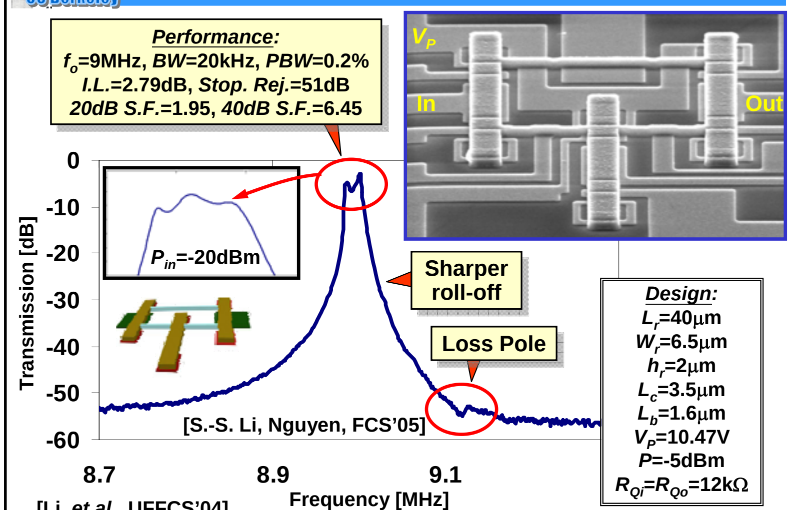
Micromechanical Filter Circuit



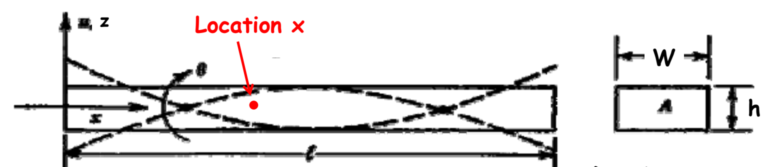
3CC 3λ/4 Bridged μMechanical Filter



Beam Resonator Equivalent Circuits (Pretty Much the Same Stuff)

Equivalent Dynamic Mass

- Once the mode shape is known, the lumped parameter equivalent circuit can then be specified
- Determine the equivalent mass at a specific location x using knowledge of kinetic energy and velocity

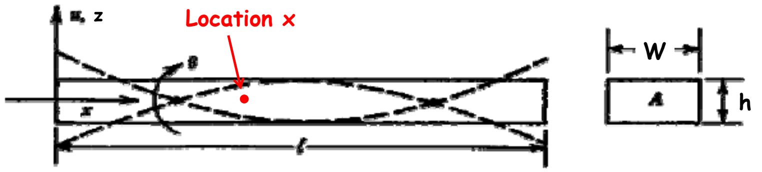


Maximum Kinetic Energy; Density

$$\text{Equivalent Mass} = M_{eqx} = \frac{K.E.}{\frac{1}{2}V_x^2} = \frac{\frac{1}{2}\rho A\int_0^\ell V^2(x)\,dx}{\frac{1}{2}V_x^2}$$

Maximum Velocity @ location x; Maximum Velocity Function

Equivalent Dynamic Mass



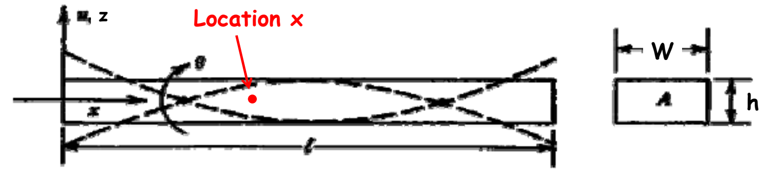
- We know the mode shape, so we can write expressions for displacement and velocity at resonance

Displacement: $u(x) = B[\varsigma(\cosh kx + \cos kx) + (\sinh kx + \sin kx)]$, $\varsigma = \frac{A}{B}$

$$[v(x) = \omega_o u(x)] \Rightarrow M_{eq}(x) = \frac{KE_{max}}{\frac{1}{2}[v(x)]^2} = \frac{\frac{1}{2}\rho A \int_0^\ell \omega_o^2 [u(x')]^2 dx'}{\frac{1}{2}\omega_o^2 [u(x)]^2}$$

$$M_{eq}(x) = \frac{\rho A \int_0^\ell B^2[\varsigma(\cosh kx' + \cos kx') + (\sinh kx' + \sin kx')]^2 dx'}{B^2[\varsigma(\cosh kx + \cos kx) + (\sinh kx + \sin kx)]^2}$$

Equivalent Dynamic Stiffness & Damping



- Stiffness then follows directly from knowledge of mass and resonance frequency

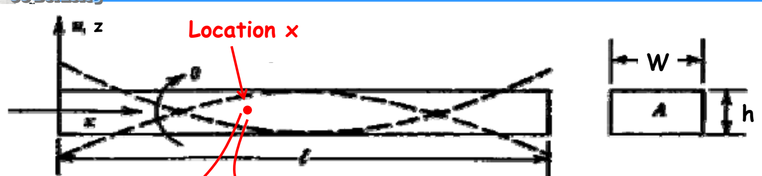
$$\omega_o = \sqrt{\frac{K_{eq}(x)}{M_{eq}(x)}} \longrightarrow K_{eq}(x) = \omega_o^2 M_{eq}(x)$$

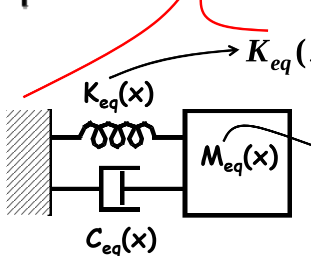
- And damping also follows readily

$$Q = \frac{\omega_o M_{eq}(x)}{C_{eq}(x)} \longrightarrow C_{eq}(x) = \frac{\omega_o M_{eq}(x)}{Q} = \frac{\sqrt{K_{eq}(x) M_{eq}(x)}}{Q}$$

($C_{eq}(x)$: damping)

Equivalent Lumped Mechanical Circuit





$$K_{eq}(x) = \omega_o^2 M_{eq}(x)$$

$$M_{eq}(x) = \frac{\rho A \int_o^l [u(x')]^2 dx'}{[u(x)]^2}$$

$$C_{eq}(x) = \frac{\omega_o M_{eq}(x)}{Q}$$

Equivalent Lumped Mechanical Circuit

Example: Polysilicon w/ ℓ=14.9μm, W=6μm, h=2μm → 70 MHz