Dynamic Characterization and Mechanical Simulation of Cantilevers for Electromechanical Vibration Energy Harvesting

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Introduction:

- Ambient vibration energy harvesters

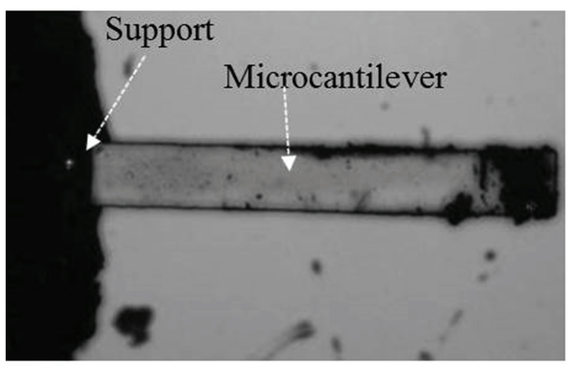
Ambient vibrations → 1- Sources power densities ~ 10-100 μW/cm²; 2- Acceleration (a) ~1 g; 3- Frequency (f) < 1 kHz

Ambient vibrations → Mechanical-to-mechanical converter → Mechanical-to-electrical converter → Electricity → Wireless Sensor Networks

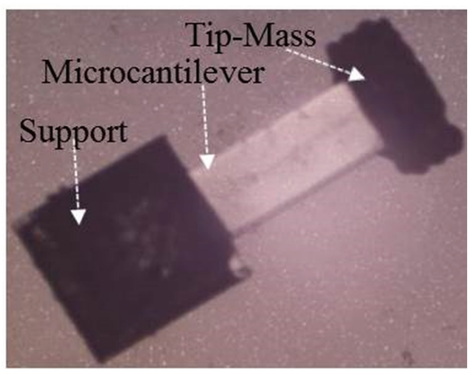
- Viscoelastic polymer → Large strain; Resonant frequency → High power

Design, Fabrication and Characterization:

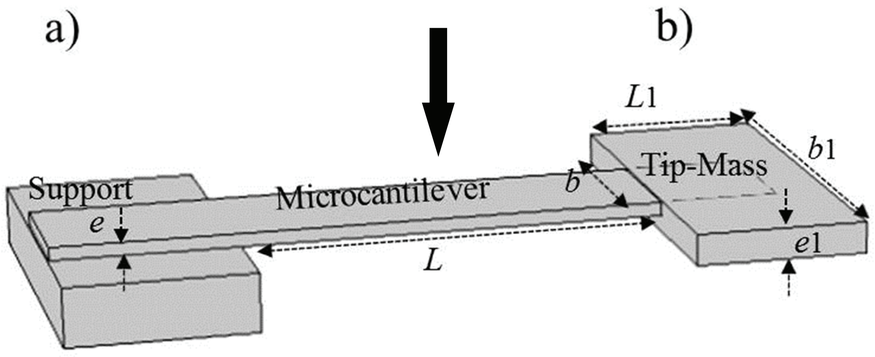
- Two geometries:



a)



b)



- Material parameters:

1- Support: ρ= 960 kg/m³, E= 3 GPa and v=0.44

2- Beam: ρ= 1150 kg/m³, $E=E'+jE''$(E=4.6 GPa and E''=0.1 GPa), v=0.4

3- Tip-Mass: ρ_m= 4500 kg/m³, E_m= 3 GPa and v_m=0.4

- Dimensions parameters:

Structures	L (mm)	b (μm)	e (μm)	$L1$ (μm)	$b1$ (μm)	$e1$ (μm)
A	1	200	20			
B	0.94	600	24	380	0.91	48
C	0.94	600	25	380	0.91	48
D	0.94	300	30	380	0.91	70

Results and Discussions:

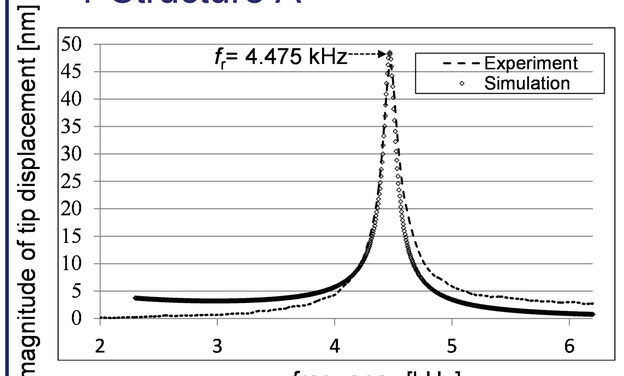
- Beam Harmonic analysis to deduce

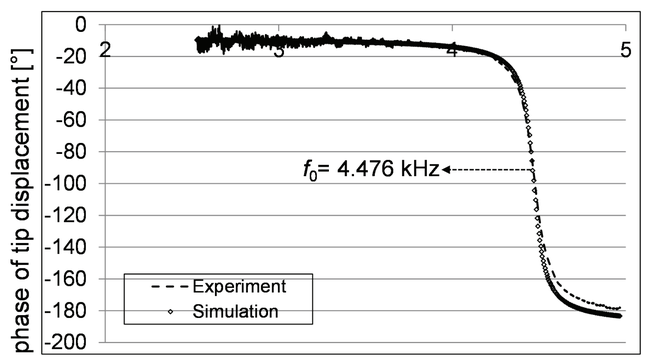
The resonant frequency (f_r) → 1-Structure A

The undamped natural frequency (f_0) → 1-Structure A

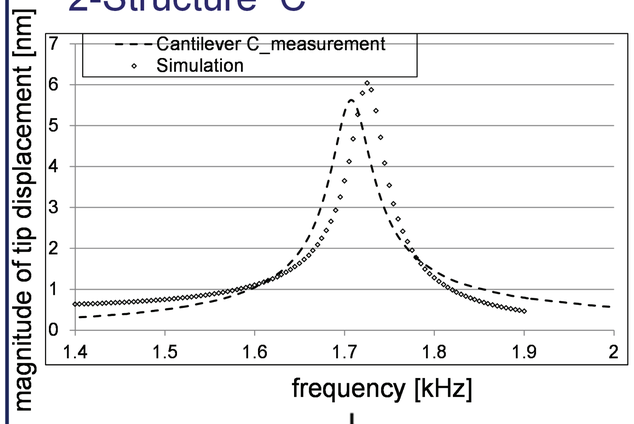
The quality factor $Q = \frac{1}{\sqrt{2\left(1-\left(\frac{f_r}{f_0}\right)^2\right)}}$

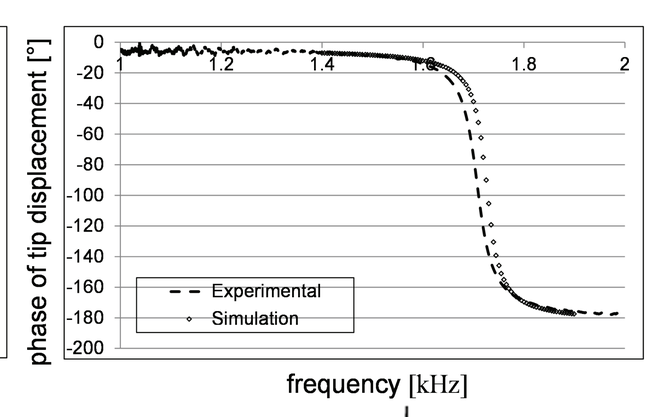
1-Structure A





2-Structure C

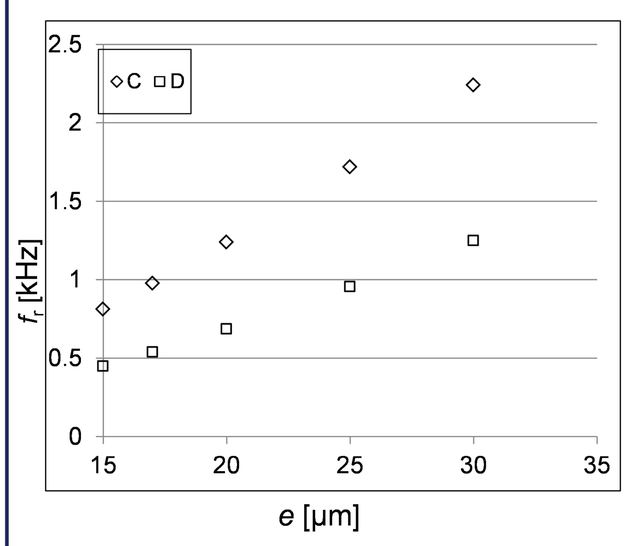


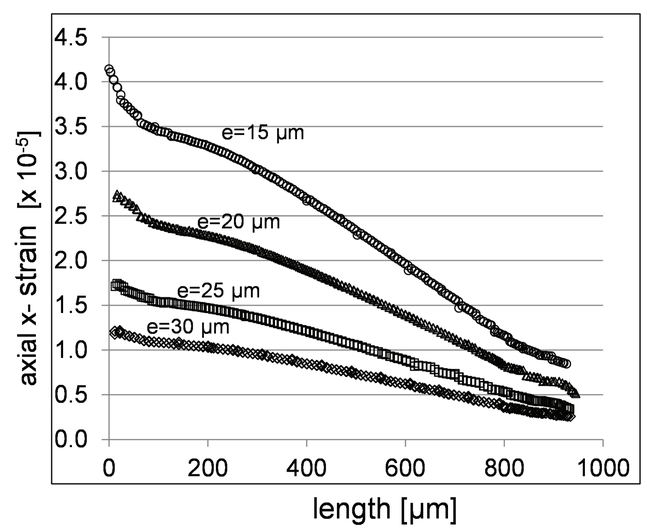


Q_{exp} = 40
Q_{sim} = 39.9

Structures	$f_{r,exp}$ (kHz)	$f_{r,sim}$ (kHz)
A	4.47	4.47
B	1.59	1.62
C	1.70	1.72
D	1.28	1.25

→Good agreement between COMSOL simulation and measurements





e → High longitudinal strain at resonance; Low resonant frequency

e = 15 μm → f_r<500 Hz; Strain =4x Strain (e=30 μm)

Conclusions

- Resonating MEMS devices made of viscoelastic polymer have been simulated in harmonic analysis in COMSOL
- The geometry and the mechanical properties of microcantilevers have been optimized in COMSOL to obtain low resonant frequency and large strain

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