Determination of Fundamental Resonant Modes of a Polysilicon H-Beam Using COMSOL Multiphysics®

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Introduction: Our objective is to simulate a MEMS structure that is characterized by a very sharply defined characteristic vibration modes. The H – Bridge design, is especially suited to this purpose as it has two very well defined oscillatory modes: symmetric and anti-symmetric, which is the principal component capacitive-coupled electronic frequency filter for mobile and embedded applications. MEMS based filter solutions can attain extremely hlow values of damping[1], which allows these filters to operate at high levels of frequency discrimination, filter stability, and low drift.

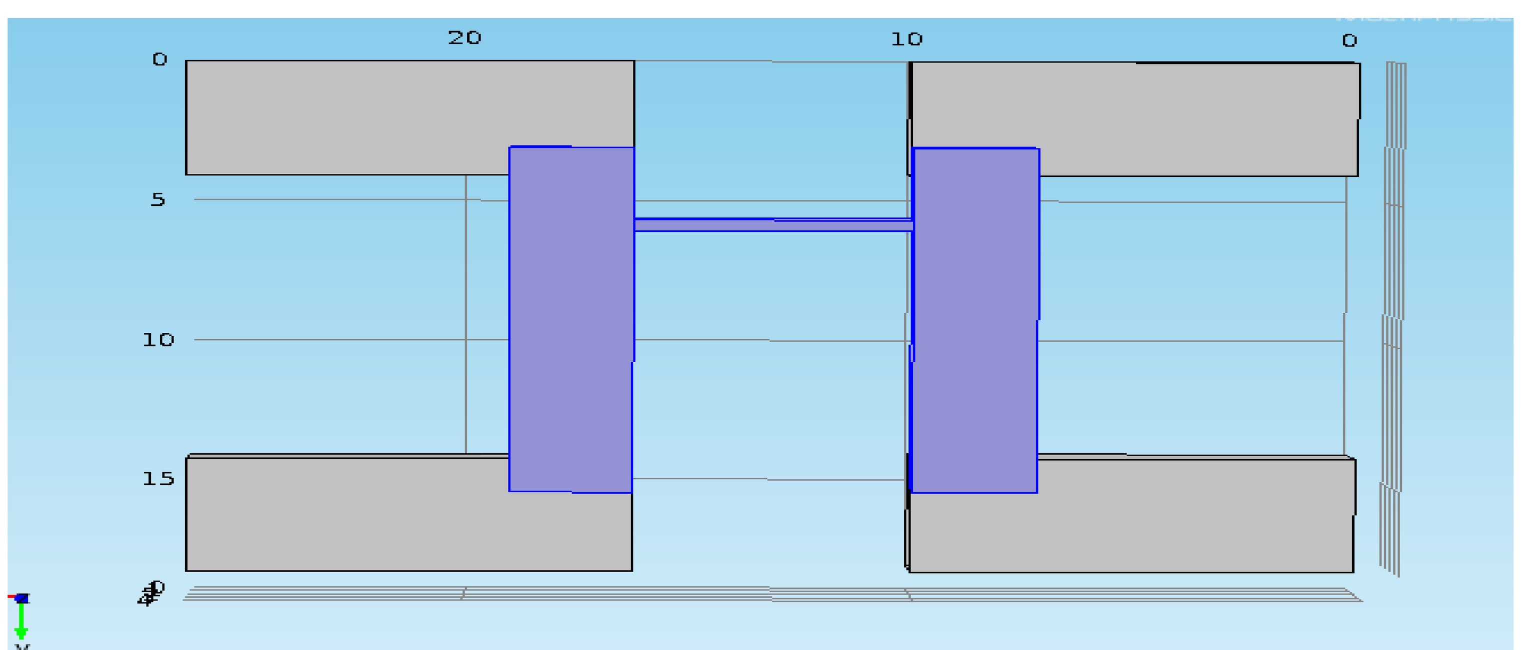


Figure 1. Simulated Structure (Top View)

Computational Methods: Due to the complex design of the microstructure, conventional analytically-driven approaches would become intractably complex, even with a large degree of approximations and underlying assumptions. COMSOL Multiphysics allowed us to abstract the design in terms of devising the structure geometry and allowing us to manually configure constraints for the structure, greatly simplifying the simulation procedure.

The resonating structure consists of two Poly-Silicon rectangular prismatic members anchored to a Silicon Nitride base[2]. The members are connected via a Poly-Silicon member that is 370nm in thickness. This clamped-clamped arrangement displays far better Q-factor than transistor devices[1]. The Eigen frequency analysis was conducted o the structure with constraints assigned as shown in figure 2, a physics-controlled superfine mesh was generated to ensure that the solver converged to the correct resonant frequencies.

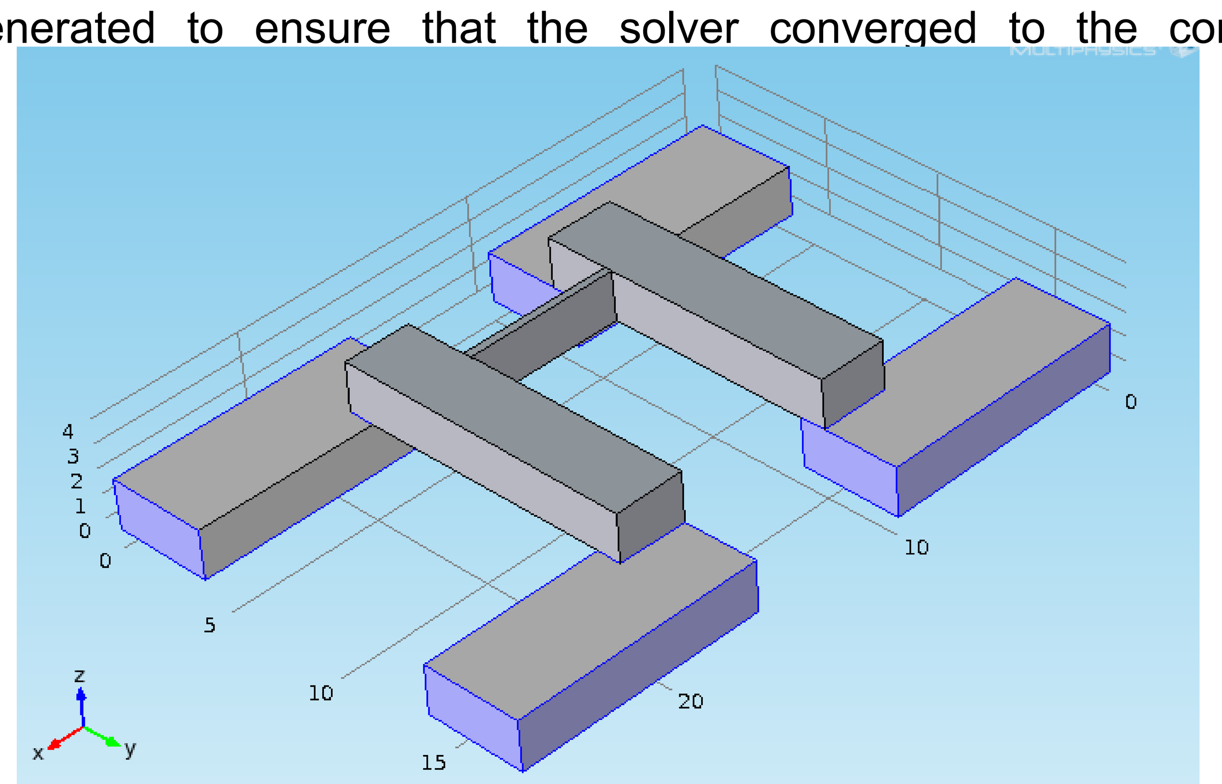


Figure 2. Fixed-Constraint assignment

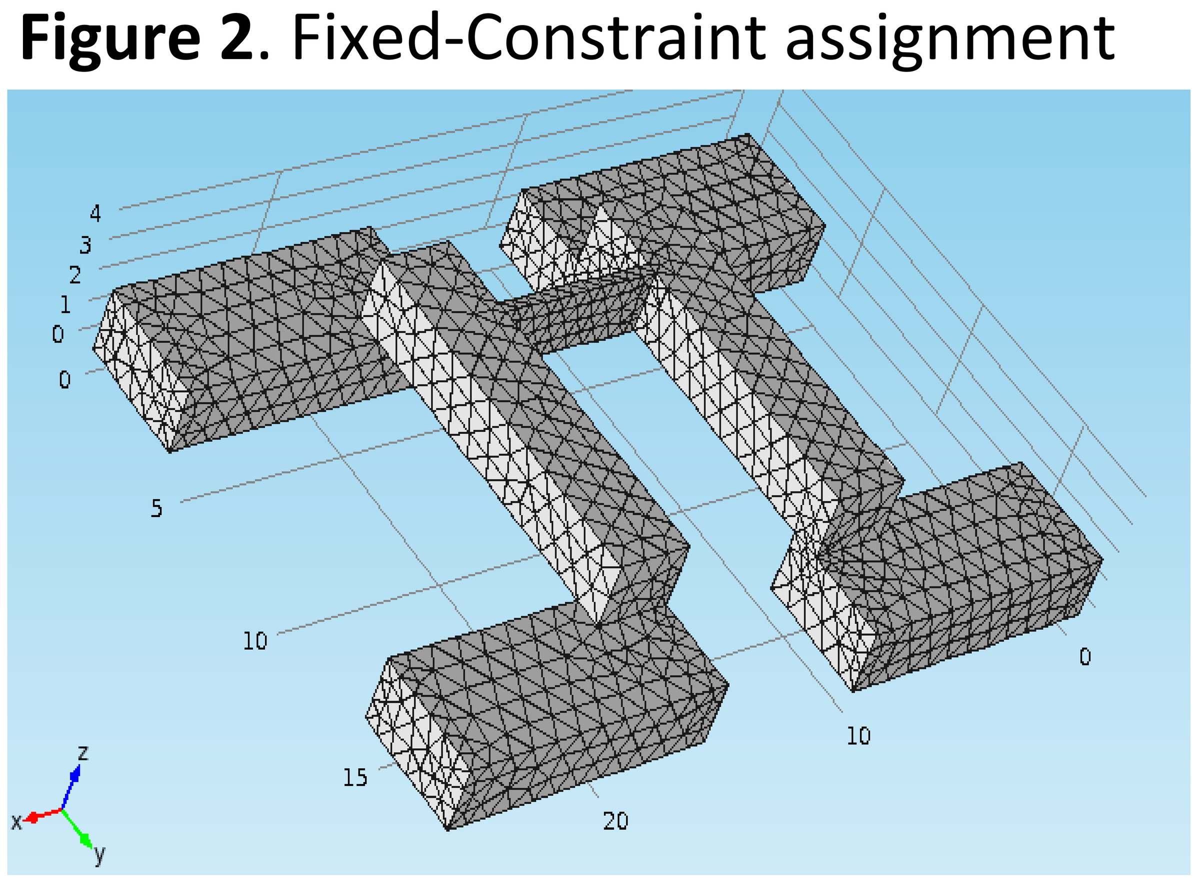
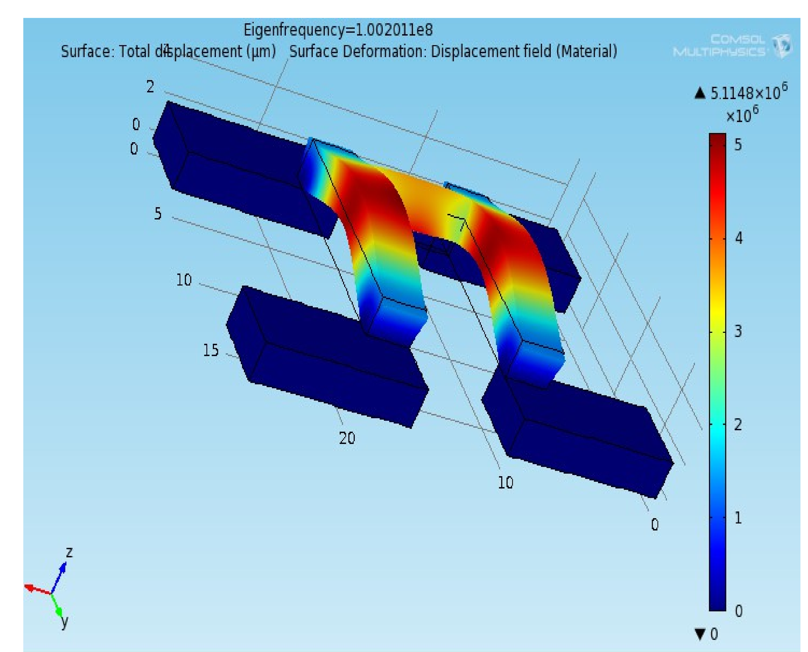


Figure 3. Physics-controlled mesh (extra fine)

Results: The COMSOL Multiphysics solver for Eigen frequency analysis computed six resonant mode frequencies; only two modes are of note from our standpoint. The symmetric mode is centered at 100.20MHz , whereas the anti-symmetric mode is centered at 101.91Mhz, giving a bandwidth of 1.71 MHz these two modes are of special importance to the design of MEMS based frequency filters, as they also allow for the introduction of phase reversal between the excitation and output of the filter[3].



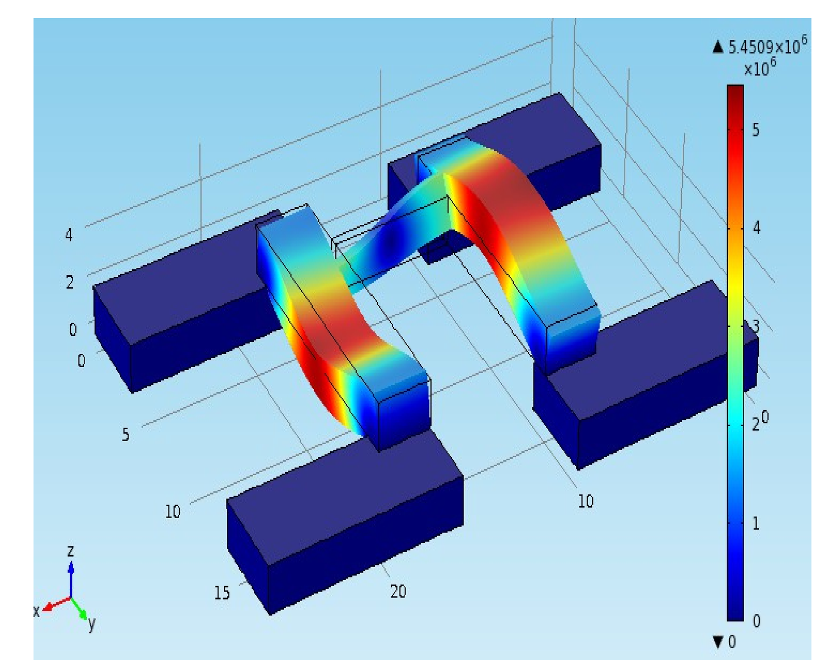


Figure 4. Symmetric Mode **Figure 5**. Anti-Symmetric Mode

Material	Poly-Silicon	Silicon Nitride	Units
Density	2320	3100	Kg/m3
Poisson's Ratio	0.22	0.23	N.A.
Young's Modulus	160e9	250e9	Pa
Relative Permittivity	4.5	9.7	Pa

Table 1. Materials used in fabricating structure

Conclusions: The simulation of a Poly-Silicon H-Beam resonator was attempted in COMSOL Multiphysics. Boundary conditions that dictate the degree of freedom for the structure were assigned manually, allowing for greatly more detailed analysis of the structures' resonant modes. The symmetric and anti-symmetric vibration behavior of the structure was noted, future work shall include more detailed analysis of the Poly-Silicon and silicon Nitride interface behavior and the capacitive coupling between the Poly-Silicon members and a conductive substrate.

References:

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