How to excite anti-symmetric modes in a symmetric MEMS?

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Abstract. This study reports on experimental investigation of modal interaction in a symmetric electrostatically driven micro resonator. The MEMS is made of a clamped-clamped curved-beam electrostatically actuated via a side electrode. A two-to-one ratio exists by design between the second natural frequency (first anti-symmetric in-plane bending mode) and the third natural frequency (second symmetric in-plane bending mode). Because the beam, its boundary conditions, and its actuation force are all symmetric, anti-symmetric modes cannot be directly excited due to the null projection of the excitation force onto the modes. This study shows that those anti-symmetric modes can be indirectly excited by channelling energy from a symmetric mode to the target anti-symmetric mode. The results reveal energy transfer from the directly excited second symmetric mode to the first anti-symmetric mode resulting in an M-shape frequency-response curve with trivial and large-amplitude stable branches.

Introduction

Nonlinear dynamics in Micro-Electro-Mechanical Systems (MEMS) features interesting phenomena that can be employed to improve the performance of MEMS actuators and sensors. In recent years, nonlinear modal interaction has become the focus of attention of many researchers working on the dynamics of MEMS. This phenomenon forms an energy channel between two vibration modes of structures under a special condition, the existence of a commensurate ratio between their natural frequencies. The vibrations of the two modes may occur in one direction [1] or in two perpendicular directions [2]. To the best of our knowledge, modal interactions between symmetric and anti-symmetric modes in electrostatic MEMS resonators are yet to be addressed.

Results and discussion

To excite the first anti-symmetric mode, the MEMS is excited with an electrostatic force whose frequency varies near the third natural frequency to directly excite the second-symmetric mode, thereby indirectly exciting the first anti-symmetric mode 'from above'. The measured frequency-response curve of the MEMS is M-shaped composed of both trivial and non-trivial stable branches. A Laser Doppler Vibrometer (LDV) was used to measure the velocity of the microbeam optically. To this aim, we put the laser spot on the second-symmetric mode node to measure only the contribution of the first anti-symmetric mode in constructing the MEMS response. As seen in figure 1, while the AC voltage amplitude is set to be 52.5V, below the activation level of modal interaction, no motion is sensed at this degree-of-freedom. However, as the electrostatic force increases further, the energy channel forms between the two engaged modes, causing the first anti-symmetric mode to be excited, interacting with the second-symmetric mode, creating an M-shape steady-state dynamics.

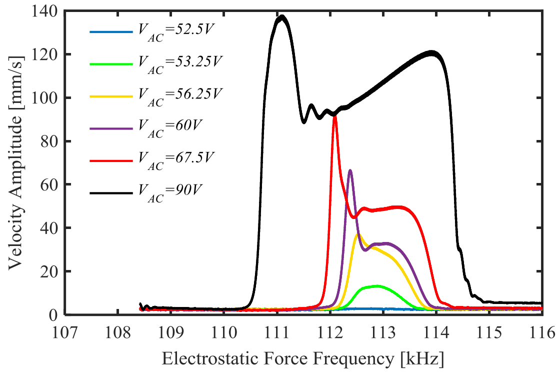

Figure 1: Measured frequency-response behaviour of the MEMS for different values of the AC voltage. The laser spot was focused on the second symmetric mode node, measuring the first anti-symmetric mode contribution.

References

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