Mode Localization of Electrostatically Coupled Shallow MEMS Arches

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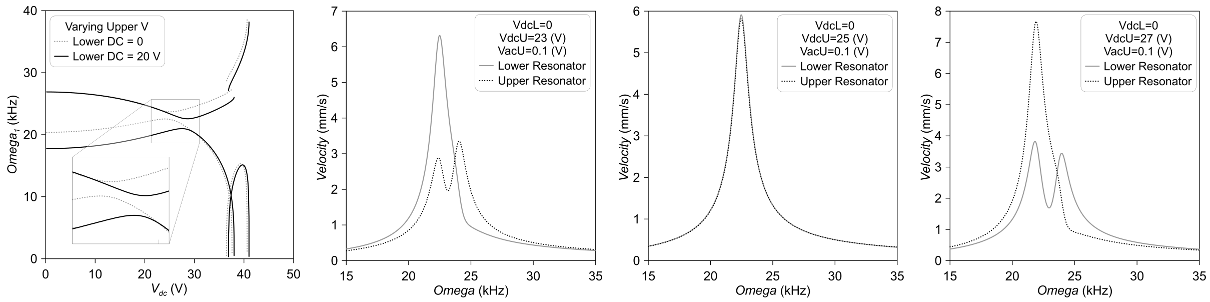
Abstract. This work examines the dynamic behavior of a micro-system design consisting of two electrostatically coupled shallow micro-arches and electrically excited using one stationary electrode. Such coupled arrangement develops nonlinear phenomena such as the multiple snap-through motions, which in turn portray certain mode veering/mode crossing and ultimately mode localization. Essentially, such rich nonlinear dynamics behavior would definitely lead to increasing the design sensitivity if used as a mode-localized micro-sensor. In addition, the use of two different beam configurations in one device offers the possibility of detecting two potential substances at the same time using the two coupled shallow micro-arches resonant peaks.

Introduction

Several research attempts have examined the nonlinear characteristics of single resonator-based micro-sensors in order to depict interesting nonlinear modal interaction behaviors, nevertheless, these structures have shown limitations especially when it comes to being sensitive to detect hazardous substances. Formerly, few groups [1, 2] attempted to design coupled structures to exploit the mode coupling phenomenon and to design extremely sensitive micro-sensors. Consequently, the aim of this research is to suggest and examine a micro-system design consisting of two shallow-arched microbeams coupled and excited electrostatically via one lower in-plane stationary electrode.

Results and Discussions

To examine the dynamic behavior of the coupled resonators, we excited the design using two actuation levels. In the first case, the lower beam actuation voltage is set to zero and the upper beam voltage is varying. Then, we increased the static voltage of the lower beam to 20 (V) and maintain similar actuation conditions for the upper beam. After that, we explore the effect of these excitation signals on the fundamental frequencies of both microbeams. Figure (1)(a) shows the variation in the first resonance frequency of the lower beam (dashed lines) and resonance frequency of the upper beam (solid lines). The veering phenomenon has been noticed for both cases where the lower beam frequency increases and the upper beam frequency decreases.



(a) (b) (c) (d)

Figure 1: (a) The variation in the first resonance frequency of the lower beam and of the upper beam as a function of the upper static voltage and a lower voltage sets to 0 and 20 (V). Frequency-response curves of the two resonators: (a) before, (c) at and (d) after veering zone.

Furthermore, we examine the frequency-response curves of the first lower and upper resonance frequencies in the vicinity of the veering zone. Employing different excitation voltages will give further insights into the dynamic interaction between the two initially curved-up resonators and how the energy is exchanged among them as the voltage varies. Before entering the veering zone, linear responses have been computed for both resonators with two distinct peaks as shown in Fig. (1)(b). We note that a small peak appears in the vicinity of the fundamental frequency of the lower resonator indicating that an energy channel starts to be activated, however, most of the vibrating energy begins to be more localized at the lower resonator. Increasing the upper voltage leads to a merge between the two frequencies with a single peak as illustrated in Fig. (1)(c). Then, swapping between the two frequencies occurs with a peak dominated by the upper resonator as shown in Fig. (1)(d). This is true because the two frequencies start moving away from each other. Indeed, we carried out an analytical study of the vibration of weakly electrostatically coupled initially curved-up microbeams. Multiple nonlinear behaviors have been obtained which are useful for potential MEMS applications such as mode-localized based inertia sensors.

References

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