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# Dynamics of Coupled Micromachined Resonators for Ultra-Sensitive Sensors

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**Abstract:**

We present recent results on the dynamics of coupled oscillators and their exploitation for ultra-sensitive sensing. In particular, we investigate veering and mode localization phenomena in two mechanically coupled micromachined resonant microbeam systems through combined analytical modeling and experimental validation. The structures are electrostatically actuated and perturbed via electrothermal stiffness tuning induced by Joule heating. A new concept of double perturbation is introduced, involving the simultaneous reduction of stiffness in one microbeam and an increase in stiffness in the other. Analytical predictions are presented and shown to be in good agreement with experimental measurements. The results demonstrate that the proposed double-perturbation approach significantly enhances sensitivity compared to conventional single-perturbation techniques.

As a case study, we demonstrate a highly sensitive thermal-conductivity gas sensor that exploits mode localization and buckling in a coupled micromechanical resonator system. The device consists of two electrothermally heated microbeams, where one beam is tuned via thermal axial loading to operate just beyond its buckling point, while the other operates just below buckling. The microbeams are designed to have nearly identical stiffness, placing the system initially in a balanced state. Upon exposure to high-thermal-conductivity gases, such as helium or hydrogen, convective cooling reduces the thermally induced compressive axial load. This results in a decrease in stiffness of the buckled beam and a concurrent increase in stiffness of the unbuckled beam. These opposing perturbations break the initial symmetry and induce strong mode localization. The resulting amplitude difference between the coupled vibration modes is used as the sensing metric. Experimental results demonstrate orders-of-magnitude improvement in sensitivity compared to traditional single-structure thermal-conductivity gas sensors. The proposed approach provides a promising pathway toward part-per-million-level gas detection based on intrinsic thermal-conductivity mechanisms.