Engineering Sciences
MEMS Devices

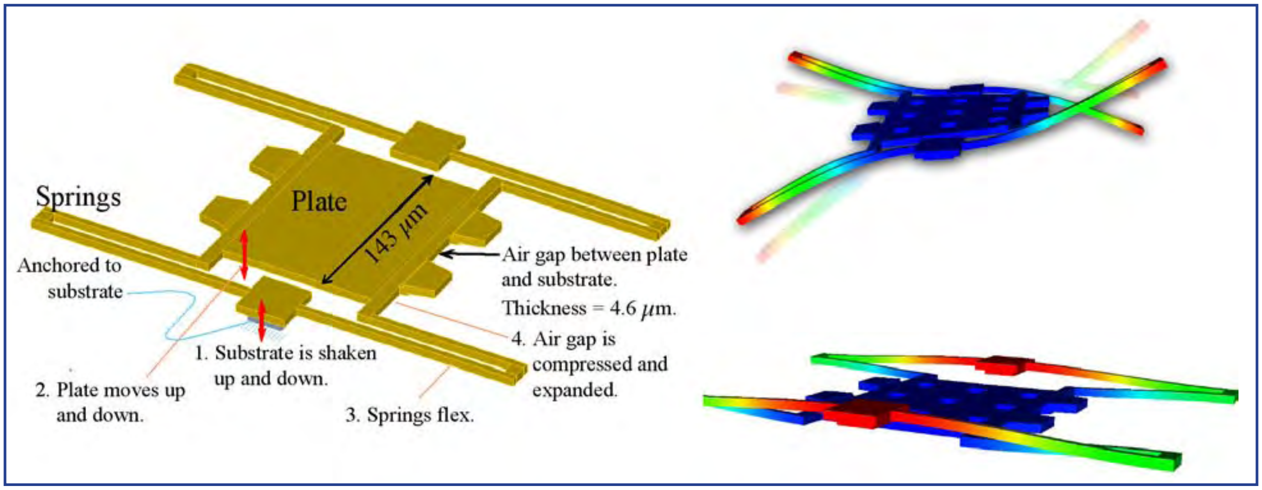

Figure 1. Micro plate device and deflection simulations.

Experimental tools for characterization of microscale fluid-structure interaction

New Sandia tools improve understanding of fluid-structure interaction at the microscale, leading to more reliable and better-performing MEMS devices.

Fluid-structure interaction plays an important role in the performance of many microscale devices. Because of the sub-micron length scales involved in these systems, the motion of MEMS parts is highly coupled, and non-continuum and rarified gas effects, surface roughness, and surface charge must all be factored into accurately predicting part performance.

The unique capability to measure, predict, and model this highly coupled phenomenon is critical if we are to produce more reliable and better performing MEMS devices, such as MEMS accelerometers, radio-frequency MEMS switches, and MEMS gyroscopes. Fortunately, Sandia scientists have created a unique set of tools that allow for complete characterization of fluid-structure interaction at the microscale.

The gas-filled gaps between structures require high-fidelity computational techniques to accurately capture the fluid velocity, temperature, and pressure. Direct measurements of the fluid flow are critical for a full understanding of fluid-structure interactions. We use the Direct Simulation Monte-Carlo (DSMC) method to simulate a variety of non-continuum microsystem flows, including gas damping of moving microbeams and gas-phase heat conduction between a heated microbeam and an adjacent ambient substrate. To measure these quantities and thereby validate both model and system performance, we developed laser-doppler vibrometry and gas-phase microscopic particle-tracking velocimetry.

With laser doppler vibrometry, we can measure the velocity of MEMs features as small as 1 micron vibrating at frequencies of several megahertz. The Microscopic

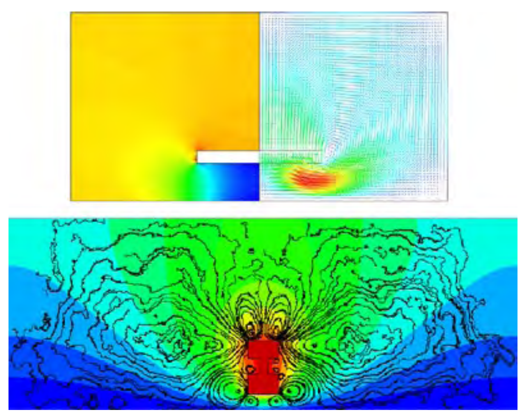

Figure 2. (Top) DSMC simulation of gas pressure and velocity induced by microbeam motion. (Bottom) Simulation of a heated microscale I-beam 2 microns above a substrate at ambient temperature, with ambient-pressure nitrogen present between the solids.

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Particle-Tracking Velocimetry technique measures fluid velocity by tracking the motion of microscale (0.3-2 micron) seed particles.

Sandia has assembled a set of unique experimental and computational tools to measure gas velocity, temperature, pressure, and structural motion in MEMs systems. Because of our computational capabilities, our capability to perform high-fidelity coupled 2-D fluid-structure interaction simulations with DSMC is unique. Our experimental capability to measure both the structural response and gas motion within a MEMs device is also unique.

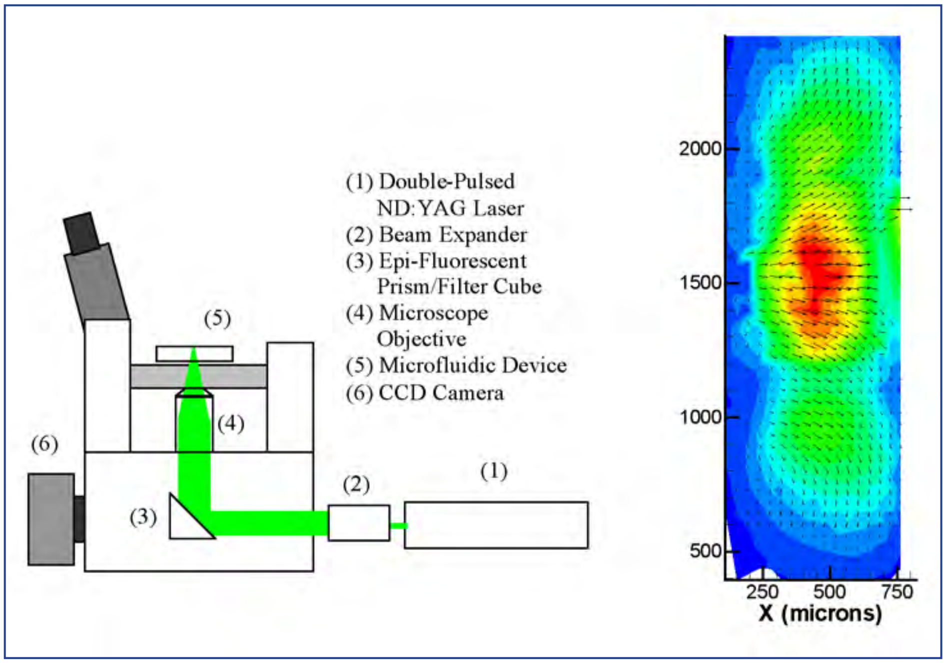

Figure 3. Schematic of Particle-Tracking Velocimetry system (left) and 2-D velocity field initiated by surface-accoustic wave device in a microchannel determined by Micro-PIV technique

Publications:

J. R. Torczynski, M. A. Gallis, and E. S. Piekos, “Simulations of Gas Flow Around Moving Microbeams,” *Bulletin of the American Physical Society* **47** (10), 131 (2002).

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