Spring 2017

Design verification of MEMS Resonators with FEM Simulator

Joshua Wiswell
University of Southern Maine

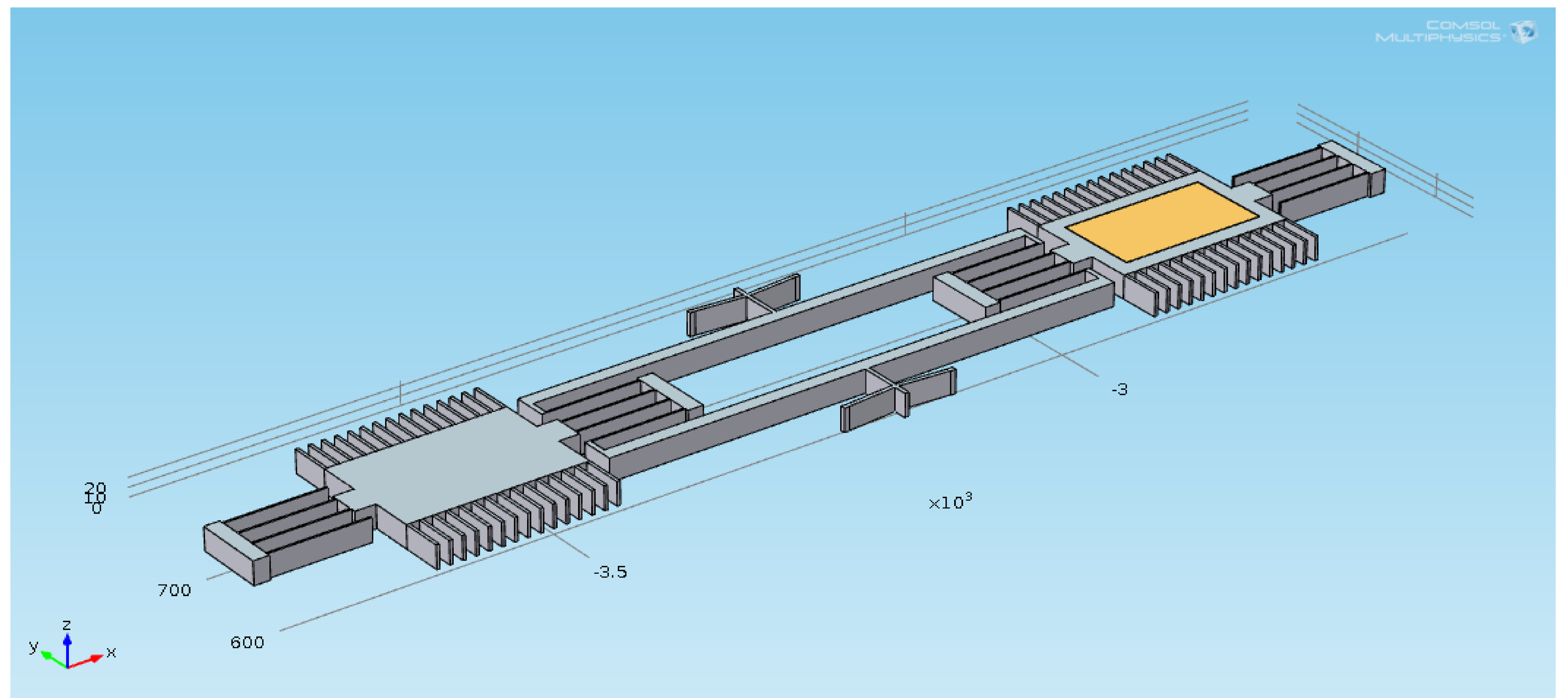
Design verification of MEMS Resonators with FEM Simulator

Author: Joshua Wiswell, Advisor: Dr. Mustafa Guvench
USM Department of Engineering

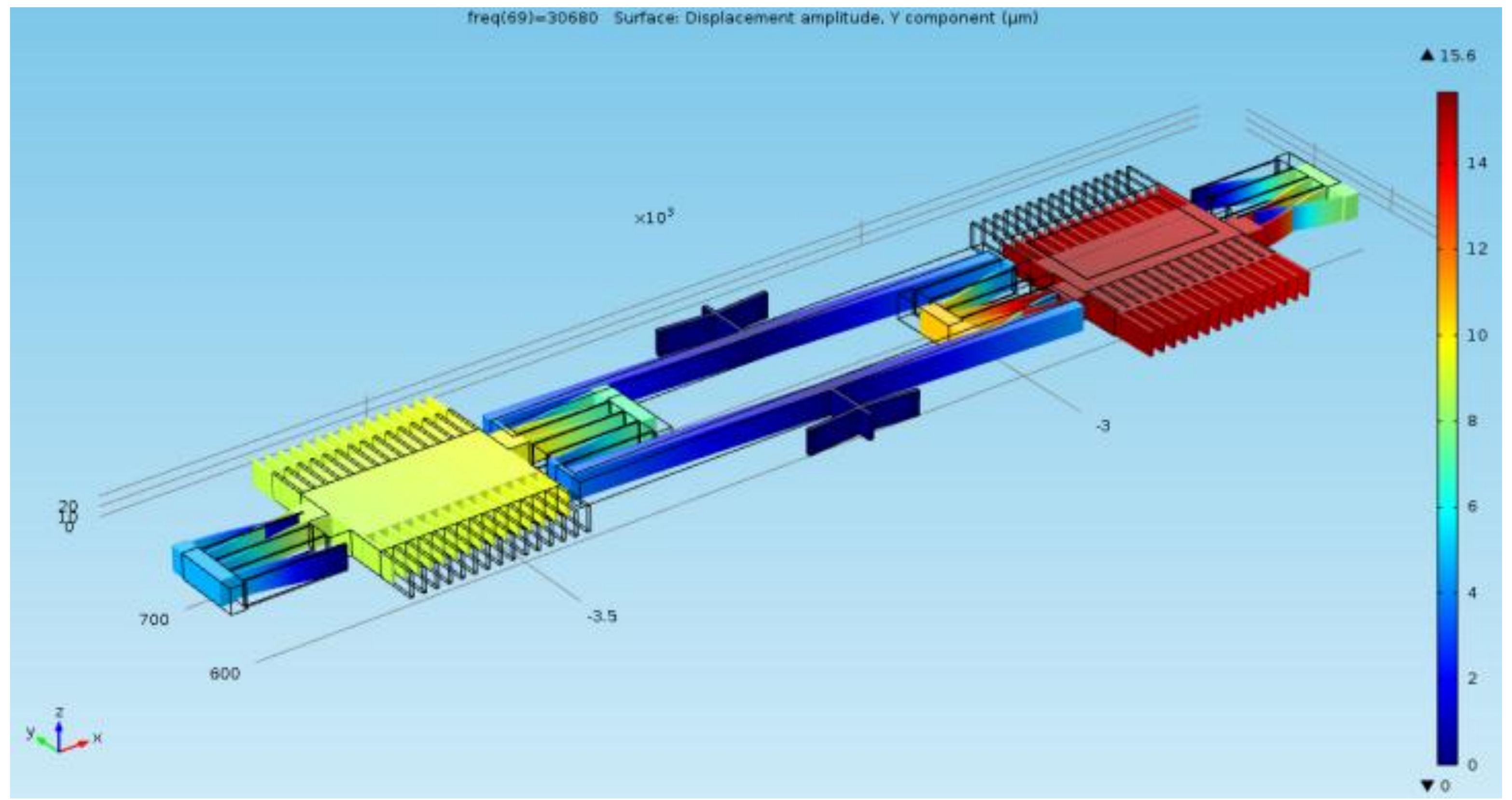
Introduction

The purpose of this project was to use COMSOL, an advanced FEM (finite element modeling) software, to analyze a Coupled Thermal Resonator. This Coupled Thermal Resonator was previously constructed in L-Edit, but when analyzed in COMSOL, it produced undesirable results. This project focused on improving the design and model of the Resonator to improve simulation results and evaluating the actual response of the MEMS device to determine if simulated results were accurate for the actual device. Many different factors may have contributed to producing the double peak seen in the simulation, including the weak coupling between the two resonators. These factors were analyzed to determine how to correct the model or simulation parameters to produce the expected and desired results. Simulation of the actual DC heating of the device, which was previously determined to be too complex, was attempted in an effort to produce a fully-simulated model of the actuator. Also, measurement of actual fabricated MEMS resonator frequency response was measured and compared with the simulated results.

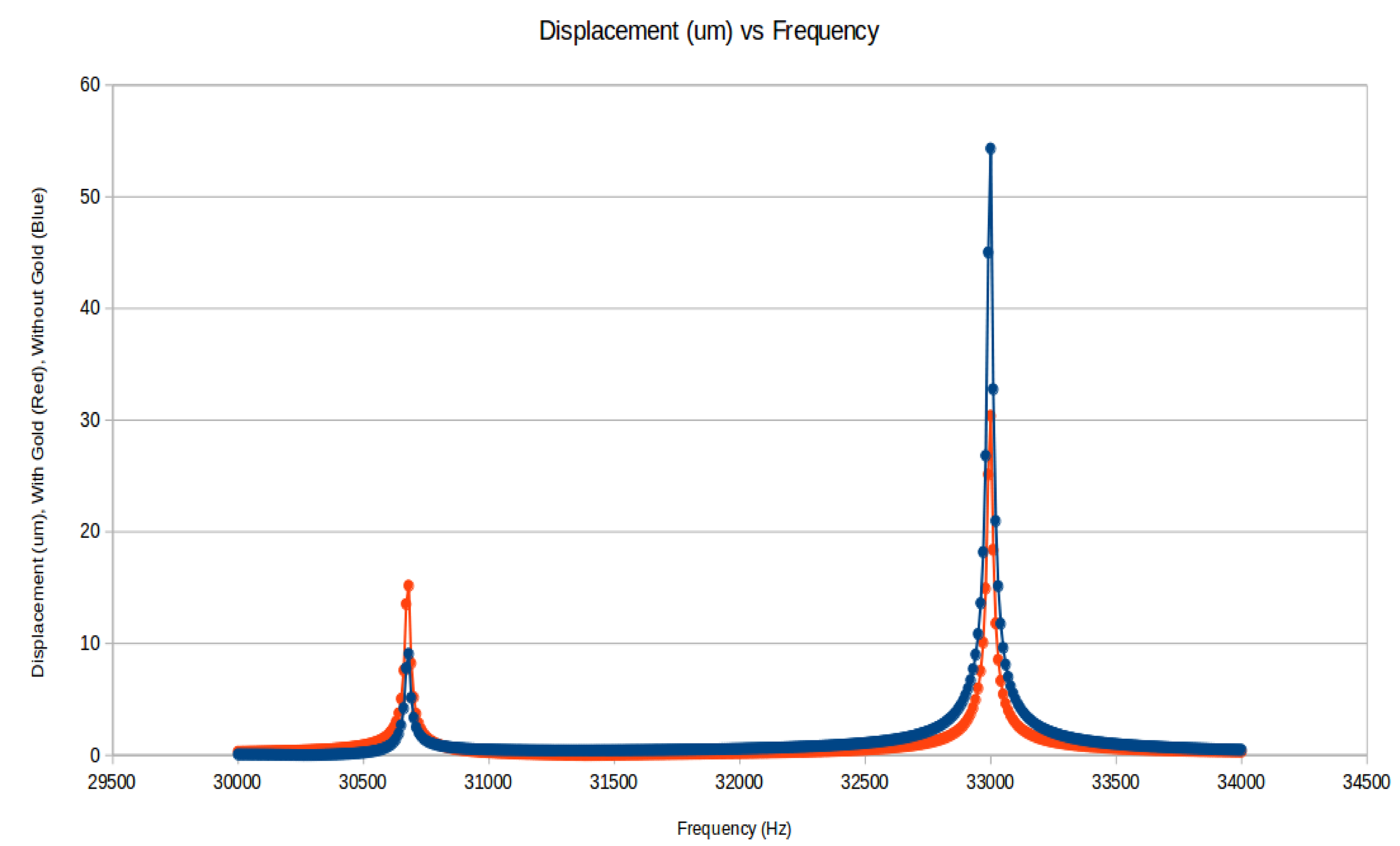
Simulated Results



Coupled Resonators with different shuttle masses

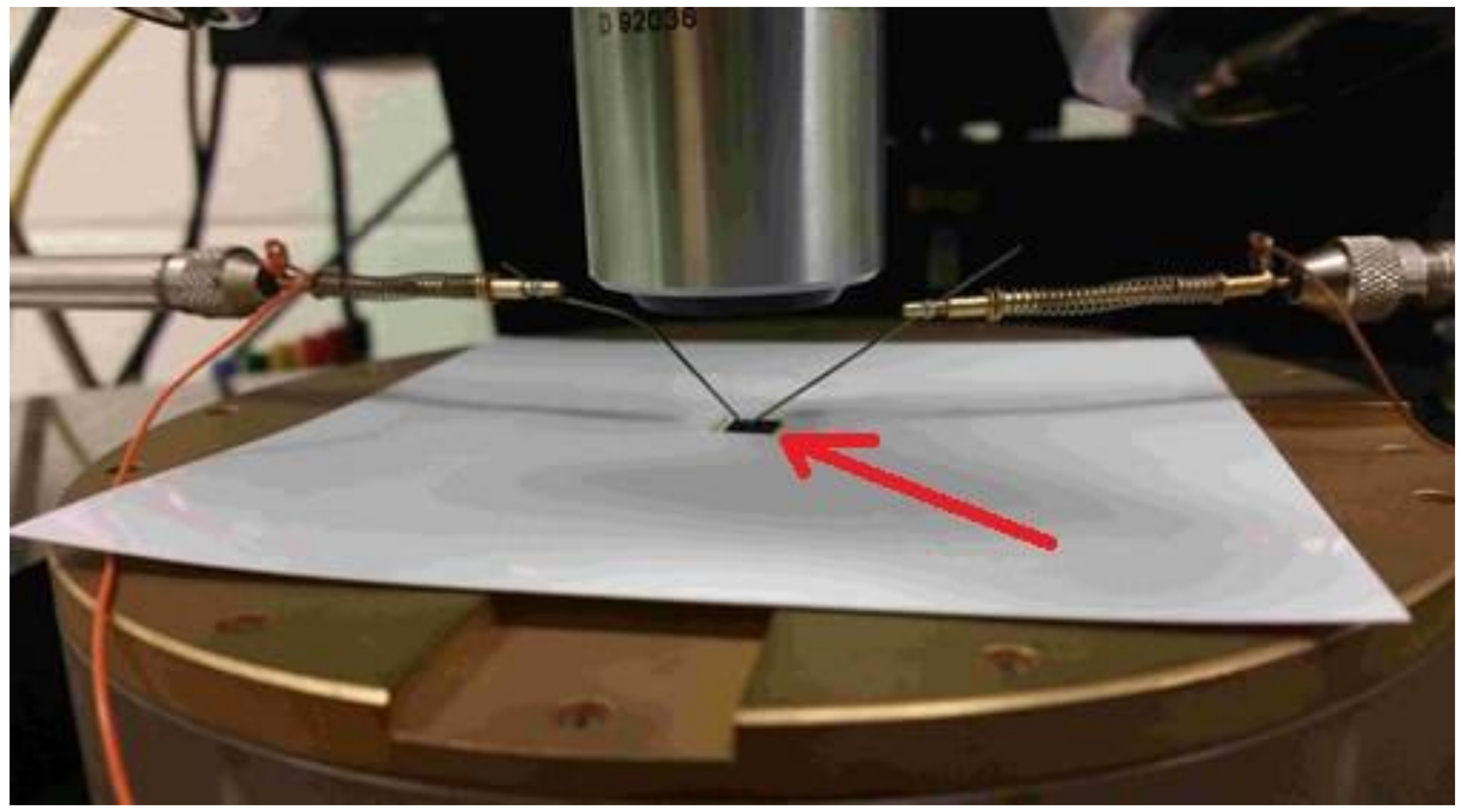


Displacement graph of coupled resonators at 30,680Hz

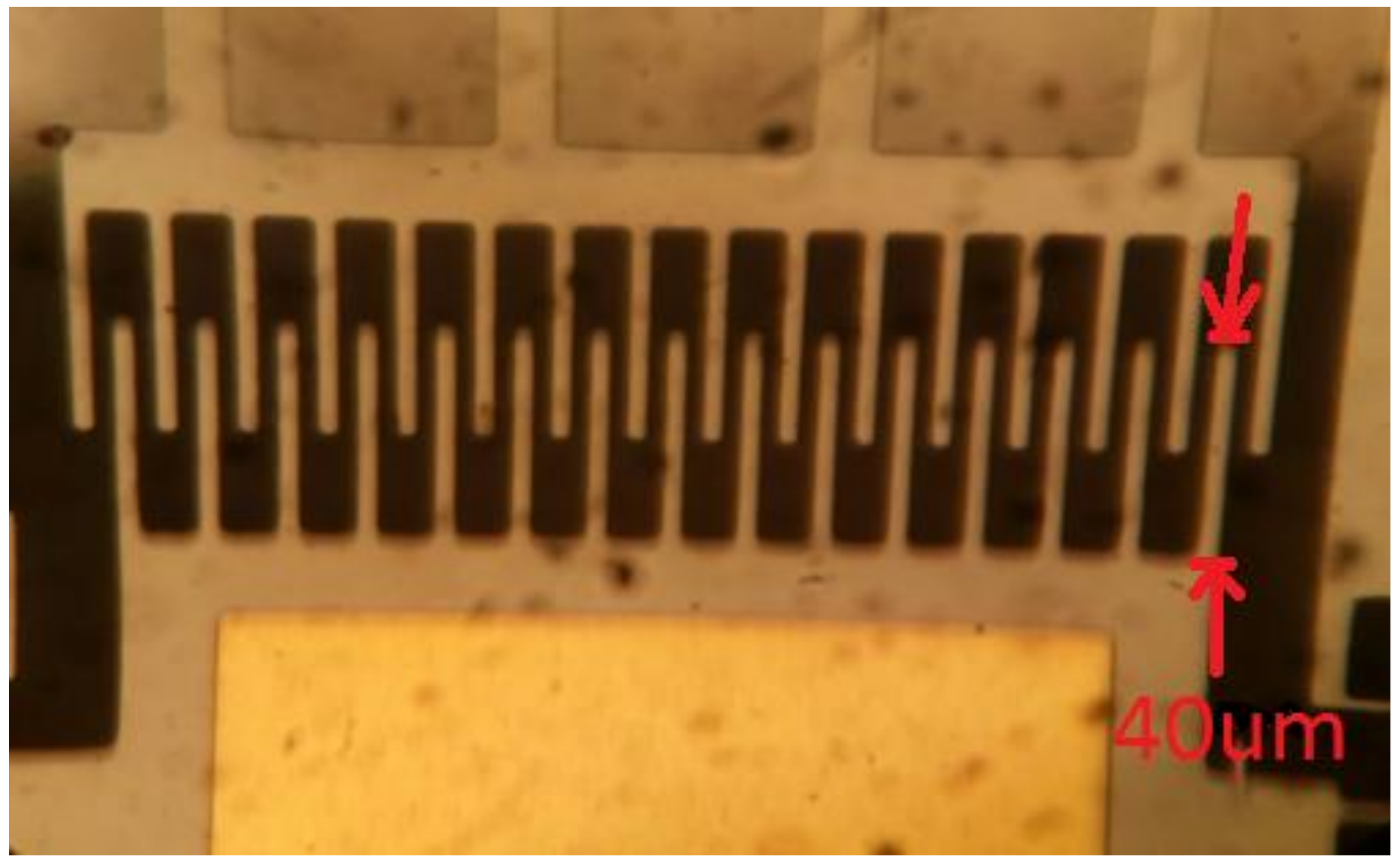


Simulated frequency response (displacement vs. frequency) of the coupled resonators

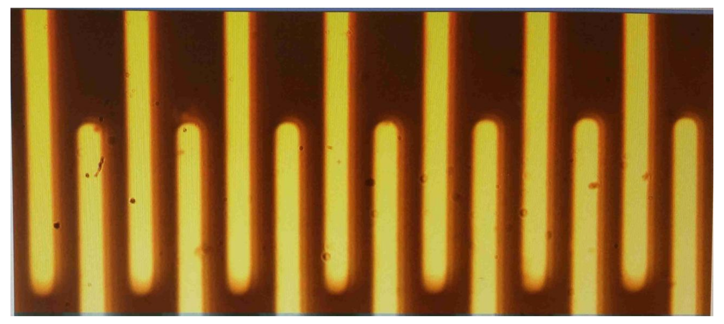
Fabricated Device



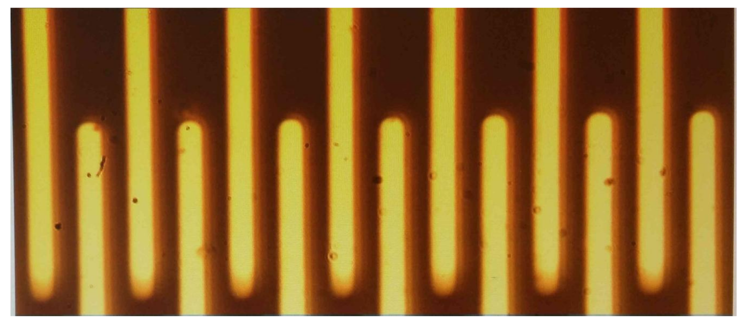
Actual device with test probes connected



Actual device at resonance (gold side) under microscope



Gold Side at 29,650Hz



Gold Side at 31,964Hz

Actual vs. Simulated Results

	Actual	Simulated
With Gold Resonant Frequency	29,650 Hz	30,680 Hz
Without Gold Resonant Frequency	31,964 Hz	33,000Hz
Displacement At Resonant Frequency (With Gold)	≈1 µm	15.16 µm
Displacement At Resonant Frequency (Without Gold)	≈4 µm	54.30 µm

	Resonant Frequency Difference (Simulated - Actual)	% Difference
With Gold (30,680-29,650)	1,030 Hz	3.41%
Without Gold (33,000-31,964)	1,036 Hz	3.19%
Difference between The peaks	6 Hz	0.58%

The simulated and actual devices showed similar characteristics at the gold side's resonant frequency (29,650Hz) and the non-gold side's resonant frequency (31,964Hz) with displacements of 1um and 2um, respectively. The gold side's simulation showed twice the displacement at the non-gold side's frequency as at its own. The simulation showed displacements of 15.16um and 30.38um, whereas the fabricated device showed displacements of 1um and 2um, respectively.

Conclusion

Everything expected from this project was completed and the simulated vs. real values were very close. There was some difference in where the resonators resonated (shifted by about 1kHz), but the distance between the two peaks was almost exact (6Hz). The max displacement shown at the resonant frequencies was still not accurate, but this is likely due to over exciting the system by applying too large a prescribed displacement. Further work will include correcting the displacement values at resonance by including non constant values for thermal conductivity, thermal expansion, and resistance. Steve Nelson's previous work characterized single crystal silicon non constant thermal conductivity and thermal expansion, which will be the starting point of the project continuation.

References

1. Crosby, J. V., & Guvench, M. G. "Finite Element Modeling of Resonating MEMS Micro-Heater Structures for Design Verification and Optimization", Proc. of Applied Modeling and Simulation Conference, Palma de Mallorca, Spain, AMS-2009.
2. Nelson, S., & Guvench, M. G. ,"COMSOL Multiphysics Modeling of Rotational Resonant MEMS Sensors with Eletrothermal Drive" Proc. of 2009 COMSOL Conference, . https://www.comsol.com/paper/download/44730/Nelson.pdf
3. Crosby, J.V. and Guvench, M.G., "Experimentally Matched Finite Element Modeling of Thermally Actuated SOI MEMS Micro-Grippers Using COMSOL Multiphysics," Proc. of 2009 COMSOL Conference, https://www.comsol.com/paper/download/101075/Guvench.pdf

Acknowledgements: This project would not have been possible without the previously received Grants from NASA and Maine Space Grant Consortium.