جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology

COMSOL CONFERENCE 2015 BOSTON

Simulation of Buckled Cantilever Plate with Thermal Bimorph Actuators

BY ARPYS AREVALO

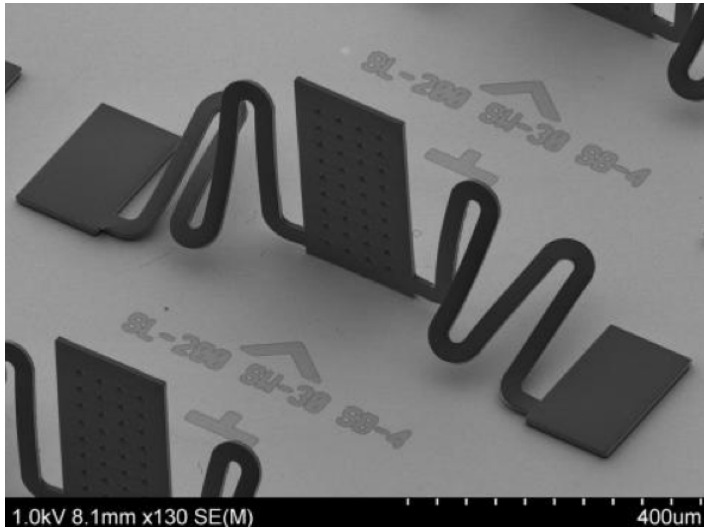
Outline

- Out-of-plane structures
- Applications
- Benefits of Out-of-plane structures
- Thermal Bimorph Mirror
- Conclusions

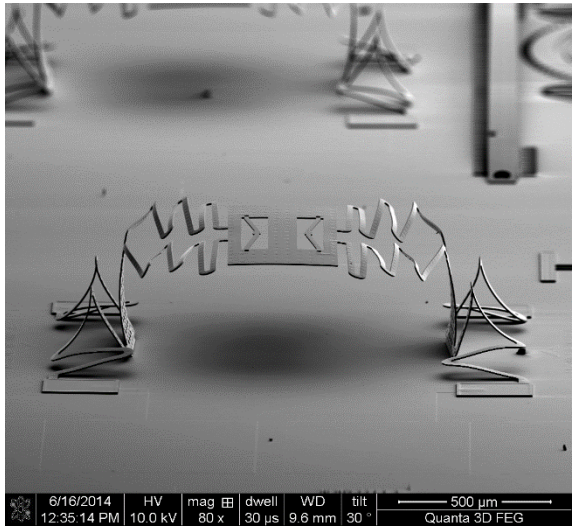
Out-of-plane Structures

- The world of Micro Electro Mechanical Systems (MEMS) is flat!
- Out-of-plane structures can help separate devices from the substrate, to provide good **electrical and thermal isolation.**

Hinged-less Structures

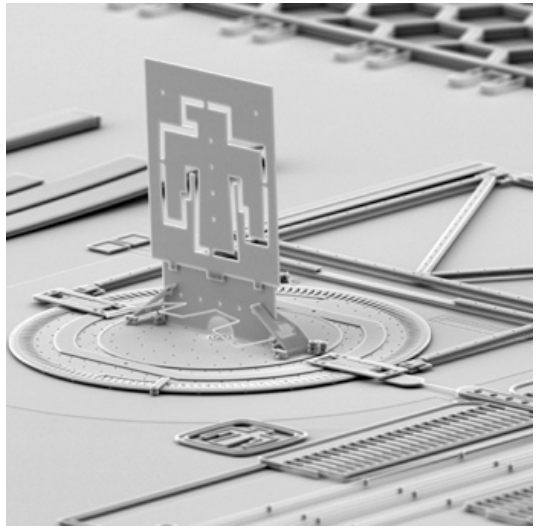


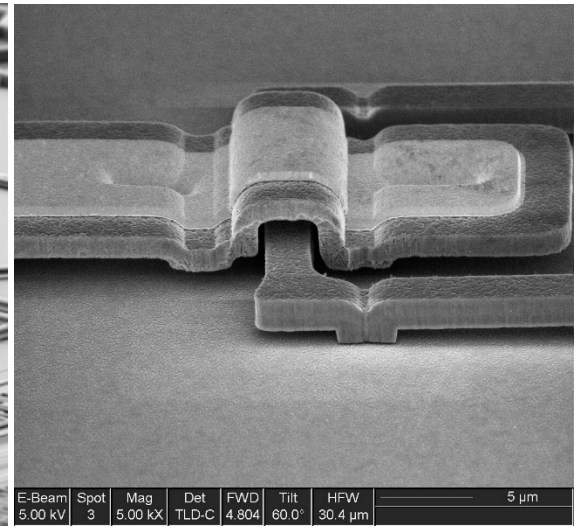
(Castro, 2014)



(Carreño, 2014)

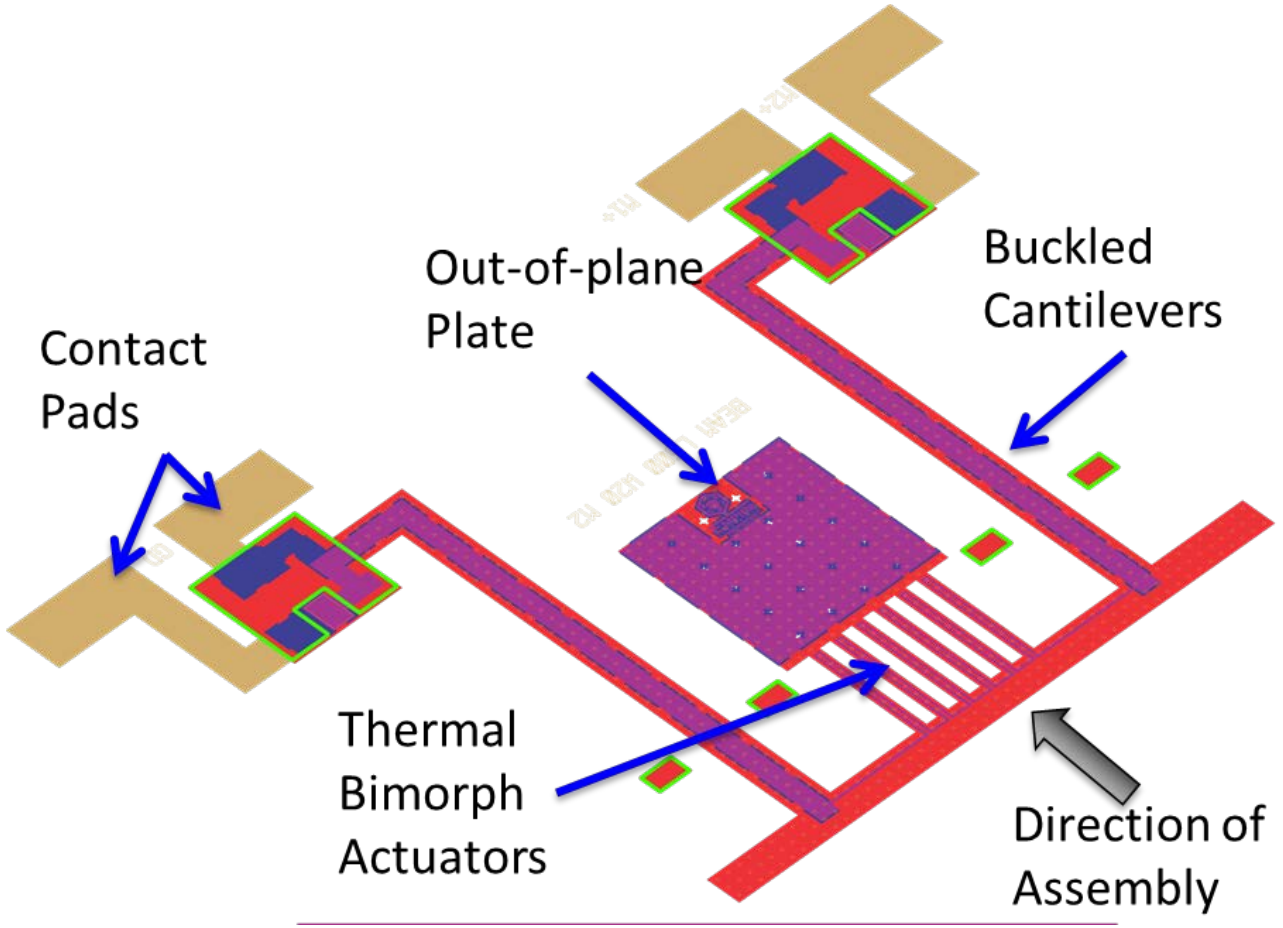
Hinged Structures

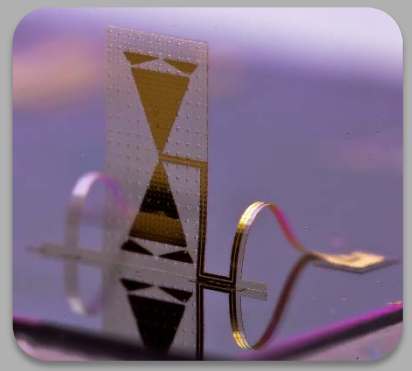




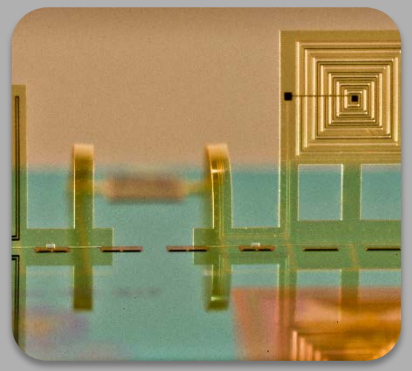
(Sandia National Labs)

Buckled Cantilever Platforms

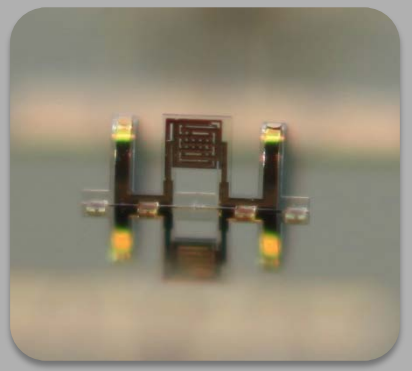




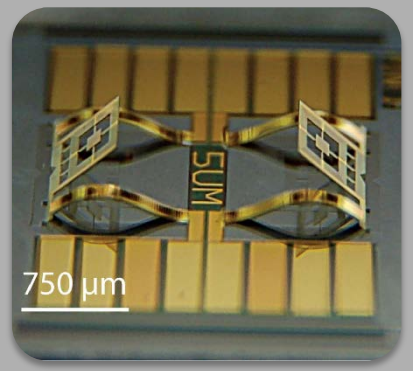
Radio Frequency Antennas
(Loic, 2013)



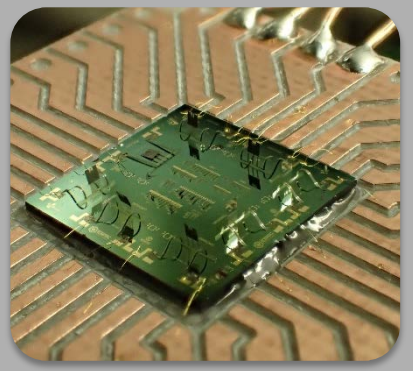
Magnetic Field Sensors
(Alfadel, 2013)



µHeaters for Gas Sensing
(Carreño, 2012)



Thermal Accelerometers
(Ma, 2008)

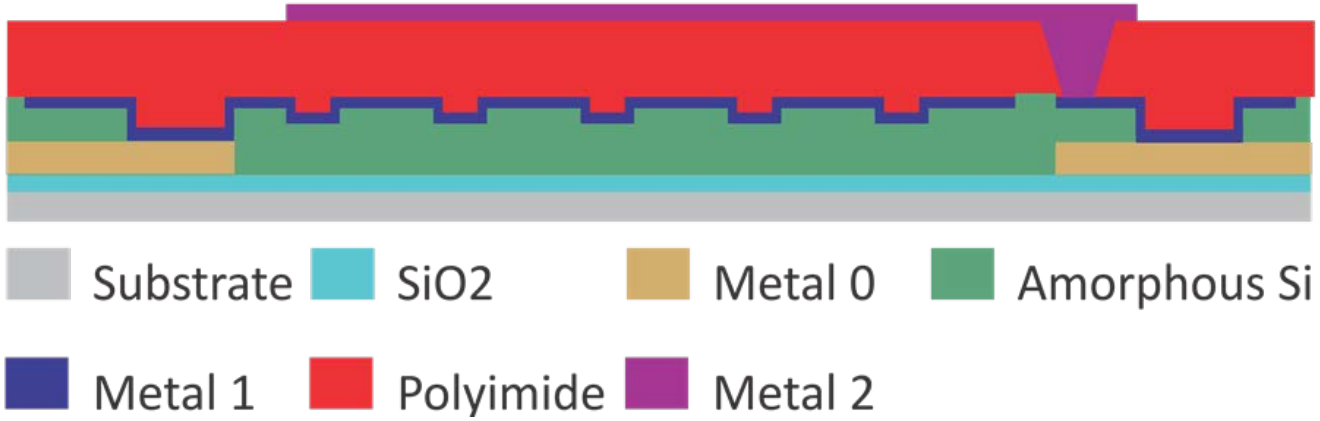


MEMS Optical Bench Mirrors
(Conchouso, 2015)

Benefits of Out-of-plane Structures

- **Thermal Isolation:**
  - Reduces the heat loss drained through the substrate due to conductivity
  - Allows localized heating
- **Electrical Isolation:**
  - Eliminates parasitic capacitances between a transducer and the substrate
  - Reduces Radio Frequency (RF) Interference
- **Magnetic Orientation:**
  - Allows magnetic sensing/ actuation in a desired orientation
- **Inertial Orientation:**
  - Enables the interpretation of inertial components in the transducers

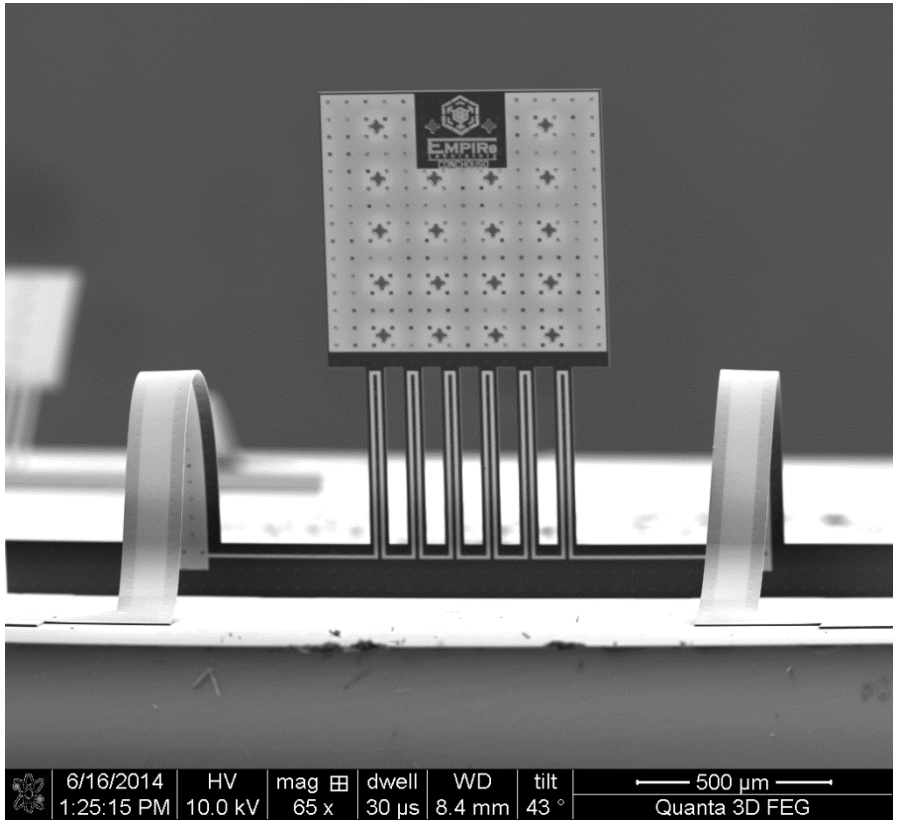
Polyimide-Metal MEMS Fabrication Process (PiMMP)



Further Details of the **Polyimide-Metal MEMS Fabrication Process**, please refer to the following paper:

Arevalo, D. Conchouso, D. Castro, , and I. G. Foulds, "***A Versatile Multi-User Polyimide Surface Micromachinning Process for MEMS Applications***" in *10th IEEE International Conference on Nano/Micro Engineered and Molecular Systems NEMS2015*, Xia'an, Apr. 2015.

Out-of-plane Bimporh µMirror with Adjustable Angle



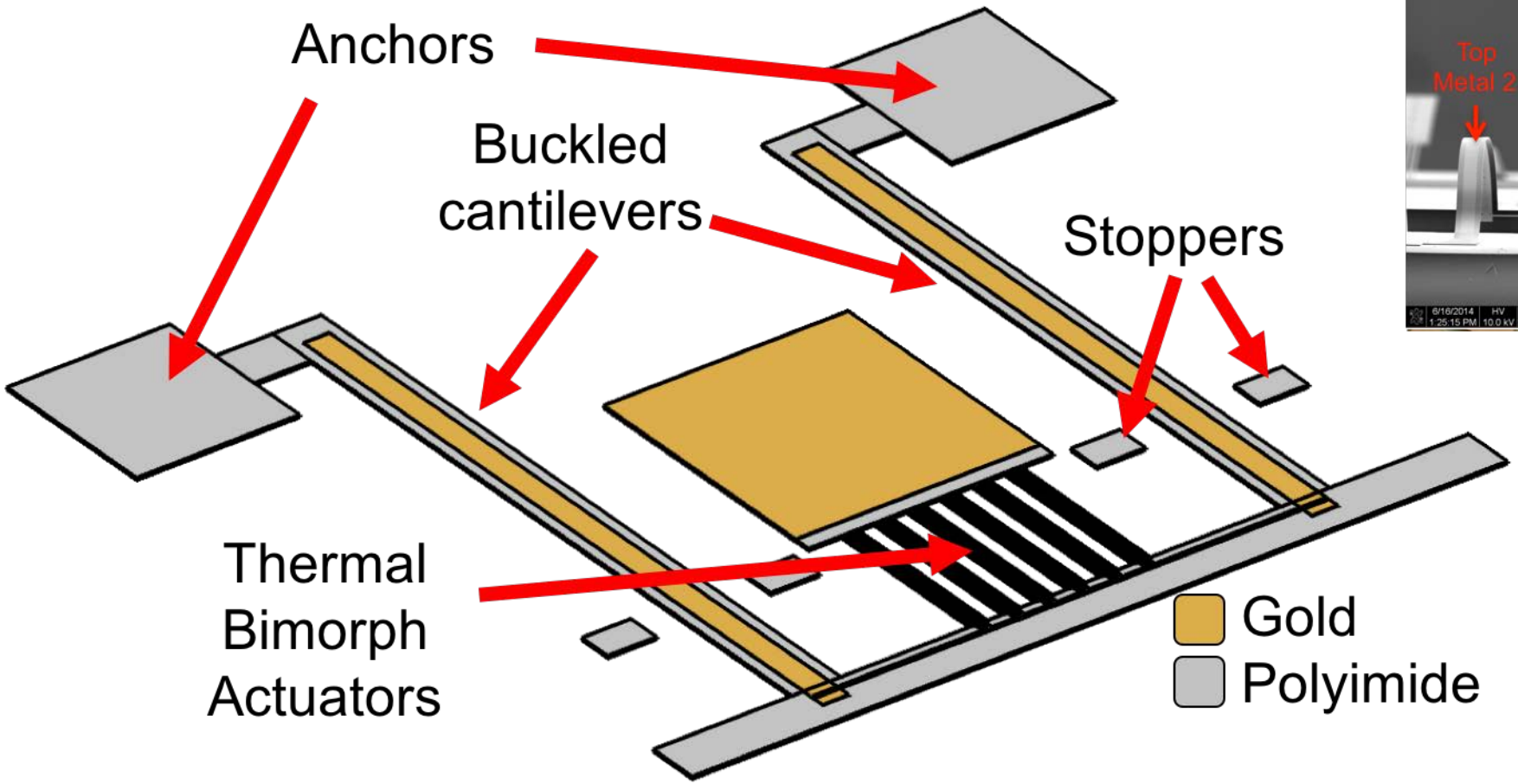
Angle Adjustment by Mechanical Design:

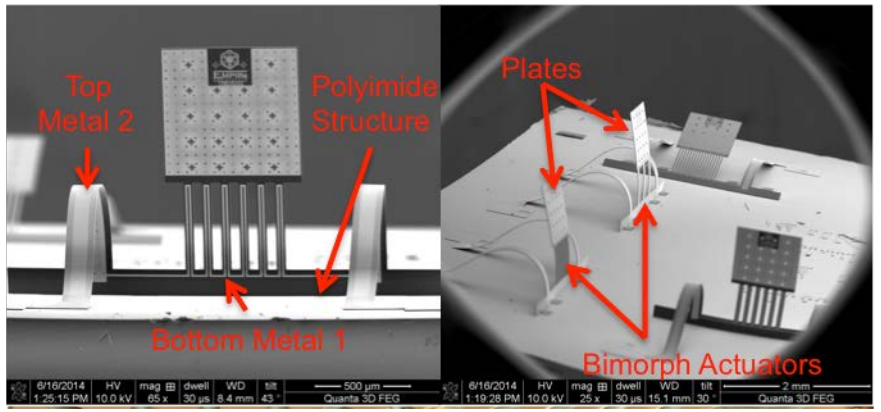
- Depending on the position of the stoppers (anchored structures) and the position of the plate's attachment links

Angle Adjustment by Electro-thermal Excitation:

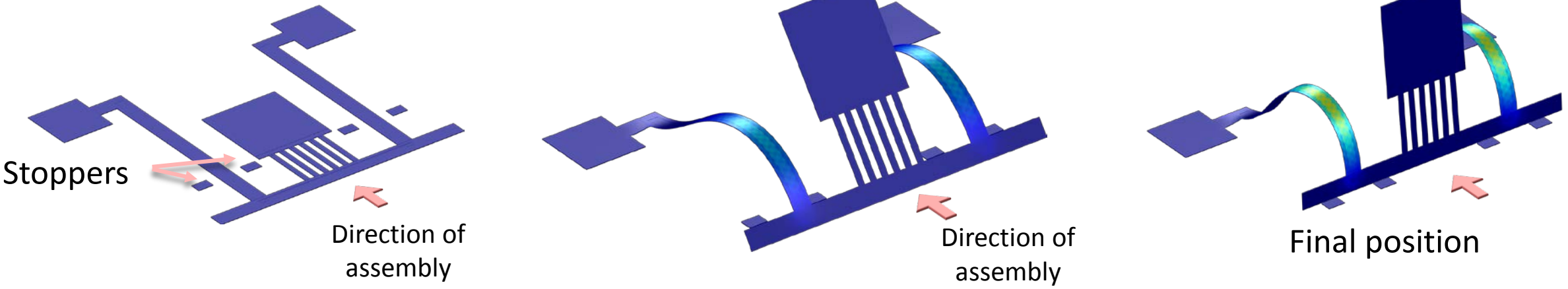
- Electrical lines at the attachment links work as both conductive layers and composing bimorph layer.

Simulation Setup





Assembly of the Out-of-plane Structures



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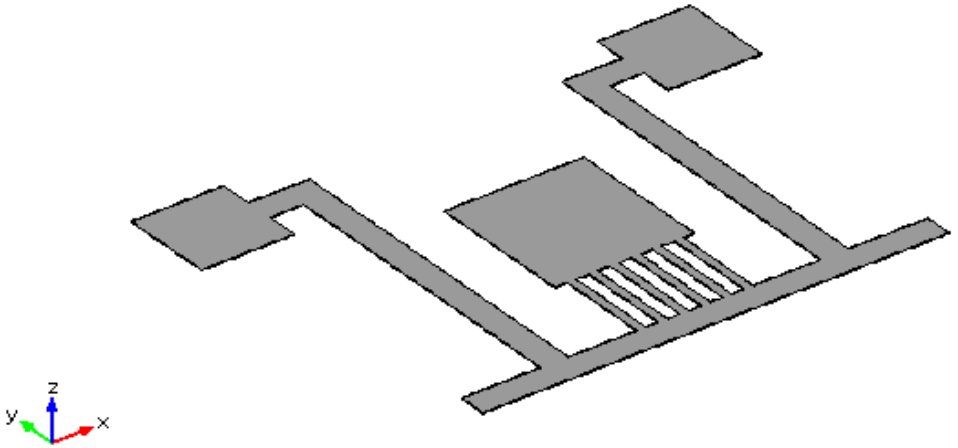
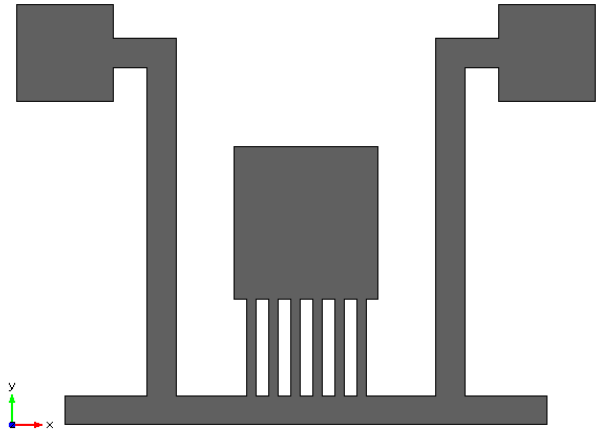
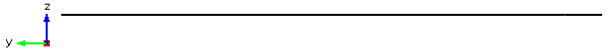


Isometric View

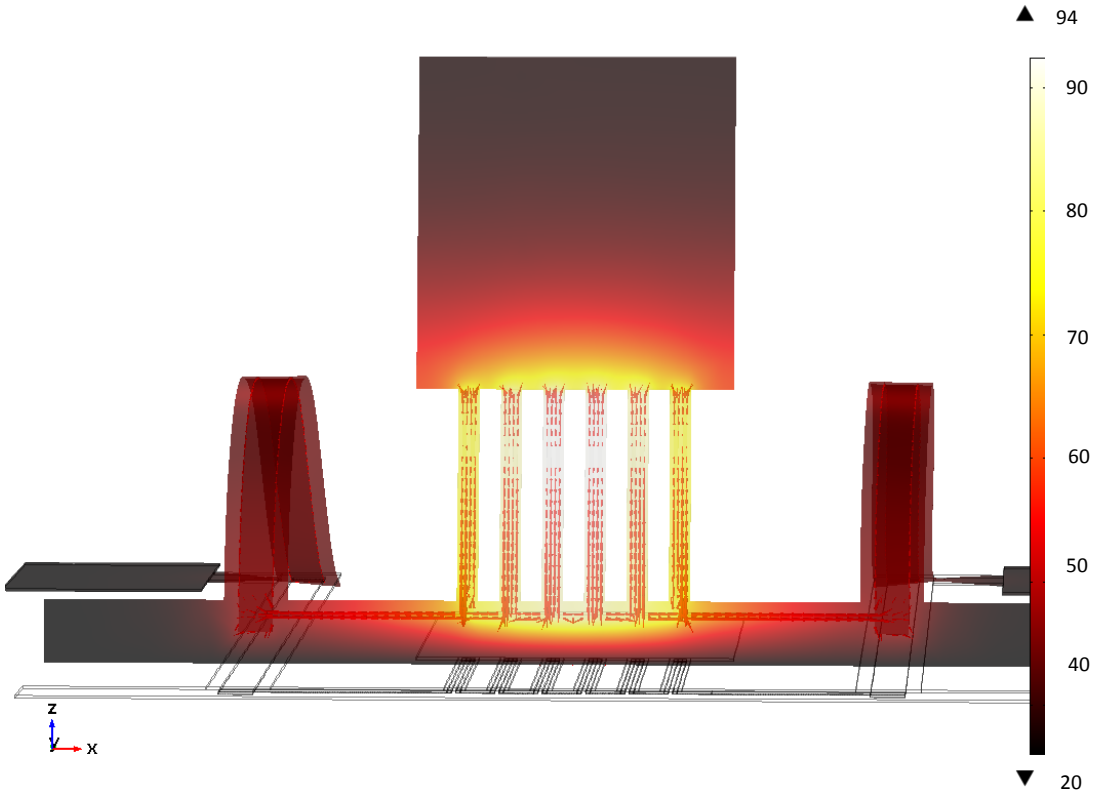


Top View (XY-plane)

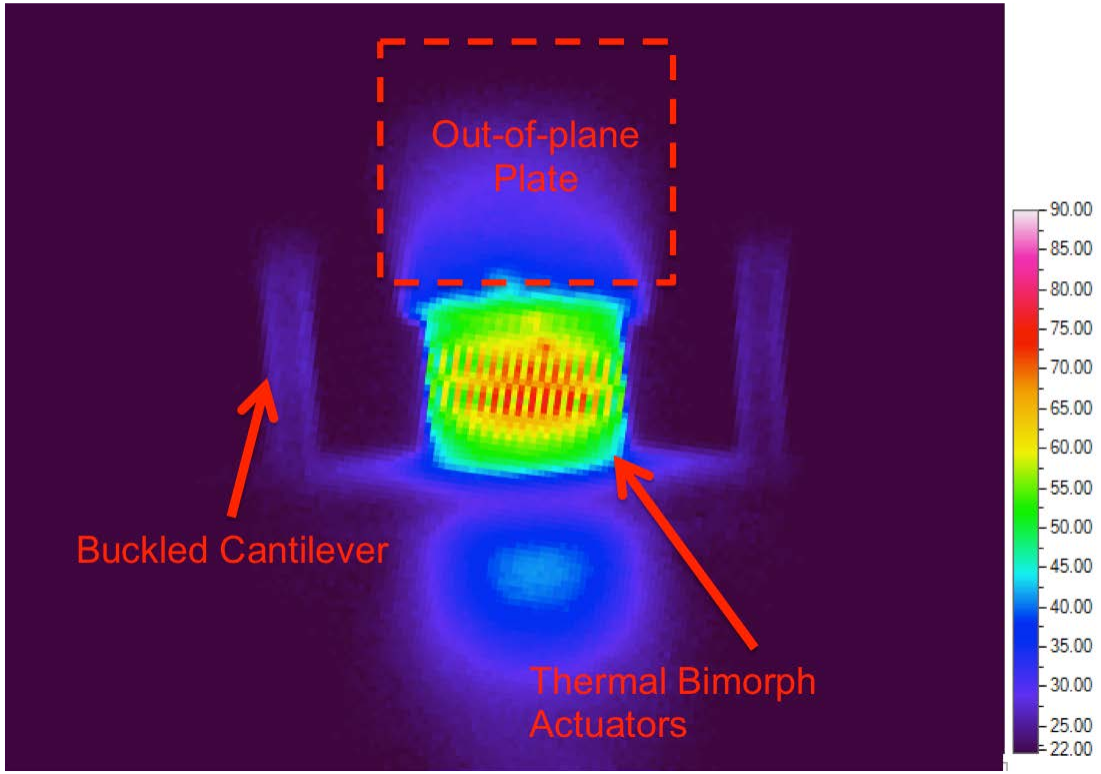


Side View (YZ-plane)

Bi-directional Thermal Bimorph µMirror

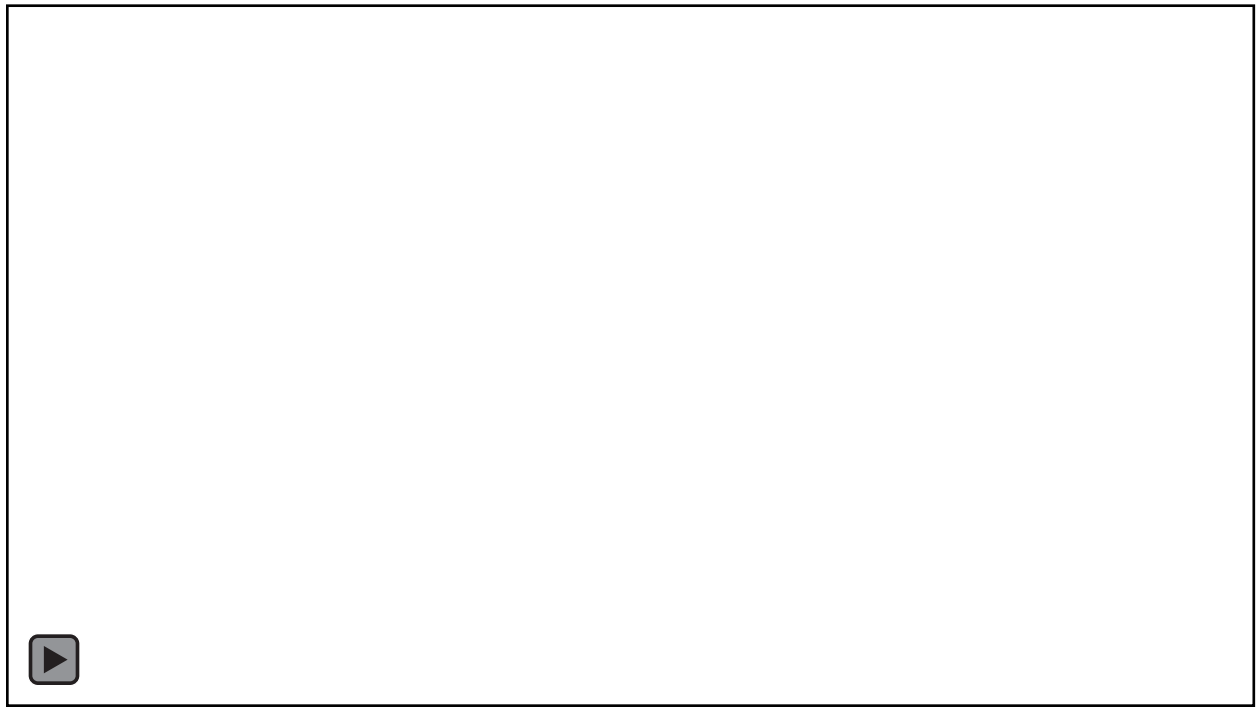


Simulation at equivalent 6V

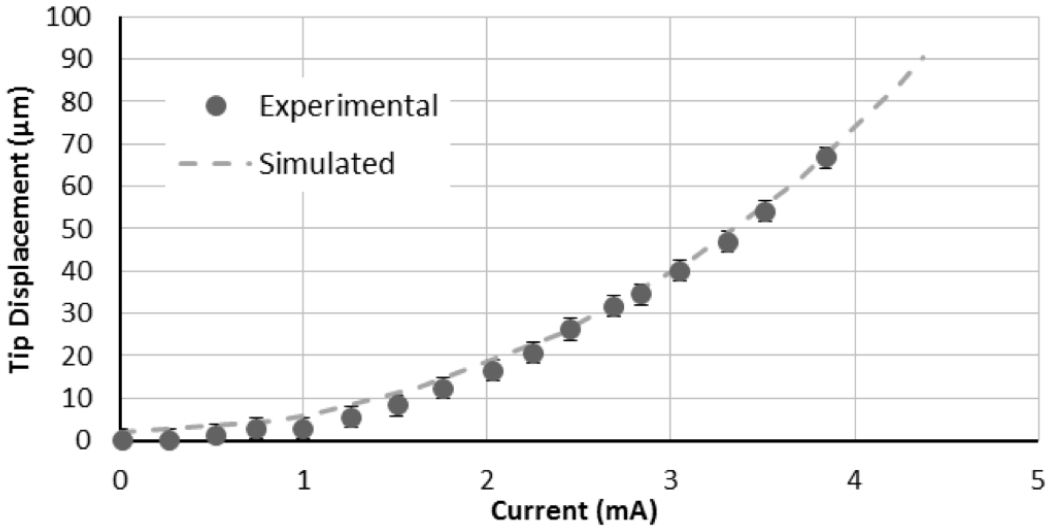


Experimental measurement @6V

Temperature of the plate ≦40°C !

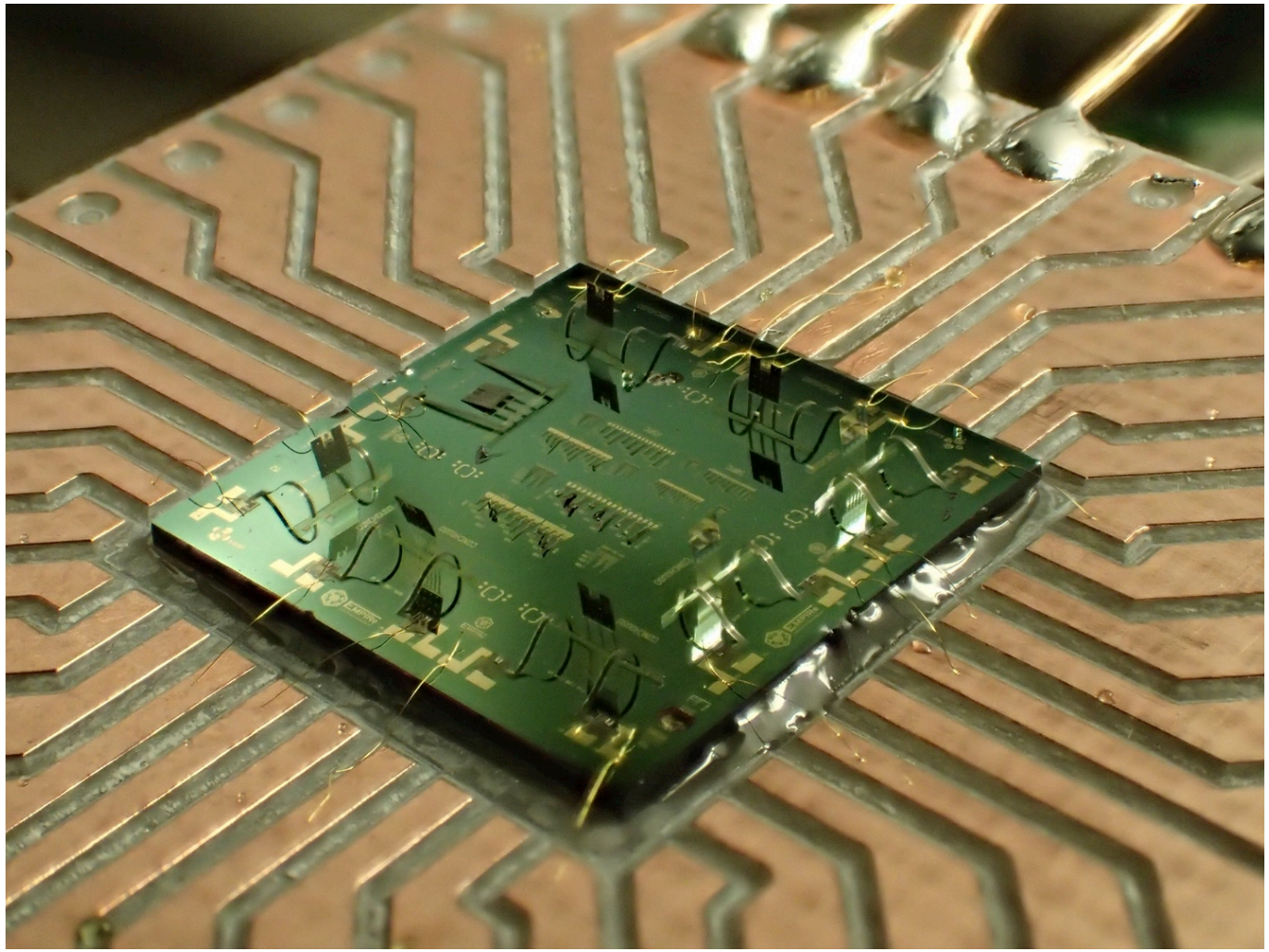


Experimental Validation

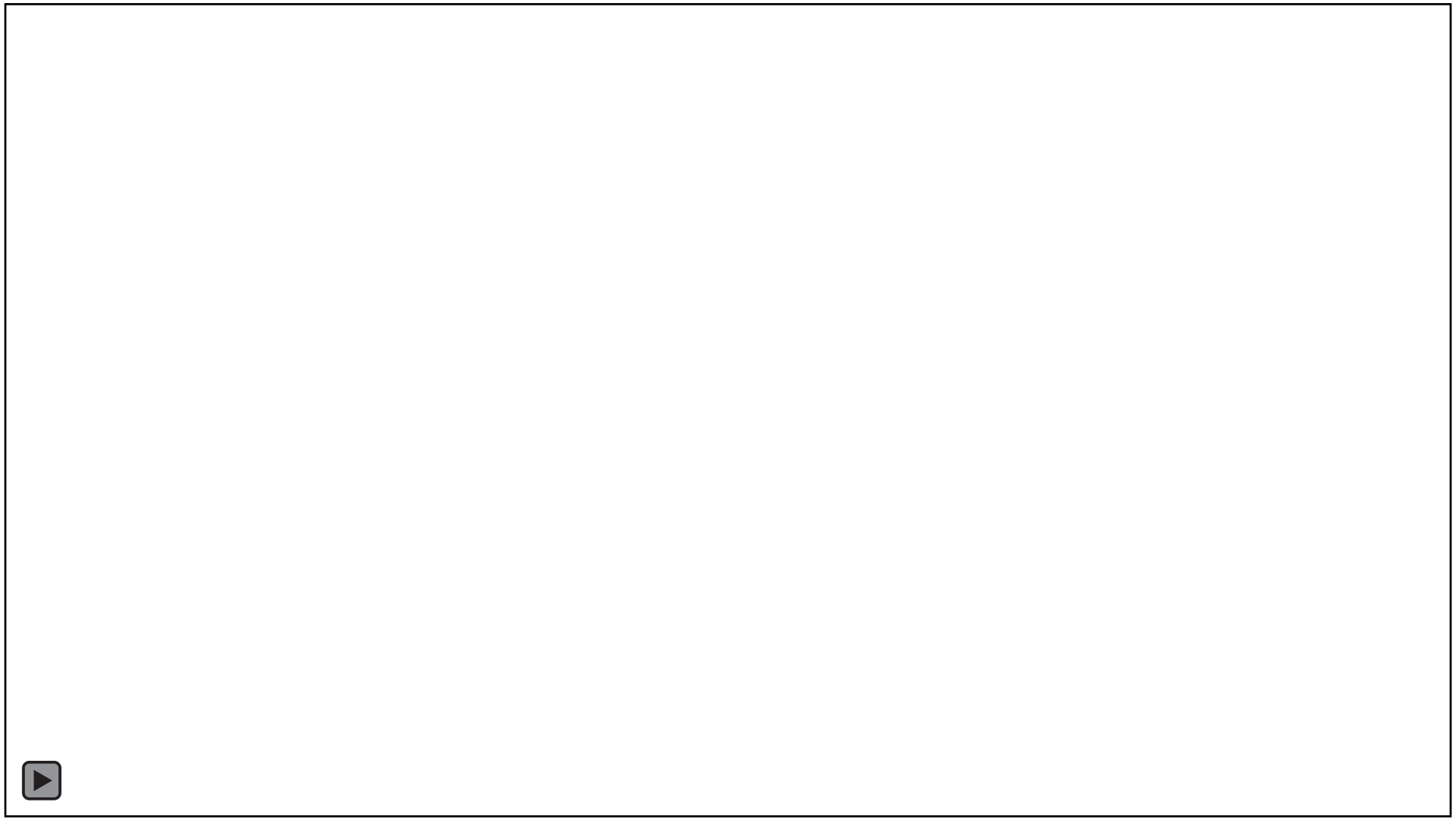


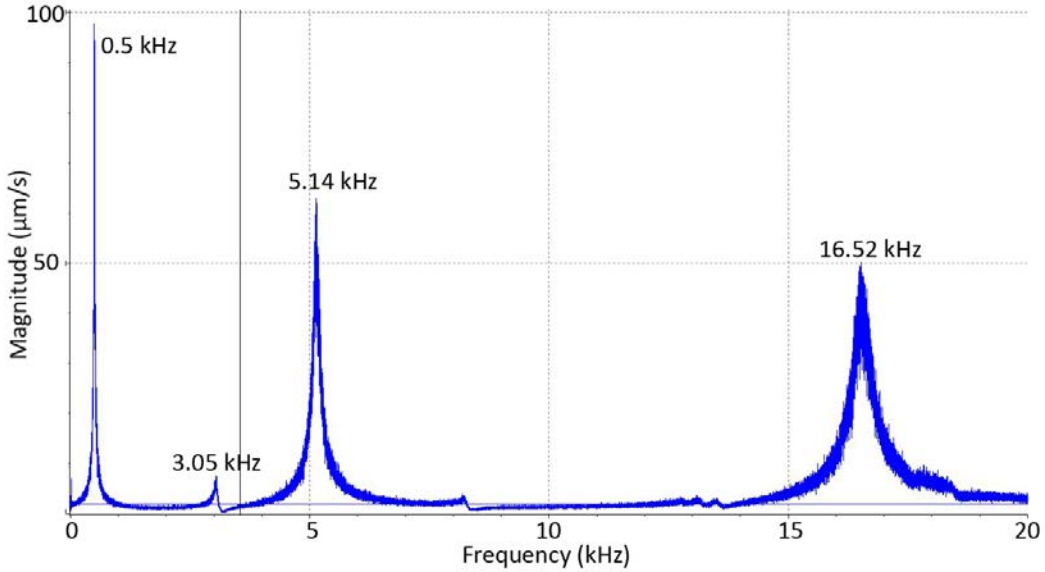
Tip Displacement vs Current [*]

*Arevalo, et al., “Out-of-Plane Buckled Cantilever Micro-structures with Adjustable Angular Position Using Thermal Bimorph Actuation for Transducer Application”, Micro & Nano Letters, 2015.



MEMS Optical Bench





(Polytec, Laser Doppler Vibrometry)

- **Mechanical Oscillation** can also be achieved by the excitation of the bimorph actuators with an AC source
- Since the total displacement it's affected by the frequency of operation, **a modal analysis** was performed to find the peaks for greater displacement at different oscillation frequencies.
- The structure showed its first mode at **500Hz**

Conclusions

- Demonstrated a **low-power consumption** out-of-plane platform with adjustable bi-directional angle through thermal bimorph actuators
- Showed **high accuracy (in the nanometer range**), control and repeatability of the thermal actuation
- Used thermal imaging to determine a **low influence in the BCP thermal isolation**
- These structures could aid in the control for switching and blocking optical paths towards a **MEMS Optical Bench**
- Since their actuation can be oscillated many other **sweeping applications** could be benefited

References

- A. Arevalo, D. Conchouso, E. Rawashdeh, D. Castro, and I. G. fould. (2014, Aug.) Platform Isolation Using Out-of-Plane Compliant Mechanisms.
- D. Castro, A. Arevalo, E. Rawashdeh, and N. Dechev, “Simulation of a Micro-Scale Out-of-plane Compliant Mechanism,” in *2014 COMSOL Cambridge, England*, 2014.
- L. Marnat, A. Arevalo Carreno, D. Conchouso, M. Galicia Martinez, I. Foulds, and A. Shamim, “New Movable Plate for Efficient Millimeter Wave Vertical on-Chip Antenna,” *IEEE Transactions on Antennas and Propagation*, vol. 61, no. 4, pp. 1608–1615, 2013
- A. H. Ma and A. M. Leung, “Three-axis thermal accelerometer based on buckled cantilever microstructure,” pp. 1492–1495, 2008.
- A. Alfadhel, A. A. Arevalo Carreno, I. G. Foulds, and J. Kosel, “Three- Axis Magnetic Field Induction Sensor Realized on Buckled Cantilever Plate,” *Magnetics, IEEE Transactions on*, vol. 49, no. 7, pp. 4144–4147, 2013.
- A. A. Carreno, E. Byas, and I. G. Foulds, “µHeater on a Buckled Can- tilever Plate for Gas Sensor Applications,” *2012 COMSOL Conference, Milan, Italy*, 2012.
- S. Oak, G. F. Edmiston, G. Sivakumar, and T. Dallas, “Rotating Out- of-Plane Micromirror,” *Microelectromechanical Systems, Journal of*, vol. 19, no. 3, pp. 632–639, 201
- A.Arevalo,E.Byas,D.Conchouso,D.Castro,S.Ilyas,andI.G.Foulds, “A Versatile Multi-User Polyimide Surface Micromachining Process for MEMS Applications,” in *10th IEEE International Conference on Nano/Micro Engineered and Molecular Systems NEMS2015*, Xia’an, Apr. 2015.
- Sandia National Laboratories, MicroElectroMechanical Systems (MEMS). url: http://www.sandia.gov/mstc/mems/

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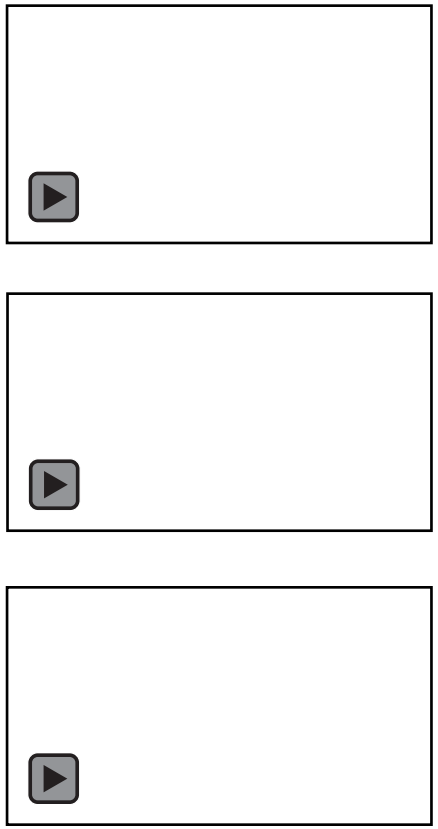
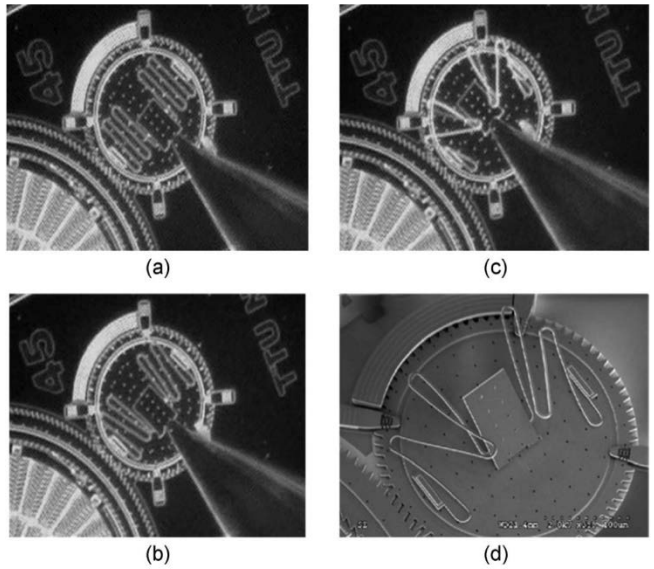
Thank you!

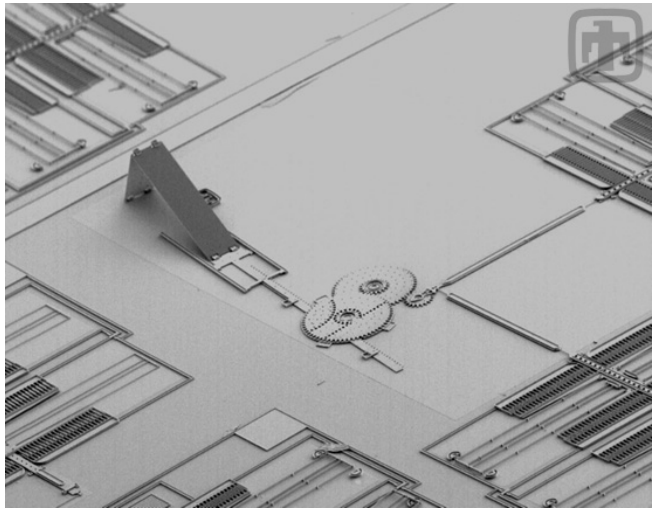
ANY QUESTIONS?



(Sandia National Labs)



(Oak, 2010)



(Sandia National Labs)