Feasibility Study of Thermal Actuators for MEMS Variable Emittance Radiators

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Abstract

Based on COMSOL Multiphysics® software, an analysis of an innovative thermal actuation system capable of overtaking the traditional electrostatic comb drive, nowadays used for actuating the shutter array of variable emittance radiators, has been conducted as to validate this technology for the future active thermal control of CubeSats operating in an harsh environment, where thermal actuators overtakes comb drives due to their higher radiation hardness.
Actuators based on electrostatic forces operate at low power and high frequency, and are highly desirable.
However, they have typically small deflections and require either close dimensional tolerance or high voltage to achieve large deflections. On the other hand, actuators based on thermal expansion effect can provide a large force and a deflection perpendicular or parallel to the substrate. They have been shown to be a valuable complement to electrostatic actuators. In particular, polysilicon thermal actuators can operate in an integrated circuit (IC) current/voltage regime and may be fabricated by a surface-micromachining technology that is compatible with IC technology.

As a starting point, the stiffness of the array has been neglected, in order to assess the validity of the actuator model itself by comparing the results with analytical models and existing knowledge about temperature and displacement distributions.
Then, by considering the stiffness of the shutter array model, an estimate of a more realistic performance has been found. An optimization study has been set by varying the geometry and the applied voltage, and a tip displacement that almost coincide with the displacement required to optimize the shutter performance has been found.
Further improvements in the Optimization study finally led to a decrease in the applied voltage, satisfying the actual need to reduce power in CubeSats applications. Throughout the simulations, a 2D radiation model of the array has then been used to monitor the effect of varying the displacement on the radiator temperature.

The simulation shows that, with a single thermal actuator, only the shutter array of a geometry-limited radiator can be controlled. Indeed, a constraint has been superimposed in terms of the stiffness k, and for big scale applications, where the array is bigger, more than one thermal actuator will be needed as to return the same displacement with an increased, combined force.
Moreover, nothing has been said about the distribution mechanism that eventually transmits the displacement from the actuator to the shutter array. However, the feasibility

of thermal actuators for thermal control applications has been proved, and the results obtained with the present study increase our knowledge about optimized thermal actuators.

Reference

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Figures used in the abstract

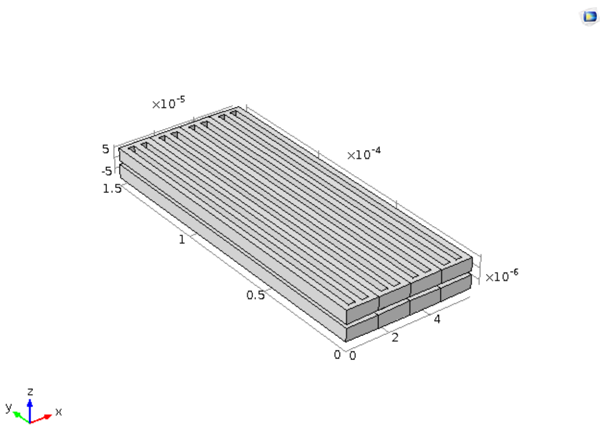

Figure 1: 3D Shutter Array for Stiffness calculation.

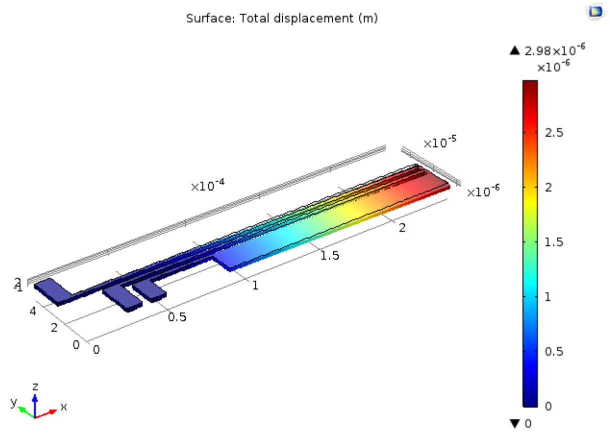

Figure 2: Optimal displacement achieved with Optimization.

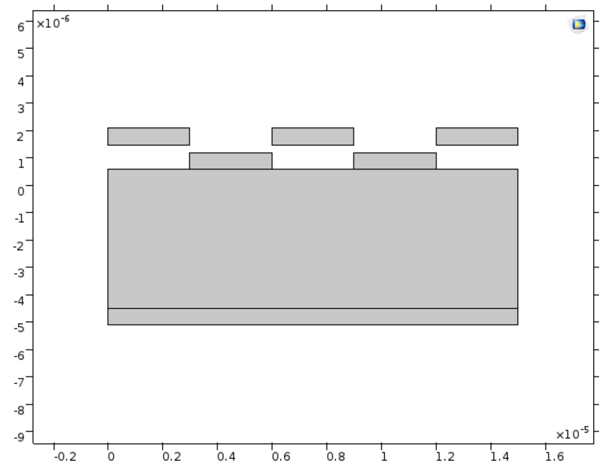

Figure 3: 2D Shutter model to compute the displacement.

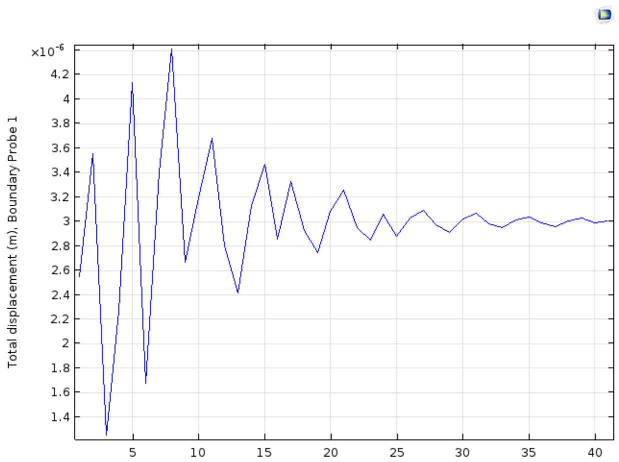

Figure 4: Optimization Solver Convergence.