Design and Optimization of Electrostatically Actuated Micromirror

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Abstract

MEMS devices are very small devices, and their microscopic size accounts for strong coupling effects which arise between the different physical fields and forces. Micromirrors are essential parts of microswitches in fiber optic network telecommunication. Micromirror assemblies are usually of 1 to 3 mm in size which are fabricated from single crystalline silicon and mostly are electrostatically actuated.

The project aims at designing an individual micromirror of size in order a few micrometers. The finite element method (FEM) is used to model the strong coupled electro-mechanical interactions and to perform static and transient analyses taking into account large mesh displacements. These analyses will be used to study the behavior of electrostatically actuated micro-mirrors. The coupled multiphysics simulation and study of the electrical and mechanical behaviour of the mirror system is done using COMSOL Multiphysics®.

The objective is to design the micromirror to obtain maximum tilt angle with minimum driving voltage. The tilt angle of the micromirror depends on the driving voltage applied to it and also on the stiffness constant for the various structures of the spring. The deflection obtained on the torsional micromirror is the function of the torque developed due to the applied voltage. The actuation of the micromirror is achieved by quadrant electrodes. These electrodes would help to tilt the mirror virtually to any angle between -70 deg to + 70 deg in all three axes. Optimization in mirror structure including placement of electrodes, beam design and applying substantial bias voltage has been achieved using COMSOL Multiphysics®. The proposed serpentine structure is much better when compared with conventional torsional beam structures. The response of the micromirror (displacement versus voltage) would be studied to optimize the design for achieving maximum tilt angle displacement. Figure 1 illustrates the two electrode actuation system with serpentine springs. Figure 2 illustrates the quad electrode actuated micromirror. This model was exhibiting higher degree of control of tilt when compared to the previous model. The spring dimensions and electrode position, dimensions were optimized after simulating the model using COMSOL Multiphysics' Electromechanics Physics. Figure 3 illustrate the tilt of the micromirror when two electrodes are applied with same polarity of actuation voltage as top electrode and other two with opposite polarity voltage.

Reference

Fangrong Hu, Jun Yao, Chuankai Qiu, Hao Ren, “A MEMS micromirror driven by electrostatic force”, Journal of Electrostatics, Volume 68, Issue 3, June 2010, Pages 237–242
Tae-Sun Lim et al. , “Electrostatic MEMS variable optical attenuator with rotating folded micromirror”, IEEE Journal of Quantum Electronics, Volume 10 , Issue 3, June 2004, Pages 558 - 562
Yuan Ma et al., “Electrostatic Torsional Micromirror With Enhanced Tilting Angle Using Active Control Methods”, IEEE/ASME Transactions on Mechatronics, Volume 16, Issue 6, December 2011, Pages 994 - 1001

Figures used in the abstract

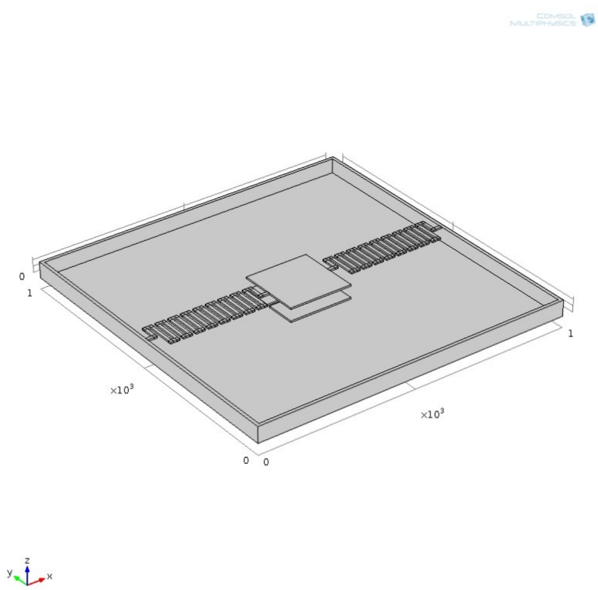

Figure 1: Two Electrode Micromirror

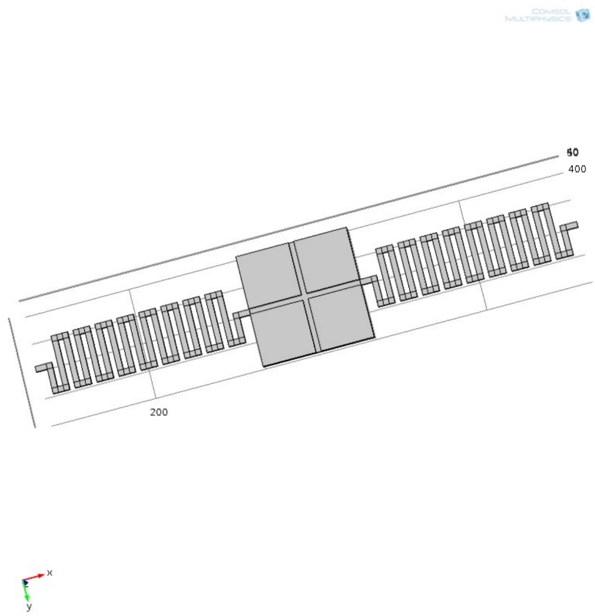

Figure 2: Quad Electrode Micromirror with Serperntine Spring

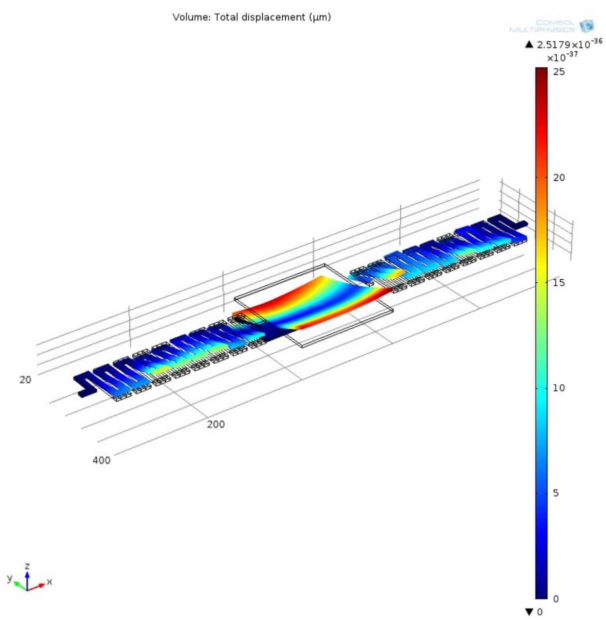

Figure 3: Displacement and Tilt of Quad Electrode Micromirror