# Design and Optimization of Electrostatically Actuated Micromirror

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**Introduction**: This paper describes the design and analysis of a particular micro-electromechanical-system (MEMS) micromirror device that can be used for an optical switching and communication application. The project aims at designing an individual micromirror of size in order of a few micrometers to obtain maximum tilt angle with a minimum driving voltage. The set up consist of a frame in which the micromirror is mounted on to it by springs on the either sides of it. The tilt angle of the micromirror depends on the factors such as 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 response of the micromirror (displacement versus voltage) would be studied to optimize the design for achieving maximum tilt angle displacement

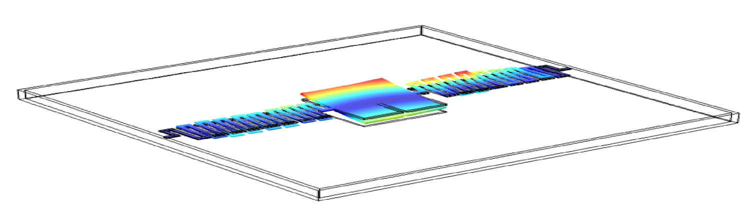


**Figure 1**. Micromirror with serpentine beam with four electrodes on the top and single bottom electrode

## Methods and materials used:

Software used: **COMSOL Multiphysics**

Physics used: **Electromechanics**

Principle used: **Electrostatic principle**

Type of spring used: **Serpentine spring**

## Operating Principle

Voltage is applied between the upper and bottom electrode which is separated by a dielectric medium. The electrodes act as parallel plate capacitors separated by a small distance with air as dielectric. Determination of pull in voltage is important in analysing the electrostatic actuation of micromirror. The factors that influences pull in voltage are

- The upper electrode thickness;
- The length of the spring;
- The gap between the electrodes;
- The structure and dimensions of the bottom electrode;

The relation that connects pull in voltage and angle of tilt is given as

**$V = (kq^3/e_0 w)^{0.5}$**

V – Pull in voltage (V)

k – Spring constant (N/m)

q - Angle of tilt (degree)

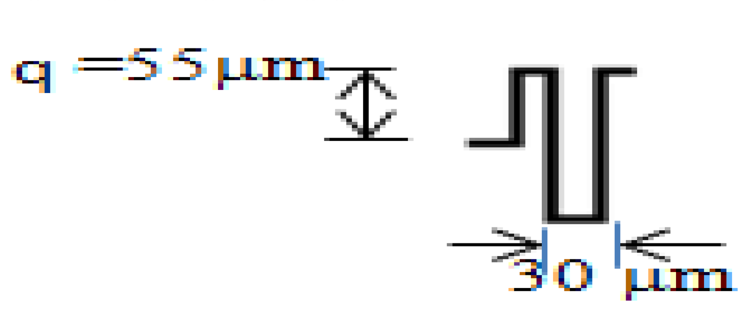
$e_0$ - Permittivity of free space

w – Width of the electrode (mm)

## Micromirror structure and design

•Consist of frame of size 1000 mm with micromirror of size 200 mm supported to frame by springs.[model pic]

## Serpentine beam




**$\theta = ML/EI = Tq/EI = T(2Q)/EI$**

$\theta$ - Deflection

M – Torque

L – Length

E – Young's modulus

I – Moment of inertia (**$I = bt^3/12$** )

Theoretical force ,**F = kd**

Spring constant,**$k = 192\ EI/L^3$**

**d-** Deflection

**Results**

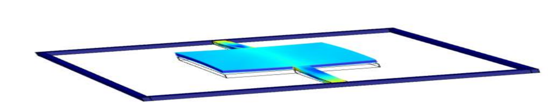


Fig 3 – Simple Beam

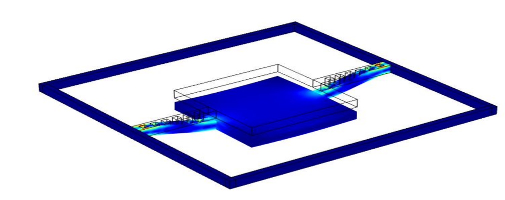


Fig 4 – Corrugated Beam

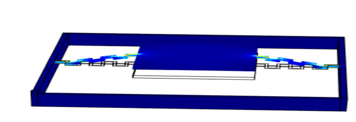


Fig 5 – Actuated Deflection – Serpentine Beam

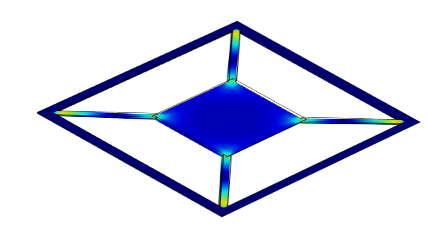


Fig 6 – Four Sided Beam

| Type of Beam | Stress | Units |
|---|---|---|
| Simple(fig 3) | 4.559*10 ^4 | N/m^2 |
| Corrugated Beam(fig 4) | 2.516*10 ^5 | N/m^2 |
| Serpentine Beam(fig 5) | 2.498*10 ^6 | N/m^2 |
| Four sided Beam(fig 6) | 7.113*10 ^4 | N/m^2 |

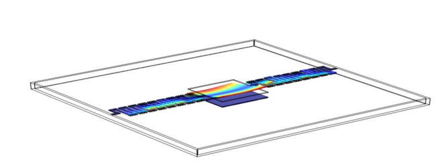


Fig 7. Serpentine beam as spring and two electrodes on the bottom and single top electrode

Deflection obtained: :2.5179*10^-36 *10^-37mm

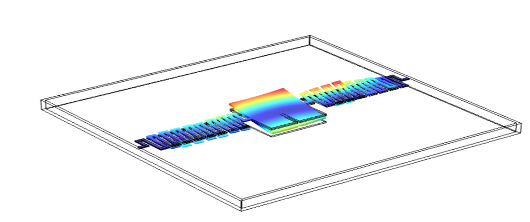


Fig 8. Serpentine beam with four electrodes on the top and single bottom electrode

Deflection obtained: 1.4116 *10^-36 *10^-37mm

**References**:

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[2]K.M Vinayaka Swamy, G Ravi Prakash, B G Sheeparamatti "The Spiral RF MEMS Switch in COMSOL Multiphysics" Department of Electronics and communication Basaveshwar Engineering collage, Bagalkot, Karnataka, India.

[3]Hasan Tareq Imam and Yuan Ma "A Study of 2-Dimensional Electrostatic Torsional Micromirror" Electrical and computer Engineering Department Dalhousie University Halifax, NS, B3J 1Z1, Canada.

Excerpt from the Proceedings of the 2013 COMSOL Conference in Bangalore