Multiphysics Analysis of a Micromirror System

Nkorni Katte[1]
1. Department of Electrical Engineering, Wilberforce University, Wilberforce, OH, USA

Introduction

Microelectromechanical (MEMS) technology in recent years has provided various micromirror devices which are used in many applications. These sensitive devices are used in Lidar systems for Unmanned Aerial Vehicles (UAV), Optical Coherence Tomography (OCT) and for endoscopy Medical imaging. There are several techniques which have been used to actuate the mirrors including electrostatics, piezoelectric effects, electrothermal and electromagnetic technique [1-2]. There are a few reasons why the electromagnetic technique which uses a Lorentz force is advantageous over the other techniques. First, this technique will require low power, compared to the electrostatic technique and it also provides high frequency of oscillation of the mirror. This technique suffers from the set back of electromagnetic interference (EMI). Modern Lidar systems using micromirrors need typically larger micromirrors in order to reflect light at broad angles and transmit all possible information necessary to control the vehicles hosting the Lidar. These types of micromirrors are in the order of a few millimeters, typically a lot larger than the ones that are just a few microns in dimension. In this work I have simulated an 18mm by 18mm Square cross section Micromirror device paper. I studied how the current in the coil loop affects the displacement of the device and hence the Mechanical and Optical deflections.

Theory

An electric current is introduced in a coil which sits on the micromirror, in the presence of a magnetic field. This condition creates a Lorentz force ***F*** which will rotate the mirror about an axis. This Lorentz force is shown in equation (1) below

$$\boldsymbol{F} = I\boldsymbol{L} \times \boldsymbol{B} \tag{1}$$

$$\nabla . \mathrm{S} + \boldsymbol{Fv} = 0 \tag{2}$$

In the above equation I is the current, **L** represents the length of wire, and ***Fv*** a force per unit volume. **B** is the magnetic flux intensity**.** **S** is stress term. In my calculations ***I*** used a **B** field of about 0.1T

In the solving this coupled, where the electric currents setting is coupled with the Solid mechanics. A current density, normal to the surface of the Aluminum wire which forms a coil is used to create a body load force term that provides a torque which rotates the entire mirror. This body load force term The mirror about the z-axis as the boundary condition of the surfaces normal to the z-axis are set as fixed constraint. The coil wire and has a cross section area of 0.5mm by 0.5mm on mirror which carries the current is made of Aluminum and the mirror is made of Silicon.

Simulation Results

Without any current in the wire, the mirror will not deflect. Once a current is introduced in the coil loop just above the mirror in the presence of a magnetic field along the x-axis. A Lorentz force is produced which rotates the mirror and the mirror deflects by some angle. The optical deflection angle is two times the mechanical deflection angle. It is the angular difference between the original reflection ray when there were no electromagnetic forces present and the secondary reflected ray once electromagnetic forces are activated. Larger optical deflection angles are desired by most modern Lidar systems [3]. This should only be possible by maintaining the current and the magnetic flux intensity at appropriate higher values.

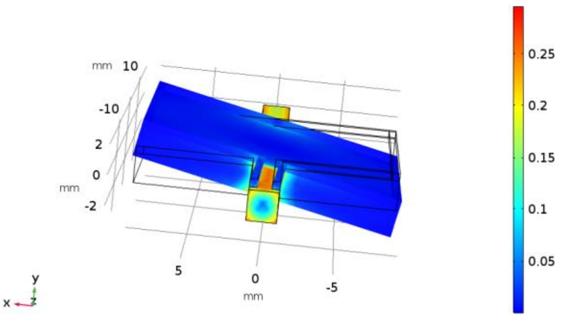

Figure 1. The deflection of the Mirror after, the action of Lorentz force on the coil above the mirror substrate. This force also creates stress in the material.

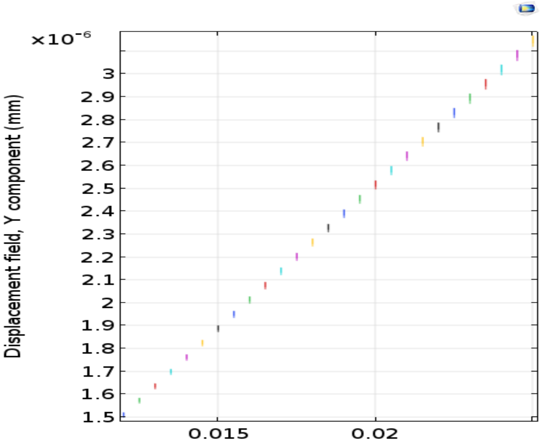

Figure 2. The y-displacement of the lower left edge of the micromirror was calculated as function of the current circulating in the aluminum coil above the mirror.

A mechanical deflection angle of 15^o will be quite an achievement. Ye et al in [1] showed a deflection angle of 13^o, when a current of 250mA was used to and the magnetic flux intensity of 0.2T were applied in the region surrounding a 12mm by 12mm mirror. A 50mm focal length lens is used in **Figure 3** is used to focus the light on a deflected micromirror.

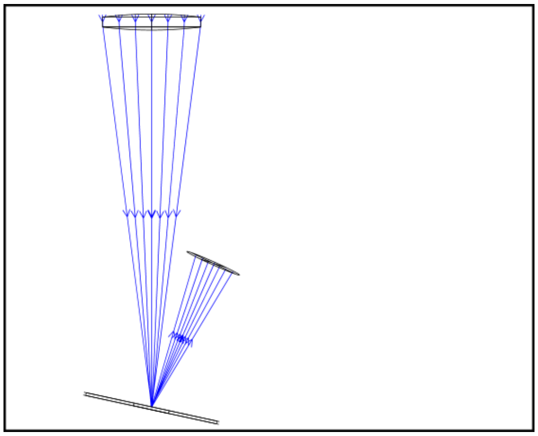

Figure 3. Reflection of light by a micromirror, after it has been deflected by Lorentz force. A 50mm lens is used to focus light at a mirror deflected by 12^o. This Ray diagram was produced Optic studio Zemax software.

Conclusions

This work demonstrates how larger Micromirrors needed for modern Lidar systems can be designed to functioned in a fully integrated environment. This work should be supplemented by experimental work in order to arrive at adequate conclusions. A material study should be performed in order to select the materials with the best mechanical and electrical properties. A Resonance study is also necessary to completely understand the mechanical oscillations of the mirror. A thermal study which examines, the heat deposited by the laser light and one due to electrical current in the loop will also be important. A much more critical study will examine a typical scenario in the presence of factors that contribute to EMI.

References

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