

# A Review on Emerging Digital Micromirror for Various Applications

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**ABSTRACT:** Micro Mirror .have a wide range of applications in automotive, biomedical, defense, aerospace, multimedia, communication and consumer electronic systems. One of the most important features that differentiate MEMS from traditional CMOS electronics is the presence of suspended and/or moving parts with air gaps or cavities in the device structure. This fact imposes severe challenges to the packaging and reliability of MEMS device.a single-crystalline silicon (SCS) micromirror used for laser beam scanning in an endoscopic optical coherence tomography (OCT) system. The micromirror is fabricated by using a deep reactive-ion-etch (DRIE) post-CMOS micromachining process. a Micromirror model is simulated using COMSOL Multiphysics, the results obtained from the simulation help to reduce .fabrication of MEMS Micro mirror. a Mems based rectangle shape Micro mirror with four straight centilevers using COMSOL Multi physics. Research is carried out to design a micro mirror to reduce lift off stress. a square shape micro-mirror with the lift-off of the structure used four springs simulating a prestressed cantilever beam. Few base materials were introduced such as Alumina, Aluminum 3003 H18, Aluminum 6063 T18, Copper and Aluminum. To make the leg or cantilever more efficient the structural steel was introduced.

**KEYWORDS:** cavities, endoscopic optical coherence tomography, micromachining, centile.

## I. INTRODUCTION

The term MEMS is an acronym for MICROELECTROMECHANICAL SYSTEMS MEMS, an acronym that originated in the United States, is also referred to as Micro Systems Technology (MST) in Europe and Micromachines in Japan. Micro-electromechanical systems (MEMS) is a process technology used to create tiny integrated devices or systems that combine mechanical and electrical components. They are fabricated using integrated circuit (IC) batch processing techniques and can range in size from a actuate on the micro scale, and generate effects on the macro scale. The device electronics are fabricated using 'computer chip' IC technology, the micromechanical components are fabricated by sophisticated manipulations of silicon and other substrates using micromachining processes. .

A digital micromirror device (DMD) is an array of individually switchable mirrors that can be used in many advanced optical systems as a rapid spatial light modulator. With a DMD, several implementations of co focal microscopy, hyper spectral imaging, and fluorescence lifetime imaging can be realized. The DMD can also be used as a real-time optical processor for applications such as the programmable array microscope and compressive sensing. Advantages and disadvantages of the DMD for these applications as well as methods to overcome some of the limitations will be discussed in this article. Practical considerations when designing with the DMD and sample optical layouts of a completely DMD-based imaging system and one in which acousto-optic deflectors (AODs) are used in the illumination pathway are also provided.

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### MODULATING LIGHT FOR DISPLAY APPLICATIONS

For the most advanced DMD today, the mirrors are made to rotate to either a +12 degree or -12 degree position depending on the binary state of the SRAM cell that exists below each mirror. The SRAM voltage is applied to the address electrodes, creating an electro-static attraction. When a voltage pulse is applied to the mirrors, each mirror then either stays in place or quickly rotates to its opposite states according to the memory data.

In addition to being highly efficient, the speed at which each mirror can modulate between the "on" and "off" states is another key DLPTM advantage. Fast switching speed has enabled a compelling range of end products including the world's smallest video and data projectors HDTVs, and digital cinema.

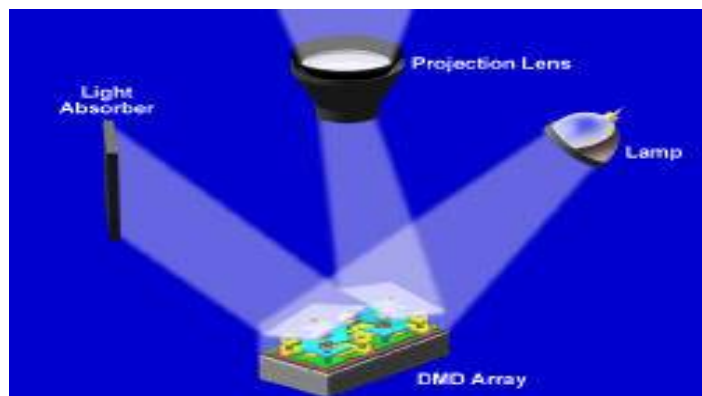


Figure 1.1 schematic of two dmd mirror-pixels next to a typical dmd light modulator.

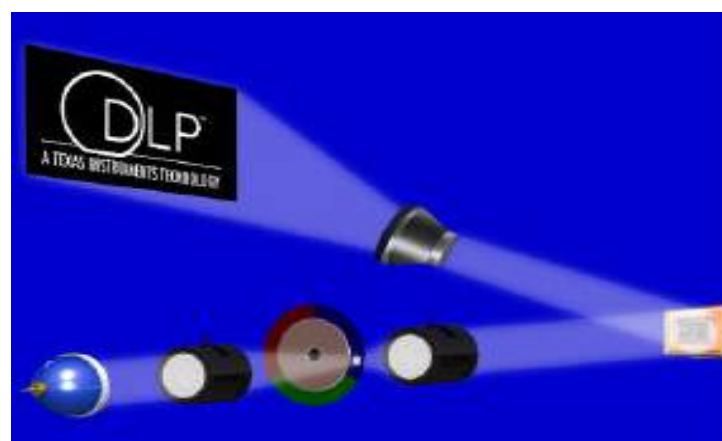


Figure 1.2 A one-chip DLPTM projection system. White light is focused down on to a spinning color wheel filter system

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## II. LITERATURE REVIEW

**1. Martin Glimtoft et al. [2016]** Concluded that explosives particles at stand-off distances. However, large light losses are inherent in the design due to sequential imaging at different wavelengths, leading to effective transmission often well below 1 %. The use of digital micromirror devices (DMD) and compressive sensing (CS) in imaging Raman explosives trace detection can improve light throughput and add significant flexibility compared to existing systems. DMDs are based on mature microelectronics technology, and are compact, scalable, and can be customized for specific tasks, including new functions not available with current technologies. This paper has been focusing on investigating how a DMD can be used when applying CS-based imaging Raman spectroscopy on stand-off explosives trace detection, and evaluating the performance in terms of light throughput, image reconstruction ability and potential detection limits. Concluded that imaging Raman spectroscopy based on tunable filters is an established technique for detecting single

**2. Lih Y. Lin et al. [2015]** presented a work on “Progress of MEMS Scanning Micromirrors for Optical Bio-Imaging”. In this paper, Microelectromechanical systems (MEMS) have an unmatched ability to incorporate numerous functionalities into ultra-compact devices, and due to their versatility and miniaturization, MEMS have become an important cornerstone in biomedical and endoscopic imaging research. To incorporate MEMS into such applications, it is critical to understand underlying architectures involving choices in actuation mechanism, including the more common electrothermal, electrostatic, electromagnetic, and piezoelectric approaches, reviewed in this paper. Each has benefits and tradeoffs and is better suited for particular applications or imaging schemes due to achievable scan ranges, power requirements, speed, and size. Many of these characteristics are fabrication-process dependent, and this paper discusses various fabrication flows developed to integrate additional optical functionality beyond simple lateral scanning, enabling dynamic control of the focus or mirror surface. Out of this provided MEMS flexibility arises some challenges when obtaining high resolution images: due to scanning non-linearities, calibration of MEMS scanners may become critical, and inherent image artifacts or distortions during scanning can degrade image quality. Several reviewed methods and algorithms have been proposed to address these complications from MEMS scanning. Given their impact and promise, great effort and progress have been made toward integrating MEMS and biomedical imaging

**3. M. Archana et al. [2014]** presented a work on “Structural Mechanical Analysis of MEMS Micromirror using COMSOL Multiphysics”. In this paper, a Micromirror model is simulated using COMSOL Multiphysics, the results obtained from the simulation help to reduce the displacement associated with the stress developed due to the plating process during the fabrication of MEMS Micro mirror. The model consists of a square shaped Micro mirror with four serpentine or zigzag shaped beam. The results obtained for different material combinations showed that the best material combination was Aluminium 3003 for the Micromirror substrate and structural steel for the cantilever legs this reduces the stress at the edges. The reason for selecting steel for the Micro mirror substrate is to reduce the surface deformation as it is stiffer than Aluminium. The lift-off level and the associated stress for the Micromirror with S-shaped cantilever beams is  $36 \times 10^{-6}$  m and  $0.032$  N/m<sup>2</sup> respectively, which is lesser than that of the Micromirror with straight shaped cantilever beams (lift-off= $50 \times 10^{-6}$  m and stress level= $0.0543$  N/m<sup>2</sup>).

**4. Olav Solgaard et al. [2014]** presented a work on “Optical MEMS: From Micromirrors to Complex Systems”. In this paper a study has been presented on applications and advantages of optical MEMS in different fields. Micromachining allows the tools of the integrated circuit industry, lithography and parallel processing to be applied to optical devices and systems. The payoff is integration of mechanics, fluidics, magnetics and optics into highly functional microsystems with numerous advantages in terms of functionality, flexibility, stability, sensitivity, size and, ultimately, cost. The application areas for these types of Optical MEMS include tunable optics, spatial light modulators, fiber optical communication devices and systems, opto-fluidic systems for biological and chemical analysis, and interferometric sensors. The augmentation of Optical MEMS by nanostructures has led to the development of Optical Nanosystems based on photonic crystals and ultra-compact optical resonators that are applicable to a wide range of systems across all the sub disciplines of optics.

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5. **Hazian Mamat et al.[2013]** designed a “COMSOL Model to Analyse the Structural Mechanical Problem in an Electrostatically Controlled Prestressed Micro-Mirror”. In this paper, the structural mechanical properties of the actuation mechanism of a square shape micro-mirror with the lift-off of the structure used four springs simulating a prestressed cantilever beam. Few base materials were introduced such as Alumina, Aluminum 3003 H18, Aluminum 6063 T18, Copper and Aluminum. To make the leg or cantilever more efficient the structural steel was introduced. The characteristics of lift-off prestress and surface deformation were also studied. According to this paper, the best result is achieved by using Aluminum 3003 + Structural steel.

6. **Anna Thomas et al. [2013]** developed a “Design and Optimization of Electrostatically Actuated Micromirror”. In this paper, an individual micromirror of size in order of a few micrometers to obtain maximum tilt angle with a minimum driving voltage designed. The micromirror is based on the electrostatic principle and performed by using COMSOL multiphysics. Different beams are considered and stress is compared to each other. Serpentine Beam has minimum lift-off stress that is  $2.498 \times 10^6 \text{ N/m}^2$ . This device can be used for an optical switching and communication application.

7. **B.Bharanipriyaa et al. [2013]** demonstrated a work on “Two-axis Analysis of Micromirror Using Electrothermal Actuators for Optical Switching Applications”. In this paper, MEMS based electro thermal actuators and micromirror was designed and analysed using COMSOL Multiphysics 4.2a. A 4-arm U-shaped actuator with a micromirror has been designed. The driving voltage is given in the anchor end which produces larger displacement. For various applied voltage, it produces displacements in eight different directions. By applying 10V, the maximum Stress obtained is 3985 N/m and the stress increases exponentially with increasing voltage. The maximum Displacement is  $3.65 \mu\text{m}$  and the maximum current density obtained is 5388.6 A/m.

8. **D. Mallick et al. [2011]** addresses about the “Design and Simulation of MEMS Based Electrothermal Micromirror for 3D Spatial Movement”. This paper describes about the design and simulation results of an electrothermally driven micromirror that is capable of producing 3D spatial movement. Electrothermal actuation is used to achieve in-plane as well as out-of plane displacements. The coupled multiphysics simulation and study of the electrical, thermal and most importantly the mechanical behavior of the mirror system is done using COMSOL Multiphysics. The device has an in-plane displacement range of  $3.56 \mu\text{m}$  ( $1.78 \mu\text{m}$  in either direction) and an out-of-plane displacement of approximately  $22 \mu\text{m}$  is achieved for an input voltage of only 2V. The transient cooling response has also discussed and response time is found to be satisfactory. The high temperature generated due to Joule heating is drawback of the thermal actuation process. This is however offset by the simpler fabrication processes required for these devices. The ability of precise control of movement of the micromirror in space is likely to lead to potential applications in diverse fields.

9. **Adam D. Mathias et al. [2011]** designed a “High Speed Electrostatically Actuated Al-MEMS Micromirror Array”. The purpose of this paper is to optimize the design of micromirror in order to achieve the maximum deflection of micromirror with minimum pull in voltage. For this an electrostatically-actuated, aluminum, torsional micromirror ( $20 \times 20$ ) microns, is presented. The design is repeated in  $25 \times 25$  arrays for high-speed deflection of incident light. The micromirror arrays are fabricated using an Al-MEMS fabrication process. The developed fabrication process uses a 4 micron sacrificial photodefinable polymer and a submicron thick aluminum layer suspended over patterned gold electrodes. The sacrificial polymer was plasma ashed to release the deformable aluminum structures. The COMSOL Multiphysics finite element analysis environment is utilized to study the optimized design. Within the finite element analysis software, a 132 V electric potential is applied to an underlying electrode in order to produce a minimum of  $5^\circ$  tilt which yields a downward mirror-edge displacement of  $1.39 \mu\text{m}$  into a  $4 \mu\text{m}$  gap between the electrode and the bottom of the micromirror. When the electric potential is removed, the micro-mirror has a settle time  $\sim 10 \mu\text{s}$ .

10. **Quan Sun et al [2010]** presented “Optimization designed large-stroke MEMS micromirror for adaptive optics”. In the following paper, efforts are made to optimize design of micromirror to reach the largest lift-off height. A novel piston/tip/tilt micromirror based on Poly- MUMPs process is designed and explored. The hexagonal micromirror with a diameter of  $450 \mu\text{m}$  consists of three supporting bilayer cantilevers and a mirror plate. Two kinds of cantilevers are

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introduced and both designed structures of the bilayer cantilevers, formed with a polysilicon layer and a gold layer, elevate the mirror plate according to residual stress-induced bending. The first design had gold film deposited only on the first half of the cantilever, whereas the second design had gold film deposited on the entire cantilever. Both designs had the same geometry, consisting of two 195- $\mu\text{m}$ -long beams. Poly2 should enclose 3  $\mu\text{m}$  of Gold on each side. An analytical solution was conducted on a rectangular cantilever to estimate the elevated height of the free end of the cantilever. The lift-off heights of the micromirror with the Design I and Design II cantilevers are 3.9 and 2.8  $\mu\text{m}$ , respectively. Both analytical solution and FEA performed in COMSOL are illustrated to calculate the lift-off heights of the different cantilever structures. Calculations show that the analytical result is in accordance with the FEA simulation results, whereas stresses are applied longitudinally only. Results of a three-dimensional (3D) simulation with two direction stresses applied shows the elevated height to be proportional to the width of the cantilever and the length of the gold layer.

11. **Il-Joo Cho et al. [2009]** presented a work on “A low-voltage three-axis electromagnetically actuated micromirror for fine alignment among optical devices”. In this paper, a new three-axis electromagnetically actuated micromirror structure has been proposed and fabricated. It is electromagnetically actuated at low voltage using an external magnetic field. The purpose of this work was to obtain a three-axis actuated micromirror in a mechanically robust structure with large static angular and vertical displacement at low actuation voltage for fine alignment among optical. The mirror plate and torsion bars are made of bulk silicon using a SOI wafer, and the actuation coils are made of electroplated Au. As per results the maximum static actuation values of the three-axis actuated micromirror have been measured as  $\pm 4.2^\circ$  for x-axis actuation and  $\pm 9.2^\circ$  for y-axis actuation, respectively. The actuation voltages were below 3 V for all actuation. The maximum static vertical displacement was measured as  $\pm 42 \mu\text{m}$  for z-axis actuation. The simulated resonant frequencies are several kHz, and this implies that the fabricated micromirror can be operated in sub-millisecond order. The measured radius of curvature (ROC) of the fabricated micromirror is 7.72 cm, and the surface roughness of the reflector is below 1.29 nm which ensure high optical performance such as high directionality and reflectivity. The additional degree of freedom with z-axis actuation can decrease the difficulty in the assembly of optical components and increase the coupling efficiency between optical components. The mechanically robust torsion bar and lifting bar structure formed by bulk silicon allows the proposed micromirror to stably operate and extends the lifetime of the fabricated micromirror.

12. **Volker Viereck et al. [2009]** discusses about “Large area applications of optical MEMS: micromirror arrays guide daylight, optimize indoor illumination”. This paper suggests that future indoor light distribution of living and office spaces will improve significantly when large area micromirror arrays are used in conventional double glazed window. In contrast to macroscopic solutions, such micromirror array based solutions are nearly invisible, weatherproof and maintenance free.

13. **Sangtak Park et al. [2008]** presented a work on a “Design analysis of micromirrors in stacked configurations with moving electrodes”. In this paper, various actuation mechanisms for micromirrors are described. A new geometric configuration of a stacked micromirror that is actuated by electrostatic force is proposed and analyzed to show its superior performance in terms of deflection angle, actuation voltage, and frequency response. Two different stacked micromirror configurations are studied and numerically analyzed in this paper. In first stacked geometry a micromirror is placed 250  $\mu\text{m}$  directly above another square plate along the z-axis and in second stacked geometry a micromirror is placed above another mirror with a 250  $\mu\text{m}$  gap in the z axis and a 500  $\mu\text{m}$  offset along the x-axis. The top plate is the micromirror, and the bottom plate is used as moving electrodes. The result shows at low actuation voltage, there is not much difference in deflection, since the initial air gap between the micromirror and its electrodes is the same (250  $\mu\text{m}$ ). However, the difference in deflection becomes clear at higher actuation voltage until the pull-in occurs. Furthermore, the micromirror in the first stacked configuration shows the most deflection. The reason is that charges are concentrated at the far edge of the micromirror, where the gap between the micromirror and its electrodes is the smallest. Thus, the surface charge density is the highest in the far edge thereby creating the most torque.



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## III. CONCLUSION

Micromirror devices are devices based on microscopically small mirrors. The mirrors are [Microelectromechanical systems](#) (MEMS), which means that their states are controlled by applying a voltage or current between the two electrodes around the mirror arrays. Micromirror is a versatile MEMS device, which finds use in many application areas. While research in this particular field has been carried out for more than 30 years, the actual push came in the 90's for the development of optical switching systems. Specifically, significant efforts have been made for the development of scanning micromirrors for optical switching and display applications. They are also used in biomedical fields for non-invasive optical imaging techniques such as optical coherence tomography and nonlinear optical microscopy for cancer detection. There are digital micromirror devices used in video projectors and optics and micromirror devices for light deflection and control. Micromirror actuation has gained tremendous interest in both industry and academia. Micromirror actuation has widespread applications in the field of telecommunications, display technology, medical equipment, space technology and consumer electronics.

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