Building a Practical and Cost-efficient Driver to Steer a Static Beam of Light

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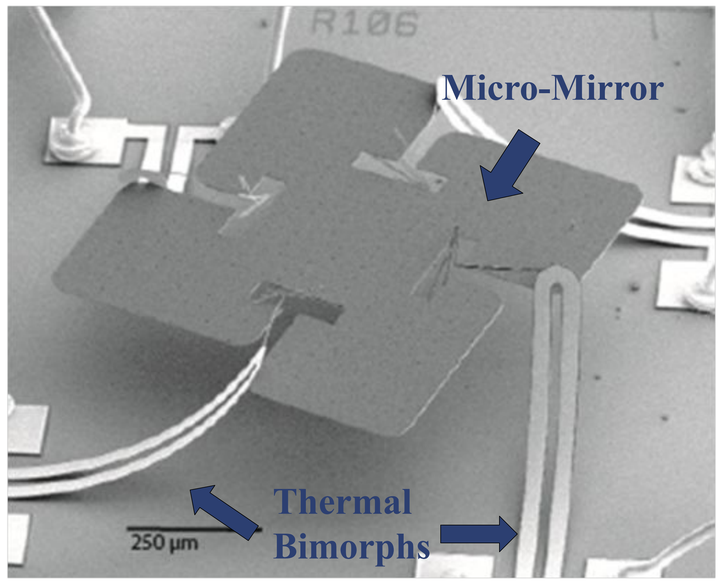
Abstract

Microelectromechanical systems (MEMs) have become more prominent in society today and are utilized in modern technologies from airbags to pressure sensors. These devices have been proven to be very cost efficient and reliable, as well as easily fabricated in large numbers.

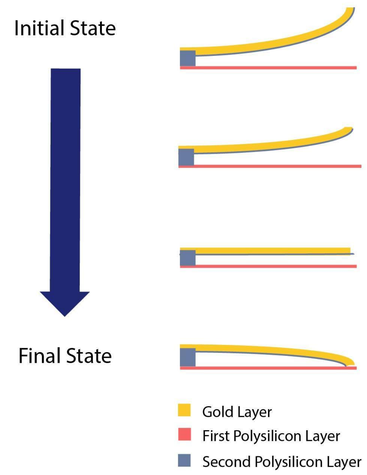
According to the US Energy Information Administration, 17% of the total energy consumed is used in lighting, a very significant portion of energy. Incandescent lights have efficiencies of up to 3% and fluorescent lights up to 12%. While LEDs (Light Emitting Diodes) can have efficiency up to 50% and can lead to significant energy savings[1]. The key idea is to use a MEMS micro-mirror to steer a beam of light produced by an LED. The light will be focused on the micro-mirror, and the curvature/orientation of the mirror will be dynamically changed in a controlled fashion, effectively "painting" a room with light. While the procedure of actuating the devices was traditionally done by manually operating voltage sources, this research intended on actuating the devices in a more practical fashion; by utilizing an Arduino and a joystick. The resulting beam would be manipulated in a matter of milliseconds, making the motion completely static to the human eye. This smart-lighting concept will decrease energy usage by illuminating only the portion of the room that is occupied. Another application is using steerable light as non-interacting data streams which allow the building to 'talk' to data appliances located within the rooms, creating an internet of things.



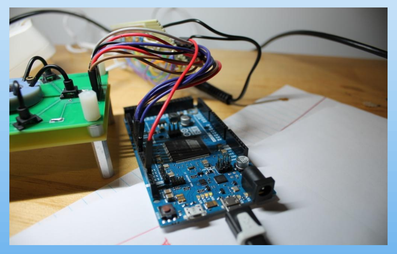
Goals of this Project

- **Dynamically steer a beam that is produced by a light source placed above a MEMs micro-mirror.**
- **Utilize a microcontroller to solve the problem of the device needing multiple voltage sources to actuate all four bimorphs.**
- **Replace the need for multiple voltage sources with a joystick with the intention of mapping the deflection of the joystick with the same movement of the mirror.**

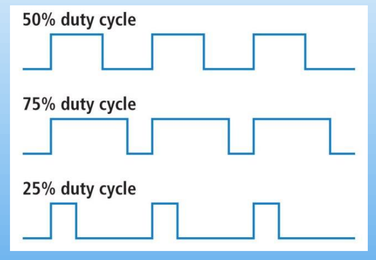
How do these Thermal Bimorphs Work?



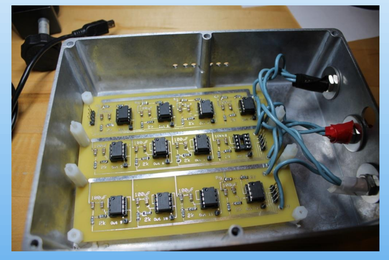
- These Bimorphs require a voltage of 550 mV in order to move.
- As current flows through them, the bimorphs heat up and fold down.
- When certain bimorphs are lowered, it results in a deflection in the mirror.



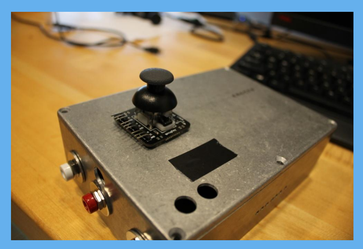
A microcontroller was needed to control the multiple bimorphs.



An Arduino is capable of outputting a pulse width modulation (PWM). The average value of the PWM is dependent on its duty cycle.

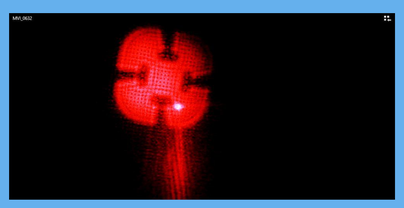


A PCB board was used to filter the Arduino's output in order to ensure the mirrors would not be damaged.

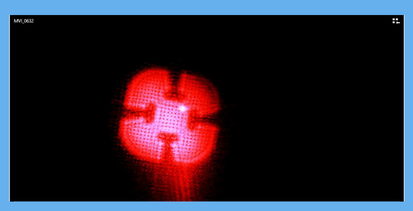


By changing the analog values (moving the joystick) it was possible to change the duty cycle of the pulse width which would effect the output voltage.

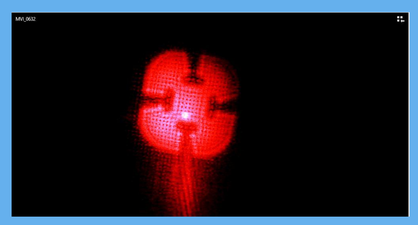
Results



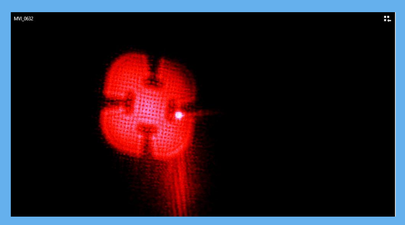
Mirror moved in positive Y



Mirror moved in Negative Y



Mirror moved in Positive X



Mirror moved in Negative X

Future Direction

- Replace the joystick with a more practical option to actuate these devices in the real world (Sensors)
- Direct streams of data to create an internet of things where devices will be able to communicate with each other
- Integrate fiber optics so the position of the light source will not always have to be positioned over the mirror

Conclusion

By using the op-amps to filter the output of the Arduino, the mirrors could be controlled with only one voltage source. When that circuit was connected with the joystick, the mirror could be moved in a much simpler fashion allowing for experiments in the future to run much more efficiently. The data collected for this project along with the videos of the moving beam will be helpful for further research as well.

Bibliography

1.) U.S. Energy Information Administration, How much electricity is being used for Lighting in the United States? May 23, 2014.

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