A COMPACT MEMS-BASED WIDE-ANGLE OPTICAL SCANNER

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ABSTRACT

A compact laser scanner that scans approximately 90° has been demonstrated, which is enabled by an electrothermal MEMS mirror encapsulated in a 3D printed holder with a curved dome for optical amplification.

Keywords - Wide-angle scanning, compact, lens, 3D printed holder, LIDAR

INTRODUCTION

LIDARs are highly demanded for autonomous driving, but they are expensive and bulky [1] . MEMS mirrors have the ability to enable compact and low-cost optical systems, but their scanning range is usually limited to less than 25° as LIDARs require the mirror plate with relatively large size. Operation at resonance [2] and submersion in liquid [3] have been used to boost the scanning angle of MEMS mirrors. The MEMS mirror working at resonance requires delicate control [2], while the submerged MEMS mirror in liquid utilizes the Snell's law to amplify the scanning angle but greatly reduces the scanning frequency due to high viscous damping [3]. This paper will present a wide-angle scanning MEMS device that can enlarge the scanning angle without sacrificing the scanning frequency.

DEVICE DESIGN

The wide-angle scanning device includes a MEMS mirror, a lens (PMMA), a laser diode (LD) (diameter: 5 mm, wavelength: 630 nm), and a 3D printed holder. The schematic is shown in Figure 1. The MEMS mirror is mounted on top of the 3D printed holder, and the LD is inserted into the hole of the sidewall of the holder. The bottom surface of the cover lens is hemispheric, while its top surface is flat. The light

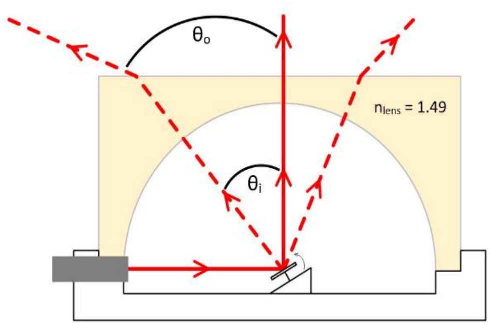

Figure 1: The concept of wide angle scanning with a MEMS Mirror

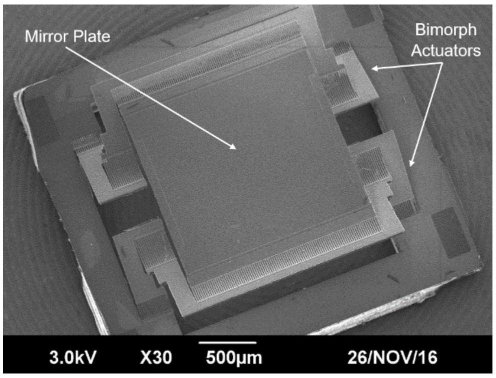

Figure 2: SEM of the MEMS mirror

emitted from the LD is shined directly to the center of the MEMS mirror, and then transmitted through the lens. The scanning angle is enlarged once the light reaches the interface between air and lens. Because the refractive index of the lens (n_{lens}) is about 1.49 which is larger than that of air, the angle will be amplified according to Snell's law, i.e., $\theta_o = \arcsin(n_{lens}\sin(\theta_i))$. The electrothermal MEMS mirror is shown in Figure 2 and its fabrication process is similar to the one reported in [4]. The mirror plate is $1.5 \times 1.7\ mm^2$. The initial displacement of the mirror plate is 700 µm upward because of the residual stresses built inside the films after fabrication [5]. There are four actuators which link the mirror plate and the frame together. Each actuator includes three segments of bimorphs which not only provides pure lateral shift free out-of-plane movement but also tip tilt rotation. The 3D printed holder is made from VeroClear which is strong and clear. The center part is a slanted platform for mounting the MEMS mirror. Holes are located around the slanted platform, so thin wires can be inserted into them to form pads on which bonded gold wires hanging from the MEMS mirror are glued.

EXPERIMENTAL RESULTS

The final assembled device is shown in Figure 3, which is around 26 mm in diameter, 15 mm in height.

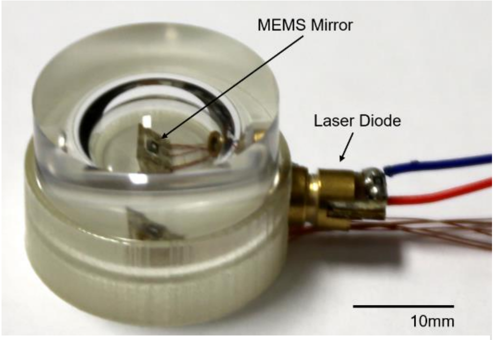

Figure 3: View of the assembled device

The static response of the MEMS mirror with and without the lens is shown in Figure 4, where only one actuator was driven by a DC voltage. The maximum optical scanning angle reached 28° without the lens and 45° with the lens both at 6.0 volts. The frequency response of the MEMS mirror was shown in Figure 5. The resonant frequency is 201 Hz. Using known geometric parameters, the beam divergence through the lens was calculated for a range of tilt angles and compared to experimentally derived values. The results can be seen in Figure 6. The assembled scanning device as shown in Figure 3 is tested. With the MEMS mirrors mounted on top of a holder with a 45° slanted platform, the scanning angle can cover around 90° from one actuator. Around 1.4 times amplification was achieved by using the lens when comparing Figures 7 and 8, demonstrating the utility of the miniaturization.

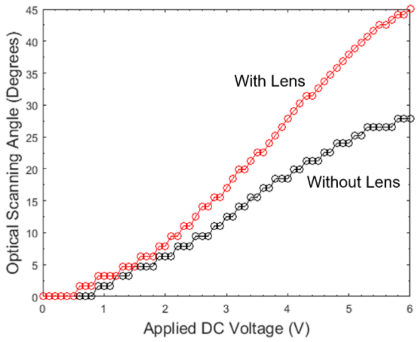

Figure 4: Static response of the mirror with and without a lens showing maximum amplification of about 1.6 times

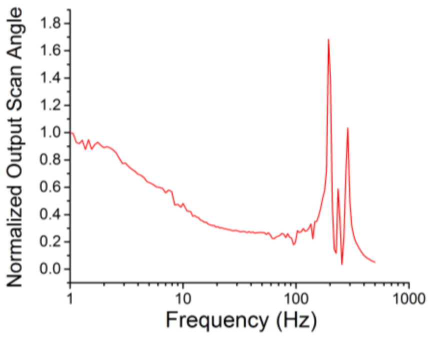

Figure 5: Frequency response of the MEMS mirror without the cover lens

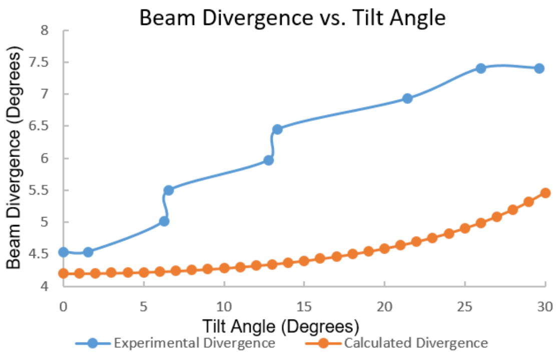

Figure 6: Calculated and experimental beam divergence for various tilt angles

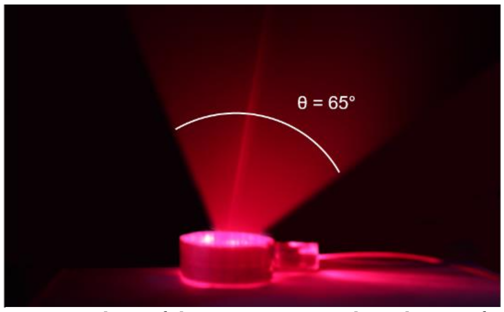

Figure 7: Photo of the 65° scanning without the use of a lens

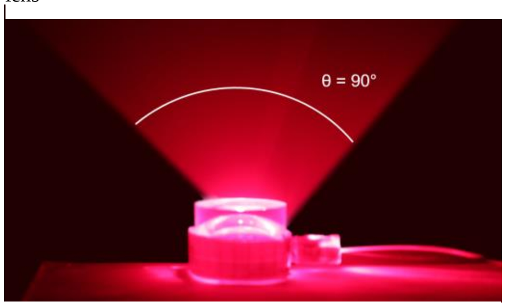

Figure 8: Photo of the 90° scanning with the use of a lens

CONCLUSION

A novel approach to enlarge the scanning angle by combining the dynamic response properties of the MEMS mirror with a simple lens was demonstrated. The device was able to achieve a 1.4 times amplified scanning angle at a maximum of 5 volts without sacrificing its functionality or compactness. Further work is to be done in implementing 2 actuators for full-range 1-D scanning as well as 4 actuators for 2-D scanning. In doing so, the device can be used for applications such as compact LIDAR scanning.

ACKNOWLEDGEMENTS

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