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Abstract

# Thermal behavior of biaxial piezoelectric MEMS-scanner for 1550 nm long-range LIDAR †

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**Keywords:** Biaxial non-resonant MEMS scanner, 1550 nm Long-Range LIDAR, Piezoelectric actuator

This paper presents the thermal behavior of a non-resonant (quasi-static) biaxial piezoelectric MEMS scanner. Such MEMS mirrors, whose design originates from [1], use either a Bragg coating (multiple (n) dielectric bilayers of amorphous Si and SiO<sub>2</sub>) or a reflective gold coating. In our case, they are intended for LIDAR (Light Detection And Ranging) applications, using a 1550 nm pulsed laser with an average power of 2W. LIDAR is a crucial sensor for autonomous driving as it can provide high-density point clouds with accurate three-dimensional information [2]. For long-range (> 100 m), the MEMS-LIDAR approach, based on MEMS mirrors, seems to be currently the best solid-state beam-steering option [2].

In this way, 2x2 mm<sup>2</sup> square mirrors were fabricated with Bragg and Gold reflectors. The best result obtained, using a quasi-static mode, is optical angles close to 8°, on both axes, for a driving voltage of 20V, as reported in Figure 2. The optical angles obtained with 1x1 mm<sup>2</sup> and 0.5x0.5 mm<sup>2</sup> square mirrors are also reported in Figure 1, using the FoM (Figure of Merit) defined in [2]. Our results are at the state-of-the-art, with FoM values between 0.6-0.7, as shown in Figure 1.

This paper presents a series of experimental results concerning the thermal behavior of the Bragg reflector compared to the reflective gold coating. Experimental absorption measurements, performed at 1550 nm with p- and s-type laser polarization, show in Figure 4 that the use of the Bragg reflector can lead to up to 24 times lower incident power absorption than the best metallic (Au) reflective coating (s-polarisation, 4 Bragg bilayers (n=4)). These results pave the way for reducing mirror heating and increasing the tolerable incident laser power. A key parameter of MEMS mirrors is the impact of mirror overheating, in particular the effect of reflector absorption on mirror flatness. To study such evolution, a 400°C/10 min annealing in air was performed on a full sheet Bragg reflector. It shows a 50% decrease of absorption (p-polarization) after the annealing step, which means a better resistance to incident power.

Regarding the evolution of mirror flatness with temperature, a stress-compensated technology has been developed, which allows a static radius of curvature (SCR) of 250 m at room temperature (25°C), as shown in Figure 3Figure 4. Measurements done at 200°C shows that the SCR remains close to 300 m, meaning that the mirror remains flat even during overheating.

Finally, the evolution of the 2D scan was carried out at mirror temperatures of 30° and 150°C, showing no difference in terms of optical angles and 2D scan figures.

These MEMS-scanners have been packaged and integrated into a LIDAR system and three-dimensional (3D LIDAR) point cloud images were obtained.

**Author Contributions:** L.Mollard: Project administration, Writing - original draft. C.Dieppedale: Investigation. A.Hamelin: Investigation. F.Gardien: Investigation. J.Hue: Validation, Investigation. L.Frey: Validation,

Investigation. G.Castelan: Investigation. All authors have read and agreed to the published version of the manuscript

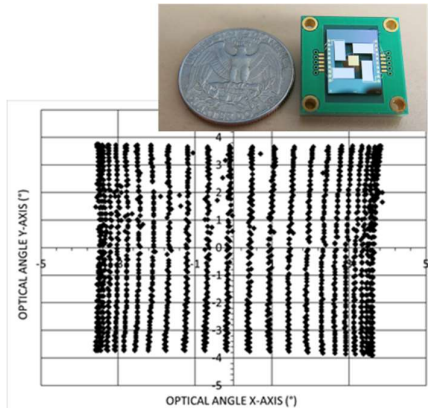


Figure 2 – 2D scanning/optical angles – 2x2 mm<sup>2</sup> squared mirror with Bragg reflector (n=2)

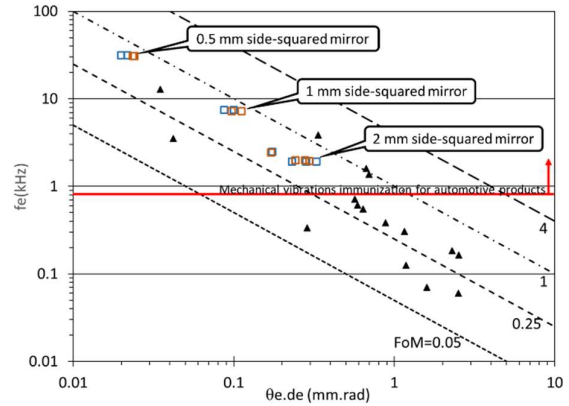


Figure 1 - FoM values ( $f_e$ ,  $\theta_{e.de}$ ) previously reported in [2] (▲) and this work with ◻ Bragg (n=2) and ◼ Gold reflector for 2x2 mm<sup>2</sup>, 1x1 mm<sup>2</sup> and 0.5x0.5 mm<sup>2</sup> side-squared mirror

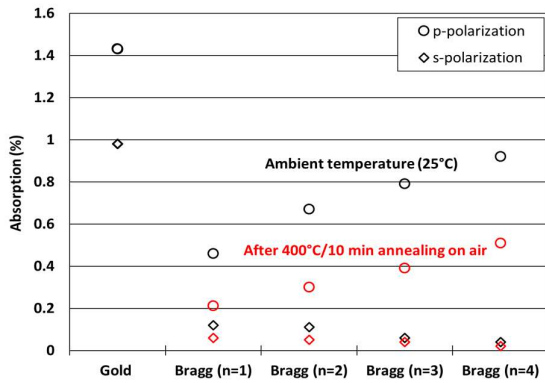


Figure 4 - Variation of reflector absorption (%) with p- and s-type polarization @1550 nm - 45° incident laser- Bragg and gold reflector- Ambient temperature (o,◊) and after 400°C annealing (o,◊)

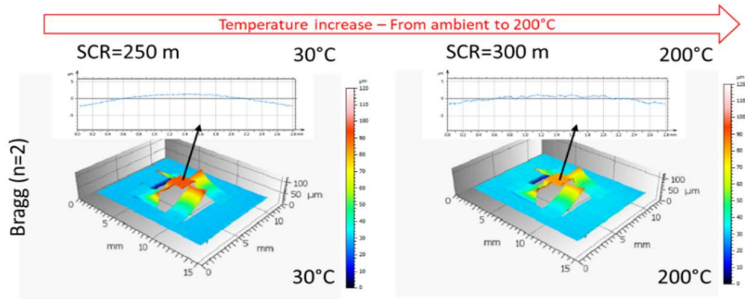


Figure 3 - Mirror SCR evolution with temperature from ambient to 200°C - Bragg mirror (n=2)

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**Conflicts of Interest:** The authors declare no conflict of interest.

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