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Laurent Mollard, Antoine Hamelin, François Gardien, Christel Dieppedale, Thierry Verdot, Mikael Colin, Santiago Royo, Jordi Riu

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LOW ABSORPTION OPTICAL COATING ON BIAxIAL PIEZOELECTRIC MEMS MIRRORS FOR 1550 nm LONG-RANGE LIDAR

This paper reports the first biaxial PZT (Lead Zirconium Titanate) piezoelectric MEMS mirror, which incorporated low-absorption dielectric multilayers coating, i.e. Bragg reflector. These MEMS-mirrors, developed on 8-inch silicon wafers, are dedicated to long-range LIDAR (Light Detection And Ranging) applications with a high power 1550 nm pulsed laser.

LIDAR is believed to be a crucial sensor for autonomous driving as it can provide high-density point clouds with accurate three-dimensional information. Thus, the MEMS-LIDAR approach, based on MEMS-mirror, is the best-option for long-range (> 100 m) LIDAR application, compared to OPA and Flash-LIDAR system [1]. Additionally, biaxial quasi-static MEMS-mirror offers scanning stability and flexibility with a simple linear control. Concerning MEMS-mirror actuation, PZT material, deposited on 200 mm Silicon by sol-gel method, offers compact mirror, low driving voltage and low power consumption [2]. Piezoelectric shows real advantages: no bulky magnet unlike magnetic mirrors, and moderate excitation voltage near 30V compared to 150V for electrostatic mirrors.

This paper will show for the first time a complete set of experimental results of low absorption dielectric multilayers coatings, dedicated to 1550 nm LIDAR, and incorporated into a piezoelectric MEMS-mirror. The reflectivity/absorption of Bragg reflector are compared with Gold reflective MEMS-mirror, as well as optical angles and mirror planarity.

Due to its eye safety, which enables to use at least 10-time larger incident laser power than 905 nm laser source, high-power 1550 nm pulsed laser is the best-option for long-distance LIDAR application [3]. However, in MEMS-mirror with metallic reflector (Au or Al), absorption limits the incident maximal power density because of induced heating. Additionally, metallic coatings are not CMOS compatible resulting in a complex process for silicon foundry integration. Consequently, a piezoelectric MEMS-mirrors technology have been developed to incorporated dielectric multilayers reflectors composed of amorphous-Si and SiO₂.

Experimental measurements of reflectivity and absorption, at 1550 nm show, in Figure 1, that, using two Bragg bilayers ($n=2$), entails 3 times less incident power absorption compared to the best metallic reflective coating (Au). These results demonstrate that it is possible to decrease the induced heating, and so to increase the incident laser power. MEMS-mirror temperature has been monitored using in-situ temperature probe. These temperature probes, based on evolution of resistivity with temperature, are integrated directly into the mirror arms and required no additional fabrication steps. As show in Figure 2, under 1550 nm incident laser with average power up to 5.5 W, Bragg reflector ($n=2$) enables to divide by two the temperature increase compare to Gold reflector.

Using Bragg and Gold reflective coatings, biaxial piezoelectric mirror has been developed, driven by the LIDAR system requirements, i.e. a mirror diameter of 2 mm with non-resonant scanning in both axis. As shown in Figure 3, these MEMS-mirrors enables to obtain a 2D scan near 4.5° on both axis, for 25V driving voltage, at 600 Hz and 12.5 Hz for respectively fast and slow axis. These mirror present high-resonant frequency near 2.4 kHz. The same results are obtained with Bragg and gold reflective coating into piezoelectric MEMS-mirrors.

Finally, the packaged MEMS-mirror, see Figure 4, has been integrated inside biaxial LIDAR system of BEAMAGINE using a wide-angle optical lens in order to expand the scanning angle up to 20°. As illustrated in Figure 5, three-dimensional (3D LIDAR) point cloud image was obtained. LIDAR images has been obtained at 1064nm for intermediate test before final demonstrations, which will be done at 1550 nm. These results demonstrates the scanning stability and operability of this MEMS-mirror.

Word count: 571

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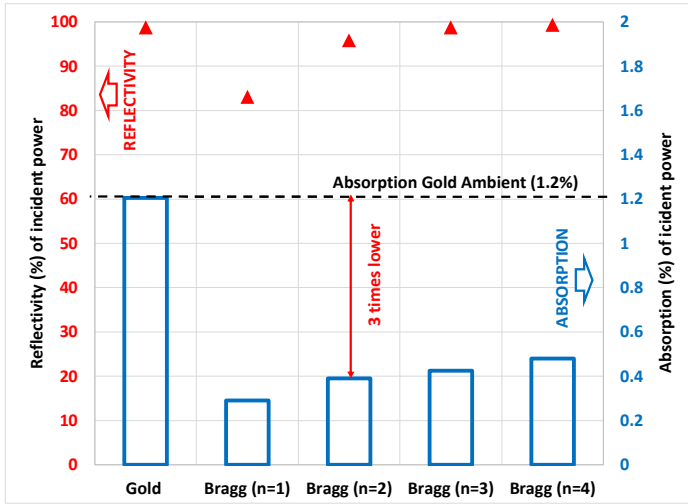


Figure 1: Evolution of reflectivity (%) and absorption (%) at 1550 nm for Bragg reflector vs (n) the number of Bragg bilayer – comparison with Gold reflective layer

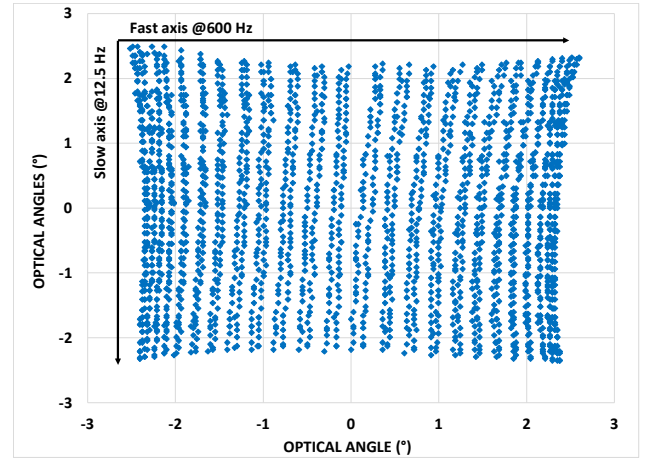


Figure 3: 2D scanning– 4.5° optical angle on both axis – Bragg reflector- 600 Hz & 12.5 Hz at 25V

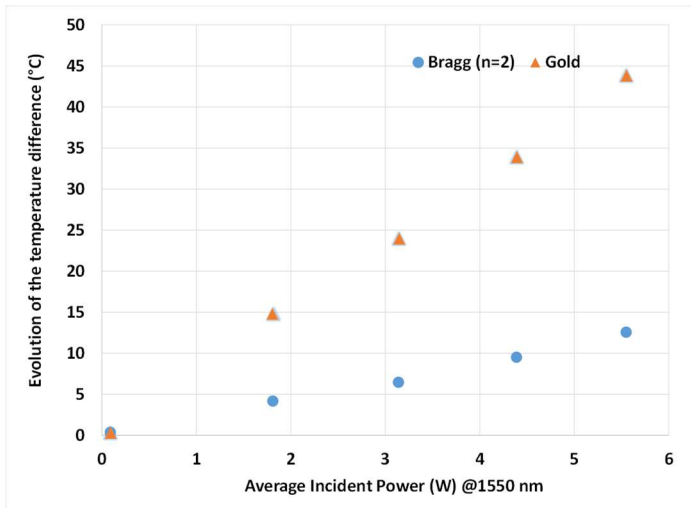


Figure 2: Evolution of the temperature difference under 1550 nm incident power - Bragg (n=2) and Gold reflector comparison.

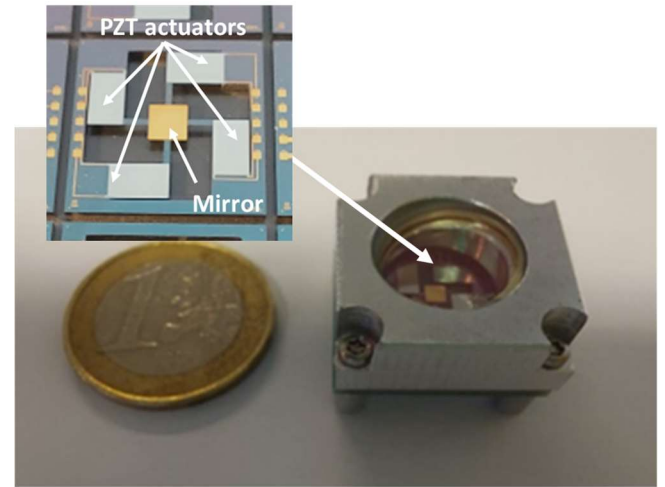


Figure 4: Packaged MEMS-mirror

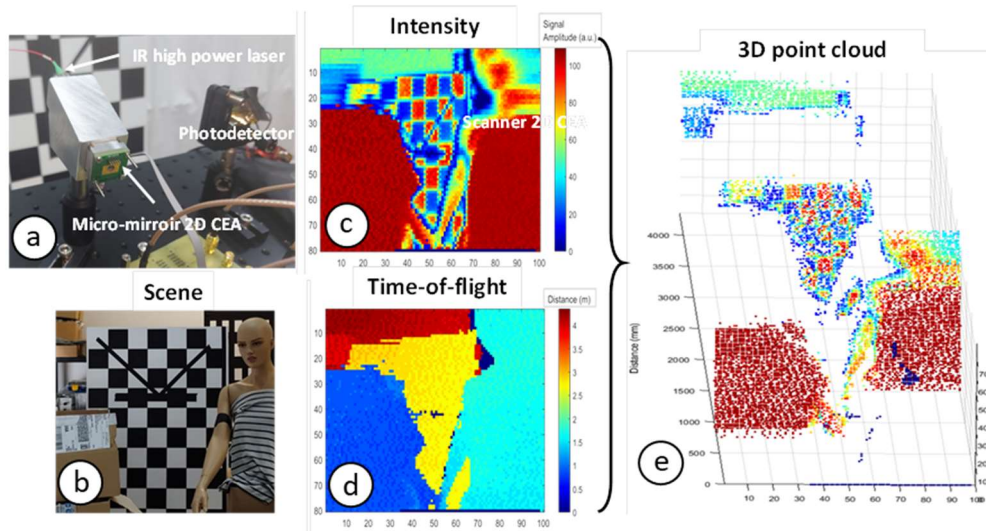


Figure 5: a) BEAMAGINE biaxial LIDAR system with packaged 2D MEMS-mirror, b) object scene for testing, c) and d) colored scene points according to their light intensity and their depth value respectively obtained at 1064 nm, and e) reconstructed 3D Point Cloud.