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Abstract

A Comprehensive Characterization Procedure for Resonant MEMS Scanning Mirrors †

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Abstract: We demonstrate an experimental assessment of a high-Q, high-angle piezoelectric (2 µm PZT) MEMS scanning micromirror featuring distributed backside reinforcement, suitable for applications demanding energy-efficient and high-quality image projection. Frequency response measurements at 10 different vacuum levels ranging from atmospheric pressure to 10^{-6} mbar allow for the quantitative separation of damping mechanisms (air and structural). Stroboscopic digital holographic microscopy was used to assess the static and dynamic deformation of the mirror surface. The experimental results are in good agreement with simulations and models.

Keywords: MEMS; scanning micromirror; air damping; dynamic deformation

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1. Introduction

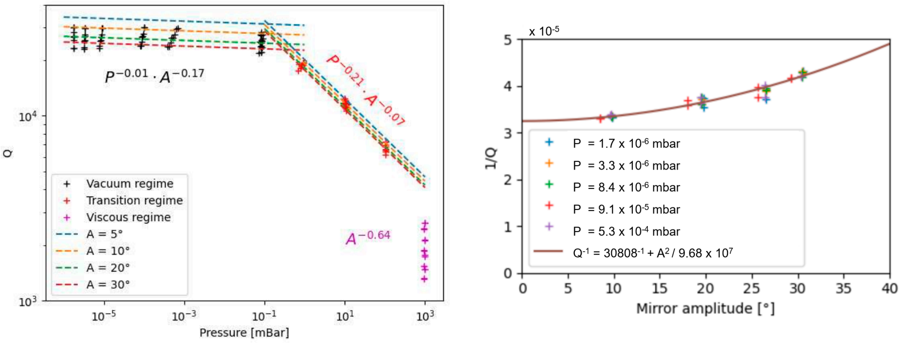
Numerous studies have presented resonant 1D scanning micromirrors exhibiting large optical scan angles, sometimes higher than 100° [1,2]. The in-depth characterization presented in this study, including frequency response measurements at different pressure levels and a quantification of dynamic deformation, enables a substantially more profound analysis and understanding of the microelectromechanical structures investigated.

2. Materials and Methods

The measurement of the Q-factor dependence on pressure was performed at pressures from 10^{-6} mbar to ambient pressure. The device (STMicroelectronics Castor resonant mirror) was actuated inside a vacuum chamber and illuminated by a laser beam. A CMOS camera was used to assess the optical scan angle by measuring the length of the projection of the reflected beam on a screen. The Q-factor was extracted from a Lorentzian fit to the frequency response. The dynamic deformation was measured with a digital holographic microscope [3] at a resonance frequency of 27,505 Hz at atmospheric pressure. The actuation of the mirror was set to 9 VDC + 18 VPP in phase on the top electrode of the first actuator and out of phase on the top electrode of the second actuator, with the bottom electrode of both actuators on the ground for a 14° mechanical scan angle (56° optical).

3. Discussion

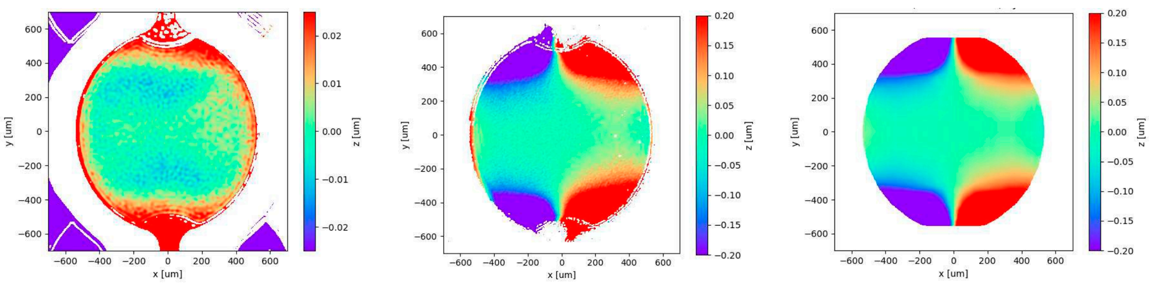
The Q factor dependence shown in Figure 1a can be divided into three regimes: vacuum, where pressure plays no role; viscous at ambient pressure, where Q decreases with amplitude; and a transition regime that shows little amplitude dependence, as losses come from laminar air flow damping. In the vacuum regime (Figure 1b) the losses are shown to depend on the amplitude as an intrinsic loss, plus a loss that would agree with anchor damping [4]. This experiment shows that packaging at 10^{-1} bar is sufficient for optimal driving.



(**a**) (**b**)

Figure 1. (**a**) Measured Q factor vs. pressure, (**b**) 1/Q vs. optical amplitude in the vacuum regime.

Figure 2a shows that the static deformation of the mirror is around 40 nm from peak to valley, whereas Figure 2b,c show that the total deformation of the mirror (measured and simulated) in the center of the mirror is effectively kept flat as per the design target. The angular response and topography are used for both the optical system design and as feedback to MEMS designers.



(**a**) (**b**) (**c**)

Figure 2. Measured static (**a**), measured total (**b**), and simulated dynamic (**c**) mirror deformation at 14° mech. angle (56° opt.).

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