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Last developments in the angular response and deformation characterization of resonant micromirrors

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Summary:

Characterization of micromirror in terms of optical performance during actuation has always been challenging. Two years ago, we introduced a method that makes use of digital holography and variable mirror positioning to sample the shape of the mirror at an arbitrary position in its movement. Here we present further development of the technique, including a methodology to perform fast frequency sweeps. We demonstrate the capabilities by comparing the deformation to analytical derivation from amplitude and frequency.

Keywords: MEMS mirrors, characterization, dynamic deformation

Background, Motivation an Objective

Resonant MEMS mirrors are a component of choice for numerous applications such as Pico projection, LIDAR, and endoscopy. Depending on the use, the critical parameters are the resonant frequency, scanning angle and optical quality. Deformations produce aberrations, and increase drastically with mirror diameter, which is required to lower diffraction. Increasing thickness lowers deformation, but also affects resonance frequency. Localized backside reinforcement (BSR) has been used to reduce deformation while keeping the mass low. This complex tradeoff must ultimately be assessed through characterization. We propose here a fast method to collect all relevant parameters of a resonating mirror to give fast feedback to MEMS engineers.

Description of the New Method

The method is an improvement on the method presented in [2]. It makes use of a commercial Digital Holographic Microscope (DHM R2200 by Lyncee Tec) and a 6 axes goniometer stage (Standa 8-0021), enabling virtually unlimited mirror amplitude. An automated turret for the microscope objective enables a fully automatized sequence.

The new method works in two main steps: Angular response, and shape measurement.

If the resonance frequency is unknown, or if a mode search is needed, a frequency sweep is performed using the DHM in 100% laser duty-cycle mode over a large frequency range. A high magnification objective is used, targeting the center of the mirror to enable capturing high slope topography. Once the mode is localized, a second sweep with a lower step and range is performed, this time with 4 samples per period at a laser duty cycle of 1%. From the analysis of the data, rotation axis, amplitude and phase of the mirror movement is extracted for every frequency.

The shape measurement is then performed at the desired frequencies – often resonance. The objective is changed to lowest magnification to cover the whole mirror. Using the motorized goniometer, the previously gathered information of the rotation axis, amplitude and phase of the mirror is used to keep the MEMS in such a way that the mirror part lies in the object plane for the measurement at each phase. The data is then analyzed to determine the amplitude map of the mirror for different harmonics (including 0^{th}, corresponding to static deformation). As a demonstration, an experimental validation of the analytical formula (eq. 1) for deformation is performed on a mirror like the one presented in [2], where the RMS of the deformation amplitude map in and between two modes is compared to the following model [3].

Eq. 1 $$\delta = c\frac{Af^2D^5}{Et^2}$$

With δ the deflection, A the amplitude, f the frequency, D the diameter of the mirror, t its thickness, and E its Young modulus. c is a constant. We substitute deflection for RMS as it is less sensitive to noise than min/max values.

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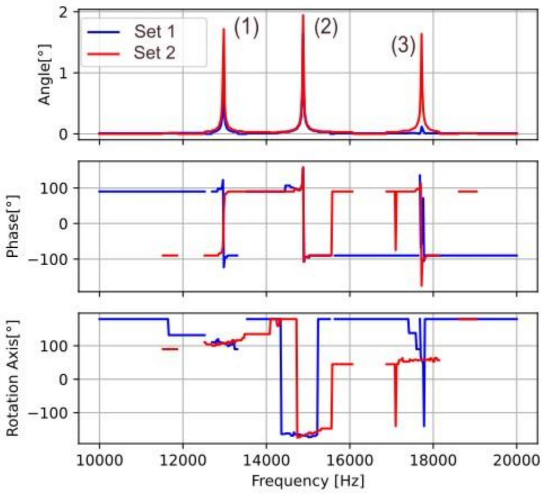

Fig. 1. Amplitude, phase and rotation axis vs. frequency of the mirror without BSR.

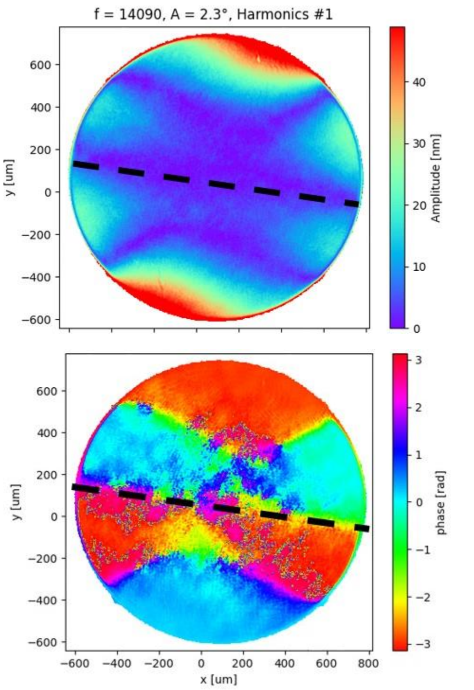

Fig. 2. Mirror (with BSR) amplitude and phase map at resonance (2). Axis shown with dashed line.

Results

Figure 1 shows the result of two frequency sweeps using the presented measurement technique using 4 x 1% duty cycle on a 2D mirror. Two sets of electrodes are used, one optimized for the actuation of different modes. The actuation of set 1 is shown in red and set 2 in blue. Three peaks are visible in amplitude, corresponding to three different modes. Each amplitude peak corresponds to a typical phase response for a resonance mode. The rotation axis can be seen in the last figure. For mode (1) and (2), a frequency dependence in the rotation axis is visible.

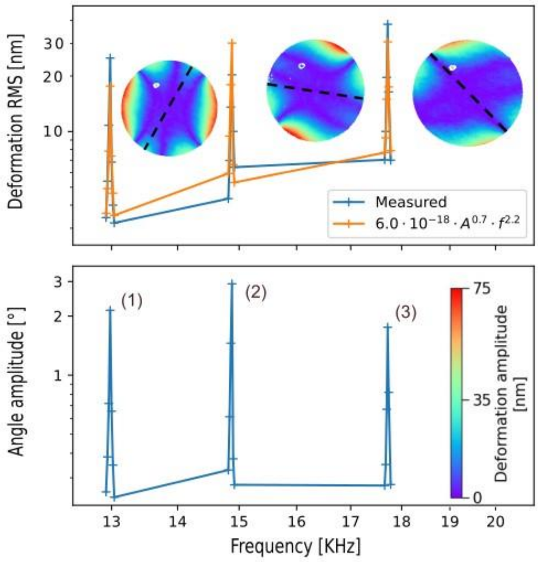

Fig. 3. RMS of the dynamic deformation (with deformation shape and axis) and amplitude of the mirror (without BSR) vs. frequency (log-log).

Figure 2 shows the amplitude and phase map of the deformation at the resonance corresponding to the middle peak. Such a measurement was made for frequencies that display an amplitude higher than .2°.

Figure 3 shows the RMS values versus frequency for the three peaks, with the corresponding amplitude shown below. Fitting the exponents gives dependencies in 0.7 for A, and 2.2 for f. The small difference between the model parameters and extracted parameters may be due to the asymmetry created by the anchor geometry, also visible in the difference between deformation shapes.

Acknowledgement

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