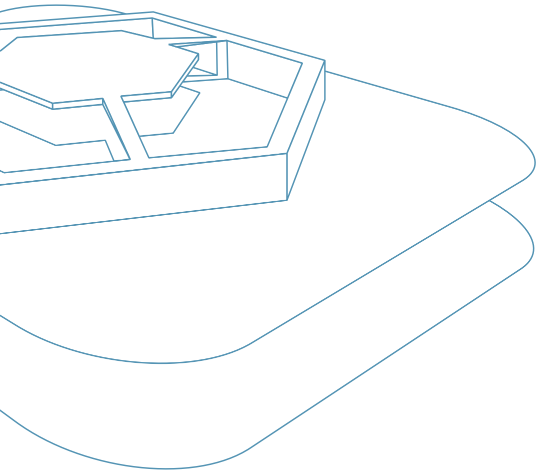
DIGITAL HOLOGRAPHIC MICROSCOPY

DHM™ R1000



Dynamic characterization of MEMS and MOEMS

Digital Holographic Microscope (DHM™) is an ideal tool to investigate MEMS and MOEMS. It allows:

- **3D topography: in plane and out of plane**
- **Dynamic behavior of samples**
- **Fast image acquisitions**
- **Stroboscopic acquisition mode**

It is illustrated by the investigation of resonant frequencies of a dual axis micro-mirror and allows the definition of the linear, non linear, and modal resonance zones of its dynamic response.

MEMS and MOEMS developments require an interferometric resolution for both their static and dynamic characterization. From the resonant frequency analysis of structures, such as cantilevers, flexure joints, micro-bridges or membranes, one can evaluate for instance the geometric factor effects, the Young's modulus, the mean residual stress, the effect of air damping, or the study of micro-systems ageing. When developing MEMS and MOEMS, there is a constant need to efficiently compare numerical simulations to the real micro-device movements and to adapt the production process by modifying geometric characteristics.

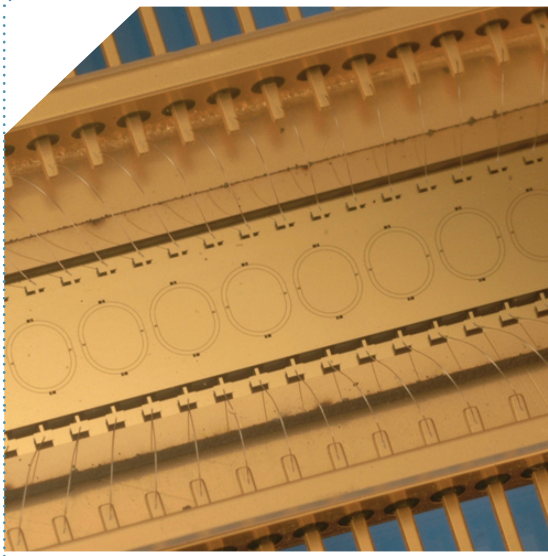
Optical measurement of the movements of micro-systems is a commonly used method for the characterization of the mechanical properties of micro-systems. Most of the methods provide only a point measurement of the out-of-plane vibrations and a time consuming mechanical translation of the sample or a scan of the beam is needed to obtain the vibration amplitudes on several locations of the micro-device. These measurements are very sensitive to vibrations making full-filed measurement techniques, such as stroboscopic systems using phase shifting interferometry (PSI) or Fast Fourier Transform (FFT) analysis of interferograms, highly desirable.

Nevertheless, their speed is limited and they are sensitive to vibrations as information from several interferograms taken successively over a relatively long period of time need to be combined.

Digital Holographic Microscope (DHM™ R1000) allows the retrieval of the full three dimensional information with a nanometric vertical resolution from a single image acquisition. Some important features makes DHM™ system a unique tool for MEMS and MOEMS characterization in-plane and out-of-plane:

- Short acquisition time (a few microseconds) makes DHM™ systems insensitive to external vibrations.
- Digital procedures enable correction for any vertical movement between two successive measurements or tilt of the sample associated with ambient vibrations. DHM™ systems operate without vibration insulation methods, making them a cost effective solution for R&D and for implementation on production lines.
- Real-time measurements (up to 15 fps) can be achieved using standard cameras. Higher rates can be achieved with fast cameras and postponed reconstructions.
- Stroboscopic mode can be used for up to 100kHz excitation frequencies by synchronizing the camera acquisition with the micro-device driving signal to capture the optical topography along the whole movement cycle of the micro device.

Sequence obtained with DHM™ R1000:
Half cycle of a two-axis micro-mirror motion. The frame moves along the vertical axis. The mirror is linked to the frame by the horizontal axis. The driving voltage is 30V at an excitation frequency of 60Hz on both axis.



Packages mirror array for optical beam steering by Colibrys.

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Micro-system description and movement characterization of micro-mirrors

The MOEMS characterized here is an array of ten dual-axis micro-mirrors. It can be used for various applications such as optical switches, 2D scanning and image projection. Each micro-mirror consists of a silicon plate of 1.5 x 2.0mm² (Fig. 1a) held by flexures suspended over four control electrodes. The geometrical parameters of the flexures have been changed for the aim of this study. A thin gold layer is deposed over the silicon die to create the reflective surface and the bonding pads.

The purpose of the study is to investigate the combined effect of different resonant frequencies along both axes. The mirror has resonant frequencies between 100 and 200Hz which are low operating frequencies with respect to the capacity of DHM™ R1000.

The vertical displacement of five different areas has been measured. Figure 1a shows the location of these areas, one in the center and one on each extremity of each rotation axis of the mirrors. This choice allows the examination of the characteristics of each axis. Figure 1b shows the relative displacement of these areas for a sinusoidal driving voltage ranging between 3 and 30V, at an excitation frequency ν = 60Hz.

Figure 2 shows the vertical displacement of area 3 for a sinusoidal driving voltage ranging between 3 and 30V, and for frequencies ranging from 10Hz to 240Hz. Three distinct zones can be distinguished. One for frequencies less than 60Hz (Fig. 2a) in which the vertical displacement of the area is linear with the driving voltage, one for frequencies ranging between 60Hz and 120Hz, in which the amplitude of the oscillation increases with the driving signal frequency and the dynamic behavior clearly shows more complex features, and the last one for frequencies higher than 120Hz, in which development of asymmetric resonant modes are observed.

DHM™ R1000 measurements show clearly the relationship between the driving parameters and the dynamic behavior of the system. Additional studies have been performed for sinusoidal peak voltages of V = 45V and 60V. The results are summarized in Fig. 3 which shows the amplitude of the displacement as a function of the excitation frequency. Such dynamic response analysis permits the determination of the operating parameters of the micro-device.

Conclusion

The DHM™ R1000 used in conjunction with a high frequency acquisition camera or in stroboscopic acquisition mode enables a very fast and efficient investigation of the dynamics of micro-systems. Resonance modes have been analyzed, but DHM™ R1000 also allows the measurement of the deformation of the mirror as a function of both driving voltage and vibration frequency.

References

Y. Emery et al., "Digital Holographic Microscopy (DHM) for metrology and dynamic characterization of MEMS and MOEMS", SPIE Proceeding Strasbourg 2006

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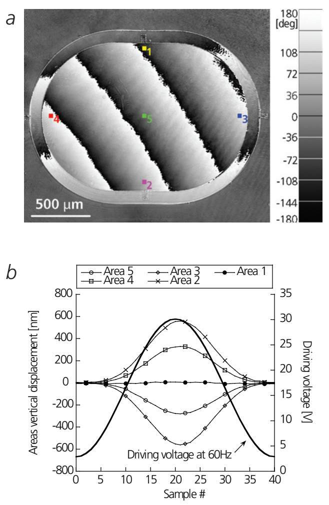
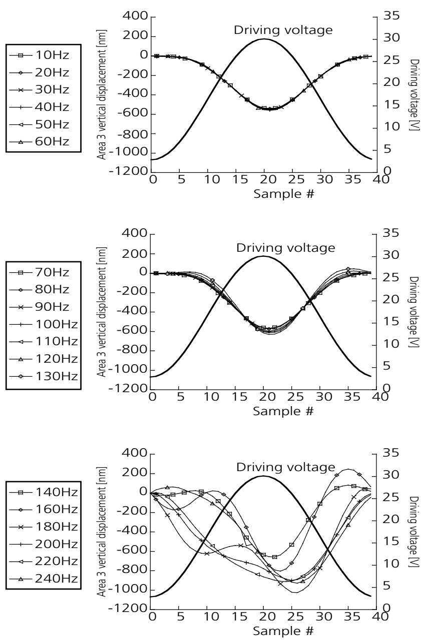


Figure 1: (a) Phase image of a 2-axis micro-mirror by Colibrys. (b) Vertical displacement of the areas (left Y-scale) for a sinusoidal driving voltage (right Y-scale) with a peak V = 30V at an excitation frequency ν = 60Hz.



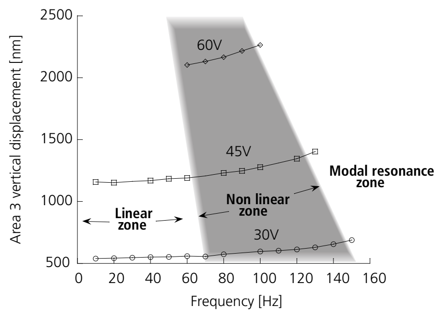


Figure 3: The dynamic response of the micro-mirror enables to distinguish the linear, non linear and Modal resonance zone of the micro-system.

Figure 2: The dynamic behavior of the micro-mirror driven by a sinusoid voltage of 3 to 30V (a) Linear working zone below 60Hz (b) Non linear working zone between 60Hz and 120Hz, and (c) Modal resonance zone above 120Hz.