Interference Microscopic Techniques for Dynamic Testing of MEMS

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Experimental analysis and test of micro electromechanical systems regarding the dynamic properties resonant frequency, resonant mode shapes, resonant bandwidth, sensitivity or gain and uniformity of these properties across a wafer or within arrays of MEMS/MOEMS elements is most important in the R&D process and at the end of fabrication sequence. Measurement techniques on base of image recording and processing offer an effective way to collect this information very fast. A parallel observation of many chips of a wafer or of all cells arranged to an array is possible. Interference methods particularly phase shift interferometers often have been applied to reach the desired resolution of the motion in the range of some tenth to some ten nanometers. The observation and measurement of out of plane and in plane motion is provided by means of Speckle interferometry and image processing.

The measurement set-up of a Speckle interferometer is depicted within Fig. 1. A Nd:YAG-Laser is used to illuminate the sample. The reflected light produces a Speckle pattern by the interference of the elementary waves arising at the grains of a metallisation if it exists or at the crystals of an evaporated ammonium chloride layer in case of very smooth surfaces like polished Silicon. A motion of the sample changes the Speckle pattern. A further light beam is stepwise phase shifted by a piezoelectric driven mirror and superimposed to the Speckle image. The phase image is calculated after taking a sequence of three images each with an incremented phase shift by 120° of this additional beam. It contains the information of the sample deformation. The 3D information is obtained by performing this procedure with three different directions of the illumination. An acousto-optical modulator provides a stroboscopic illumination for dynamic measurements. Hence it is possible to trigger with the mechanical excitation of the sample in order to observe the deflection at a certain phase angle of the vibration.

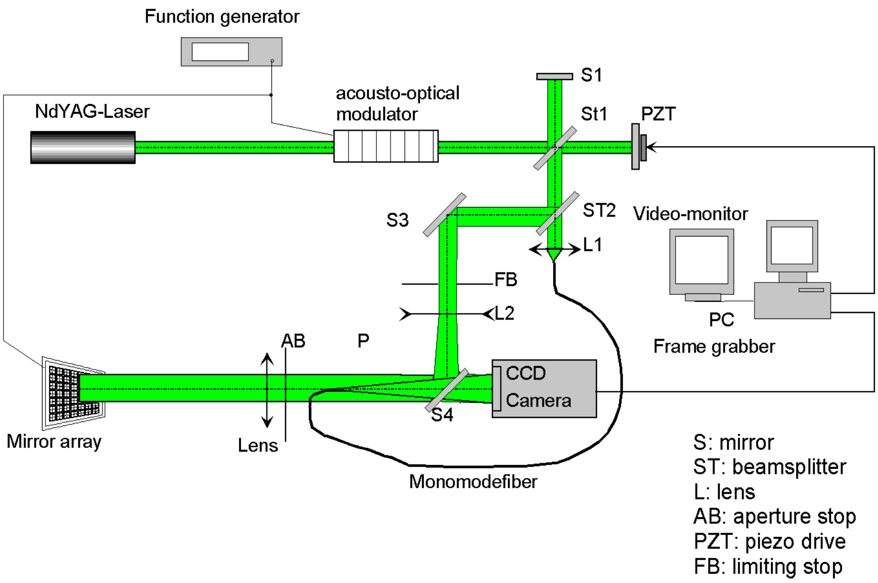

Fig. 1 Schematic view of an electronic Speckle interferometer (ESPI)

An electronic Speckle interferometer has been applied for simultaneous measuring the deflection of all cells of a micro mirror array (Fig. 2 left). The mirrors are specially hinged in a way that they tilt concerning to orthogonal axes in the plane of the wafer surface. They are synchronously forced to a combined deflection regarding both axes with 90° phase in excitation close to their resonant frequencies. As a result (Fig. 2 right) we get information about the homogeneity of the resonance frequencies and the gain of the mirror cells.
One can slightly alter the set-up depicted in Fig. 1 by replacing beam splitter ST2 by a mirror and inserting a beam splitter with the PZT piezoelectric driven reference mirror in front of the lens to get a stroboscopic illuminated phase shift interferometer. A special preparation of the sample with an ammonium chloride layer is not necessary, however only an out of plane motion can be detected. The stroboscopic illuminated phase shift interferometer has been used to observe a dynamic deformation of a mirror for laser scanning (Fig. 3). The acoustic-optical modulator is triggered at 90° phase. The reference mirror is horizontally tilted according to the mirror tilt during the deflection maximum (2°) and vertically tilted to produce a few stripes in the interference pattern.

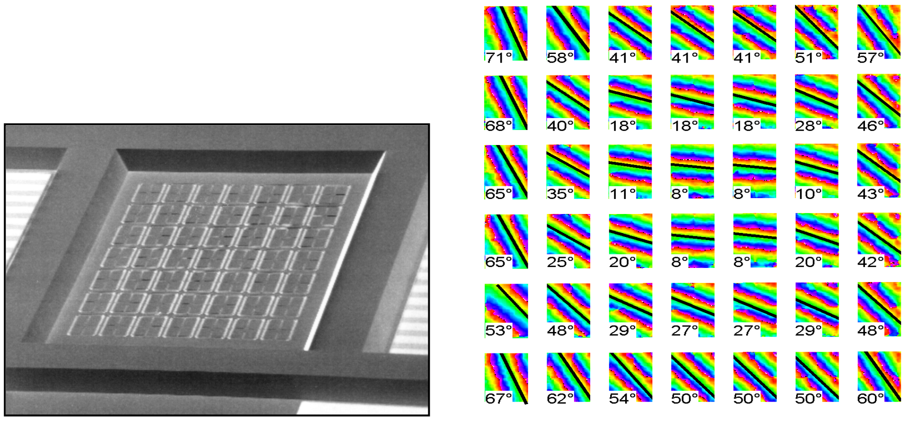

Fig. 2 Micro mirror array (left) and result of a dynamic ESPI measurement using stroboscopic illumination. The distribution of resonant frequencies affects the actual phase of the mirrors tilt while driving by the same voltage

The deformation of this stripes gives the information about the warp of about ± 20 nm per degree deflection (Fig. 3). The phase values at the crossings of straight lines and the vertical line indicated by the peaks determine the deformation.

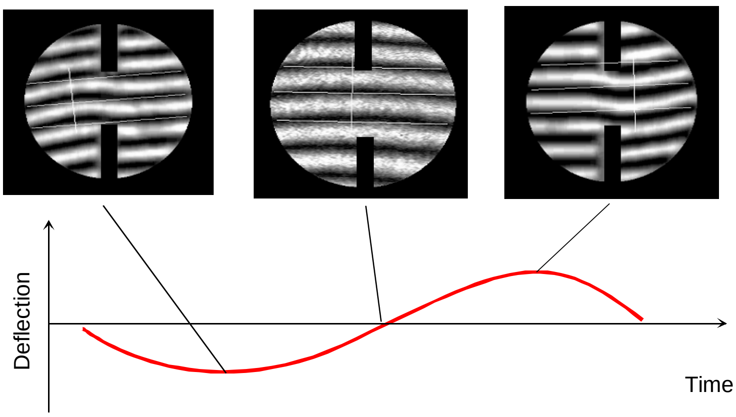

Fig. 3 Dynamic warp measurement of a resonating laser scanner, interference pattern with straight lines for reference in the left image, intensity profile along the vertical line in the right figure.

ESPI measurement of in plane and out of plane vibrations of a silicon resonator consisting of a mass and a bending beam attached in the inner area of the mass is a further example. Due to this attachment an out of plane torsion, an out of plane motion with S-shaped bending of the beam and an in plane rotation are the main resonant mode shapes. The center of rotation is located outside of the mass which is to be seen in Fig. 4.

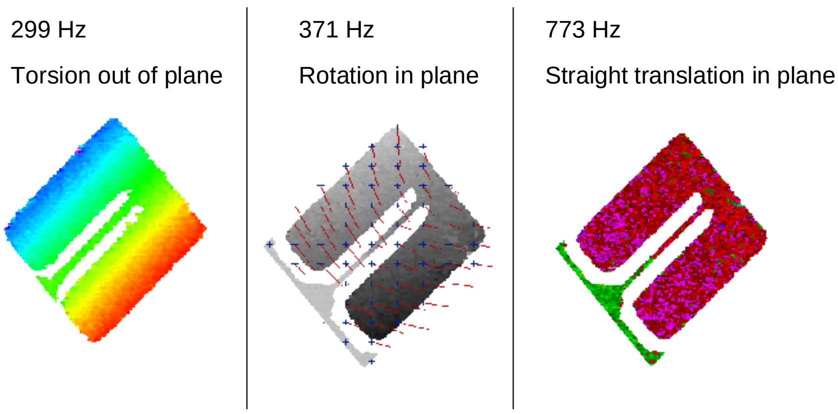

Fig. 4 Silicon resonator with in plane motion detected by an ESPI