微分干渉顕微法による MEMS デバイスの 2 次元共振特性の測定

Measurement of the two-dimensional resonance features of MEMS devices using differential interference contrast microscopy

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The measurement of resonance characteristics is an essential process for the development of micromechanical-system (MEMS) devices. Laser Doppler vibrometer can detect mechanical vibrations of MEMS devices of high sensitivity, but the measurement is restricted to a single point. Two dimensional (2D) measurement is needed to observe the resonance mode shapes. Mode shape measurements have been achieved using stroboscopic interference microscopy[1-3], where a Michelson interferometer is utilized to detect the surface profile change of MEMS resonators caused by their mechanical resonances. However, to keep a monotonic relation between the image contrast and the surface deflection, the peak-peak surface deflection must be smaller than $\lambda/4$ (λ: the wavelength of the illumination light), limiting the measurement range of the vibration amplitude to be typically ~100 nm. Such a measurement range is good for the study of the linear oscillations of MEMS resonators, but not sufficient for investigations of the nonlinear oscillation regimes, which contains lots of attractive physics such as chaos oscillations and internal mode coupling.

In this paper, we report the measurement of two-dimensional, out-of-plane vibrations of MEMS resonators using stroboscopic differential interference contrast (DIC) microscopy, for the study of the linear and nonlinear resonances of MEMS resonators. The measurement setup is schematically shown in Fig. 1(a). The DIC microscope measures the interference of two light beams reflected from the sample surface with a small lateral shift to generate a DIC image, which enables to observe the surface deflection that is larger than the illumination light wavelength. The measured sample is a GaAs MEMS beam resonator as shown in Fig. 1(b). With the modulation of the illumination light at the resonance frequency of MEMS resonator, the DIC images of the MEMS resonator is captured with a CMOS camera, which are used to derive the resonance amplitude and mode shapes of bending and torsional modes of MEMS resonator. Fig.1(c) shows the contrast change as a function of the phase difference between the illumination light and the driving signal of the MEMS resonator. The derived mode shape of the first bending mode is shown in Fig. 1(d). The results show that the stroboscopic DIC microscopy can measure the 2D distributed mechanical vibrations with a high vertical resolution < 1nm, and a large measurement range of over ~1 μm, which is very promising for the investigation of linear and nonlinear resonance of MEMS resonators.

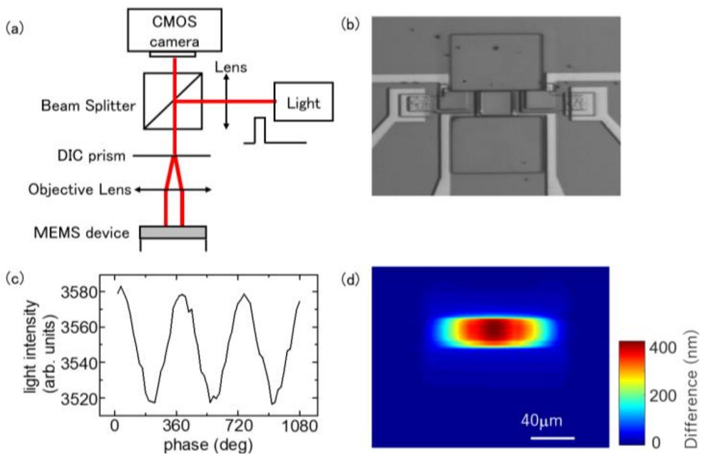

Fig. 1:(a) The measurement setup. (b) A GaAs MEMS beam resonator used for measurement. (c) The contrast changes as a function of the phase difference between the illumination light and the driving signal of the MEMS resonator. (d) Derived mode shape of the first bending mode.

Reference
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