A stroboscopic DIC microscopy with enhanced temporal resolution for visualizing the vibrations in MEMS devices

Ya Zhang[1*], Qian Liu[1], and Mirai Iimori[1]

[1]*Institute of Engineering, Tokyo University of Agriculture and Technology, Koganei-shi, Tokyo, 184-8588, Japan*

Abstract

We proposed a stroboscopic differential interference contrast (DIC) microscopy for the visualization of vibrations in Microelectromechanical-system (MEMS) devices with a high temporal resolution and a large vertical measurement range. The DIC microscopy observes the vibrations of the MEMS devices as the contrast change in their DIC images, and the stroboscopic method samples the high frequency vibration motions by using pulsed illumination light with a frequency that is the same or similar to the vibration frequency. Comparing with conventional interference microscopy, the DIC microscopy can observe the surface deflection larger than the wavelength of the illumination light, enabling the measurement of nonlinear oscillations with a large amplitude. The second advantage is about the stability. Since both light beams in the interference are from the sample surface, the common-mode mechanical noise is very much suppressed, and no precise optical adjustments or anti-vibration facilities are needed, which greatly decreases the total cost of the system. Furthermore, we have proposed a doubly-modulated illumination method to greatly improve the temporal resolution of the stroboscopic method. The conventional stroboscopic method is a time-averaged measurement, and the analysis of the distributed vibrations needs to capture many frames at variable delay-times between vibration motion and illumination pulse, giving a low temporal resolution (typically, ~10s). This is too slow to observe the transient response of MEMS actuators and sensors. To break this limitation, we utilize a doubly-modulated illumination method, i.e., the pulsed illumination light is modulated again with a function that is synchronized with the transient events. With this method, we have achieved a temporal resolution of ~1 ms, that is over ~1000 times faster than conventional method. This technique has been applied to study the dynamics in GaAs and SOI MEMS resonators, which are used for sensitive and fast detection of terahertz radiation. This research is partly supported by JSPS KAKENHI Grant Number 21K04151, A-STEP program of JST, and the Futaba Foundation.

Biography:

Dr. Ya Zhang carried out his PhD in the University of Tokyo (Japan), where he studied terahertz(THz) spectroscopy of single zero-dimensional quantum nanostructures, under the supervise of Prof. Kazuhiko Hirakawa. Afterwards, during a 3 and a half years' postdoc in the same group, he developed a novel THz thermal detector using MEMS beam resonators. In 2018, he moved to Tokyo University of Agriculture and Technology as an associate Professor. The research in his group focuses on the physics and applications of semiconductor micro/nano structures in the THz frequency range.