

PROCEEDINGS

Feature Extraction and Mode Reconstruction for Visualizing Subnanometer-Level MEMS In-Plane Vibrations

Jinbo Zhang¹, Junfeng Zhou², Jiahao Wu¹, Wenming Zhang², and Lei Shao^{1,*}

¹Global College, Shanghai Jiao Tong University, Shanghai, 200240, China

²State Key Laboratory of Mechanical System and Vibration, School of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai, 200240, China

*Corresponding Author: Lei Shao. Email: lei.shao@sjtu.edu.cn

ABSTRACT

Microelectromechanical systems (MEMS) used in clocks and inertial sensing typically rely on resonators operating in in-plane vibrational modes, with amplitudes ranging from the micrometer scale down to the nanometer or even picometer regime. Visualizing and analyzing these modes are crucial for improving the performance, stability, and functionality of MEMS chips. However, existing techniques, such as the Polytec MSA-600, cannot reliably identify and reconstruct in-plane vibrations with nanometer-level amplitudes, limiting their accurate characterization. Herein, we develop a novel algorithm for in-plane vibration measurement using videos acquired by a stroboscopic microscope which freezes vibrations by synchronized strobe illumination. The proposed algorithm integrates speed-up robust feature extraction, inter-frequency modulation noise suppression, Fourier ptychographic image reconstruction, and Eulerian visual magnification to enable high-precision recognition and visualization of in-plane vibration modes.

Experimental results demonstrate that, under identical device and excitation, our algorithm produces results consistent with those of the Polytec system when the vibration amplitude exceeds 20 nm. Furthermore, when the amplitude falls below this threshold, our method continues to operate reliably, revealing a linear decrease in vibration amplitude with decreasing d.c. excitation voltage, whereas the Polytec system loses tracking capability. The proposed algorithm achieves a minimum detectable amplitude of at least 0.19 nm, and can visualize and reconstruct in-plane vibration modes on a standard personal computer in less than 30 s with minimal distortion. Such a performance in detection capability is 2 orders of magnitude better than that of the Polytec MSA-600, the most widely used commercial instrument for MEMS vibration measurement. Beyond providing a rapid and accurate imaging solution for measuring high-frequency in-plane vibration modes in MEMS, this generalized algorithm also holds considerable promise in other fields such as machinery and civil structure monitoring.

KEYWORDS

MEMS; in-plane vibration; subnanometer resolution; vibrational mode

Funding Statement: This work was supported by the National Key R&D Program (Grant No. 2023YFF0723000).

Conflicts of Interest: The authors declare no conflicts of interest to report regarding the present study.



Copyright © 2026 The Author(s). Published by Tech Science Press.

This work is licensed under a Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.