

FIBER OPTIC INTERFEROMETRY FOR NANOMECHANICAL DISPLACEMENT DETECTION

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Nanoelectromechanical Systems (NEMS) with their small masses, high resonant frequencies, and low energy dissipation, show potential for usage in wide range of applications from sensitive and precise detection of mass, force, and other physical quantities, to RF electronics, to fundamental problems of quantum physics and engineering. Poised to make the NEMS research accessible for small schools with limited resources, we present the progress in developing a compact and cost-efficient fiber-based optical interferometer for detecting NEMS displacements and oscillations. Important advantage of the proposed interferometer is that it can be used in the conditions of restricted spaces, e.g. inside cryogenic, fluidic, or other equipment.

Introduction

NEMS, in the simplest case, are represented by small bridge or cantilever resonators, whose resonant properties (frequencies and Q-factors) are extremely sensitive to various physical factors: temperature, pressure and composition of the environmental fluid, electric and magnetic fields, etc. As fabrication technology develops, the NEMS dimensions are getting smaller and the range of their potential applications increases. This drives the growing interest of the scientific community to the NEMS research. However, the problem of achieving reliable readout of NEMS displacements represents a serious limiting factor in the progress of these studies. Optical interferometry is known to be a sensitive and powerful tool for detecting and studying NEMS oscillations, but majority of the experimental setups are cumbersome, tedious in alignment, require numerous expensive components and considerable monetary investments. These factors limit the NEMS research to large institutions possessing significant expertise, and material and human resources. To remove this barrier from the path of scientific progress we concentrate on developing methods that would make NEMS research accessible for broader circles of scientists. We believe, one of the ways to achieve our goal goes through developing new methods for electrical and/or optical readouts. The progress of our work with electrical readout is described in Ref. [1]. In the present communication we focus on our work dedicated to developing a fiber-based optical interferometer [2] that is taking advantage of using commercial fiber optic equipment.

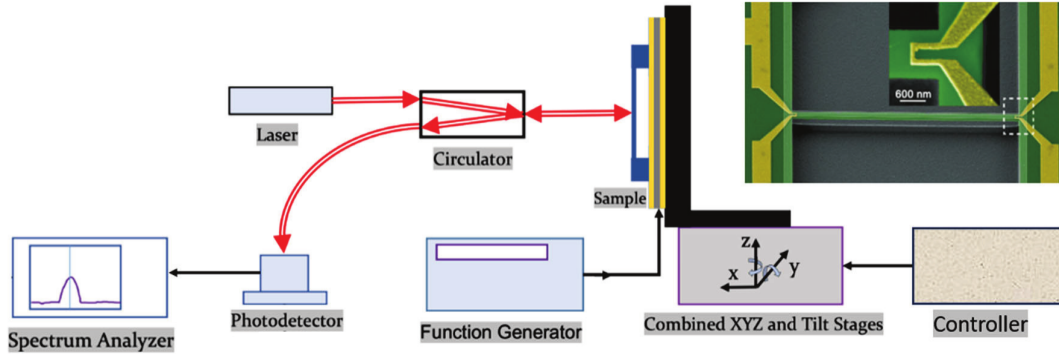


Fig. 1. Schematic of the interferometer. Inset shows colored scanning electron microscopy image of NEMS

Experiment

Block-diagram of the proposed instrument is shown in Figure 1. A 633 nm 0.05 - 0.10 mW laser beam is carried by a single-mode optical fiber, through a circulator, toward the sample where the light reflects partly from the sample, and partly from the tip of the fiber. The reflected light beams travel back through the fiber and circulator, and interfere at the photodetector (PD). The circulator represents a three-port optical fiber device that consecutively directs light between ports: 1 $\rightarrow$ 2, 2 $\rightarrow$ 3, 3 $\rightarrow$ 1. Excitation of NEMS is done with the help of a function generator. To facilitate alignment of the light beam on NEMS, we use a 5D XYZ translational and tilting stage equipped with micromechanical and piezoelectric positioning drivers. The signal from the

photodetector is submitted to a spectrum analyzer. The output data from the spectrum analyzer are submitted to a computer. This computer also controls the 5D positioning stage and the function generator.

To test the interferometer, we used a Y-cut LiNbO₃ plate, whose vibrations were excited by an AC signal from RF generator. Figure 2, left panel, shows vibrational spectrum of this plate at two values of excitation amplitude. To detect vibrations of the NEMS beam, such as that shown in the inset in Fig. 1, a problem of aligning the tip of the fiber with the beam needs to be solved. For that, we have used scanning optical interferometry imaging capability that we included in our design. The right panel in Fig. 2 shows example of optical interferometry image of our bridge near one of the supports. The interference fringes here are due to a slight tilt of the bridge with respect to the fiber. Unfortunately, we were not able to observe vibrations of this beam because it was damaged in the previous experiment.

In the future, we will carry out this experiment on a new NEMS chip with series of bridges vibrating in the range of frequencies between a few MHz to ~200 MHz. This experiment will allow us to fully characterize and optimize properties of our instrument.

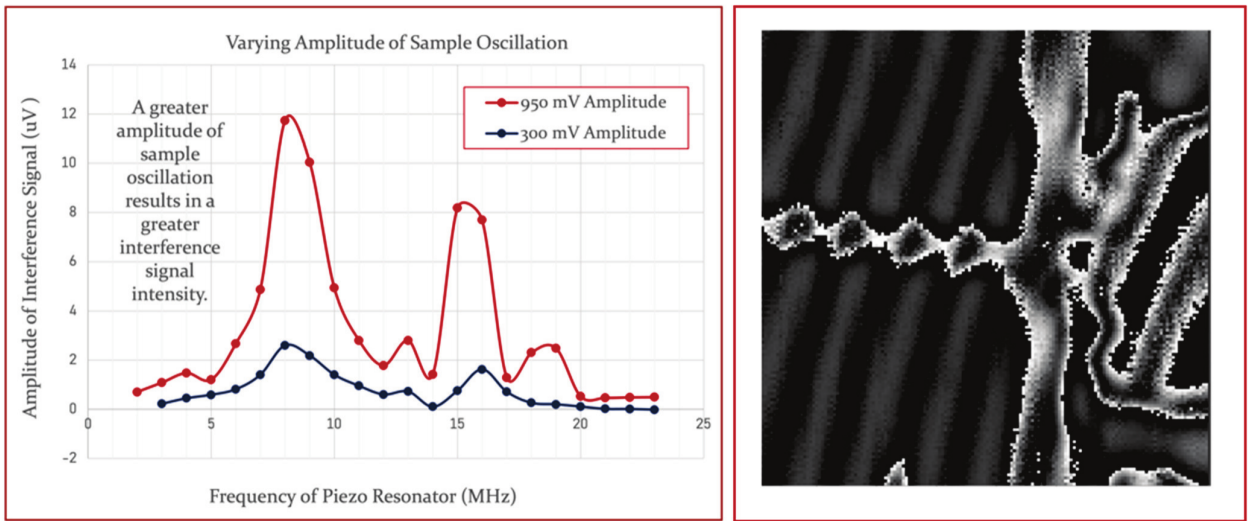


Fig. 2. Left: spectrum of vibrations of LiNbO₃ testing plate. Right: optical interferometry image of NEMS bridge.

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