Parallel optical readout of a cantilever array in dynamic mode

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Abstract

In this work we present parallel optical readout of a cantilever array which operates in dynamic mode using a standard optical beam deflection configuration containing only one laser-detector pair. We show accurate readout of the resonance frequency shift of an individual cantilever within an array by designing arrays where each cantilever has a different resonance frequency. The different resonance frequencies are created by giving each cantilever a different length and allow parallel readout of all cantilevers within the array. We show that even if the cantilevers are closely spaced each cantilever resonance frequency can be individually tracked without signs of cross-talk at current measurement precision (below 12 mHz). Interference of the laser light reflecting of each cantilever is observed when the amplitude of the cantilever is on the order of the wavelength of the laser light.

***Key words*:** optical readout, cantilever array, dynamic mode, parallel readout, resonance frequency

1. Introduction

Arrays of microcantilevers are fast and highly sensitive sensors having enormous potential in a variety of applications, among which biochemical analysis, gas detection [1] and probe-based data storage [2]. Optical illumination of cantilever arrays can provide an accurate, reliable and non-invasive readout. Previous work has shown sequential optical readout [3, 4] using time-multiplexing. Parallel readout was also demonstrated, however requiring one detector for each cantilever in the array and considerable modification of the cantilever design [5]. Others have detected the multi-frequency response of a cantilever array [6], but neither a selective shift of a cantilever resonance frequency was measured, nor the absence of cross-talk between cantilevers.

2. Experimental

Frequency separation is created by giving each cantilever within an array a slightly different length L, since the resonance frequency of a cantilever is proportional to $1/L^2$. The array has a frequency response with neighbouring peaks corresponding to the individual cantilevers. To be able to control the resonance frequency of one cantilever within the array a thin magnetic film is deposited on this cantilever. When the cantilever is subjected to a magnetic field, the resonance frequency of the magnetic cantilever changes linearly with applied field, provided that the magnetic field is weak compared to the saturation field.

In our experiment the functionalized cantilever array is fabricated from a single cantilever with rectangular cross-section. First a layer of CoNi (80/20) is deposited by e-beam evaporation on the side of the cantilever. The cantilever is machined by focussed ion beam into three cantilevers of different length (Fig. 1).

As a result only one cantilever has a magnetic layer on one side-wall. The cantilever array is piezo electrically actuated in a vacuum environment (10^{-2} mbar) to increase the quality factor of the cantilevers' vibration. A Helmholtz coil configuration provides a magnetic field. A laser spot of approximately 60 µm in size is focused on the free ends of all three cantilevers. The reflected light is collected on a split-photodiode.

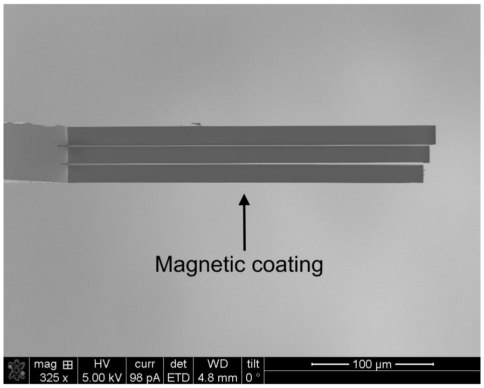

Figure 1. SEM photograph showing an array of cantilevers of different length (L_1=304, L_2=298, L_3=293 µm). The shortest cantilever is side coated with a magnetic layer.

3. Results and Discussion

A frequency sweep was applied to actuate the cantilever array. Fig. 2 shows a resonance peak for each cantilever. A closer look at one of the peaks reveals that the shape of the response shows indents depending on the actuation voltage of the cantilever array (Fig. 3). The indents are caused by interference of light reflected of the adjacent cantilevers. A cantilever deflection equal to an odd number of quarter-wavelengths leads to destructive interference. Although this effect possibly can be exploited, for current purposes interference is avoided by reducing the cantilever vibration amplitude.

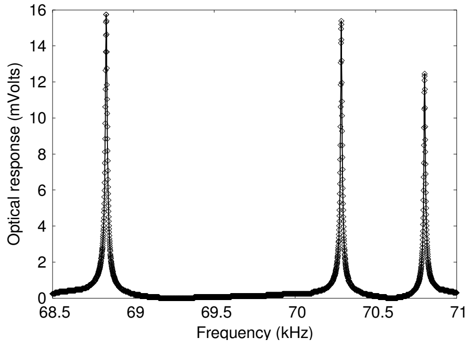

Figure 2. Measurement of the frequency spectrum showing three individual resonance peaks of the three cantilevers

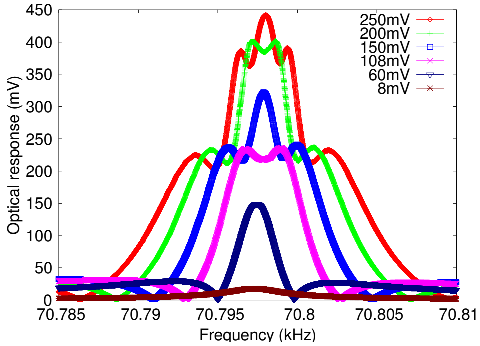

Figure 3. Measurements showing the response on the photo detector for different actuation voltages. Interference of light causes indents in the measured amplitude, the number of indents rises with increasing cantilever amplitude.

By frequency selective measurement the resonance of the functionalized cantilever is accurately tracked as a function of the magnetic field. Fig. 4 shows a clear linear response (46 mHz/mT) in the resonant frequency of the magnetic cantilever to the applied field. In contrast the resonance of the neighbouring cantilever is not affected by the applied field.

The measurements show that parallel detection of shifts in the resonant frequency of cantilevers in an array can be achieved with a standard optical beam deflection setup containing a single laser-detector pair. This opens the route towards a very elegant and versatile technique to read out cantilever frequency shifts in a parallel fashion.

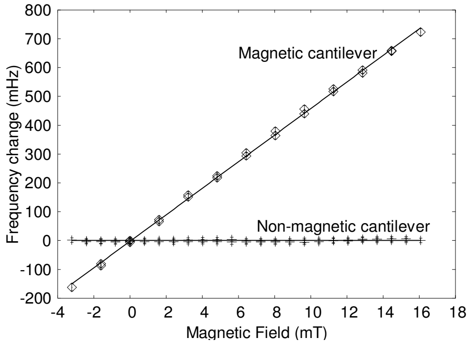

Figure 4. Measured frequency change of the magnetic cantilever showing a clear change in resonance frequency of 46 mHz/mT. The non-magnetic neighbouring cantilever does not show any cross-talk on this scale. Note the extremely small vertical scale, demonstrating the accuracy of the measurement.

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