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DYNAMIC CHARACTERIZATION OF MICRORESONATORS BY STROBOSCOPIC OPTICALMICROSCOPY

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ABSTRACT

Optical techniques are well suited for the dynamic characterization of microresonators because they are able to provide a direct, spatially resolved and quantitative measurement of the motion with minimum disturbance of the device mechanical behaviour [1]. This paper reviews our works on optical stroboscopic microscopy combined with full-field image processing for in-plane vibration mode, resonant frequencies and quality factor measurements of microresonators. Application of this technique to nanoresonators is also discussed.

An optical stroboscopic microscope is a microscope equipped with a monochromatic or white light source that can be pulsed in intensity with a high repetition rate. To perform dynamic measurements, the resonator is typically driven by a sinusoidal excitation signal and enlightened with light pulses having a repetition rate fp slightly different from f/n (n≥1) where f is the vibration frequency. For light pulse widths δT much shorter than the vibration period T, the apparent motion is a slowed down version of the real motion with a frequency equal to |fp-f/n|. This apparent motion is captured by a camera and image processing algorithms with subpixel resolution based on brightness conservation are applied to extract the displacement field and/or the mean displacement in X and Y directions within a region of interest. In the special case where fp=f and the light pulse delay t_0 is chosen equal to ±T/4 (vibration extrema), the measured displacement field gives directly the vibration mode shape.

For quality factor measurements [2] or non-linear vibration characterization [3], the mean displacement field is recorded as function of frequency by scanning simultaneously the light pulse and the device vibration frequencies. Then the vibration amplitude and phase can be extracted by amplitude and phase demodulation of the resulting signal (Fig.1). This can be performed in flight at each frequency by combining displacement values for 3 or more known light pulse delays [4] or by a final FFT demodulation [2,3]. The former technique has a better resolution but is very sensitive to noise while the later one allows an efficient noise filtering in

the frequency domain around |fp-f/n|. A detection limit down to 0.6nm for 2D displacements vacuum measurements at video rate can then be reached with a 40x objective [2]. We could apply this technique to damping measurements of Si MEMS devices and of microbeams with width below 1.8μm and with submicron gaps. The frequency bandwidth is limited in practise by the achievable minimum light pulse width and maximum light pulse repetition rate. By using visible LEDs based light sources with response times in the 20-50ns range, we already demonstrated measurements up to 4.5 MHz [4]. With a duty cycle ration $\delta T/T=0.3$, the theoretical bandwidth of measurements with subnanometer resolution is 6-15 MHz.

Measurements with defocused images show that measurements of devices with feature size close to the microscope objective lateral resolution (600 nm) should be possible but with a higher detection limit. For nanoresonator sizes in the 100nm-1μm range, we are developing a DUV stroboscopic microscope with an expected 10 times larger frequency bandwidth.

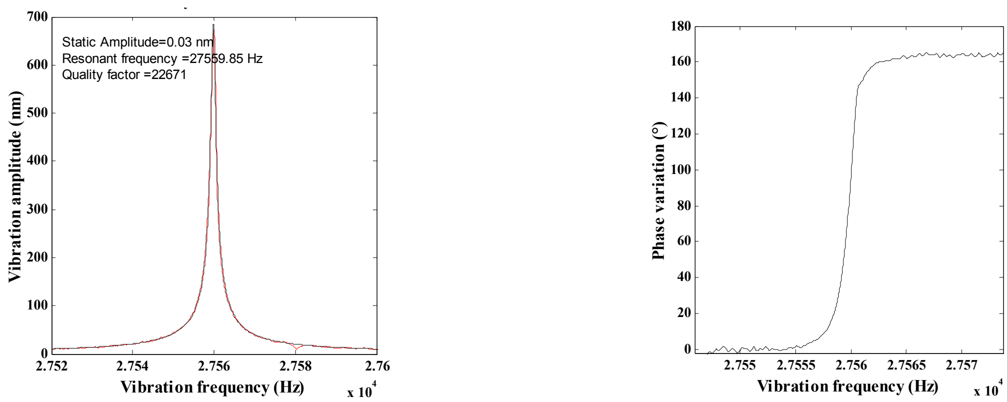

Fig.1. *Vibration amplitude and unwrapped phase variation around the fundamental mode of a 10μm wide Si microbeam extracted by FFT demodulation of its frequency response measured in vacuum (P=5x10^{-4} mbar).*

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