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META 2022, TORREMOLINOS - SPAIN, JULY 19 – 22, 2022

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Abstract: Nano-optomechanical sensors enable precision sensing of displacement, force and mass. However, the complexity and limited efficiency of light coupling to the sensor hinders their practical application. Here, we present a solution by placing a nano-optomechanical structure on a cleaved fiber facet. The structure is designed to enable efficient coupling to the fiber mode without any optics. Our process is based on wafer-scale fabrication in combination with a simple wafer-to-fiber transfer method. The sensor displays displacement imprecisions around 20 fm/Hz$^{1/2}$.

Nano-optomechanical sensors enable precision sensing of displacement, force and mass due to the strong co-localization of optical and mechanical fields [1]. Nevertheless, application of these structures in practical situations is hindered by the complexity and limited efficiency of light coupling to and from the sensor. Additionally, while the sensor is typically micron-scale, the packaging needed for the coupling optics significantly increases the total footprint. In this talk, we present a solution to this problem by combining nano-optomechanics with optical fiber sensing. This is done by placing a nano-optomechanical structure on the cleaved facet of a fiber, forming a nano-optomechanical fiber-tip sensor. The used nano-optomechanical structure is a double-membrane photonic crystal guided mode resonance with a rectangular unit cell. It is designed to enable efficient coupling to the fiber mode without any optics. The bottom membrane is fixed to the fiber and the top membrane is suspended and therefore free to move in the vertical direction. The resonant frequency of the optical mode is affected by the spacing between the two membranes. From simulations an optomechanical coupling rate of around 49 GHz/nm was found.

Our process is based on the combination of standard wafer-scale lithography and etching with a simple wafer-to-fiber transfer method. The transfer method has been previously demonstrated in our group for single slab photonic crystals [2]. In order to facilitate the transfer, we surround a suspended micro- or nano-optical device with a structure that has breakable supports. Aligning and etching a window on the substrate side allows us to insert a single-mode fiber through the substrate. Upon mechanical contact with our pick-up structure the supports are broken and the optical device will stick on the fiber-facet without the use of adhesives.

Optomechanical measurements are done by directly probing the nano-optomechanical fiber-tip sensor in reflection. Our sensors show an optical resonant wavelength around telecom wavelengths with relatively broad optical linewidths of 2 – 5 nm. The top membrane oscillates with a natural frequency in the 1 – 3 MHz range with mechanical quality factors over 1000 at low pressures. The thermomechanical noise peak was measured and the noise floor allows estimating displacement imprecisions of around 20 fm/Hz$^{1/2}$. Our results open the way to practical application of nano-optomechanical sensing by enabling a simple and inexpensive coupling method and ultrasmall footprint of the complete sensing head.

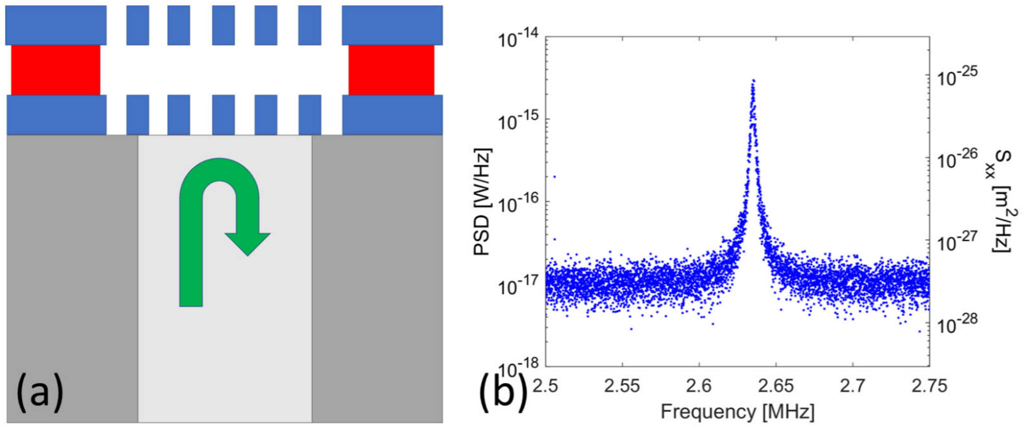

Figure 1. (a) Sketch of double membrane photonic crystal (in blue) aligned on top of a SMF with the incoming/reflected beam indicated in green. **(b)** Thermomechanical noise peak measured with an ESA.

References

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