Fibre-based Optomechanical Acoustic Sensing

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Many applications, including medical diagnostics, industrial processes, sonar, navigation and trace gas sensing rely on the detection of acoustic waves [1]. Most applications require high directional, spatial and temporal resolution, which has motivated development of acoustic sensors that operate at ultrasonic frequencies, corresponding to short acoustic wavelengths, and micro-scale sensing devices that can resolve waves close to, at, or beyond their diffraction limit. Degradation in acoustic sensitivity becomes a significant obstacle when operating at high frequencies and with devices with smaller sensing areas. Most acoustic sensors are limited by electronic noise and this has motivated progress in photonic acoustic sensors [2].

Cavity optomechanical sensors present a new class of ultra-precise photonic sensors, emerging over the last 15 years [3,4]. The sensors integrate a high-quality optical cavity with a high-quality mechanical resonator, where the mechanical resonator amplifies the mechanical vibrations induced by resonant signals and the cavity enhances the optical response to the mechanical vibrations. They also allow sensing performance to reach its intrinsic limits, as the sensors are often only limited by optical shot noise and mechanical thermal noise [5]. In this talk I will outline recent work towards developing a nanometer sized acoustic sensor based on 1D photonic crystals (PhC) (as shown in Figure 1). We have demonstrated that the sensor can detect ~mPa noise pressures from 10kHz to 300kHz. Furthermore, the sensor is significantly smaller than commercial hydrophones which could enable high spatial resolution imaging of micrometer sized acoustic features (i.e., living cell vibrations).

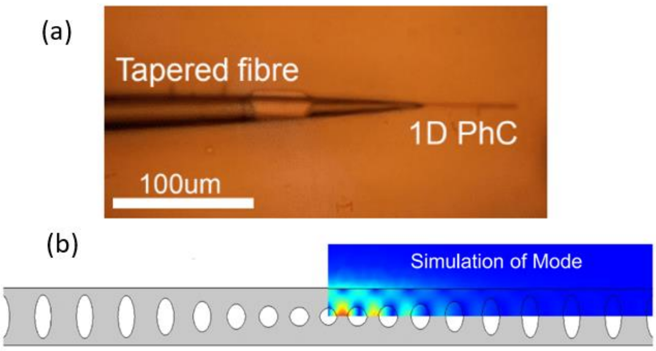

Figure 1: **(a)** Microscope image of nanometer sized 1D PhC-based acoustic sensor attached to tapered fibre. **(b)** Finite-element model (FEM) of simulation showing the electric field of the 1D PhC.

[1] Fischer, B., *Nat. Photon.* **10**, 356–358 (2016).

[2] Wissmeyer, G. et al., *Light Sci. Appl.* **7**, 53 (2018).

[3] Li, B. et al., *Nanophotonics* **10**, 2799-2832 (2021).

[4] Bowen, W.P. et al., *Nat. Comm.* **10**, 1-9 (2019).

[5] Bowen, W.P. et al., (CRC Press, Boca Raton, 2015).