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# Sensitive Optomechanical Ultrasound Sensor in a Silicon Photonic Chip towards Single-shot Photoacoustic Imaging with an Ultrasound Sensor Matrix

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**Abstract:** We propose a new opto-mechanical ultrasound sensor (OMUS) enabled by an innovative silicon photonics waveguide. We present experimental results up to 30 MHz, a 10-sensor array proof-of-concept and our latest findings. 

Photoacoustic imaging is an advancing medical imaging modality that can deliver morphological, functional and structural information by combining optical excitation contrast with the deep focusing capabilities of ultrasonic waves [1]. However, these pressure waves are weaker than conventional ultrasound, which sets up a challenge for lowering the sensor's detection limit. Using a matrix of fine-pitch ultrasound sensors, an entire 2D or 3D image can be captured from a single shot of the photoacoustic illumination laser, without the need for mechanical scanning. These sensors need to be able to demonstrate a low detection limit, small pitch ($< \lambda/2$), sensor element size ($< 100\mu m$), affordability and scalability to matrices [2]. To fulfill these aims optical sensors based on integrated photonic chips, interrogated by optical rather than electric signals, have been proposed. Optical sensors yield a higher noise equivalent pressure (NEP) times unit area compared to piezoelectric detectors ($< 6mPa \cdot mm^2/\sqrt{Hz}$) [3]. Silicon photonic sound detectors also allow for matrix read-out via few optical fibers using on-chip passive optical multiplexing [4].

In this presentation, we report on a new type of opto-mechanical ultrasound sensor that has a very high sensitivity enabled by an innovative opto-mechanical waveguide. It consists of an acoustic membrane on top of an optical ring resonator that modulates the optical resonance inside a ring resonator (Fig. 1). A minute sound-induced change received by the membrane results in a large shift of optical ring resonance. The resonance shift is measured as an intensity change by a photodetector. These sensors were optimized towards high sensitivity for a given acoustic membrane resonance frequency with a semi-analytical opto-acoustic-mechanical model. We found that the sensitivity of this new OMUS is two orders of magnitude higher than an OMUS based on the elongation of a conventional silicon photonics waveguide [5, 6]. Next, these devices where fabricated in imec's CMOS pilot line and characterized in water with broadband ultrasound pulses. We also report on an array of ten ultrasound sensors interrogated via only two optical fibers by using passive optical multiplexing. Working towards large matrices, we present our latest results on the influence of laser noise on device performance to use cost-effective lasers. Moreover, we study reflection-based interrogation schemes to reduce the amount of cables by half. In short, we believe a matrix of these sensors combined with passive optical multiplexing may cause a breakthrough in photoacoustic imaging.

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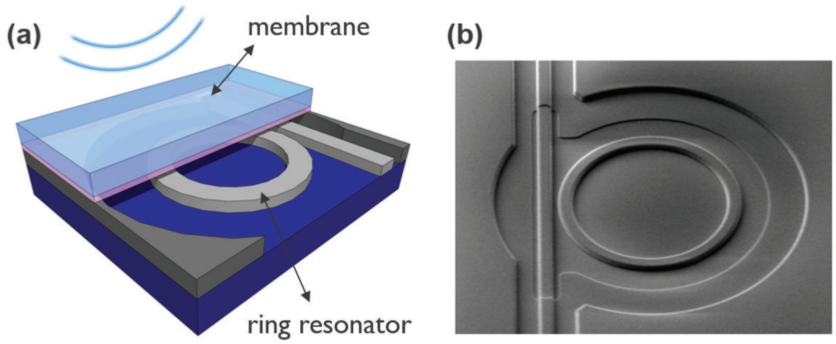


Fig. 1. a. Sketch of OMUS with an acoustic membrane positioned on top of an optical ring resonator. b. Scanning electron microscope (SEM) picture of an OMUS bottom wafer


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