'Click & Measure' optical interfacing to Silicon-On-Insulator chips

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We present a desk-top instrument to establish a low-loss multi-channel optical coupling to and from a Silicon-On-Insulator (SOI) chip. This instrument enables us to use our SOI-based ring resonator sensor platform in bio-chemical laboratories, and to study bio-chemical processes relevant for Point-Of-Care diagnostics applications. It takes less than a minute to align a chip with microfluidics to the instrument and to achieve robust low-loss coupling. The instrument can be operated by a lab technician after only 30 minutes training. The concept can be modified to accommodate edge-coupled chips (InP, TriPleX, polymer), and has potential for miniaturization to a hand-held device.

Introduction

Label-free bio-chemical sensing by means of photonic chips provides a potential route towards advanced low-cost Point-Of-Care (POC) diagnostics, for example at the general practicioner. Ring resonator sensing in the Silicon-On-Insulator (SOI) material system is well-known (for example [1]), and foundry services are available for technology development and volume production [2]. Permanent (multi-channel) fiber pigtailing is far too expensive for optically interfacing the single-use sensor to a read-out unit. We present a user-friendly and robust desktop tool for bio-chemical tests using ring resonator sensors without the need for permanent fiber-chip coupling. Establishing a multi-channel optical connection to the chip takes less than a minute.

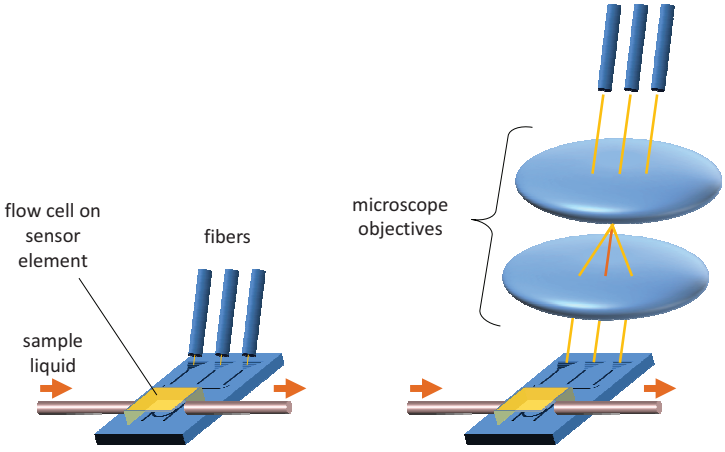

Figure 1: fiber-chip pigtailing (left) and a free-space coupling (right)

Concept

The basic concept is shown in *Figure 1*. A SOI sensor chip contains a number of (ring resonator) sensor elements, Vertical Grating Couplers (VGCs) for optical interfacing, and integrated microfluidics for sample delivery. Permanent mounting of the fibers is too expensive for single use applications. Since the fiber array needs to be in close proximity to the VGCs, chip replacement has a high risk of causing damage to either the fibers or the chip. This can be solved by a high-end fiber positioning system which actively moves the fibers, but this increases costs, maintenance and system vulnerability.

We have inserted a unity-magnification imaging system between fiber array and chip (*Figure 1*, right). The chip and the fiber array are in the focal planes of the lower and upper 10x microscope objective, respectively. The distance from chip to read-out system equals the objective working distance, which is several mm, providing a safe distance to allow chip replacement without any risk of damage. We obtain an alignment-tolerant system by using a single-mode input fiber and multi-mode output fibers. Alignment of the input fiber using a simple vision system ensures that all the light of each output VGC is captured by the corresponding large-core multi-mode fiber. This works only if the outputs are connected to multi-mode devices such as photodiodes, and therefore we use a wavelength-scanning laser to obtain the sensor spectral responses.

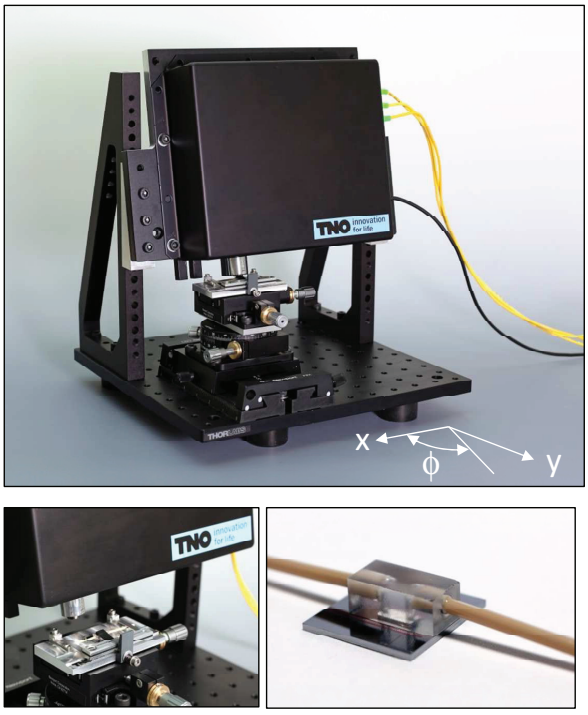

Figure 2: photograph of desktop tool (top), a zoom-in on the sensor chip with flow cell with the stage sled forward to the chip replacement position (lower left), and a chip with flow cell (lower right).

Realization and operation

The imaging system is mounted on a breadboard (*Figure 2*), and is tilted with respect to the horizontal chip to match the VGC coupling angle. The chip is positioned on an (x,y,ϕ) stage assembly for alignment using a vision system, though the ϕ is never used in practice. To replace the sensor, the stage assembly is sled towards the operator over a rail for easy access. The chip with flow cell is then clampded ('clicked') in position, sled back to the measuring position and manually aligned. Mounting a sensor chip and obtaining the signals is a matter of less than a minute. Sample liquid is directed over the sensor by means of a syringe pump which draws the sample liquid from a reservoir (*Figure 3*). Our dedicated software provides a 0.1 pm wavelength resolution.

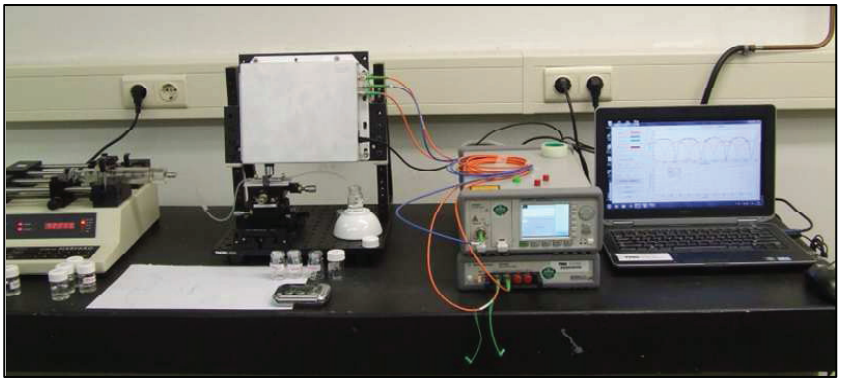

Figure 3: the system in action in a bio-chemical test. From left to right: syringe pump, chip system, tunable laser and detector (Agilent), and laptop with dedicated software.

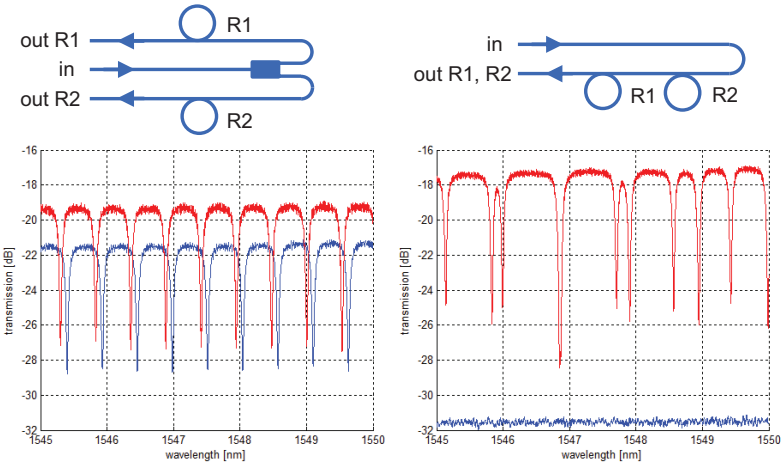

Figure 4: typical signals for parallel rings (left) and rings in series (right). In the right figure, the blue curve corresponds to a device of which the input is not excited, and shows the system reflection.

Measurement results

The over-all coupling efficiency is in the order of -18 dB (*Figure 4*), which is explained by the VGC coupling efficiency (2 × 5 dB for non-overlay VGCs), the imaging system (2 × 2 dB) and on-chip losses. By probing the output of an adjacent device of which the input is not excited, we obtain the system reflection just above -32 dB (blue curve in the right graph in *Figure 4*). We can reduce this baseline level by using optics better optimized for 1550 nm to provide a higher dynamic range. Clean binding curves are regularly obtained with this system, as demonstrated by *Figure 5* showing a poly-electrolyte multilayer deposition by the TU Delft [3].

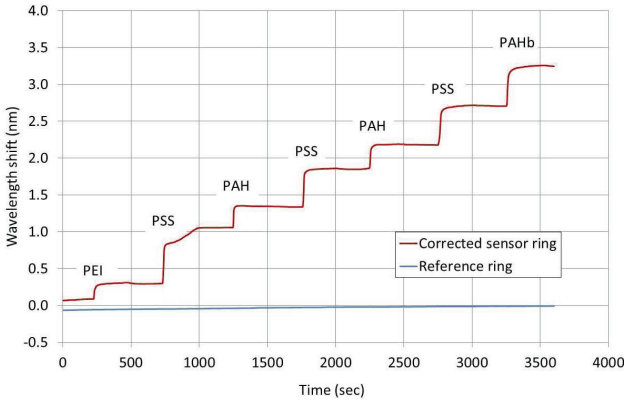

Figure 5: binding curves of poly-electrolytes obtained using this system. system. PEI, PSS, PAH, and PAHb stand for polyethylenimine, poly(styrene sulfonate, poly(allylamine hydrochloride), and biotinylated poly(allylamine hydrochloride), respectively.

Conclusions

We have demonstrated an easy-to-use tool to establish a multi-channel optical connection to a photonic chip without the need for permanent fiber-chip coupling. The concept is ideal for (bio-chemical) sensing applications. The scope of this paper is SOI sensors, and can be extended to TriPleX, InP or polymer devices as well. We believe that by combining this coupling concept with low-cost read-out systems as described in [4], a photonic sensing system can be miniaturized to size and price of a mobile phone, making it perfectly suitable for Point-Of-Care diagnostic applications.

References

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