SUMMARY

One of the most significant challenges facing scientists is the accurate detection and identification of single molecules. The ability to perform such sensitive and selective measurements opens new avenues for a large number of applications in biological, medical and chemical analysis. Access to information at the single or few molecules scale is rendered possible by a fine combination of recent advances in nanotechnologies [1].

In photonics, high-Q microcavities allow sensing down to the single/few molecule sensitivity [2] through resonance response measurement.

Exploiting nanopores, it is possible to control the translocation of biomolecules through the pore using dielectrophoretic forces [3]. This work relates to a novel detection platform that combines resonant sensing with translocation control through nanopores.

Figure 1 illustrates the resonant response from a microring resonator, with nanopores close from the ring. The translocation of biomolecules through the nanopores induce a refractive index change and therefore modification of guiding properties. This results in a shift in the resonant response which can be used for sensing. For this purpose, two implementations are possible:

(a) Approaching a glass nanopore (at the end of a glass capillary) to the resonant structure (Fig. 1(a))
(b) Fabricating solid state nanopores through a membrane (Fig. 1(b))

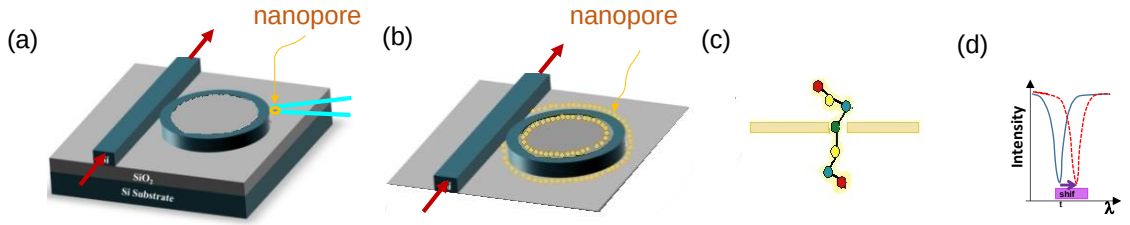

Figure 1: Microring resonators (a) with a nanopore at the end of a glass capillary approached from the ring and (b) through a membrane sustaining the microring (c) molecule translocating through a nanopore (d) at resonance, light from the waveguide couples to the ring. This results in a peak in the transmitted signal. Molecules translocation in the nanopore induce a change in refractive index, and therefore a shift in the resonant response.

PERFORMED WORK AND RESULTS

Optical sensing at the end of a nanopipette

Glass nanopipette are simple to fabricate and readily available. This makes the implementation attractive for label-free detection of events at the end of a pipette. Particles/biomolecules can be moved thanks to dielectrophoretic forces. Precise control of the pipette position is necessary.

For this implementation, we choose to perform sensing with SOI microrings, at a wavelength of λ=1550 nm. This choice is supported by well-established knowledge of SOI microrings for telecom applications or sensing with immobilized biomolecules [4]. We choose to perform sensing by approaching a nanopipette close from the ring, enhancing the interaction between the approached element and the guided wave. To measure resonant signal and combine it with pipette approach measurements, an optical set-up was implemented. It takes into account precise in-coupling and output coupling, with positioning and direction constraints. The approach of the pipette close from the ring requires simultaneous imaging. As such, 2D imaging is performed using a microscope and camera. Proper fixation of the chip and fluidic measurement compatibility were also taken into account. Figure 2 gives a scheme of (a) the measurement set-up, with (b,c) details of imaging and spectrum measurements and (d,e) SEM images of a SOI microring and a nanopipette. An additional laser light source is used to perform parallel fluorescence imaging.

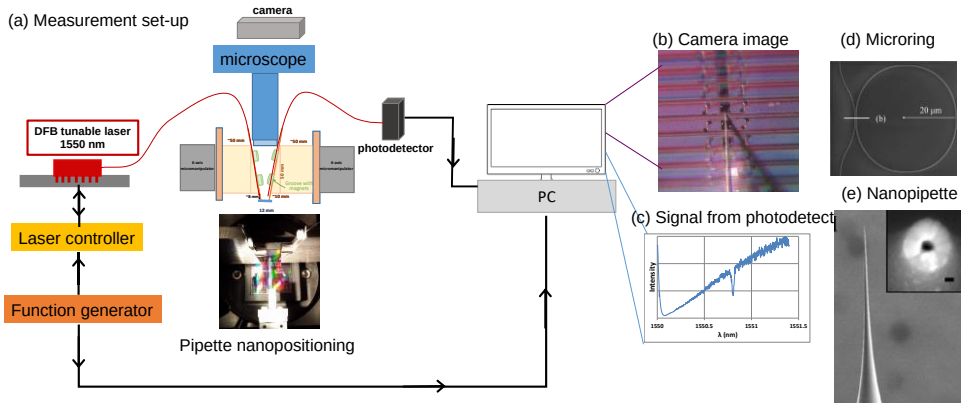

Figure 2: (a) Measurement set-up to perform nanopipette approaches with simultaneous imaging and resonant signal measurements (b) Image of the nanopipette approach (c) Typical resonant spectrum at λ=1550 nm (d) SEM image of microring with 20 microns diameter (e) SEM image of nanopipette, with outside diameter 100 nm and inside diameter 20 nm

Beads and DNA manipulation for optical sensing

By using dielectric forces to attract molecules at the tip of a nanopipette, samples of extremely low concentration can be studied [6]. Kinetic is no longer dominated by diffusion, and can be fastened by attracting molecules at the end of a nanopipette. This can be implemented using double barrel electrodes to attract and release DNA molecules/beads at the end of a nanopipette tip. This is illustrated in Figure 3. This is particularly interesting in the case of optical sensing with microrings, since the molecules can be attracted and released, and single beads can be sensed with microring resonators [7]. Figure 3 shows the attraction and release of 1 microns fluorescently labelled polystyrene beads.

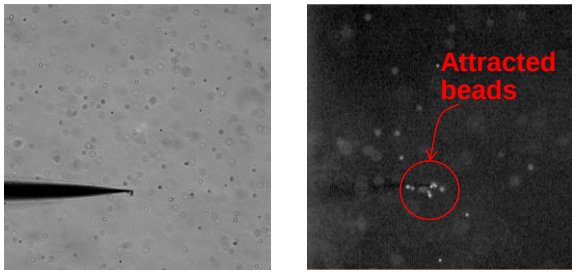

Figure 3: (a) Bright field image of a nanocapillary with polystyrene beads (b) x40 confocal microscope with beads attracted and released through an electric potential application

FINAL OUTCOME

This work combines optical sensing using resonant detection and position control using dielectrophoretic forces with nanopores. Combining latest advances in resonant sensing and solid states nanopores, this paves the way to sensing at extremely low concentration with optical label-free sensing.

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