Towards a lab-on-a-chip: detecting proteins with light

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I. Introduction

Analysis of biological samples is important for many applications, such as medical diagnostics, food quality control, drug development and environmental monitoring. Nowadays this is typically done in a large-scale laboratory, where skilled personnel needs to perform time-consuming experiments with expensive equipment. By miniaturizing the functionality of these laboratories in a so called *lab-on-a-chip*, the cost and duration of analysis would be reduced significantly. It would also enable analysis at the point of care, not only facilitating existing applications, but also opening the gates towards a whole new range of applications.

A lab-on-a-chip would be able to measure the concentration of hundreds or even thousands of different biomolecules, such as proteins and DNA, in parallel on a very small sample volume. A very compact, fast and accurate detection method for biomolecules is thus essential for a lab-on-a-chip.

At the *Photonics Research Group* of Ghent University we are able to make very dense *photonic integrated circuits* - chips which process information in the form of light - with mass fabrication technology. With this technology we can make a matrix of biosensors, each of which only measures $10\mu m \times 10\mu m$, in a very fast and cheap way. We think our biosensors can be an important contribution towards the creation of a complete lab-on-a-chip.

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II. Concept

Light is a wave of electromagnetic radiation which has a certain wavelength that corresponds with the color of that light wave. In our photonic integrated circuits, infra-red light is guided in very small waveguides. To determine the presence of a certain biomolecule, we use a *ring resonator* (Figure 1.a). When light with different wavelengths (I_{in}) is sent to this ring resonator, only some specific wavelengths will fit an integer times on the ring. The light waves with this resonance wavelength will start circulating in the ring, and for these wavelengths a dip (I_{out1}) or peak (I_{out2}) will occur in the wavelength spectrum (full line in Figure 1.b).

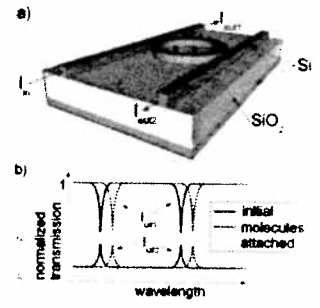

Figure 1. a) illustration of a ring resonator biosensor, b) impact of selective binding of biomolecules on the sensor surface on the output spectra

To turn this device into a biosensor, the surface of the ring will be covered with a chemical layer that has receptors for the type of biomolecule we are looking for. When a fluidic sample with different types of molecules is flown over the device, this layer will make sure

that only the type of molecule we want to detect (if present) will chemically attach to the surface, while other molecules won't. The binding of molecules to the surface of the ring will change the light propagation properties of the ring, resulting in a shift of the dip and peak in the output spectra (dashed line in Figure 1.b).

III. Towards higher accuracy

At the *Photonics Research Group* of the University of Ghent this concept already showed to be very promising for future applications [1]. To further increase the accuracy, it is important to maximize the resonance wavelength shift for a certain concentration of biomolecules. Therefor the interaction between the light in the waveguide and the biomolecules attached to the waveguide needs to be increased.

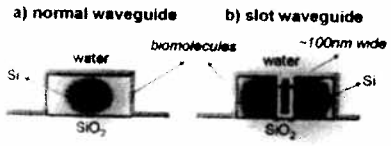

Figure 2. comparison between the light intensity profiles in the cross section of a normal waveguide and of a slot waveguide

As can be seen in Figure 2.a, light travels inside the core of a normal photonic waveguide, so that only a very small fraction of the light can interact with the biomolecules that attach to the surface of the waveguide. A promising waveguide design to increase this interaction is shown in Figure 2.b. By etching a narrow slot in the middle of the waveguide, a vast fraction of the light propagates in that slot [2], so that more light is concentrated along the bio-activated surface of the waveguide. This will cause attached molecules to have a larger impact on the propagating light, so that the resonance wavelength shift of a ring resonator consisting of slot waveguides will be larger than that of a normal ring resonator.

IV. Results

In this work, the dimensions of slot waveguides were numerically optimized for biosensing and slotted ring resonators, with slot widths down to 100nm, were fabricated with mass fabrication technology.
We experimentally verified the increased sensitivity of this sensor. In cooperation with the *Department of Organic Chemistry* of our university, the surface of the slot waveguides was covered with biotin-receptors, which very selectively bind to avidin, a protein found e.g. in bird eggs.

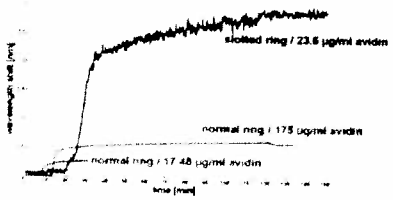

Figure 3. comparison between the respons of our new slotted ring biosensor and that of a normal ring biosensor, when a certain avidin concentration in a fluid is flown over the sensor chip

Figure 3 displays the improved answer of our sensor to an avidin concentration. A 4x sensitivity increase has been accomplished as compared to normal ring biosensors.

V. Conclusions

We presented a photonic integrated biosensor with a 4 times increased sensitivity over conventional biosensors, proving it to be a viable candidate to be the sensor of choice in future labs-on-a-chip.

References

[1] K. De Vos, I. Bartolozzi, E. Schacht, P. Bienstman, and R. Baets, "Silicon-on-insulator microring resonator for sensitive and label-free biosensing," *Optics Express*, vol. 15, no. 12, june 2007.
[2] V. R. Almeida, Q. Xu, C. A. Barrios, and M. Lipson, "Guiding and confining light in void nanostructure," *Optics Letters*, vol. 29, no. 11, june 2004.

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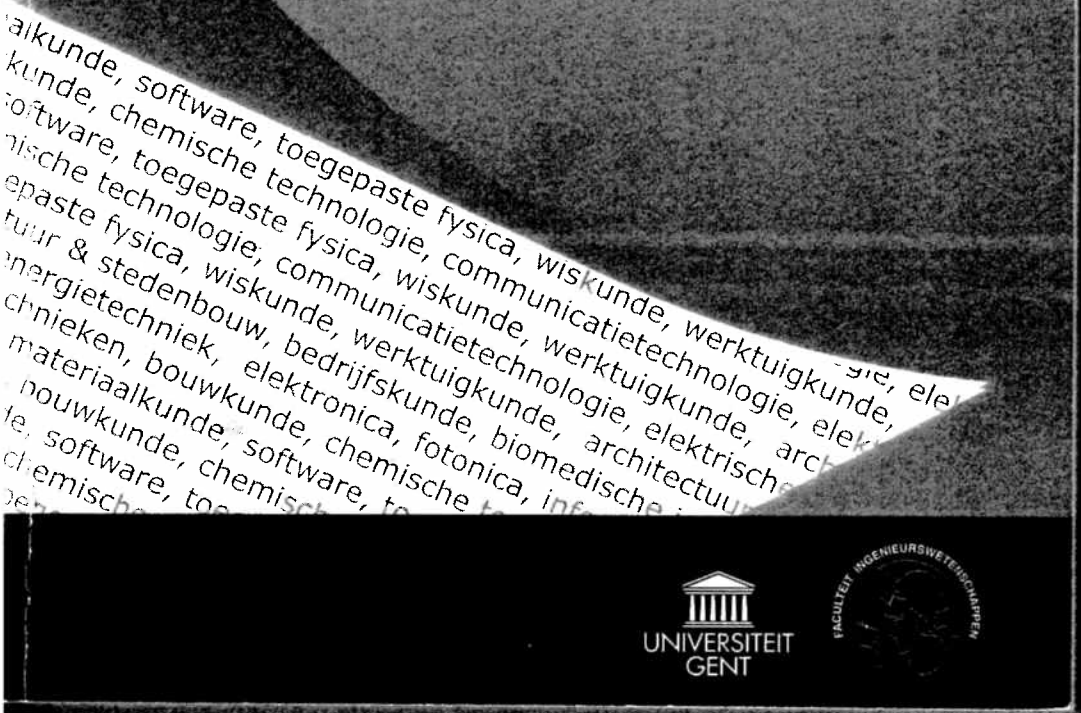

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