**Nanoscale Optofluidic Devices for Biomolecular Analysis**

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**Abstract:**

The recent interest in the development of nucleic acid biosensors and high-throughput screening techniques has been in part driven by the need to rapidly diagnose emerging viral threats. Currently the key challenges are to develop label free biosensors with low mass sensitivity and high specificity without sacrificing the extreme parallelism of the microarray format. In this project, we will present our work towards the development of nanoscale optofluidic sensor arrays (NOSA), which represent a potential solution to this problem.

**Summary of Research:**

Figure 1 shows a 3D illustration of our sensor design. A central defect in the 1D photonic crystal \([1]\) gives rise to a defect state in the photonic bandgap. By varying this defect cavity spacing we can tune the resonant wavelength of this defect state across the bandgap of the side resonator. Analogous to ring resonators \([2]\), light corresponding to the resonant wavelength couples evanescently into the side resonator and is sustained within it. This results in a dip in the output spectrum of the waveguide at the resonant wavelength. Since the resonant structures lie to the side of the waveguide the bandgap does not interfere with the light transmission outside of that which lies in the resonant peak. Thus our unique design allows multiplexing along a single waveguide by simple placement of a large number of side resonators along the waveguide, each of which is fabricated to have a slightly different resonant wavelength.

An SEM image of a typical nanoscale optofluidic sensor array (NOSA) \([3]\) device is shown in Figure 2. These resonators are extremely sensitive to refractive index changes in the innermost holes. We use a two stage fluidic architecture to first immobilize the necessary DNA capture probes onto the sensing sites and then subsequently flow the sample liquid over the NOSA to...
perform the target detection. Figure 3 shows the working principle of our NOSA architecture. The plot shows the spectrum of a sensor having 5 side resonators with water in the channels targeting them. When we flow a higher refractive index solution of calcium chloride through one of the channels, we observe a redshift in the resonant peak of the corresponding resonator. It is important to note that the other resonances are not affected.

In this manner we can perform a large number of detections in parallel using this sensing architecture. With the $Q$-factor of these devices being between 2000 and 3000 and given the operational range of a standard 1550 nm laser, we estimate that we could have at least 50 such resonators on a single bus waveguide, thus allowing the possibility of performing 50 detections in parallel on a single waveguide. The $Q$-factor of such resonators can be significantly improved so these devices could be used to perform more than a hundred parallel detections.

The Si devices were hydroxylated, aminated, and then subsequently treated with dendrimers to increase the capture efficiency of DNA capture probes. Figure 4 shows preliminary results from an experiment where we successfully detected one of the serotypes of the Dengue virus using the NOSA. As can be seen, the resonance corresponding to the resonator which was functionalized with Serotype-3 capture probes shows the largest redshift. We see some minor shift in the resonance for Serotype-1 due to cross reactivities between the different serotypes.

References:

