Probing the THz Response of Biological Cells using Photonic Crystal Resonators

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Terahertz and microwave dielectric spectroscopy in combination with microfluidics is an emerging approach for cancer investigation at the cellular level[1]. The technique works by measuring the complex dielectric response of biological cells when exposed to terahertz and microwave radiation. The strength of this technique lies in the fact that it can be non-invasive, label-free and contactless, allowing measurements to be made in real-time with the cells remaining in their culture medium. The technique has been shown to be capable of distinguishing between different cancerous cell types[2].

In this work, we are developing a terahertz bio-sensor based around a photonic crystal resonator (PCR) and microfluidics. The PCR is formed from an L3 defect in a 2D silicon photonic crystal slab. A capillary tube is used to flow cells in a culture medium through the resonant mode's EM field as shown in Fig. 1. The sub-wavelength geometry of the cells in this frequency range poses a challenge from a measurement perspective and here we exploit the PCR's high quality factor resonance[3] to enhance the light-matter interaction. An operating frequency of 100 GHz was chosen for the PCR as it is sufficiently high to achieve a small modal volume and avoid ionic losses but not too high that the permittivity contrast between water and the other cellular constituents is diminished.

The interaction between the PCR's field and cells leads to a perturbation of the resonance parameters. We describe an analytical model which uses perturbation theory to relate the changes in the resonance's centre frequency and unloaded Q-factor to the average complex permittivity of the cells or other bio-liquid flowing in the capillary[4].

These results represent a step towards a lab-on-a-chip device for the analysis of nano-litre volumes of biological, toxic, explosive, and other liquid types at terahertz frequencies.

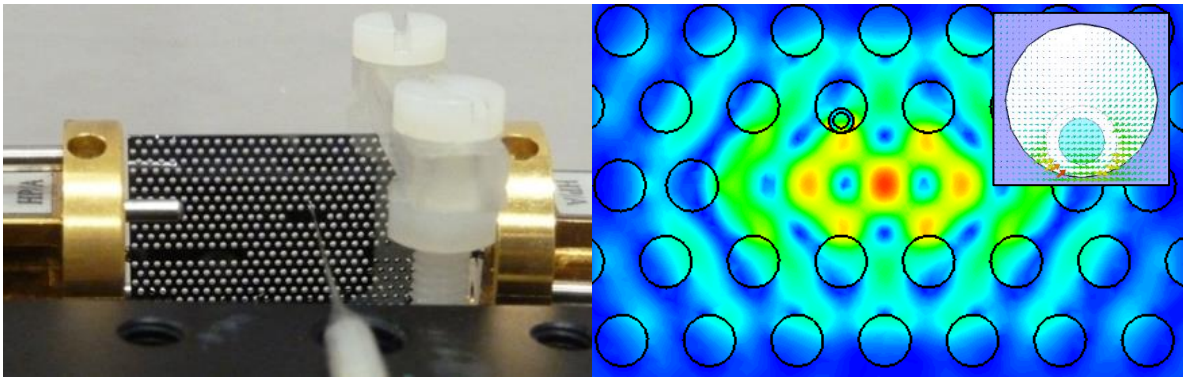

Fig 1. (a) A THz 2D PCR with a capillary for sensing bioliquids. (b) The simulated electric field distribution of the PCR resonant mode. Inset: close-up view of the field inside the capillary tube.

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