Photonic Crystal Resonators for Terahertz Sensing Applications

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Abstract— Photonic crystal (PC) based devices, principally developed for the infrared and visible domains, hold great promise for the terahertz band where they offer the possibility of realising low-loss micro-photonic integrated circuits as an alternative to the conventional metal rectangular waveguide based systems. In this presentation, we describe how the integration of terahertz PC resonators with microfluidic systems enable the creation of extremely sensitive terahertz fluid sensing systems capable of the analysis of liquid volumes smaller than 4 nL [1, 2].

We first demonstrate how PC resonators with quality factors in excess of 10,000 can be realised in the terahertz band using defects in two dimensional PC slabs [3] and one dimensional PC microbeams [4] and fabricated through the bulk micromachining of high resistivity silicon. We then show how microfluidic systems can be incorporated so that a fluid can be flowed through the high intensity region of the resonant mode's electric field. The resulting perturbation of the resonant mode directly relates to the dielectric properties of the liquid. Furthermore, by combining perturbation theory and the electrostatic solution for the electric field inside the liquid, an analytical model can be developed which allows the relative complex permittivity of the liquid analyte to be estimated.

The terahertz liquid sensor has been used for the characterization of a range of liquids from basic solvents to biological liquids [1] as well as particle-in-liquid type measurements with the long term goal of developing a method for the label-free detection of circulating tumour cells. These early results lay the basis for a terahertz lab-on-a-chip device for the analysis of nano-liter quantities of biological, toxic, explosive, and other liquid types.

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