

Significant sensing performance of photonic crystals



PHYSICS

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ABSTRACT

Photonic crystals (PhCs) exhibit a strong optical confinement of light to a very small volume which enable strong detection property which in turn can be used in fields like healthcare, defense, security, automotive, aerospace, environment, food quality control etc where demand of sensing applications is great.

1.1.1: INTRODUCTION:

Photonic crystals possess internally and alternately repeating regions of high value and low value dielectric constant regions. Photonic bands predict the behavior of light accurately. In photonic band gap, light cannot enter the crystal because the gap acts as an insulator of light and the light velocity will be changed from c to Zero similar to the situation of an electron motion in a periodic potential field [4] where velocity is changing along with the mass of the electron, the mass may become infinite (increases) and electron behaves as a positive particle (it suffers Bragg's reflection). Such variation in mass is called effective mass. By making a suitable geometry of the periodic dielectric medium, a photonic crystal can be used as an optical fiber.

Photonic sensors have been the subject of intensive research over the last decade especially for detection of a wide variety of biological and chemical agents. Also, they are expected to exhibit higher sensitivity and selectivity as well as high stability, immunity to electromagnetic interference and product improvements, such as smaller integration sizes and lower costs.

Photonic crystals (PhCs) [1] represent an intriguing solution for achieving high performance in sensing applications. In fact, since a lot of photonic architectures have been widely investigated and employed in photonic sensing (e.g., ring resonator, surface Plasmon resonance (SPR) – based sensors, micro disks, microspheres, to name a few), PhCs exhibit a strong optical confinement of light to a very small volume, enabling the detection of chemical species characterized by nanometer dimensions. In addition, by using advanced chemical surface functionalization techniques and integration with micro fluidic systems, very high performance can be achieved in ultra compact sensor chips.

PhC-based sensors [6] have been also proposed as gas sensors in mid infrared (mid-IR), since many gases (e.g., CO_2 , CH_4 , CO) exhibit absorption lines in mid-IR wavelength region. Other applications include the detection of temperature, pressure, stress and humidity measurements.

1.1.2: The sensing mechanism and principle:

The sensing mechanism consists in changing fiber optical properties [6] (i.e., cladding effective refractive index) by filling air holes with chemical/biochemical liquids or gases. In this way, the interaction between the propagating light and the analyte to be detected and the principle is light propagates in the high refractive index region by the total internal reflection (TIR) principle at the interface between the core and the low refractive index cladding.

1.1.3: Results and Discussion:

In PCFs, light can be guided by two different mechanisms [3], i.e., index-guiding and bandgap-guiding, as a function of the principle of the light confinement. In particular, in PCFs characterized by a solid core or by a core with a refractive index higher than the micro-structured cladding's one [2], light is guided as in conventional silica fibers (i.e. doped silica core surrounded by the silica cladding). In fact, light propagates in the high refractive index region by the total internal reflection (TIR) principle at the interface between the core and the low refractive index cladding. In addition, air holes periodically arranged over the fiber cross-section characterize the micro-structured silica cladding, resulting in an effective cladding index. Consequently, the TIR at the core-cladding interface is known as modified TIR and it can occur with very low core-cladding refractive index (RI) contrasts, enabling the fabrication of both core and cladding by the same material.

In both index-guiding and bandgap-guiding PCFs [5], the sensing mechanism consists in changing fiber optical properties (i.e., cladding effective refractive index) by filling air holes with chemical/biochemical liquids or gases. In this way, the interaction between the propagating light and the analyte to be detected is improved as it is not possible to achieve with standard optical fibers, where the sensing area is realized by removing the cladding from the fibers and directly exposing the fiber core to cover medium where the sample is concentrated.

CONCLUSIONS:

Photonic crystals special properties make them very attractive for a very wide range of applications especially in achieving high performance in sensing applications.

Rapid advancements in photonic technologies have significantly enhanced sensing performance and have led to drastic improvements in sensor sensitivity, enhanced limit of detection (LOD), advanced fluidic handling capability, lower sample consumption, faster detection time, and lower overall detection cost per measurement.

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