Microchannel-based plasmonic refractive index sensor for low refractive index detection

A microchannel incorporated photonic crystal fiber (PCF)-based surface plasmon resonance (SPR) sensor for detection of low refractive index (RI) at near-infrared wavelength is presented in this paper. To attain a simple
and practically feasible mechanism, plasmonic material gold (Au) and sensing medium are placed outside the fiber. A thin layer of TiO2 is employed as an adhesive layer to strongly attach the Au with the silica glass. In the sensing range of 1.22 to 1.37, maximum sensitivities of 51,000 nm/RIU (RI unit) and 1872 RIU−1 are obtained with resolutions of 1.96 × 10−6 and 9.09 × 10−6 RIUs using wavelength and amplitude interrogation
methods, respectively. To the best of the authors' knowledge, the obtained maximum wavelength sensitivity and resolution are the highest among reported PCF-based SPR sensors to date. The sensor also exhibits a maximum figure of merit of 566. Therefore, the proposed sensor would be an excellent candidate for a wide range of RI detection with higher accuracy for applications such as pharmaceutical inspection and leakage monitoring, bio-sensing, and other low RI analytes.

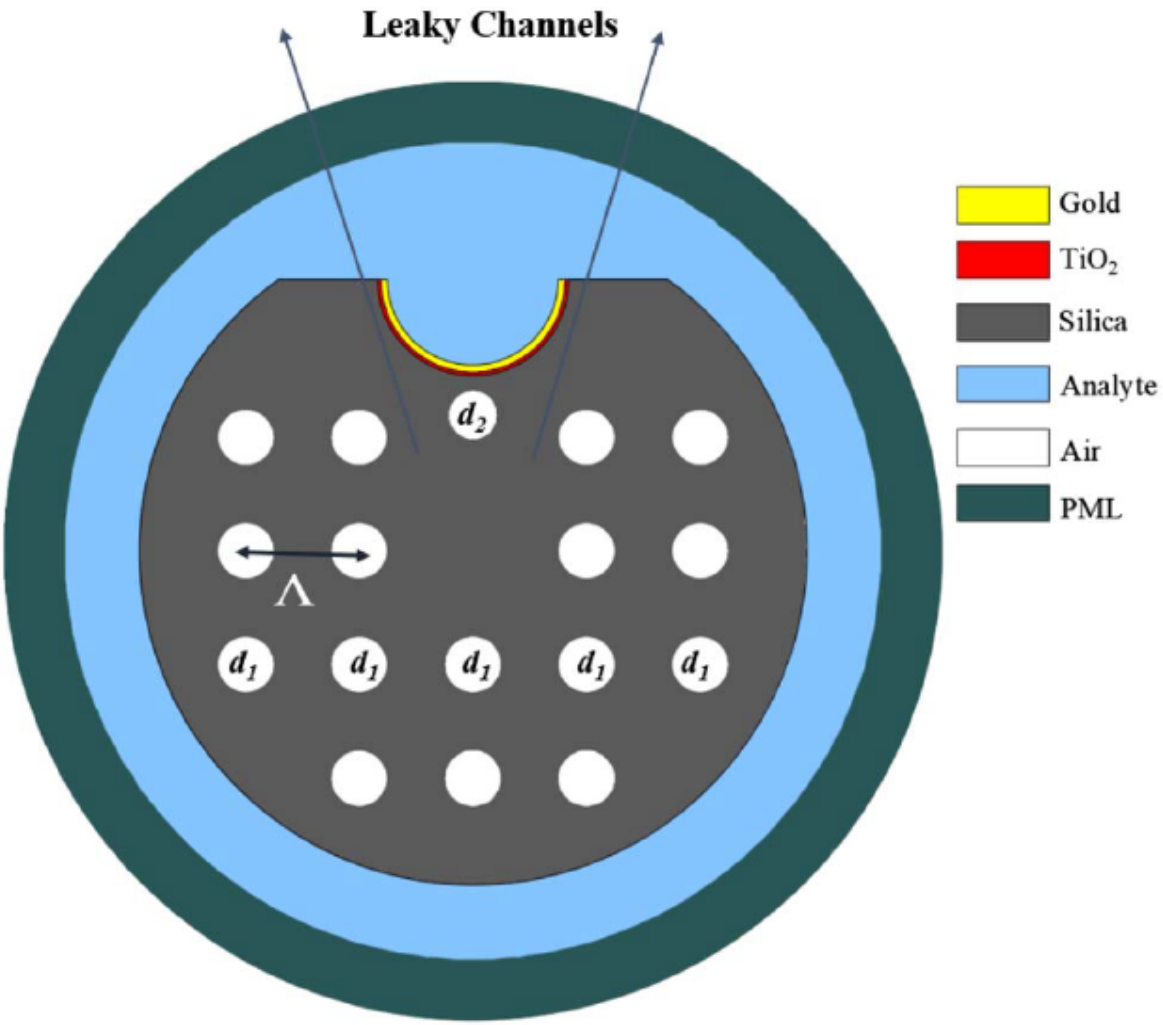
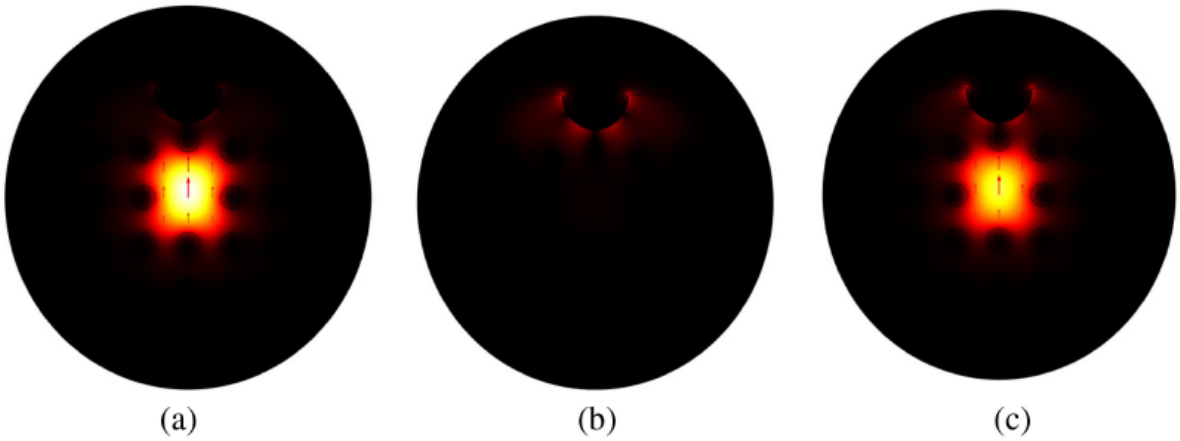


Fig. 1. Schematic diagram of the proposed sensor.

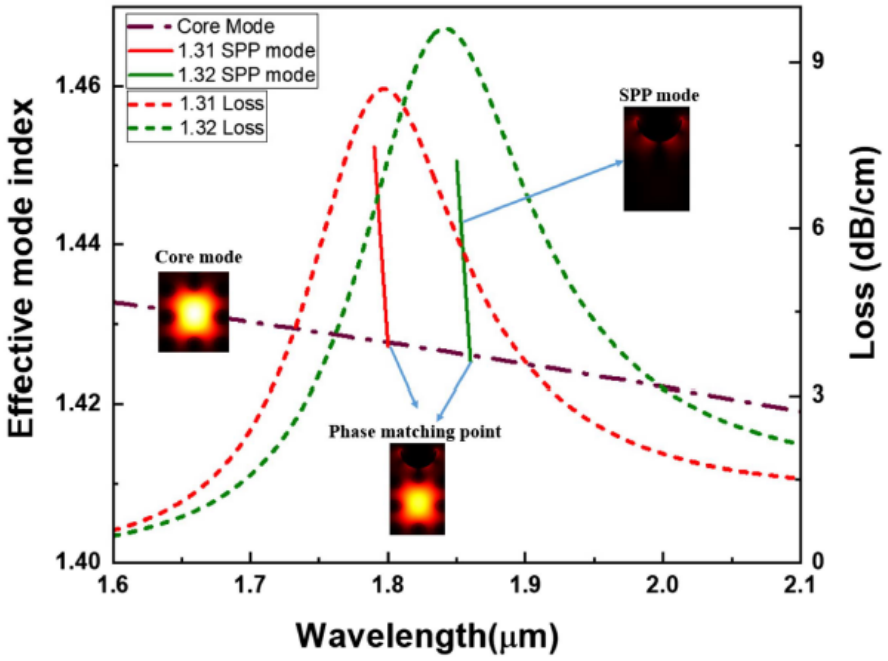
The surrounding medium adjacent to the sensing layer plays an important role to determine the phase-matching condition at resonance frequency. Moreover, there are other physical phenomena as well that are responsible for altering the phasematching condition of the SPR, namely, interparticle coupling, change in particle size or shape, charging of particles, and change in electron dynamics. The influence of shape can be very complex and leads to shifting resonance frequency toward shorter or longer wavelengths.

Under phase-matching point, also known as resonance condition, a sharp peak loss can be seen at which effective RIs of the fundamental core-guided

mode and SPP mode are equal.



(a) (b) (c)



(d)

For the analyte having RI of 1.31, Figs. 2(a) and 2(b) represent
the field distribution of the core-guided mode and
plasmonic mode, and Fig. 2(c) shows field distributions at resonance
point. It is seen that the entire optical field is confined in the core for the core-guided mode, whereas plasmonic mode is seen between the metal-coated microchannel and sensing medium.

A highly sensitive PCF-SPR sensor for low RI detection has been proposed and numerically analyzed in this paper. Square

lattice and two leaky channels toward the Au-TiO2 coated microchannel have been designed to enhance the resonance effects significantly. As a result, in the sensing range of 1.22–1.37, the proposed sensor exhibits maximum wavelength and amplitude sensitivities of 51000 nm/RIU and 1872 RIU−1 with corresponding resolutions of 1.96 × 10−6 and 9.09 × 10−6 RIU, respectively.

A high FOM of 566 is also exhibited by the sensor. Moreover, incorporation of a microchannel reduces the amount of Au-TiO2 film as well as analyte in order to sense the changes in RI. The lower propagation loss of the proposed sensor is another attractive feature that makes the proposed sensor a well-suited candidate for an integrated SPR sensor, such as a lab-on-fiber technology.

For more information: https://doi.org/10.1364/AO.58.001547