Enhancement of Birefringence Using Metal-filled Suspended Core Microstructured Optical Fibers

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Abstract

Microstructured optical fiber (MOF) has carved out a niche in the field of photonics in the last decade. On the other hand, the field of plasmonics is also rapidly emerging as a fascinating research area. Combining the advantages of both these fields therefore seems imperative for newer applications in interdisciplinary areas, thereby leading to the development of metal-incorporated MOFs. A MOF structure consists of a solid silica core surrounded by a hexagonal lattice of air holes running along the entire length of the fiber. The hole diameter (d), pitch (distance between two adjacent air holes denoted by Λ) as well as their ratio (d/Λ) play an important role in designing any MOF structure. Certain applications of MOF need very small core size. Instead of decreasing the Λ, an alternative way to reduce the core size is by elongating and tapering the air holes adjacent to the core (Fig. 1(a)). This reduction is quantified by a parameter called suspension factor (SF) and MOFs thus developed are called suspended core MOFs (SC-MOFs). Such a complex structure of MOF naturally renders its electromagnetic analysis extremely challenging. The existing analytical methods fail to provide accurate results and offer only an approximate idea about the modal characteristics and transmission properties of MOFs. For this reason, rigorous numerical analysis is required which can be done satisfactorily using the COMSOL Multiphysics® software.

For the present study, we have used the RF Module of COMSOL Multiphysics® for '2D mode analysis' in the frequency domain. The proposed SC-MOF designs have Λ = 2 μm, d/Λ = 0.95 and SF lying within the calculated range of 0.95 ≤ SF ≤ 1.55. The cross-sections of the proposed SC-MOF structures are drawn in the 'Geometry' section using quadratic Bézier polygon with specific control points for denoting different SFs. One of the air hole in the first ring is filled with gold (Au) as shown in Fig. 1(a). The interaction between the core-guided light and metal is increased due to the suspended core structure eventually leading to enhancement of surface plasmon polariton (SPP) coupling and surface plasmon resonance (SPR) phenomenon thereof. Refractive index of pure silica and gold are taken into account in the analysis through Sellmeier's equation and Lorentz-Drude model respectively, by specifying the parameters under 'Global definitions' and variables under 'Model (Definitions)'. Material properties are then assigned to the respective domains in 'Materials' section. In the next step, the structure was divided into minute elementary subspaces using 'Physics-controlled Mesh' and finally the effective indices of the fundamental modes are determined for the required wavelength range using a 'Parametric Sweep'.

We noted the indices of the two orthogonal polarization of the fundamental mode and studied the variation of birefringence as a function of wavelength for the above-mentioned structures. Fig. 1(c) clearly shows the improvement in birefringence with the increase in SF. For maximum SF, it is an order of magnitude higher than the existing values. Hence such SC-MOFs may serve as efficient in-fiber polarizers for a particular wavelength range.

Figures used in the abstract

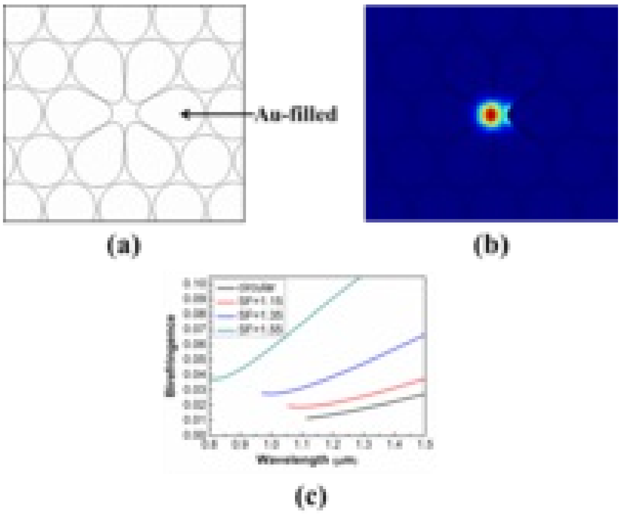

Figure 1: Fig. 1: (a) Magnified schematic representation of a metal-filled SC-MOF in COMSOL GUI, (b) Modal profile, (c) Birefringence variation with wavelength.