A pressure sensor based on the loss birefringence of a Microstructured Optical Fiber containing metal coated elliptical inclusions

E. Pone, A. Hassani, S. Lacroix and M. Skorobogatiy

Ecole Polytechnique de Montreal, Department de Genie Physique, Montreal H3C 3A7, Canada
www.photonics.phys.polymtl.ca

Abstract: By measuring splitting in the wavelengths of maximum propagation losses of the two originally degenerate plasmonic/fiber core modes, one can detect 8.10^{-4} ellipticity of the silver coated air inclusions. Application in pressure sensing is suggested.

OCIS codes: (060.4005) Microstructured fibers; (240.6680) Surface plasmons

1. Introduction

Over the past decade various configurations enabling coupling between optical waveguide modes and surface plasmonic waves have been investigated [1, 2, 3, 4]. Here we consider the loss birefringence of the fundamental mode of a microstructured optical fiber (MOF) containing six elliptical air holes coated with a thin silver layer. When holes are circular, two hybrid plasmon/core modes of orthogonal polarizations are degenerate. When ellipticity in the hole structure is introduced, the losses of two modal polarizations become different. By measuring splitting in the wavelengths of maximum loss for the two plasmon/core modes one can develop a pressure sensor, which is able to detect hole ellipticities as low as 8.10-4. The modes the MOF are calculated with the boundary integral method [5].

2. Pressure sensing

We consider the loss birefringence of the fundamental mode in a MOF containing six elliptical air holes coated with a thin silver layer. The geometry is given in Fig. 1. The inclusions are coated with silver. The refractive index of silver is calculated from the interpolation of measured data [6]. The glass cladding is assumed to have a refractive index $n_g = 1.45$, while the air holes have $n_c = 1$. The hole to hole pitch is $\Lambda = 1.5\mu m$. Six coated elliptical inclusions are described by the outer major axis $a_o = 0.8\mu m + \delta$, $b_o = 0.8\mu m - \delta$ and the inner major axis $a_i = 0.7\mu m + \delta$, $b_i = 0.7\mu m + \delta$. In our simulations we use $\delta = 0.04\mu m$, which defines the hole ellipticity of $\overline{\delta} = 2|a - b|/(a + b) = 10\%$. We now characterize losses of the two fundamental mode polarizations as a function of the wavelength.

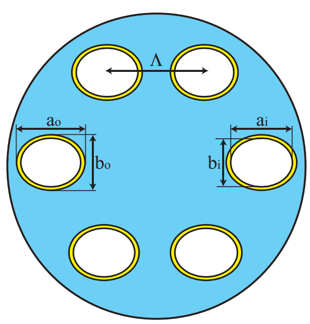

Fig. 1. Solid core MOF with six silver coated elliptical holes; the outer hole principal axis are $a_o = 0.84\mu$m and $b_o = 0.76\mu$m, the inner hole principal axis are $a_i = 0.74\mu$m and $b_i = 0.66\mu$m, the pitch is $\Lambda = 1.5\mu$m.

When ellipticity parameter is taken to zero $\delta = 0$ (circular inclusions), both polarizations are degenerate. Here, loss curve of the fundamental mode is presented as dashed in Fig. 2. The wavelength of maximal loss ~ 1.41 corresponds to the point of phase matching of a core guided mode with a plasmon propagating on the interface between silver and glass. When ellipticity is introduced, wavelengths of phase matching of a fundamental core guided mode with a plasmon become somewhat different for the two polarizations. For example, for $\delta = 0.04\mu m$, dispersion curves for the

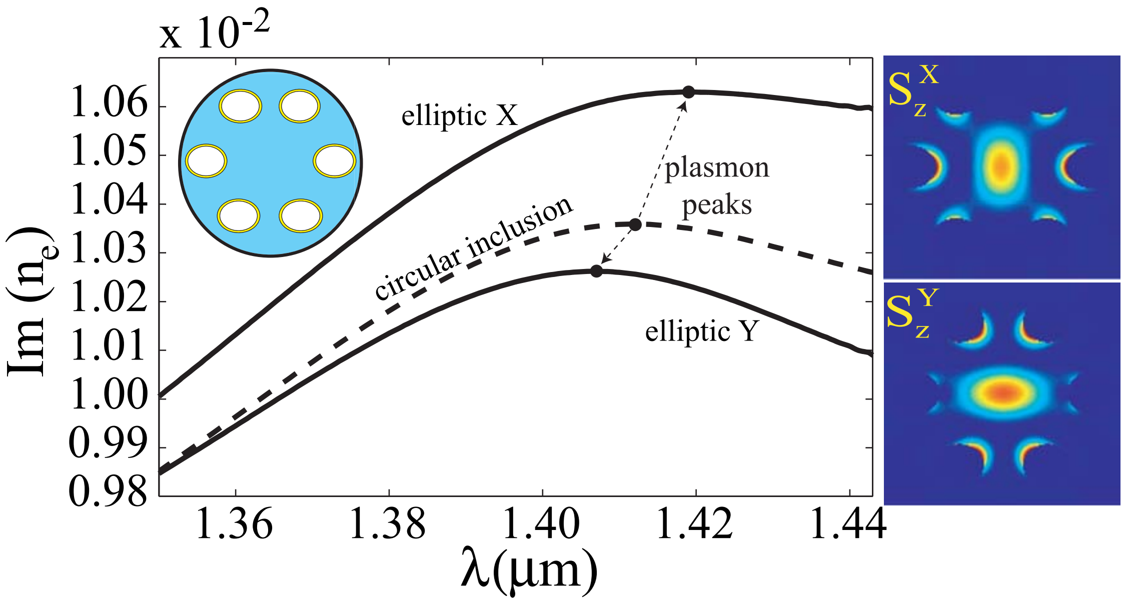

Fig. 2. Loss dispersion curves for the two polarizations of the fundamental mode of a MOF with one ring of metallized elliptic holes. Outset: S_z fluxes for the x and y polarizations of the fundamental mode at the wavelengths of the two plasmon excitation peaks.

losses of the two polarizations are presented in Fig. 2 (solid curves). Plasmonic resonances for both polarizations are clearly identifiable as maxima in the modal losses. For the x-polarization the maximum of losses is at $\lambda_m = 1.419\mu m$, while for the y-polarization it is at $\lambda_m = 1.407\mu m$. The corresponding S_z fluxes are shown in the outset of Fig. 2. From the flux distributions it is clear that at the wavelengths of phase matching with a plasmon, core guided mode is well mixed with a plasmonic wave propagating on the silver-glass interface.

In principle, by measuring spectral splitting in the plasmon excitation peaks $\Delta\lambda_p$ for the two polarizations of a fundamental core guided mode, one can envision detection of the hole ellipticity $\overline{\delta}$. This principle can be used in pressure sensors. Thus, by starting with a fiber containing circular metallized inclusions and by compressing the fiber uniaxially one will induce ellipticity in the hole structure. Such an ellipticity can then detected by measuring splitting in the plasmon excitation wavelengths. To characterize sensitivity of a pressure sensor we define sensitivity as $S_\lambda[nm] = \frac{\partial(\Delta\lambda_p)}{\partial\overline{\delta}}$, which in our case gives $S = 120nm$. Assuming that $0.1nm$ shift between two plasmonic peaks can be resolved, ellipticity detection limit is estimated at $8 \cdot 10^{-4}$.

3. Conclusion

A pressure sensor is proposed based in the loss birefringence of the fundamental mode of a MOF containing six elliptical air holes coated with a thin silver layer. Introduction of the ellipticity in the hole structure makes the losses of two modal polarizations to become different. By measuring splitting in the wavelengths of maximum loss for the two plasmon/core modes one can develop a pressure sensor, which is able to detect hole ellipticities as low as 8.10-4. The boundary integral method is used for an accurate calculation of the propagation constants.

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