A complementary study to "Hybrid hollow core fibers with embedded wires as THz waveguides" and "Two-wire terahertz fibers with porous dielectric support:" comment

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Abstract: In a recent paper, Anthony et al. [Opt. Express 21, 2903 (2013)] demonstrated broadband terahertz pulse propagation through the hollow core fibers with two embedded Indium wires. In another paper by A. Markov et al. [Opt. Express 21, 12728 (2013)], we proposed a plasmonic THz fiber featuring two metallic wires held in place by the porous dielectric cladding functioning as a mechanical support. Although the cross sections of the two waveguides look very similar, we were surprised to find that the guidance mechanisms for these two waveguides are quite different. In fact, waveguide considered by A. Markov et al. was guiding a plasmonic mode, while the waveguide presented by Anthony et al. was guiding a dielectric waveguide-like mode. Finally, we have realized that by reducing the waveguide dimensions by a factor of ~10-20 one can transition from the dielectric waveguide guidance as it is demonstrated by Anthony et al. to plasmonic guidance as reported in A. Markov et al. Therefore, we conclude that both waveguide are essentially identical, while their guidance mechanism changes as a function of the waveguide overall size.

OCIS codes: (040.2235) Far infrared or terahertz; (060.2280) Fiber design and fabrication; (250.5403) Plasmonics; (300.6495) Spectroscopy, terahertz.

References and links

1. J. Anthony, R. Leonhardt, and A. Argyros, "Hybrid hollow core fibers with embedded wires as THz waveguides," Opt. Express **21**(3), 2903–2912 (2013).
2. A. Markov and M. Skorobogatiy, "Two-wire terahertz fibers with porous dielectric support," Opt. Express **21**(10), 12728–12743 (2013).

In a recent paper, Anthony et al. [1] demonstrated broadband terahertz pulse propagation through hollow core fibers with two embedded Indium wires. In another paper [2], Markov et al. proposed a plasmonic THz fiber featuring two metallic wires held in place by the porous dielectric cladding functioning as a mechanical support. Although the two waveguides appear very similar, as they both contain a plastic cladding and two metal inclusions, their guiding mechanisms are surprisingly quite different. Particularly, the waveguide in [1] guides a hollow waveguide mode of a plastic capillary, a HE_{11}-like mode concentrated in the centre of the hollow core and with longitudinal field components, while the waveguide in [2] guides the plasmonic mode bound to the surface of metallic wires. As we have discovered, the main reason for this difference is that the core size of the waveguide in [1] is 10-20 times bigger than the core size of the waveguide studied in [2].

Particularly, in [1] Anthony et al. start with a large hollow tube that is known to support hollow waveguide modes, and then add metallic inclusions. In this case, the large plastic tube is essential for guidance. As a result, the guided mode has an effective refractive index smaller than 1 as expected. In [2], A. Markov et al. use a different approach. They start with a two-wire waveguide whose size is comparable to the guided wavelength, and then add plastic web for mechanical support. In that case, the plastic cladding is not essential for guidance as the guided mode is a plasmonic one supported by the wires and not by the cladding. Also, the effective refractive index of this mode is higher than 1, which indicates plasmonic guidance.

In this Comment we present the results of additional simulations whereby shrinking the waveguide presented in [1] by a factor of 10-20 we demonstrate that such a waveguide changes its guidance mechanism from a hollow waveguide to a plasmonic waveguide. The waveguide in [1] is composed of a Zeonex cladding and two Indium wires. The operational frequency is fixed at 1.0 THz while the waveguide size is consequently decreased, while keeping the proportions between all its geometrical parameters constant. In Fig. 1 we present the longitudinal flux distributions of the modes of such waveguides for different values of the waveguide dimensions. The numbers below each figure indicate the size of the gap between metal inclusions. We only show the modes that have the highest coupling efficiency from a linearly polarized Gaussian beam of 750 µm waist diameter. We start with the gap between the two wires equal to 2 mm (as in paper [1]). In this case, the dominant mode is an HE_{11}-like mode that can propagate in the hollow core even when metal wires are removed. The use of metal wires is justified for this geometry since it greatly lowers the material absorption losses compared to the losses of a corresponding dielectric-only waveguide. This is because the mode is expelled by the metal wires from the lossy plastic cladding into the low-loss air region. As we decrease the fiber size, we observe significant increase in the absorption loss of the HE_{11}-like mode. Moreover, modal refractive index decreases from 0.99 for the largest fiber down to 0.5 for the fiber with 0.4 mm gap between the two wires [see Fig. 1(a)].

The loss of the hollow waveguide mode increases as the core size is reduced, and this mode finally disappears when the distance between the two wires becomes smaller than 0.4 mm. In this regime, the guiding mechanism switches to TIR guidance that features much higher absorption losses. By shrinking the fiber dimensions further we observe plasmonic modes localized in the hollow core that are described in paper [2] [see Fig. 1(b)]. The modes in Fig. 1(b) have refractive indices of 1.15 - 1.35 which clearly demonstrates the different guiding mechanism compared to the modes described in [1]. Thus, we have confirmed that by shrinking the structure of [1] by a factor of ~20 one can change the dominant guidance mechanism in a hybrid hollow-core waveguide from that of a dielectric waveguide to a plasmonic waveguide.

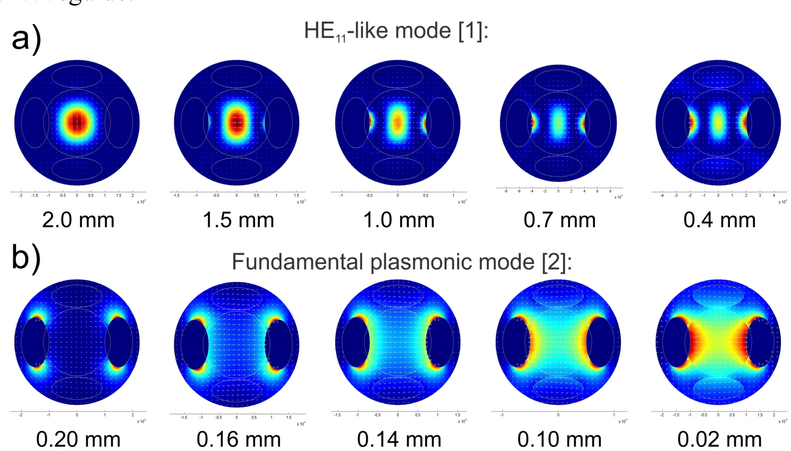

Fig. 1. a) HE_{11}-like modes described in paper [1] (2.0mm gap is used in [1]). b) Plasmonic-like similar to those described in paper [2]. The number below each pair of modes correspond to the gap between the wires.

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