Partial power recovery of bend-induced loss using a hybrid index-guiding photonic crystal fiber

Christos Markos[1, 2], **Kyriakos Vlachos**[1], **and George Kakarantzas**[2]

1. Department of Computer Engineering and Informatics, University of Patras, Rio, 26504, Patra, Greece

2. Theoretical and Physical Chemistry Institute, National Hellenic Research Foundation, 48 Vas. Constantinou Ave., 16635, Athens, Greece

Photonic crystal fibers are typically all-silica optical fibers in which a pattern of air-holes running along their entire length [1]. Such fibers allow for the introduction of polymers (and other active materials such as liquid crystals, high index fluids, etc.) into the air regions yielding hybrid polymer/silica waveguides that allow enhanced tunability of guiding properties due to the strong temperature dependence of the polymer refractive index [2, 3]. In this work, we present a solid-core endlessly single mode (ESM) PCF infiltrated with PDMS elastomer conserving index-guiding mechanism. PDMS (poly-dimethylsiloxane) is a polymeric widely used material in optoelectronics (particularly in opto/microfluidics) with refractive index lower than silica (around 1.41). Normally, the temperature dependence of the refractive index is described by the thermo-optic coefficient dn/dT (- 4.5/°C for PDMS-Sylgard 184), which quantifies the shift of the refractive index arising from an infinitesimal change of the temperature. Here, we demonstrate the combination of a conventional PCF with the aforementioned polymeric material and we show how the thermo-optic effect can act in a way to partially reconstruct the fundamental guiding mode highly attenuated by bending losses.

In our experiments, we employed an ESM-PCF (ESM-12-02, Crystal Fibre) with pitch $\Lambda = 3.5$ μm, and hole diameter 3.5 μm. A simple custom-build pressure cell was used to inject the prepared material into the air holes of PCF. The total length of the filled fiber was about 6 cm. The hybrid PCF at a bend diameter of 4.8 cm was then placed on top of a peltier element with perfect thermal contact to the surface. Using a laser source, a power meter, and a thermo-couple we measured the amount of power recovered from the bending induced loss. Figure 1 (a) shows how bending loss varies with temperature up to 75 °C at 633 nm. It is clear the increment of the power leading to a recovery of ~ 5.1% of the total transmitted power, at 75°C. Increasing the temperature, the refractive index contrast between cladding and core also increases, allowing for the fundamental guiding mode to be partially reconstructed back to the core of the fiber. Same measurements were repeated at 1550 nm, investigating the thermo-optic effect of the fiber at longer wavelengths as shown in Fig.2 (b). The corresponding power recovery of the bend-induced loss in this case is around 2.2% for the same bend diameter. Slight discrepancies appeared in our experimental results derived from a combination of losses arising in the fabrication process and experimental characterization of the device (power fluctuations, scattering, human error, etc.).

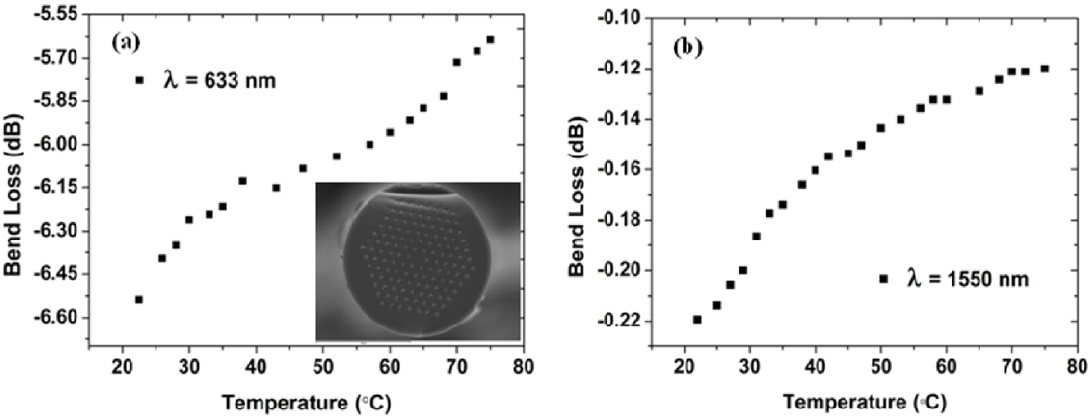

Fig. 1 Power recovery of the hybrid PCF under a constant bend diameter of 4.8 cm at (a) 633 nm and (b) 1550 nm wavelength. Inset: SEM image of the PDMS-filled PCF.

In conclusion, it was shown experimentally that bend-induced loss can be partially recovered for a range of temperatures up to 75°C using a conventional PCF combined with a low cost elastomer. The presented hybrid PCF has the potential to act as a temperatured-tuned device over a wide range of wavelengths.

References

[1] T. A. Birks, J. C. Knight, and P. St.J. Russell, "Endlessly single-mode photonic crystal fiber," Opt. Lett. **22**, 961-963(1997).

[2] B. J. Eggleton, P. S. Westbrook, C. A. White, C. Kerbage, R. S. Windeler, and G. L. Burdge, "Cladding-Mode-Resonances in Air-Silica Microstructure Optical Fibers," J. Lightwave Technol. **18**, 1084-1100(2000).

[3] C. Markos, K. Vlachos, G. Kakarantzas, "Bending loss and thermo-optic effect of a hybrid PDMS/silica photonic crystal fiber," Opt. Express **18**, 24344-24351(2010).