Fiberized Novel Wavelength-Scale Planar Waveguides

Xian Feng, Jindan Shi, Peter Horak, and Francesco Poletti

Optoelectronics Research Centre, University of Southampton, Southampton SO17 1BJ, UK

The modern glass optical fiber, starting from the simplest circularly symmetric waveguide geometry, has been widely inspired by the geometrical structure and functionalities of glass or non-glass based planar channel waveguides. For instance, the currently well-developed microstructured optical fiber [1] has been inspired by works on planar photonic crystal waveguides [2]. On the other hand, planar channel waveguides, such as slab waveguides, ridge waveguides and slot waveguides, are typically fabricated by various processing approaches, e.g., deposition, sputtering, etching, lithography and so on, at relatively low temperatures. Compact microstructured planar waveguide devices play important roles in various technical areas including telecoms application, sensing, and biomedical diagnostics and imaging. In comparison with planar waveguides, optical fibers have numerous advantages, e.g., long length, low cost per unit length due to the high yield, and low propagation loss. Fiberization of planar waveguides is a simple and neat idea to combine the advantages of both planar and fiber waveguides for realizing economic and compact photonic devices.

In this work we presented our first fiberized ridge waveguide. A long, narrow raised strip waveguide was constructed on top of a thin, flat substrate, which has a refractive index lower than the ridge. The ridge waveguide with the supporting substrate was built inside a glass jacket, similar to the format of holey fiber. The fiber was fabricated using a sheet-stacking method [3]. Three types of commercial glasses were employed in constructing the fiber. The outer jacket glass has significant lower viscosity than the core glass during the fiber drawing. Because of this large thermal mismatch between the cladding glass and the core glass, the ridge geometry was maintained with acceptable distortion, even when the dimension of the ridge waveguide was reduced to 1 μm. The loss of was measured to be 0.039 dB/cm at 1.55 μm in the fiberized ridge waveguide with ~1 μm dimensions, showing a low loss comparable with reported low-loss planar waveguides. A high birefringence of 9.5×10^{-3} was measured in a fabricated fiber ridge waveguide at 1.55 μm. This is close to the highest reported birefringence (1.1×10^{-2}) in optical fibers.

Because the ridge waveguide is surrounded by air on three sides, this kind of geometry allows a strong overlap of the optical evanescent field with the surrounding medium. Hence, it provides a highly sensitive structure for chemical sensing. In addition, the ridged geometry also provides a convenient platform for adding heterostructures composed of other materials such as polymer, glass, metal, and semiconductor onto the top of the ridge. Extra optical functionalities can thus be added onto the waveguides. Therefore, we believe that this fiberized waveguide can be a powerful platform to complement the lab-on-fiber technique for chemical sensing.

In addition, the fabrication and characterization of other types of fiberized planar waveguides, e.g., of a slot waveguide [4] which consists of two parallel rails of a high-index glass separated by a subwavelength (~100 nm) air-slot, is currently ongoing.

References

[1] Knight, J. C., et al., Science, Vol. 282, 1476, (1998).
]2] Yablonovitch, E., et al., Phys. Rev. Lett., Vol. 67, 2295, (1991).
[3] Shi, J., et al., Opt. Fiber Technology, Vol. 20, 395, (2014).
[4] Barrios, C. A., et al., Opt. Lett., Vol. 32, 3080-3082 (2007).