ABSTRACT

Optical waveguides are the basic building blocks in a photonics circuit, be it a fiber in communication network, signal processing integrated optic device or a photonic sensing system. Such waveguides appear in numerous structural forms depending on the type of application, materials used and foundation technology involved in the fabrication. Microstructured fibers are new additives to optical waveguides with many promising unusual properties. For modeling and design optimization of any waveguide, numerical analysis is an integral requirement for understanding and anticipating the properties quickly without any fabrication and characterization. This thesis provides a detailed discussion on the design and analysis of a variety of index-guiding optical waveguides ranging from guided-wave planar structures to complex microstructured optical fibers having both linear and nonlinear propagation nature. The developed algorithms are then used to study the characteristics of some recently developed microstructured fiber devices and also the properties of our in-house fabricated microstructures of our own design.

The first part of the thesis is devoted to the development of mode analysis methods followed by modeling the propagation characteristics of various practical waveguides encountered in photonics. The study has been successful to interpret the variety of results already known or available in the literatures or experimentally observed. As a result, the analysis enables one to optimize the design parameters for realizing a targeted structure. A notable addition to this work is the modeling of fabricated PCFs which are in general different from the ideal geometry, and we demonstrated the consistency of various experimental data through analysis of realistic structures.

Next, we focused on application-oriented studies on few PCF structures as potential host. We investigated the effects of tapering fabricated PCFs and its optimization for applications in evanescent field sensing and broadband generation. Thereafter, a detailed study of supercontinuum generation with square-lattice PCF was undertaken which showed that such PCF geometry with different glass compositions can be good supercontinuum source to emit in visible to mid infrared region with femtosecond laser pulse. Another important task we did next is the analysis and design optimization of triangular-lattice PCF as the host of Erbium-doped fiber amplifier towards improved overall performance. Using strong confinement properties of PCF, we maximized the spectral gain of the amplifier to a value higher than the best reported and a low coupling loss with conventional telecom-grade fibers.

Finally, attempts were made to work with the technology development of fabricating PCF structures using our design and analysis of fiber structures. The exercise successfully yielded a few microstructure designs for dedicated sensing application followed by a theoretical investigation to estimate the properties of the resulting sensor.

Keywords: *Optical waveguides, Propagation characteristics, Microstructured fiber, Tapered PCF, Supercontinuum generation, EDFA, PCF fabrication*