ABSTRACT

The advent of microstructure photonic crystal fibers (PCF), the so-called holey fibers exhibiting a fundamentally different guiding mechanism, have brought in many new applications, new fibers and fiber based devices in today's fiber optics and photonics. The huge flexibility in microstructure design of PCFs and several established foundation technologies involved in the fabrication offer great potential for designing new fibers with many unforeseeable transmission characteristics. This leaves a tremendous scope for continued R&D in this area. PCFs with many excellent propagation characteristics resulted in the realization of several interesting all-fiber devices both active and passive. In this dissertation, a detailed investigation of electromagnetic wave propagation inside the microstructure PCF is carried out in quest of designing new fibers and in-line active devices. The thesis describes primarily the theoretical aspects of the microstructure designing of such fibers for device applications. Some experimental studies with PCFs in configuring high-performance optical circuits are also reported here. The achievements of the research reported in the thesis are emphasized with a comprehensive understanding.

The thesis first deals with the revisiting of modal properties of PCFs leading to new microstructure design. Initially, a new *high-birefringence* PCF microstructure is proposed through a series study of the geometrical/structural parameters and a record-high birefringence using circular air-holes in cladding is achieved in single-mode regime along with other inherent properties. Then, attempts are made to enhance the properties of some well-studied fabricated PCF structures through tapering PCFs towards suitable device applications. One such improved performance is investigated for *supercontinuum generation in* the tapered PCF through increased nonlinearity due to reduced core.

Next, we focused on designing and analyzing the host fiber for two most important in-line active devices namely, *fiber amplifier* and *fiber laser*. First, a high-performance amplifier based on erbium-doped triangular-lattice PCF is proposed with a set of converged design parameters. By examining the effect of all associated parameters on the gain, noise and other characteristics of the amplifier, a very high gain and that too achievable over a short length of the fiber is reported. Aimed at field deployment of the amplifier as inline device, we minimized the splice loss of the amplifier. For further improvement of performance of the device, we brought in a new ring-shaped cladding microstructure and thoroughly investigated its amplifying properties. Thereafter, the task of designing an efficient high-performance laser based on same erbium-doped triangular-lattice PCF. Here, the effect of fiber geometry and dopant radius on the key lasing properties, namely, threshold power, output power and slope efficiency are studied in details and finally an optimized design is prescribed. Care is taken to minimize the splice loss with standard SMF through improved mode-matching. Next, the ring-shaped PCF is studied for enhancing the laser performance utilizing its strong confinement property.

The thesis finally describes some experimental works with PCFs undertaken in the lab. A few Sagnac interferometric fiber circuits are investigated for induced linear and circular birefringence in PCFs by the application stress, twist, etc. The results are nicely interpreted by theoretical analysis of the effect in inducing birefringence in PCF.

Keywords: *Optical fiber, Microstructured fiber, Modal properties, High-birefringence, Tapered PCF, Supercontinuum generation, EDFA, EDFL, Sagnac loop*