Abstract

Microstructured optical fibers (MOFs) comprising wavelength-scale manipulations in the waveguide geometry, offer wide range of possibilities for a number of unique and useful applications which are unachievable through the conventional optical fibers. Attaining large mode area (LMA) fibers while maintaining single-mode operation is one of such special features of MOFs, which are useful for high power delivery. However, these fiber designs also face challenges from large bending losses, which should be minimized for practical usages. A novel fiber design with both large mode area and low bending loss is highly desirable. Another important application area of MOFs is sensing, where a category of MOF called the photonic crystal fibers (PCFs) inscribed with long period gratings (LPGs), have drawn immense research attention in recent years. Even though these devices present high strain or surrounding refractive index (SRI) sensitivities, they are essentially insensitive to temperature. A novel concept for enhancing the temperature sensitivity based on LPG-assisted dual-mode PCF has been presented in the thesis. Finally, noting the great demand for a temperature-invariant gain spectrum of fiber amplifier, operating in varying environments, an all-silica PCF with its inherent temperature sensitivity as the host amplifying medium can be promising alternative.

With proper choice of structural parameters, the MOF considered in the thesis, called the microstructured core fiber (MCF) can exhibit a very large mode area (>2000 μm^2) under unbent conditions. To idealize the design in view of practical bending radii, two improved designs based on trench-assisted (TA) and hole-assisted (HA) MCFs, have been proposed. The results obtained (mode area >1000 μm^2, bend loss <0.1 dB/m) with TAMCF is superior to HAMCF and promise the TAMCF as an efficient fiber for practical purposes. In the LPG-inscribed, dual-mode PCF considered in the thesis, the higher-order mode is found to exhibit a non-monotonic phase-matching curve which has been further exploited to obtain a high sensitivity temperature, strain sensor and also a scheme for simultaneous strain-temperature measurements. Further a small cladding radius assures an extremely sensitive SRI-sensor. Lastly, an Erbium-doped all-silica PCF with improved design parameters aimed for short amplifier-module length and low splice loss, has been investigated theoretically. The amplifier gain spectrum has been flattened with the help of LPGs. The temperature response has been checked, which reveals apparent temperature insensitivity due to the fiber's all-silica structure.

As future scope of work, the novel fiber designs proposed in the thesis are subject to be tested for performance in practical scenario. The organization of the thesis is as follows: chapter 1 introduces MOFs with their methods of analysis. It also discusses on the applications of MOFs inscribed with LPGs. Chapter 2 gives a literature survey on MOFs. Chapter 3 discusses on MCFs, investigates a large mode area MCF design criteria and introduces two new designs: TAMCF and HAMCF intended for low bend loss. Chapter 4 proposes a novel high performance sensor based on LPG-inscribed PCF. Single parameter (strain, temperature and SRI) or multi-parameter (strain-temperature) sensing schemes have been promised. Chapter 5 proposes a novel PCF design planned for a short erbium-doped fiber amplifying module with considerably low splice loss when aligned with conventional step index fibers. The flattened gain spectrum has been numerically presented using LPGs which is and compared for different temperatures regimes. Finally, chapter 6 summarizes the important conclusions drawn from the thesis and future scope of work.