Optical Fiber Grating-based Devices for Communication and Sensing

Youngjoo Chung

Dept. of Information and Communications, Kwangju Institute of Science and Technology

ychung@kjist.ac.kr

Abstract

In this presentation, fabrication of optical fiber gratings and device applications for optical communication and sensing will be discussed. Optical fiber gratings are fabricated using various methods based on UV photosensitivity effect, azimuthally symmetric technique using CO_2 laser and strength-preserving non-contact coating removal technique. Suppression of the temperature sensitivity is done using boron-doped specialty fiber for long-period fiber gratings and using temperature-compensating packaging technique for fiber Bragg gratings. Application of optical fiber gratings for communication and sensing includes optical add/drop multiplexer, multiwavelength laser and sensors for temperature, strain, transverse load, ambient index, etc.

Optical fiber gratings, which have periodic or almost-periodic refractive index modulation along the direction of light propagation, have become essential components in various applications for optical fiber communication and sensing [1-4]. Fiber Bragg gratings (FBGs), or short-period gratings, have sub-*m*m period and are typically used as reflection-type filters. On the other hand, long-period fiber gratings (LPFGs) have the period of the order of hundred *m*m and are typically used as transmission-type filters.

Induction of the refractive index changes necessary for formation of optical fiber gratings can be done using various techniques, e.g., the photosensitivity effect [5], periodic relaxation of residual stress with a CO_2 laser [6], periodic physical deformation of the core with electric arc or CO_2 laser [7], microbending with electric arc [8], and thermal diffusion in nitrogen-doped silica-core fiber with electric arc or CO_2 laser [9].

Since the polymer coating material is usually opaque to the UV or CO_2 laser beam used for grating inscription, it is necessary to strip the protective polymer coating off the fiber prior to fabrication of the fiber gratings. In order to preserve the mechanical strength and the lifetime of the fiber, a non-contact coating removal technique using hot air stream has been develped [10]. The thermogravimetry analysis (TGA) shows that the vaporization temperature of the inner primary coating is about 100°C lower than that of the outer secondary coating, which causes the primary coating to vaporize while the secondary coating remains in the solid state. The rising temperature and pressure eventually ruptures the secondary coating, which results in quick and clean removal of the coatings without deformation or residues on the fiber surface [11].

The thermal stability of the spectral characteristics of optical fiber gratings is one of the critical issues that should be addressed for reliable operation of the systems incorporating them. The temperature sensitivity of the FBGs is typically in the range of ~1 nm/100°C, which is too large for communication applications because the channel spacing in WDM systems is 0.8 nm or even less for DWDM systems. The temperature sensitivity of the FBGs can be reduced significantly by using carefully designed packaging techniques. In a method using bi-metal, the temperature sensitivity could be reduced to –0.018 pm/°C, which is a mere 0.22% of the original sensitivity of 8.1 pm/°C [12]. Several methods have been proposed to minimize the temperature sensitivity of LPFG [13-15]. Among them, the GeO_2-B_2O_3 co-doped core fiber [14] is of particular interest since it is based on a simple step index structure with the matched cladding without resorting to elaborate waveguide design. Utilizing the opposite signs of the thermo-optic coefficients of GeO_2 and B_2O_3 referenced to SiO_2, the effective thermo-optic coefficient of the core could be adjusted to match that of the silica cladding. With the optimized doping concentrations of GeO_2 and B_2O_3, the temperature sensitivity was suppressed to as low as 2 pm/°C [16]. The strain sensitivity of the same fiber was measured to be 0.42 pm/ mstrain.

Optical fiber gratings have a wide variety of applications in optical communication and sensing due to their wavelength-selective nature. Multiwavelength fiber lasers are capable of generating multiple signal sources of equally spaced wavelengths and they can find applications for WDM communication systems and smart structure sensors. Multichannel filters incorporated in the multiwavelength laser were constructed using a pair of LPFGs based on the interference between the core mode and the cladding modes. The gain medium was Er-doped fiber pumped by 980 nm LD [17] or Raman fiber pumped by 1064 nm Yb-doped fiber laser [18]. The Er-doped fiber was immersed in liquid nitrogen in order to reduce the homogeneous line broadening. The laser output showed a total of 26 lasing channels and 0.56 nm channel spacing. Simultaneous tuning of all wavelength channels was done with a variable optical attenuator. In case of the Raman fiber used as the gain medium, the multiwavelength laser was operated at room temperature and a total of 19 lasing channels were obtained with the channel spacing of 0.33 nm.

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