광섬유 브래그 격자를 이용한 폴리머 클래딩 온도센서의 온도 특성에 대한 최적화

Optimization of thermal characteristic of the polymer-clad temperature sensor of Fiber Bragg Grating

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In recent years, fiber Bragg grating (FBG) has received much attention and been regarded as one of main approaches for future optical devices due to their in-fiber nature, simple fabrication, versatility in various applications. By controlling the period, length, amplitude, apodization, and chirp of a fiber grating, many devices can be readily produced, which are important to WDM optical communications systems, such as optical filters, optical add-drop multiplexes, fiber lasers, and various optical fiber sensors. Because FBG is very sensitive to temperature, it has been an important sensing device in measuring temperature. To improve the ability to sense temperature, it is developed to coat the temperature-sensitive polymer to the fiber cladding(1). However, larger width of the temperature-sensitive polymer cladding of FBG sensor makes narrower bandwith necessary to the wavelength multiplex. So optimization for the appropriate width of the polymer cladding is needed for the efficient wavelength multiplex.

For theoretical investigation of Bragg gratings several methods have been developed. One of the widely used methods is the well-known coupled-wave theory(2), transfer matrix method(3) and Bloch wave analysis, and beam propagation method (BPM) have been used successfully.

The BPM is presently an indispensable analysis tool for the design of optical waveguide devices and optical circuits. Starting from the FFT-BPM using the fast Fourier transform, various BPMs have been develop, including the FD-BPM using the finite difference method (FDM)(4), and the FE-BPM using the finite element method (FEM). Three-dimensional alternating direction implicit (ADI) FD-BPM is widely used for the analysis of optical wave propagation in a waveguide in which the structure varies along the propagation direction. Theoretical study on temperature characteristics of FBG temperature sensor is obtained by the three-dimensional ADI FD-BPM.

A Bragg grating is a periodic structure fabricated by exposing photosensitized fiber core to ultraviolet light. When light from a broadband source interacts with the grating a single wavelength, known as the Bragg wavelength, is reflected. The Bragg wavelength is related to the grating period, Λ and the effective refractive index of the fiber, n_{eff} by

$$\lambda_B = 2\Lambda n_{eff} \quad (1)$$

Both the effective refractive index and the grating period vary with changes in strain, pressure, and temperature T, imposed on the fiber. Temperature affects the Bragg wavelength through thermal expansion and contraction of the grating periodicity and through thermal dependence of the refractive index. If only the dominant linear effects of temperature factor on an FBG are considered, neglecting higher-order cross-sensitivities, then the amount of Bragg wavelength shift is given by

$$\Delta\lambda_B = \lambda_B(\alpha + \xi)\Delta T \tag{2}$$

where α is the fiber thermal expansion coefficient and ξ is the fiber thermo-optic coefficient.

A polymer-clad temperature sensor of FBG is shown in Fig. 1. For a common bare FBG, it is $\Delta\lambda_B/\Delta T = 10\,pm/℃$ at $1.55\,\mu m$. The wavelength-temperature coefficient is $20\,pm/℃$.

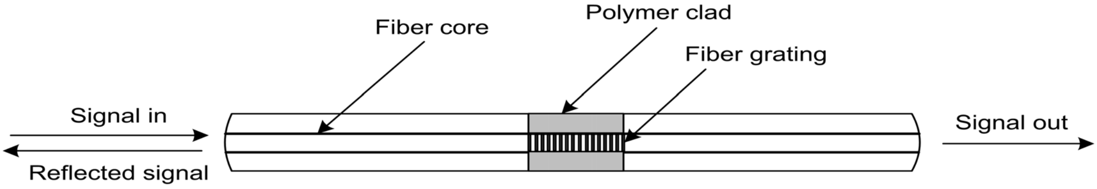

Fig. 1. Structure of polymer-clad temperature sensor of FBG

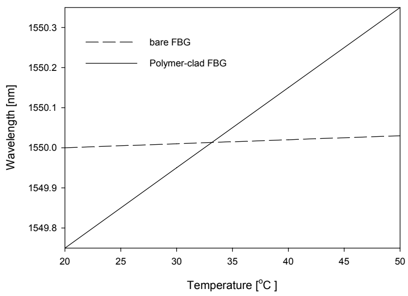

Fig. 2.Bragg wavelength versus temperature

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