ISSN: 2278-0181
Vol. 1 Issue 4, June - 2012

Study of Long Period Grating as Temperature Sensor

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Abstract

In this paper we have presented fiber optics Long period grating as temperature sensor. Temperature sensors have found a number of applications in commercial and industrial fields. In long period grating based temperature sensor a sensitivity of 0.0801 nm/°C achieved with period of 450 µm.While fibers bragg grating has sensitivity of 13pm/°C, so long period grating sensors are highly sensitive as compared to fiber bragg grating sensors. We have simulated the various results with the help of matlab (ver. R2010a)

Keywords: fiber optics, long period grating, Temperature sensors, temperature sensitivity.

I. Introduction

In recent years, a considerable amount of research has been conducted in the use of long period grating. It can be employed in number of applications just like gain flattening of erbium-doped fiber amplifiers, band reject filters [1], refractive index sensors [2], bend sensors, temperature and strain sensors [4].

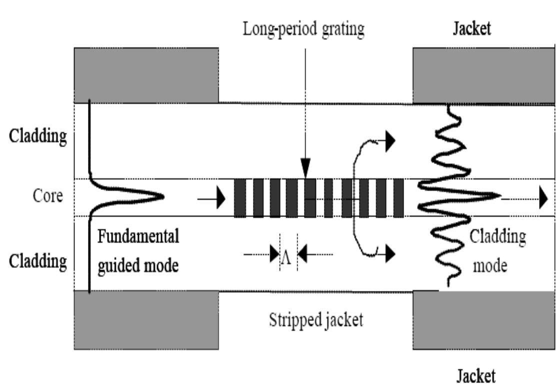

Fig 1: Coupling of a fundamental guided mode to a cladding mode in a long-period grating [1]

Long period gratings are periodic photo-induced devices which couple light from core mode to various cladding modes of a single mode fiber. Long period gratings are periodic photo-induced devices which couple light from core mode to various cladding modes of a single mode fiber. . The cladding modes are quickly attenuated and this result in series of loss bands in the transmission spectra of the grating. Each of these loss bands corresponds to coupling to distinct cladding modes.

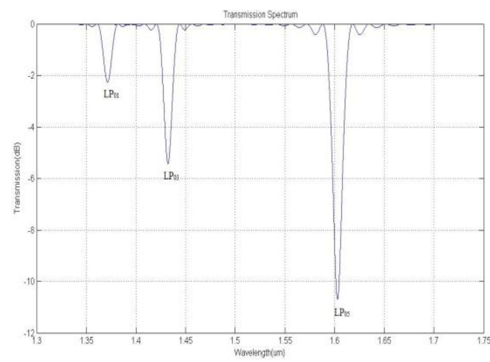

Fig 2: Transmission spectra of long period grating.

In any type of long period grating sensor, the coupling wavelength corresponds to resonant peaks changes, and this is also the basis of long period grating temperature sensor.

II. Principle of operation

The phase matching condition between the fundamental mode and the forward propagating cladding mode for the long-period grating (LPG), is given by [2]

$$\lambda_{res} = \left(n_{co}(\lambda) - n_{cl}^{m}(\lambda)\right)\Lambda \qquad 1$$

Where λ_{res} *is* the resonance wavelength, n_{co} is the effective refractive index of the core mode and n_{cl}^{m} is the effective index of the m^{th} cladding mode. Λ is the grating period. Taking the derivative of phase matching condition with respect to temperature, we yield [3]:

$$\frac{d\lambda_o}{dT} = \Lambda\left(\frac{dn_{eff,co}}{dT} - \frac{dn_{eff,cl^m}}{dT}\right) + \left(n_{eff,co} - n_{eff,cl^m}\right)\frac{d\Lambda}{dT} \qquad 1.1$$

The most reformed form of the temperature differentiated phase-matching condition is the following [4]:

$$\frac{d\lambda_o}{dT} = \frac{d\lambda_0}{d(\delta n_{eff})}\left(\frac{dn_{eff,co}}{dT} - \frac{dn_{eff,cl^m}}{dT}\right) + \Lambda\frac{d\lambda_o}{d\Lambda}\frac{dL}{dT} \qquad 1.2$$

Where $\frac{1}{\Lambda}\frac{d\Lambda}{dT} = \frac{1}{L}\frac{dL}{dT}$, and L is the length of long period grating. Since silica has a small thermal expansion

ISSN: 2278-0181
Vol. 1 Issue 4, June - 2012

coefficient, $\frac{1}{L}\frac{dL}{dT}$ =4.1×10^{-7}/^{o}C .The right-hand side of equation (1.2) contains separate terms that contribute to the thermal sensitivity of the LPG: the first term represents thermo-optic effects (the material contribution), and the second term mainly denotes the change in grating periodicity (the so called waveguide contribution) [4], [5]. From equation (1.2), changes in the LPG transmission spectrum arising from temperature are therefore dependent on the physical parameters of the fibre as well as the order of the relevant cladding mode and the period of the grating. The waveguide contribution is either positive or negative, depending on the cladding mode's $d\lambda_o/d\Lambda$ polarity. Different temperature-induced spectral behavior can be observed when coupling occurs with lower-order cladding modes as opposed to modes of higher order [4]. For a fixed resonant wavelength, the lower-order cladding modes will be accessible with a large grating period (in excess of 100 μm), and in this case the material contribution is the dominating effect [7]. The material contribution is strong function of the difference between the thermo-optic coefficients of the core dn_1/dT and cladding dn_2/dT. Since for the standard fiber under analysis, the cladding is fabricated from pure silica, we will approximate the cladding thermo-optic coefficient with that of silica, $dn_2/dT=7.8\times10^{-6}$. The core of the fiber contains Germania and the presence of external dopants modifies its thermal properties [6]. The average value of thermo-optic coefficient for the core of the SMF -28 fibers was calculated to be dn1/dT=7.97×10-6.

So far, the material effect is based on assuming that the grating period remains unchanged under temperature variations. It is seen that the material contribution also increases with the grating period and can be explained on the basis of the non-linearity of the differential effective index versus the wavelength curve for the corresponding mode. In order to keep the period constant, the phase-matching condition dictates that the ratio $\lambda/\delta n_{neff}$ should remain unchanged.

By using these values, the shifted transmission spectrum with temperature is shown in figure (3).

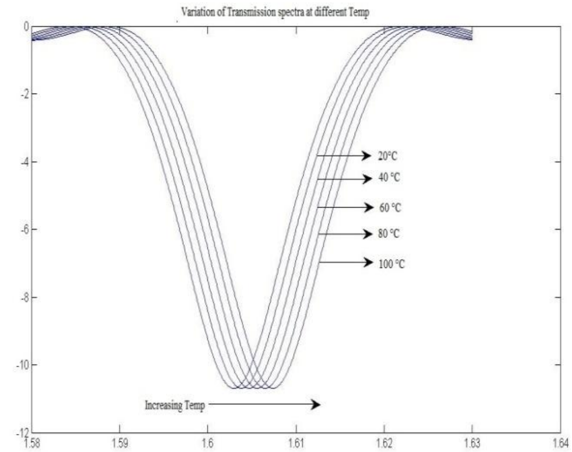

Fig 3: Shift in a band of a long-period grating with temperature. The spectra correspond to temperatures of 20°C, 40 °C, 60 °C, 80 °C and 100 °C from left to right [4].

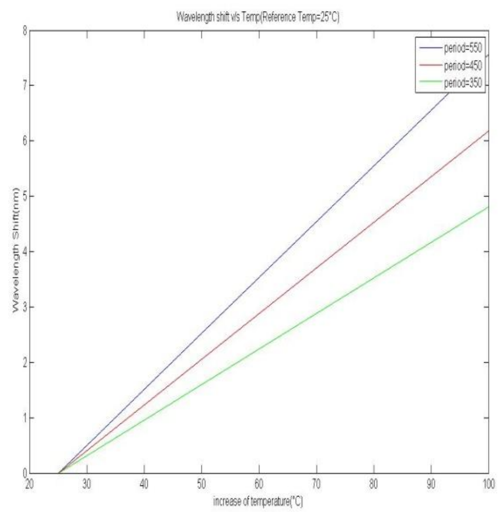

Fig. 4: Shift in the peak loss wavelengths (with respect to that at 25 °C) with temperature for various periods of a long-period grating

In figure (4), studying the wavelength shift with temperature corresponds to different grating period (at reference temperature of 25°C), we concluded that higher the grating period, more is the wavelength shift with temperature [4].

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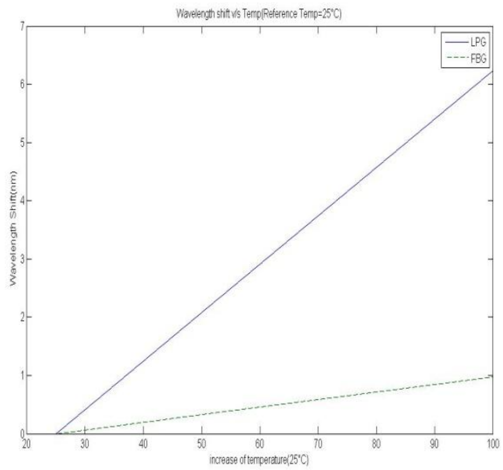

Fig. 5: Temperature-induced resonant wavelength shifts measured for the long period grating, as compared to that of a fibre Bragg grating with temperature sensitivity of 13pm/°C[4]

In fig 5, we have compared the sensitivity of long period grating temperature sensor at peak loss wavelength of 1629 nm and fiber bragg grating sensor at 1550 nm [4].In long period grating temperature sensor we achieved sensitivity of 0.0801nm/°C and in fiber bragg grating we have sensitivity of 13pm/°C.

Conclusion

The proposed model of long period grating based temperature sensor and studied various parameters which are helpful in modeling long period grating as temperature sensor. We concluded that by increasing the grating period we can achieve better sensitivity and long period grating temperature sensors are highly sensitive as compared to fiber bragg grating sensors.

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