Simulation and fabrication of Long period gratings for fluorescence sensing

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***Abstract*—In this paper the use of resonant long period gratings for extraction of weak fluorescence signals in the presence of strong excitation radiation in evanescent wave sensors is explored. The analytical technique used for modeling and the subsequent fabrication procedure that was employed to realize a long period gratings in optical fibers are discussed**

Keyword- Long period gratings (LPGs) , Evanescent wave sensing , polymer waveguide, Optical filtering

I. INTRODUCTION

Long period gratings (LPGs) are a class of popular passive optical devices used as sensors[1] , band rejection filters[2], erbium –doped fiber amplifier flatteners[3] and dispersion compensators[4]. Their simple geometry and very modest resolution requirements make them good candidates for low cost photonic applications such as evanescent wave sensing. In this sensing technique illustrated in Fig. 1, the fluorescence quenching of a fluorophore is indicative of specific binding of an analyte. Therefore, the sensitivity of analyte detection depends strongly on the sensitivity of the fluorescence detection. The detection of the latter is a challenging task since the fluorescence signal needs to be picked from a strong excitation signal. LPGs are very useful since these gratings resonantly couple light from the fundamental guided mode along the core of a single mode fibers into a forward propagating cladding modes through a refractive index perturbation induced in the core of a single mode fiber. Note that only the fluorescence is coupled out of the core region and radiated in the cladding whereas the excitation signal still propagates in the core region.

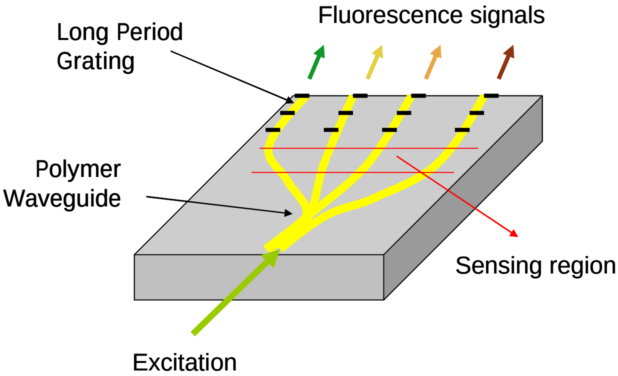

Fig. 1. Schematic of polymer based sensor for fluorescence sensing

In this paper we present a theoretical analysis of the spectral displacements of a LPG and compare it with our experimental results. The phase matching condition of a LPG is generally given as a function of mode indices of the core, n_{eff}^{co} and the cladding n_{eff}^{clp} when the core and cladding modes are guided, the center wavelengths λ_p of the attenuation bands are given by the solutions to the equation.

$$\lambda_p=(n_{eff}^{co}-n_{eff}^{clp}).\Lambda \qquad (1)$$

where Λ is the period of the grating, p is the mode number and λ_p is the wavelength of the p-th order resonance peak. The effective indices of the core and the cladding modes are a function of the propagating wavelength, the geometry of the fiber, and the refractive indices of the core and the cladding materials. As such, the peak position of the resonant mode, depth and inter-mode wavelength spacing are dependent on the fiber core and cladding diameters, the core/cladding material refractive indices difference, the total length of the grating and the index modulation depth. Each parameter must be optimized to obtain a LPG for a certain application.

LPG sensors are designed for specific substance detection, so a prearranged distribution of resonance peaks along the actual spectrum range was required. The grating should be designed to have a well–separated resonance peaks in the actual range of the spectrum. A broader spacing between lines and a wider resonance line width reduces the resolution. Hence, the grating parameters are set that provides the best combination of resonance wavelength and extinction for efficient coupling of light from core into cladding layer so as to enable evanescent wave sensing. This paper outlines the design, simulation, fabrication and analysis of an LPG with parameters optimized for use as a evanescent wave chemical sensor.

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II. MODELING OF LONG PERIOD GRATING SPECTRUMAGE LAYOUT

The long period grating design has been discussed in several papers [5], [6]. For simulation purposes, we considered a single mode fiber in our work. As seen from Equ (1), a key parameter in the design is the value of effective core and cladding index of refraction. The effective index of the fundamental core mode can be determined as a function of wavelength using the expression[7]:

$$\left(\frac{2\pi}{\lambda}\right) D_{core} \sqrt{(n_{co})^2 - (n_{eff}^{co})^2} - \frac{\pi}{2} = 2\cos^{-1}\left(\sqrt{\frac{(n_{core})^2 - (n_{eff}^{co})^2}{(n_{core})^2 - (n_{clad})^2}}\right) \tag{2}$$

where n_{co} and n_{clad} are material refractive indices of core and clad respectively and D_{core} is the diameter of the core. Similarly, the effective clad mode refractive index can be determined by the following relationship with n_{amb} as the external medium refractive index:

$$\left(\frac{2\pi}{\lambda}\right) D_{clad} \sqrt{(n_{clad})^2 - (n_{effcl\,(p)})^2} - \left(p - \frac{3}{4}\right)2\pi = 2\cos^{-1}\sqrt{\frac{(n_{clad})^2 - (n_{effcl\,(p)})^2}{(n_{clad})^2 - (n_{amb})^2}} \tag{3}$$

III. FABRICATION OF LONG PERIOD GRATINGS

The long period gratings were fabricated by periodically applying electric arc on a standard single mode fiber (as illustrated in Fig 3). The fiber was retained at the least tension to prevent fiber deformity. The unjacketed fiber is held between the electrodes of a splice machine (Furukwa, Fitel 2000) so that it can be translated using an actuator. After applying an electric arc of chosen current and duration, the fiber is translated by a specific length in the longitudinal direction and then the arc is applied again. This procedure was repeated while the transmitted power was monitored online using an optical spectrum analyzer (Agilent 86141B). The electric arc applied modifies the refractive index profile in the core as well as the cladding by out diffusion of dopants. The different arc power values and the arc duration were experimented with 500 m period.

Table 1. List of fusion splicer parameters used for the LPG fabrication.

No	Arc Power	Pre- fuse time (ms)	Arc duration (ms)	No of periods
1	59	250	50	27
2	59	250	150	19
3	59	250	250	19
4	59	250	350	16
5	55	250	350	19

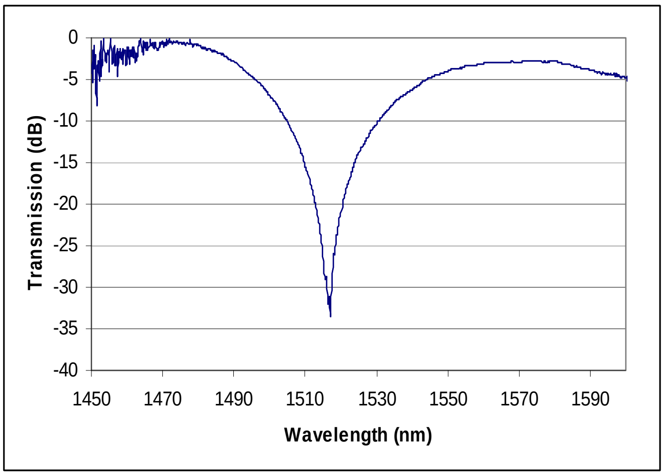

Fig. 2. Sample result of our LPG fabrication with an extinction ratio of -30dB

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REFERENCES

[1] V.Bhatia , "Applications of long period gratings to single and multi-parameter sensing," Opt.Express,vol 4,pp.457-
[2] 66,1999
[3] A.M.Vengsarkar et al, " Long – Period fiber gratings as band – rejection filters,"J.Lightw.Technol.,vol 14, no1 pp.58-65 ,1996
[4] P.F.Wysocki et al , " Broad-band erbium – doped fiber amplifier flattened beyond 40nm using long period grating filter",IEEE Photon.technol.Lett ., vol 9, no 10,pp 1343-1345,1997.
[5] M.Das and K. Thyagarajan , " Dispersion compensation in transmission using uniform long period fiber gratings," Opt.Commun., Vol 190, pp 159-163,2001.
[6] Erdogan T 1997 "Fiber grating spectra",J.Lightwave Technol.15 1277-94
[7] Othonos A 1997 "Fiber Bragg gratings", Rev.Sci.Instrum.68 4309 -41
[8] Byeong H Lee et al "Displacements of the resonant peak of a long period fiber grating induced by a change of ambient refractive index", Opt.Lett 22 1769-1771.