Ultra Long Period Reversible Fiber Gratings as a Pressure Sensor

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Abstract. We report here for the first time the fabrication and characterization of mechanically induced ultralong period fiber gratings (MULPFG) with period size up to several millimeters. In these gratings the coupling of the fundamental guided core mode takes place with cladding modes of high diffraction orders. The transmission characteristic of grating with different external applied pressure has been experimentally verified.

Index Terms: MULPFG, reversible grating, pressure sensing.

1 Introduction

The optical fiber grating is one of the key elements in the established and emerging fields of optical communication systems. Fiber grating is an infiber spectrally selective component and have low losses, high stability, and small size compatible with fiber sizes and low cost. Their applications also spread into the area of optical fiber sensing.

Long period fiber grating (LPFG) is the special case of FBG. It was first suggested by Vengsarkar and coworkers in 1996. Their spectral properties i. e. resonance wavelength, bandwidth etc. can be varied in a wide range. All these features make LPFG as an important component in a variety of light wave applications such as band rejection filter[1], wavelength selective attenuator, dispersion compensator, multichannel filters in WDM applications and gain flatteners for Erbium doped fiber amplifiers[2]. These gratings are also very suitable for various sensing applications. Sharp filtering characteristics, ease of fabrication, direct connectivity to fiber, high sensitivity to external parameters, and easiness in adjusting the resonant wavelength by simply adjusting the grating period are the strong points to push towards the detail study of this device. The period of a typical long period fiber grating (LPFG) ranges from 100μm to 1000μm.

The LPFGs with periods exceeding one millimeter are called ultralong period fiber gratings (ULPFG). The long period size makes fabrication of ULPFG very easy as well as cheap.

ULPFG can be induced optically or mechanically [3] - [5]. Optically induced gratings are permanent, whereas mechanically induced gratings are reversible.

S. Unnikrishnan, S. Surve, and D. Bhoir (Eds.): ICAC3 2013, CCIS 361, pp. 439–443, 2013.

Xuewen Shu et. al. reported fabrication and characterization of ULPFG for the first time in 2002 by using point-by-point writing technique with 244nm UV beam from a frequency doubled Argon ion laser [3]. An ultralong period fiber grating with periodic groove structure(G-ULPFG) fabricated by using an edge-written method with high-frequency CO2 laser pulses is reported by Tao Zhu and co-workers in 2009[4].

We report here, for the first time to our knowledge, the fabrication and characterization of mechanically induced ULPFGs (MULPFG) with periods up to several millimeters. Mechanically induced long period fiber gratings (MLPFG) and MULPFG induced by pressure need neither a special fiber nor an expensive writing device for fabrication. These gratings also offer advantages of being simple, inexpensive, erasable, and reconfigurable and also gives flexible control of transmission spectrum,

2 Theory

ULPFG is a special case of LPFG. In LPFG the core LP_{01} mode is coupled with cladding modes having same symmetry, namely LP_{0m} modes [6]. Whereas in ULPFG the coupling of the fundamental guided core mode to the cladding modes of high diffraction orders takes place [7]. The phase matching condition for a high diffraction order grating is given by (1).

$$\lambda_{res} = \left(n_{eff}^{co} - n_{eff}^{cl,m}\right)\frac{\Lambda}{N} \tag{1}$$

Where λ_{res} is the resonant wavelength, n_{eff}^{co} and $n_{eff}^{cl,m}$ are effective indexes of fundamental core mode and m^{th} cladding mode of N^{th} diffraction order respectively. Λ is the grating period and N is the diffraction order. N=1 for LPFG.

The resonant wavelength with the variation in the effective indexes of the core and cladding ignoring the dispersion effect is given by (2).

$$\lambda'_{res} = \left(n_{eff}^{co} - n_{eff}^{cl,m}\right)\frac{\Lambda}{N}\times\left[1+\frac{(\delta n_{eff}^{co} - \delta n_{eff}^{cl,m})\times\frac{d\lambda_{res}}{d\Lambda}}{(n_{eff}^{co} - n_{eff}^{cl,m})^2}\right] \tag{2}$$

Where λ'_{res} is the resonant wavelength with variation in the effective indexes of core and cladding, δn_{eff}^{co} and $\delta n_{eff}^{cl,m}$ are the effective index changes of the fundamental core mode and m^{th} cladding mode of the N^{th} diffraction order.

3 Experiment

Reversible MLPFG and MULPFG of different periods ranging from several hundred microns to several millimeters were induced and characterized.