Chapter 2

Experimental Techniques

Abstract

This chapter gives a generalized embodiment of invention in which pressure is applied periodically to a fiber to induce a periodic variation in the refractive index by elasto-optic effects, thereby forming an optical grating. The development of an experimental system for measuring the transmission properties of a fiber subjected to periodic variations in pressure using an unpolarized light is discussed.

2.1 Introduction

Mechanically induced Long Period Fiber Gratings (MLPFGs) belong to a class of all fiber filters that produce similar filter functions to those of photosensitive and fused Long Period Fiber Gratings [1]. The MLPFGs are simple and easy to fabricate, can be removed easily, do not require capital intensive equipment, are adjustable, are potentially easy to mass produce and exhibit very low loss. Such devices can be developed in different ways. One is to arc (with an electrical arc, e.g., from a commercial splicer) across the fiber, which locally releases the stress built into the fiber and locally modifies the index [2]. The process is repeated at regular intervals, with a period along the length of the fiber. Another method is to arc and pull the fiber slightly, which deforms it a little and thus perturbs the mode index [3]. These methods work for any fiber without prior processing (unlike photosensitive gratings) but they are also permanent. However, a main practical difficulty that arises in the manufacturing of mechanical Long Period Fiber Gratings is that the transmission function of the fiber is
difficult to control since it depends on $\Delta n$, the difference between the effective index of the $LP_{01}$ core mode $n_{co(eff)}$, and the effective index of the $m^{th}$ cladding mode $n_{cl(eff)}^m$.

Both $n_{co(eff)}$ and $n_{cl(eff)}^m$ depend strongly on fiber parameters, and small variations in either or both of these indices have a large effect on the resonant wavelengths of the long period fiber gratings, making it difficult to manufacture reproducible gratings of desired transmission. Another kind of fiber device relevant to the present discussion is a periodically stressed device. The method used is of a periodic comb of ridges made on a metallic plate [4]. When pressure is applied to a glass fiber placed on such a periodic structure, its core is deformed and a periodic change of refractive index occur in the fiber via elasto-optic effect [7].

2.2 Theory

The optical filter includes an optical waveguide and a device for maintaining pressure along the waveguide to induce local changes in the index of refraction. The induced changes in the index of refraction create an optical grating within the fiber that attenuates optical radiation passing through the fiber more strongly at certain wavelengths than at other wavelengths. The basic principle of an MLPFG in accordance with the present investigation is explained. The periodic pressure applied by squeezing the fiber between the plates induces a periodic perturbation of the refractive index $\Delta n$ of the fiber since one of the plates has a series of equally spaced comb like structure of ridges for a length $L$ and periodicity $\Lambda$. The ridges are pushed against the fiber to produce alternative stressed and unstressed area. The core and cladding of the stressed area of the fiber experience a change in refractive index, while the core and cladding of the unstressed area do not. At the beginning and at the end of each stressed region, the
deformation couples a little power from $LP_{01}$ to the $LP_{11}$ mode. For this effect to accumulate and to cause the transfer of substantial power between modes, the phase between coupling points must be correct. In particular, the ridge period must be substantially equal to the beat length between the two modes. For example, the device demonstrated by Youngquist, et.al, [5] has a proper period of approximately 430 microns and has produced up to 40 dB coupling from $LP_{01}$ to the $LP_{11}$ mode. Thus the periodic change in refractive index due to elasto-optic effects forms a periodic grating in the fiber with the same period of the MLPFG.

The transmission characteristics of MLPFGs thus formed depend on different factors such as the core and cladding index profiles, (which determine $n_{co}$ and $n_{cl}$ respectively), applied pressure on the grooved plate, the length of the region under pressure $L$, the grating period obtained by the spacing between the grooves carved on the plate $\Lambda$ etc. Now the phase matching condition that must be met by wavelengths $\lambda_m$ can be written as [6]

$$\lambda_m = (n_{co(\text{eff})} - n_{cl(\text{eff})}^m) \Lambda \quad \text{(2.1)}$$

where $n_{co(\text{eff})}$ is the effective index of the $LP_{01}$ core mode and $n_{cl(\text{eff})}^m$ that of the $m^{th}$ cladding mode, both evaluated at $\lambda_m$. In general, at a particular period $\Lambda$, several cladding modes satisfy this condition, each one at different centre wavelengths $\lambda_m$ that increases with the order $m$. The transmission spectrum of MLPFG thus exhibits a series of transmission notches distributed over a spectral range of a few hundred nanometers.

In MLPFGs, the period of the grating is controlled by the period $\Lambda$ of the grooves along the length of the fiber and the period can be as large as several hundred
microns for long period fiber gratings. This relatively large value of the period makes it easy to fabricate it with standard machining equipments. The period $\Lambda$ of the grating can be varied by rotating the grooved plate by a selected angle about its mid point. The fiber then sees a new period $\Lambda_1$ equal to $\Lambda$ divided by cosine of the angle by which the plate is rotated [1].

$$\Lambda_1 = \frac{\Lambda}{\cos \theta} \quad \text{(2.2)}$$

where $\Lambda$ is the period of the MLPFG and $\theta$ the angle between the fiber and horizontal axis of the grating.

Other parameters which can be varied are the pressure applied to the grooved plate and length of the region where pressure is applied. By adjusting the length of the region under pressure, the widths of the peaks of the attenuation notches can be adjusted as predicted in equation 2.3 [6].

$$\Delta \lambda_m = \frac{0.8 \lambda_m^2}{L(n_{co(eff)} - n_{cl(eff)})} \quad \text{(2.3)}$$

where $\Delta \lambda_m$ is the spectral width (FWHM) of the attenuation notch.

The line widths of the transmission notches become wider for short length MLPFGs. Now the amount of pressure controls the depths of the transmission notches. The depths of transmission notches generally increase with pressure up to some value. After a certain value of applied pressure the notch starts to decrease which is discussed in chapter 3 of the thesis.
2.3 Experimental

In this investigation, grooved plates of ridge periodicity $\Lambda = 700 \mu m$ is carefully carved on a metal piece using a computerized numerically controlled standard machining equipment. The material remaining between the carved grooves forms the ridges and the periodic structure thus formed acts as an MLPFG. The carved length of the metal piece is set to 7 cm in the present design. The photograph of the MLPFG developed is given in figure 2.1. Since the filter transmission spectrum of MLPFGs is sensitive to the magnitude $\Delta n$, the difference of index of core and of the $m^{th}$ cladding mode, $(n_{core^{(eff)}}$ and $n_{cl^{(eff)}}$, respectively), a precision mechanical loading system is designed and implemented for applying pressure normally onto the optical fiber placed over the MLPFG. The figure 2.2 gives the mechanical loading system designed, which consists of a loading platform with a guiding rail so as to move it up and down. The guides help the platform to apply normal pressure on to the plate placed over the fiber and the rack and pinion screws provided enable the platform for fine movements whenever necessary. The different loads are applied in steps on the loading platform and the system transfers the pressure onto the optical fiber through a plate at the bottom of the platform. This bottom plate can be changed in accordance with the requirement of the length of the region under pressure.

The filter function is effective as long as the pressure continues to be applied to the plate and the notch disappears when the pressure is removed [7]. The length of the grooved plate over which the pressure is applied controls the line width of the attenuated wavelengths of the filter. By adjusting the length of the region under
pressure, the widths of the peaks of the filter function can be adjusted [7] and this is done by placing metal pieces of different lengths such as 3 and 5 cm over the optical fiber placed on the MLPFG and then load is applied. Figure 2.3 shows the experimental set up used in the study and the procedures are discussed in each chapter of the thesis.
Fig 2.1. Photograph of the Periodic Grooves

Fig 2.2. Loading system used for providing lateral load to MLPFG
Fig 2.3. Experimental set up used in the present investigation
References


