Fabrication of tunable sampled nonlinearly chirped fiber Bragg gratings with a simple method

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Abstract. In this letter a simple method for fabricating tunable sampled nonlinearly chirped fiber Bragg gratings (SNCFBGs) is demonstrated experimentally. A SNCFBG is formed when tension is applied to an etched sampled fiber Bragg grating (SFBG), whose cross-section area’s reciprocal varies along the length of the SFBG. The chirp of the grating period and the sampled period can be tuned by adjusting the strain gradients, and the dispersion and dispersion slope can also be compensated.

Key words: dispersion, dispersion slope, fiber grating, nonlinearly chirp, sample Bragg grating

1. Introduction

In high-capacity and long-haul optical WDM transmission systems, dispersion compensation is particularly attractive. Several solutions, such as dispersion compensating fibers and linearly chirped fiber Bragg gratings (CFBG), can compensate the dispersion (Nuyts et al. 1996; Imai et al. 1998). However, the higher-order dispersion for a given channel and the dispersion slope between channels cannot be effectively compensated. So a compact passive device, which can compensate the dispersion, dispersion slope and the high-order dispersion dynamically, is necessary. A good solution is to use a sampled nonlinearly CFBG. Recently, Some ways to obtain SNCFBGs have been reported, such as using a nonlinearly or linearly chirped phase mask in the UV light writing progress and establishing a gradient of temperature or strain field to the gratings after the writing progress (Xie et al. 2000; Zhu et al. 2001; Wang et al. 2002). The method of using a nonlinearly chirped phase mask has the advantage of simplicity and reproducibility, but it is costly and difficult to form complex chirp profile in the gratings. The techniques based on temperature gradients have poor controllability and versatility in achieving a desired chirp profile.

The technique based on a strain gradient along the fiber grating for fabricating and tuning CFBGs has been reported in theory (Hill and Eggleton
1994; Dong et al. 1995; Putnam et al. 1995). But the chirp profile of the grating is simple. In this paper, we demonstrate a method to fabricate and tune a SNCF BG experimentally by nonlinearly etching the grating using HF acid. The chirp of the grating period (CGP), the chirp of the sampling period (CSP) and the chirp of the sampled length (CSL) are created when tension is applied. The CSP of a SFBG will lead to varying equivalent CGP among the channels of the SFBG (Chen et al. 2001), thus the complex effective chirp profile could be obtained. By establishing the strain gradients with nonlinearly varying profile along a SFBG, the effective nonlinear chirp in the channels is formed. The CGP, the CSP and the CSL can be tuned accurately by controlling the tension applied on the grating, and the dispersion and dispersion slope can be compensated.

2. Theory

The refractive index modulation of a sampled grating can be expressed as (Wang et al. 2002):

\[ n(z) = n_0 + \Delta n S(z) \cos\left\{2\pi z / \Lambda(z)\right\}, \]  

(1)

where \( n_0 \) is the average mode index of the unmodified fiber, \( \Delta n \) is the peak reflective-index, \( \Lambda(z) = \Lambda_0(1 + c_p z) \) is the grating period, \( \Lambda_0 \) is the nominal grating period and \( c_p \) is the CGP. \( S(z) \) is the sampling function, which is characterized by the sampling period \( Z \) and sample length \( L_s \). For a SFBG that has a chirped sampling period, the sampling period is given by

\[ Z(z) = Z_0[1 + c_s(i - 1)], \]  

(2)

where \( Z_0 \) is the initial sample period, and \( c_s \) is the CSP. For a SFBG that has a chirped sample length, the sample length is given by

\[ L_s(z) = L_0[1 + c_l(i - 1)], \]  

(3)

where \( L_0 \) is the initial sample length and \( c_l \) is the CSL. In the above expressions \( i = 1, 2, \ldots, N \) denotes the sample number and \( N \) is the total number of the samples.

If the CGP is obtained by establishing the strain gradients along a uniform SFBG, the optical period in the grating can be written as

\[ \Lambda(z, \varepsilon(z)) = \Lambda(z, 0)(1 + \varepsilon(z)), \]  

(4)

where \( \varepsilon(z) \) is axial strain at position \( z \). It can be expressed as