Analysis of Different Writing Techniques for Chirped Fibre Bragg Gratings

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Abstract — **Writing techniques for chirped fibre Bragg grating with a linear chirp profile are compared. Larger bandwidths are achieved when small subgrating lengths are used in stitching technique. Values of bandwidth and group delay for each technique are presented, as well as its inherent complexities.**

I. INTRODUCTION

Gratings in fibre optics where the Bragg wavelength changes linearly or nonlinearly along the grating length are known as chirped fibre Bragg gratings (CFBG). In long haul optical communication systems, fibre dispersion (about 17 ps/nm · km for standard fibres) degrades system performance [1]. An alternative to the dispersion compensating fibres are CFBG, which are of particular interest since they are compact, low-loss, and polarization insensitive devices.

Nowadays, the two main approaches for grating fabrication are the holographic method [2] and phase mask technique [3]. The use of phase masks for producing fibre Bragg gratings (FBG) is more attractive because of its repeatability. Several techniques have been developed to fabricate CFBG; one method involves the use of a chirped phase mask. However, a chirped phase mask is expensive, and the fabricated gratings exhibit fixed group delay characteristics. To overcome this deficiency, other methods have been proposed. In this work, different methods to produce CFBG are implemented and analyzed.

II. THEORY

A fibre Bragg grating is a periodic modulation of the refractive index in the core of an optical fibre. When the FBG is illuminated with a broadband light it will reflect a narrowband portion of this electromagnetic spectrum, consisting of a coherent scattering from the index variations. The strongest interaction or mode-coupling occurs at the Bragg wavelength λ_B given by

$$\lambda_B = 2 n_{eff} \Lambda \ , \quad (1)$$

where n_{eff} is the modal index and Λ is the grating period.

A CFBG is an FBG where there is a dependence of λ_B with the axial position along the FBG. Therefore a CFBG can be seen as an FBG in which a specific injected wavelength is reflected at a characteristic position of the grating. The simplest CFBG is obtained when the variation on the period is linear,

$$\Lambda(z) = \Lambda_0 + \Lambda_1 z \ , \quad (2)$$

where Λ_0 is the initial period and Λ_1 is the linear variation along of the grating length (z).

There are two different alternatives in order to modify the λ_B along the grating. One option is to longitudinally change the refractive index of the fibre core [4] and the other is to create an axial variation of the period of the grating [5].

In this paper, we present the inscription of chirped FBG with an arbitrary group delay response using a uniform phase mask, based on three different techniques. The first one is the stitching method [6]. The second method makes use of two exposures to create an axial change in the refractive index of the fibre core. The last one is based on an axial change of the mean refractive index with a single exposure, but with a different exposure time along the grating length.

All techniques are employed with a photosensitive optical fibre and an excimer UV laser (248 nm, *BraggStar S-Industrial LN*). The reflectivity and group delay were measured using the Agilent 86038B Photonic Dispersion and Loss Analyzer (ONA). The simulations were carried out with the commercial software *Optiwave Gratings*.

III. IMPLEMENTATION

A. Stitching Method

With this method, it is possible to write an FBG with a length higher than the length of the phase mask. The fibre is kept static, while the set composed by the mirror, slit, lens, phase mask and the UV beam is moved longitudinally along the fibre (Fig.1). This recording method depends on the *S* (exposure length): lower *S*-values result in higher precision at the expense of a slower recording speed. This process evolves according to a file that establishes the steps which correspond to the values of displacement of the stage. Each exposition writes the pattern defined by the phase mask onto the fibre; when the first exposition is completed, the set moves and then another exposition is performed after the first one. This process continues until the desired length is obtained. At the end of the process, the FBG is composed by various sections (subgratings) stitched together in phase.

In the CFBG each stitching process presents a phase shift that increases or decreases with grating length. The resultant grating will show a delay response that is dependent of the evolution of the induced phase shifts. The exposure time in each point is the same, maintaining the mean refractive index.

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