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Apodization of Optical Fiber Gratings for Sensing Application

[1]Anita Patel, [2]Geetesh Wagadre, [3]Jitendra Kumar Mishra
[1]M-Tech Scholar, [2]Assistant Professor, [3]Head of Department
Department of Electronics & Communication Engineering, PCST, Bhopal
{anita.patel06@gmail.com, geetesh_wagadre@hotmail.com, jitendra.mishra260@gmail.com}

Abstract- For fiber Bragg grating problems, widely used theories and numerical methods such as the coupled-mode theory and the transfer matrix method will be applied in the analysis, modeling and simulation. The coupled-mode theory is a suitable tool for analysis and for obtaining quantitative information about the spectrum of a fiber Bragg grating. The transfer matrix can be used to solve non-uniform fiber Bragg gratings. Two coupled-fa-mode equations can be obtained and simplified by using the weak waveguide approximation. The spectrum characteristics can be obtained by solving these coupled-mode equations. Uniform, chirped, apodized, discrete phase shifted and sampled Bragg gratings have already been simulated by using the direct numerical integration method and the transfer matrix method. The reflected and transmitted spectra, time delay and dispersion of fiber Bragg gratings can be obtained by using this simulation program. At the same time, the maximum reflectivity, 3dB-bandwidth and center wavelength can also be obtained.

KEYWORDS: FBG, Apodization, TFBG, FWHM, Analytical Method.

I. INTRODUCTION

In 1978, at the Canadian Communications Research Center (CRC), Ottawa, Ontario, Canada, K.O. Hill *et al* first demonstrated refractive index changes in a germanosilica optical fibre by launching a beam of intense light into a fiber. In 1989, a new writing technology for fibre Bragg gratings, the ultraviolet (UV) light side-written technology, was demonstrated by Meltz*et al*. Fibre Bragg grating technology developed rapidly after UV light side-written technology was developed. Since then, much research has been done to improve the quality and durability of fibre Bragg gratings. Fibre gratings are the keys to modern optical fibre communications and sensor systems. The commercial products of fibre Bragg gratings have been available since early 1995.

II. GRATING FABRICATION TECHNIQUES

The historical beginnings of photosensitivity and fiber Bragg grating (FBG) technology are recounted. The basic techniques for fiber grating fabrication, their characteristics, and the fundamental properties of fiber gratings are described. The many applications of fiber grating technology are tabulated, and some selected applications are briefly described.

There are three type of Fabrication Techniques of Fiber Bragg Grating

(1) Holographic Techniques

(2) Phase Mask Techniques

(3) Point by Point Techniques

Out of these three, the phase mask is the most common technique due to its simple manufacturing process, great flexibility and high performance.

A. Phase Mask Techniques

Historically, Bragg gratings were first fabricated using the internal writing [1] and the holographic technique. Both these methods, which have been described already, have been largely superseded by the phase mask technique which is illustrated in Fig. 1. The phase mask is made from flat slab of silica glass which is transparent to ultraviolet light. On one of the flat surfaces, a one dimensional periodic surface relief structure is etched using photolithographic techniques. The shape of the periodic pattern approximates a square wave in profile. The optical fiber is placed almost in contact with the corrugations of the phase as shown in Figure 1. Ultraviolet light which is incident normal to the phase mask passes through and is diffracted by the periodic corrugations of the phase mask.

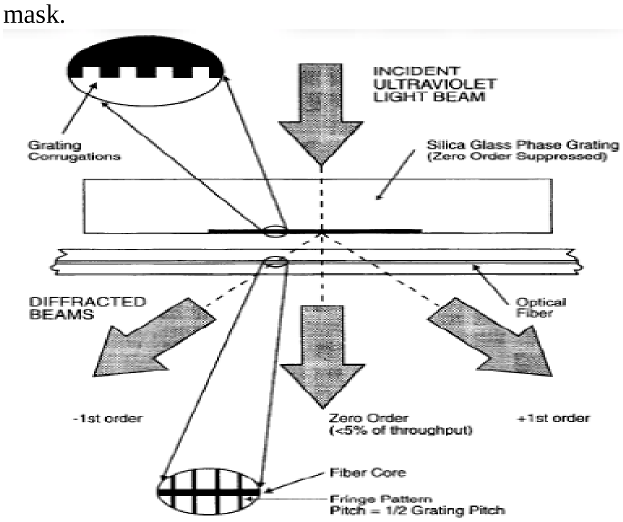

Figure 1: Bragg grating fabrication apparatus based on a zero-order nulled diffraction phase mask [1]

III. LITERATURE SURVEY

This [2] study is carried out to optimize the tilted fiber Bragg grating (TFBG) performance in the reflection mode. This optimization starts by controlling the tilt angle, that causes an intensive decrease in the full width at half maximum (FWHM) at the expense on the peak reflectivity. Grating tilt angle is compromised at 5° where a mutual point between narrower FWHM and unity peak reflectivity is achieved successfully. Then, different apodization profiles are applied with TFBG that yield a better performance concerning side-lobes. **In** general, the TFBG shows a better reflection spectrum when compared to regular FBG. The Nuttall apodization achieves the best performance. Asymptotic decay of 17 dB/nm, low main side-lobe strength (MSLS) of -206 dB, and a narrow FWHM around 0.16 nm were achieved.

The paper [3] propose identical weak optical fiber Bragg grating (FBG) arrays can be fabricated in-line on a draw tower using the phase mask technique. On the FBG arrays, some grating spectrum distortions, for example, asymmetric side lobes or deformed side lobes, low extinction ratio of the main reflection peak and comb filter-type peaks, can be observed. We collected different distorted reflection spectra of the in-line-fabricated weak FBGs and compared them with the simulated spectra of weak FBGs. By comparing the experimental and theoretical weak FBG spectra, it is found that the different kinds of spectrum distortions are caused by phase shifting, asymmetric apodization and nonlinear chirp. This analysis is helpful to improve the FBG array fabricating process by phase mask in-line on a draw tower. And we got good FBG arrays which have good central wavelength consistency, good reflectivity consistency and minor spectral distortion.

The paper [4] proposed, Fiber gratings have a growing impact on the fiber optic communication industry. The simulation result of the reflectance of the uniform and apodized fiber Bragg grating (FBG) are presented. Various apodization technique is useful to reduce secondary lobes or side lobs of reflection spectrum of fiber Bragg grating. The effect of FBG length and apodization profile are presented.

They [5] propose a new, general approach to implement an arbitrary linear optical pulse processing operation, generally requiring a non-minimum phase spectral response, using a minimum-phase optical filter. This approach is valid for implementing any desired operation, as long as it can be limited over a prescribed time window, such as for arbitrary short pulse processors or re-shapers. The proposed concept is particularly interesting for the design of optical pulse processors based on fiber/waveguide Bragg gratings (BGs) operating in transmission, enabling us to overcome the processing bandwidth limitations of their reflective counterparts. In particular, processing speeds in the THz range can be achieved using readily feasible grating apodization and chirp profiles. The approach is numerically demonstrated through the design of a relevant non-minimum phase linear pulse processor, a real-time photonic Hilbert transformer, with an unprecedented 1.5-THz bandwidth, based on a feasible linearly chirped fiber BG structure.

The paper [6] Fiber Bragg gratings (FBGs) technology has demonstrated its suitability for many applications in recent fiber technologies. Sensing application is one of the main applications of FBGs. In this work, we present a comprehensive investigation for using apodized FBGs in sensing applications. Different evaluation parameters such as, reflectivity, side-lobes, and full width half maximum (FWHM) are tested in order to determine the most proper apodization profile for sensors. According to our study, the Blackman apodization gives the best profile that can be used in sensing applications. The reflectivity of Blackman apodization is nearly unity with minimum sidelobes level, -60.3 dB, and narrow FWHM. The length of Blackman apodized FBG is 0.33 cm and $\Delta n = 14.4 \times 10^4$ and maximum reflectivity is 99.44%.

IV. CONCLUSION

The fiber Bragg grating can be viewed as an ideal fiber (as reference) plus a certain index variation (as perturbations). Fiber Bragg gratings have already been commercialized in recent years. It has become popular to use fiber Bragg gratings in sensor systems for their high sensitivity and potentially low cost. Fiber Bragg gratings have been used in many applications, such as wavelength division multiplexing communication systems, lasers, strain and temperature sensing, and fiber lasers.

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