Baseerat Gul* and Faroze Ahmad

Design and performance investigation of Gaussian apodized FBG as hybrid dispersion compensation module for long-haul optical link

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Abstract: A hybrid dispersion compensation module design, using Gaussian apodized fiber Bragg grating and 11 km long dispersion compensation fiber, is proposed for a 111 km long optical link. The proposed module is examined successively with four different chirping techniques. Further, the design is investigated thoroughly in pre-, post- and symmetrical-compensation modes. The performance characteristics of the optimized links are evaluated orderly by quality-factor (Q-factor) values, Eye-diagram and pulse width reduction percentage (PWRP). To further enhance the Q-factor value, optimal parameters of FBG are determined comprehensively by varying the effective refractive index and grating length values. The results show that the proposed dispersion compensation module using Gaussian apodized fiber Bragg grating works well for the quadratic chirping technique. The Q-factor values attained in pre-, post- and symmetrical-compensation modes are 40.5, 49 and 50, respectively, far higher than the values proposed in the literature to date. Thus the proposed technique is best suited for symmetrical and post-compensation modes. The workability of the proposed system is verified using OptiSystem software.

Keywords: chirped fiber Bragg grating (CFBG); chromatic dispersion; dispersion compensation; dispersion compensation fiber (DCF); Gaussian-apodization; pulse width reduction percentage (PWRP).

***Corresponding author: Baseerat Gul**, Department of Electronics and Communication Engineering, Islamic University of Science and Technology, Awantipora, J&K, 192122, India,
E-mail: baseerat.gul@islamicuniversity.edu.in. https://orcid.org/0000-0003-4924-4017
Faroze Ahmad, Department of Electronics and Communication Engineering, Islamic University of Science and Technology, Awantipora, J&K, 192122, India, E-mail: drferoz07@gmail.com. https://orcid.org/0000-0002-7551-7034

1 Introduction

Chromatic dispersion, attenuation and non-linear effects are the chief causes to restrict optical transmission in conventional single-mode fibres (CSMF) [1, 2]. The non-linear effects and the attenuation can be kept minimal, by keeping the power level low and using erbium doped fibre amplifier (EDFA), respectively [3, 4]. Further, the effect of chromatic dispersion rises with an increase in transmission length, hence resulting in inter-symbol interference (ISI) [2], thus restricting the high bit rate for long-distance transmission. Abundant work reported in [3–10] regarding dispersion compensation utilizes DCF and fiber Bragg grating (FBG), concluding that DCF is more dispersion compensation efficient comparatively. However, the high cost of DCF limits its use to the short-distance transmission for economical purposes, unlike FBG. Moreover, the FBG performance improves by adopting proper chirping and apodization techniques. The analysis of optimum chirping and apodization techniques for dispersion compensation module design provides a vast field of research. Ashry et al. [5] proposed that Gaussian-apodized-FBG performs well in terms of side lobe suppression and maximum reflectivity. Also, Daniele reports in [9] that the bandwidth of compensated spectrum maintains in the desired range, by choosing the proper grating length and chirp rate of CFBG. Work reported in [10] concludes that using DCF alone makes the optical link costly, and a hybrid module lets us improve the performance characteristics of the link at a cheaper rate.

The current work proposes an 11 km long DCF with Gaussian apodized FBG, as a hybrid dispersion compensation module for a 111 km long optical link. The analysis of the hybrid dispersion compensation module is carried out, at a bit rate of 10 Gbps, in all three compensation modes viz pre-, post- and symmetrical compensation. During our investigation, four different chirping techniques (linear, square root, cubic root and quadratic) are employed, successively. Further, the characteristics of the links are analyzed systematically at variable grating lengths and effective refractive indices to achieve maximum quality-factor (Q-factor).

The rest of the paper is organized as follows: Section 2 discusses the theory of FBG, the principle of operation and mathematical analysis. Sections 3 and 4 presents