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Splice loss in dual mode triangular index fibers: an analytic approach in the presence of nonlinearity for various V numbers

https://doi.org/10.1515/joc-2024-0168
Received June 28, 2024; accepted July 30, 2024;
published online August 20, 2024

Abstract: We report mathematical techniques for determining the coefficient of transmission at the splice, where anomalies like transverse and angular are present. The investigation involves the first mode of higher order (LP_{11}) in Kerr pattern nonlinear fiber. In this case, the LP_{11} mode for the triangular index (TI) profile is calculated using a standard power series. Chebyshev formalism is the source of the aforementioned term. When there is third-order nonlinearity (TON), the iteration approach is utilized on the analytical mathematical terms to obtain the characteristics listed above. It has been demonstrated that our findings closely match the simulated exact outcomes obtained with the complex finite element method (FEM). Consequently, the suggested straightforward and precise technique offers enormous promise for investigating alternative propagation characteristics in dual-mode fibers.

Keywords: triangular index fiber; Kerr nonlinearity; LP_{11} mode; splice loss; transverse and angular offsets

1 Introduction

In the last few years, a significant amount of research has been published in scientific journals on the estimation and minimization of splice loss (SL) in the case of photonic crystal fibers (PCF) and conventional single-mode fibers (SMF), both in the presence and absence of different kinds of misalignments [1–4]. In the realm of optical fiber communication (OFC) and sensing, the investigation of optical power degradation at the splice that links standard SMFs as well as PCFs has garnered significant attention during the past few decades. Reduced optical power transmission between the two communicating fibers results from this loss while splicing. Factors such as mismatched fiber parameters [5, 6] or an occurrence of transverse and angular errors [7–9], also referred to as lateral and tilt offsets, at the splice among them, must be taken into consideration while the splicing process, to transmit the maximum amount of undistorted power from the incoming fiber to the next. In the realm of OFC, the dual-mode optical fiber has become a significant optical component. In long-distance communication, fiber splicing is an inevitable process. Thus, the precise concept of SL is essential to develop a system for communication. Splice losses comprising the fundamental modal field (LP_{01}) in the case of fibers having dissimilar profile functions in linear regions have already been studied [9–12]. Meanwhile, the concept of LP_{11} modal field is also necessary to compute the transmission factor at the splice when the LP_{11} mode is propagating. The LP_{11} mode cut-off frequency of graded index fiber (GIF), estimated via the Chebyshev mechanism, is obtainable from the literature [13, 14]. Based on Refs. 14 and 15, a series expression of the LP_{11} modal field for GIF has also been made [15]. The generation of several forms of nonlinearity, including the TON, is contingent upon both the doped substrate's properties and the light source's intensity [16]. TON is another name for Kerr nonlinearity (KNL). Concerning nonlinear optics, the consequences of KNL on the different transmission parameters of PCF and GI fibers is a significant and fascinating advancement [17–19]. A notable advance in the research is the effect of KNL on the LP_{11} mode cutoff frequency of single-mode dispersion-managed fibers [20]. It comes to light that the cutoff frequency drops due to the rising of the nonlinearity and in reverse for self-focusing phenomena that correspond to an incremental variation in the index, as in silica. Refs [18–20] have been noted to require enormous computations to be executed. The existing literature contains an intuitive and reliable power series equation depending on the Chebyshev technique that may be employed to predict different aspects of the propagation properties of single-mode GIFs in the linear domain [20–24]. It has also been stated that the formalism above, combined with an iteration strategy, can be used to accurately estimate various propagation factors for dispersion-managed fibers and KNL-type mono-mode GIFs [25–29]. In

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