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Analysis of different structure and nonlinear distortion of multicore fiber for power over fiber applications

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ABSTRACT

Recently the fiber technology enabled the application in electrical domain for remote access uses. The Power over Fiber technique is a preamble for the same where in the multicore fiber is used as a channel. In this paper, we have designed the five structures like triangular, ring, square, rectangular and hexagonal of multi core fiber and their analysis in term of a number of cores, pitch and power spectrum. The hexagonal MCF has provided maximum power at output −10 dB and maximum power of current cut is 6.340e-001W at 38 mesh point and recommended for power over fiber link. The nonlinear distortions associated with multicore fiber and its impact on the performance of power over fiber link are also discussed. The simulation results are carried out on OptiFDTD 12.0 version platform.

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1. Introduction

In 1970, American Telephone & Telegraph (AT& T) proposed the idea of fiber technology for data signal transmission instead of electrical wires [1]. The reverse engineering of this idea born concept of power over fiber. The revolution of the optical communication had been a tremendous change in data transmission in the field of the telecommunication [2]. Accessing the internet now becomes very easy by contemporary wireless technologies [3]. The integration of optical technology with the radio frequency signal (RF) and electrical signal (power) is Radio over Fiber (RoF) and Power over Fiber (PoF) respectively, are well-established technology in current research [4]. The multicore finer (MCF) potentially improves the transmission of data for the spatial division multiplexing and transmission of power for high power devices [5]. The structure and losses in MCF have been reported for spatial division multiplexing [6]. But for PoF application, using MCF with its nonlinear distortions is still challenge for the researchers [7]. Recently much attention has been focused on the structure of MCF which enables the high power signal transmission through the fiber. The limitation of single mode fiber is reducing by the MCF and the different technique like image processing is proposed so far the analysis and different structure of the MCF. The performance of the MCF is depends not only the number of core also on the arrangement of the cores [8]. As per author(s) best knowledge, the novelty of this work is, to address and design the MCF structure especially for power over fiber link on the OptiFDTD platform. In this paper, we have focused on a different structure of MCF, design aspect and theoretical study of nonlinear distortions for power over fiber link.

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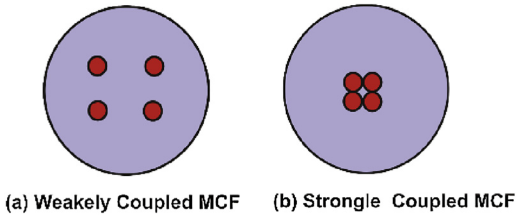

Fig. 1. Structure of Multicore fiber with coupling region.

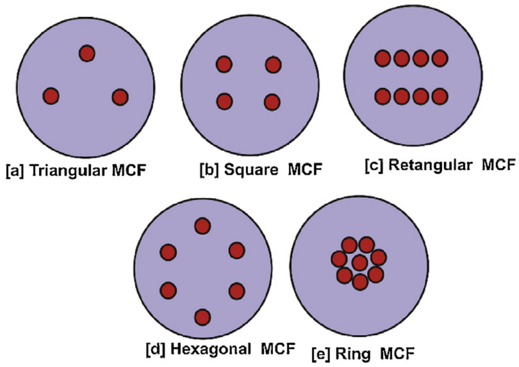

Fig. 2. Structure of Multicore fiber with different pattern.

2. Multicore fiber structure

The barricade of the traditional fiber can break down by the use of MCF comprehensively for SDM and PoF link [9]. So many structures and designs of MCF like fixed number of core with variable pitch or fixed pitch and variable number of cores have been reported for the various applications [10–12]. In this paper we analysed both variables number of cores and variable pitch as well as. There are some important design parameters like a number of cores, patterns of a core, the coupling of core/modes, pitch of core, refractive index, core diameters, and effective area that should be deliberate during the designing for the MCF [13]. In the data communication where the bit rate is seeing for SDM application same as the power range is contemplated for power over fiber link, which require more number of modes capable to propagate high power laser carrier for the high power transmission [14]. The mode coupling is considered negligible in the case of MCF which is more crucial in case of multi-mode fiber. The magnitude of the field varies mode to mode or core to core, for p^{th} spatial mode is given by time domain Manakov equation as Eq. (1) [15].

$$\frac{\partial A_p}{\partial z} = i\beta_{p0}A_p - \beta_{pl}\frac{\partial A_p}{\partial t} - \frac{i\beta_{p2}}{2}\frac{\partial^2 A_p}{\partial t^2} + \frac{i\gamma}{3}\sum_{lmn} f_{plmn}\left[\left(A_l^T A_m\right)A_n^* + 2\left(A_n^H A_m\right)A_l\right] + i\sum_m q_{mp}A_m \tag{1}$$

where $\beta_{pn} = \frac{\partial^n \beta_p}{\partial \omega^n}\Big|\ \omega = \omega_0$ and γ is the nonlinear parameter. Two more coefficients are used to define the linear and nonlinear coupling for spatial modes [15].

On the basis of coupling, MCF may classified: strongly and weakly coupled shown in Fig. 1. Strongly coupled MCF has minimum core to core distance with higher coupling coefficient, whereas the weakly coupled MCF has maximum core to core distance with lower coupling coefficient. The size of the core may be variable where the pitch of core is also varied. The effective area (A_{eff}) depends on the number of core, and its arrangement affect the receiving power at the output end. The nonlinearity is also one of the decisive parameter for any fiber which can be reduce by increasing the core diameter. In MCF large number of core having enlarge effective area and this approach has minimum dispersion and bending losses. In some of fiber design four air core MCF was proposed to compensate the bending losses [16]. The five different structure of the MCF as shown in Fig. 2.

2.1. Refractive index profile

The refractive index profile defines refraction of the field distribution for wave guide. The earlier we discussed the different MCF structures whose the refractive index profile is shown in Fig. 3.

All core has an isotropic refractive index (n = 14.8) having equal major and minor axis dimension. The constant refractive index reduces the effect of material dispersion. Coupling of core depends on its structure. The rainbow colour shows the

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