Analysis of power confinement in Trench-Assisted Fiber for Sensing Applications

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Abstract. In this paper, we have the analysis on the effect of power confinement in trench assisted fiber. In single mode trench-assisted optical fibers at a certain value of trench width, all power propagates through the cladding. Single mode operation in the fiber is realized by the small diameter of the core and low mode field diameter gives tight confinement. The optimized design parameters are obtained by introducing trench between inner cladding and the outer cladding layer. The analysis shows that the relative refractive index difference in trench affects the properties of optical fiber for sensing applications.

Keywords: trench-assisted optical fiber, mode field diameter, power confinement.

1. Introduction

Bend insensitive fibers (BIF) are exciting engineers and scientists because of the possibility of their use in fiber-to-the-home (FTTH) applications and thereby reducing a power penalty caused by sharp bends in optical fibers used in the Broadband communications networks [1]. Broadband communications and access networks, including FTTH have been evolving rapidly. BIF, which has a low bending loss, has become particularly attractive as the FTTH service has expanded [2, 3]. There have been many reports on a BIF that employ such techniques as reducing the mode field diameter (MFD) [4], depressing cladding, adding a low index trench.

When talking about trench-assisted fiber (TAF), bend-insensitive optical fiber can be used in FTTH applications [5, 6]. The trench can reduce both macro-bending loss [7] and micro-bending loss [8]. It performs perfectly in following the ITU-T G.657 standard to achieve very low bending loss. Besides reducing bending loss, the low refractive index trench affects some other parameters in the optical fiber communication system such as chromatic dispersion [9, 10], mode field diameter [11] and even crosstalk in multi-core fiber [12]. Theoretically, an ideal optical fiber used in optical communication system should have these following characteristics: small MFD, tight power confinement and low bending loss. These characteristics, which guarantee the signal quality in the FTTH, can be optimized by trench-assisted structure. Although there have been many discussions about the TAF, we will study how different parameters of the trench affect power confinement, mode field diameter and other properties of optical fiber respectively. In this paper, we have focused on optical field distribution in the fundamental mode, effective mode field diameter and power confinement for various applications.
2. Optimized Objects of Trench-Assisted Fiber

Based on the reported proposal [13], we have designed TAF with a Fluorine trench, inner cladding and outer cladding layout of this work. If layers of cladding are set inside the fiber, the cutoff wavelengths of the interior cores tend to be longer than that of the exterior cores [14]. This is due to the tight confinements in the interior cores, which are caused by the trench structure deployed around the core. Moreover, excessive MFD will also depend on the trench cladding [15]. Thus, we only arrange one layer of cores with a ring layout for the TAF. The design concept model is shown in Fig. 1. (a) Refractive index profile and (b) Cross sectional view. It illustrates the schematic of a fiber with trench-index and stand for core radius. The different parameters associated with the proposed structure can be represented as follow: the distance between the center of the core and the inner circumference of trench denoted by \( r_1 \), the distance between the center of the core and outer circumference of trench denoted by \( r_2 \), the thickness of the trench layer denoted by \( r_2 - r_1 \), the relative refractive-index difference between core and cladding denoted by \( \Delta_1 \), the relative refractive-index difference between cladding and a trench denoted by \( \Delta_2 \). Table 1 shows design parameters of proposed TAF given below.

| Parameter | Unit | Model-I | Model-II |
|-----------|------|---------|----------|
| \( R \)   | \( \mu m \) | 4       | 4        |
| \( r_1 \) | \( \mu m \) | 4       | 8        |
| \( r_2 \) | \( \mu m \) | 8       | 24       |
| \( r_2 - r_1 \) | \( \mu m \) | 4       | 16       |
| \( \Delta_1 \) | % | 0.35~0.70 | 0.35~0.70 |
| \( \Delta_2 \) | % | -0.20~0.250 | -0.25~0.30 |
3. Simulated Results and Discussion

Although the trench structure can reduce the bending loss significantly and optimize the mode field diameter, it also affects the optical field distribution and power confinement for the fundamental mode. Therefore, we will have a direct insight into the variation of the mode area and power distribution in fundamental mode with trench width. We have study effect on fundamental mode and optical power change according to change in trench properties. Fig. 2. shows the highest field in the center part of the fundamental mode and power confinement in center core. This result shows a tight power confinement gives low mode field diameter, low bending loss. These characteristics show TAF use in broadband and FTTH application.

Fig 2: Optical field distributions in fundamental \( \text{LP}_{01} \) Mode and power confinement in center of the core.

In Fig. 3. shows the highest field on the surface of the fundamental mode and maximum power confinement in an outer cladding of the fiber. This result shows a power confinement in cladding gives this fiber sensitive to stress and strain, low bending loss. These characteristics show TAF-F use in sensing application.
Fig 3: Optical field distributions in fundamental $L_{P_{01}}$ Mode and power confinement in the outer cladding.

4. Conclusion

To conclude our work, we have proposed a model of TA-F for sensing applications. The trench-index profile illustrates the advantages of the bend insensitive fiber for broadband and FTTH applications. The model shows the maximum power confinement in outer cladding. Hence TA-F second model used in sensing applications. We have studied the effect of different trench parameters on optical field distribution, bending loss, mode field diameter and power confinement of the fiber, theoretically. Based on the numerical analysis, it can be observed that important properties such as optical field distribution, power confinement and bending loss are sensitive to trench thickness. On the other hand, if the trench, thickness increase the MFD decrease with the acceptable bend loss and supporting single mode operation. The designed TA-F has low MFD of about $8.7 \, \mu m$ at 1550 nm wavelength, as well as low bending losses. It can show potential application in the field of sensing throughout the entire spectrum range of 1.3 $\mu m$ to 1.6 $\mu m$ wavelengths.

5. References

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