The Study of Coupled-Mode Characteristics from Resonant Wavelengths Inside Fiber Grating Structure

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***Abstract*-Partial wavelength of light traveling through an optical fiber can be filtered out as a resonant wavelength from coupled modes. The simulation by FullWAVE (Synopsys Inc.) shows the electric field distribution throughout the various periodic index difference of fiber core layer. The results show that higher periodic index difference yields the larger electric field distribution affecting lower optical power passing through the optical fiber.**

I. Introduction

The fiber grating structure has a periodic index difference among core layer of an optical fiber. It leads to the coupling of light from fundamental core mode to cladding modes inside a single-mode fiber [1]. In practical term, the characteristic of coupled modes is observed as resonant wavelengths in which partial light wavelengths corresponding to each mode are dropped out of the optical link. The characteristic of dropped wavelength is beneficial for optical sensing applications.

The sensing performance of the grating structure depends on the periodic refractive index difference in the region of applied grating structure that affects the electric field distribution and optical power. The refractive index of core layer region where grating structure applied becomes higher than its initial value [2] depending on the fabrication process.

In this paper, the simulation of electric field distribution with several refractive index differences of core layer at applied grating region are observed by using FullWAVE (Synopsys Inc.) as a simulation tool. The light source for the observation is the continuous wave of 1550 nm transmitting at one end of the fiber grating structure.

II. Structure Design

The fiber grating structure is divided into two regions corresponding to the refractive index difference between core and cladding layer, they are initial region (red) and grating region (blue) as illustrated in Fig. 1. The surrounding of the structure (white) refers to the cladding layer and the structure itself refers to the core layer. The purple boundary surrounding the structure refers to the spatial domain for the simulation. The 1550 nm continuous wave is a light source transmitting through the fiber grating structure.

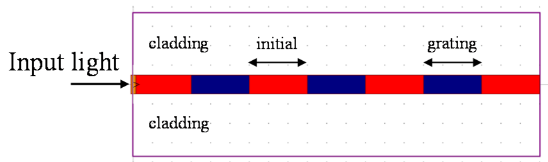

Fig. 1. Fiber grating structure with two regions.

The initial refractive indices of core and cladding layer are referred from the SMF-28 step-index fiber as 1.45205 and 1.44681, respectively [3]. The refractive index of core layer at grating region is increased to 1.65205, 1.75205, and 1.95205 as becoming index difference (Δn) of 0.2, 0.3, and 0.5, respectively. In the same structure, all grating regions have the same value of index difference along the whole structure. The dimension of the structure is 1x21 μm, divided into seven sections containing four initial regions alternating with three grating regions. The dimension mentioned above is the case study for the electric field distribution from various index difference in grating regions.

III. Simulation Results

The simulation time for each of models is different. The fiber grating structure with its index difference of 0.5 at grating regions takes shortest time. In contrast, the structure with its index difference of 0.2 at grating regions takes longest time. In addition, the spatial domain becomes wider when less value of index difference of grating region is input as seen that the model with index difference at grating regions of 0.2 have the widest domain (purple boundary) of all.

Three simulation results of electric field distribution are shown in Fig. 2(a)-(c) corresponding to the index difference at

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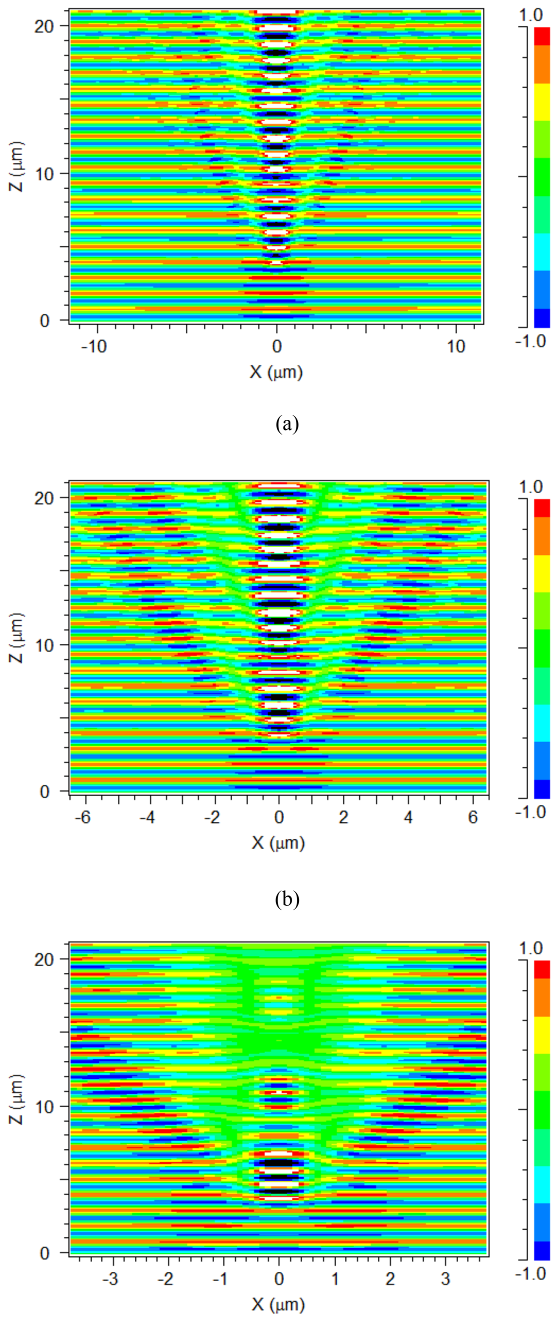

Fig. 2. The electric field distribution from various index difference of (a) 0.2, (b) 0.3, and (c) 0.5 at grating regions of core layer.

grating regions model of 0.2, 0.3, and 0.5, respectively on xz plane. The characteristic of electric field is more widely spread when the index difference at grating regions increases. As the action of spreading electric field, there is almost no field at the nearby core layer as clearly seen in Fig. 2(c). The field rib concentration also becomes wider as it widely spreads. Furthermore, when the index difference of initial regions changes, the layer of electric field along z-axis also changes and affects the spread and rib size of the distribution.

IV. Discussion

As the appearance of the electric field distribution, the size of the rib and the distribution direction refer to the amount of power passing through the structure. When the light transmits through the fiber core with different refractive index, the propagation direction absolutely changes, so that the distribution characteristic of an electric field also changes leading to the coupling mode from the fundamental core mode to cladding mode. The strength of coupled modes depends on how much the refractive index of core layer in grating regions has been changed from its initial value. Different types of an optical fiber, even the same fiber with different material dopant, give the different result for the strength of coupling mode that affects the magnitude of resonant wavelength along with the distribution characteristic of electric field when different periodic index is applied to core layer of the fiber. Moreover, relating to the fact that when the fiber core structure is periodically changed by the grating fabrication processes, the resonant wavelengths from these coupled modes are observed and applied to several types of optical sensors. The amount of index difference in fiber structure can be controlled during the fabrication process. The sensing performance from the resonant wavelength or coupled mode inside the fiber mainly depends on fiber material and how perfect of the designed written grating period on the fiber.

V. Conclusion

From the simulation results by FullWAVE (Synopsys Inc.), the distribution trend of electric field from various index difference of core layer in grating regions is proved. The higher index difference of core layer in grating regions results to wider distribution direction of an electric field and wider rib. Therefore, the larger applied index difference yields more strength of coupling mode from fundamental core mode to cladding mode affecting the larger leak of optical power that the resonant wavelength has higher magnitude.

Acknowledgement

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