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Polarization Dependency Reduction on Long Period Fiber Grating by Side Loading

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Abstract

A novel method to reduce polarization dependency on long period fiber grating (LPFG) by a side loading is proposed. The polarization dependent shift of the mode-coupling wavelength is reduced from 1.5nm to 0.2nm.

1 Introduction

LPFG has been widely used as optical signal processing device like a gain flatting filter for EDFA [1]. In general, a LPFG is fabricated by exposing an UV beam to one side of a photo sensitive fiber. Such one side-exposed LPFG has some amount of birefringence caused by its asymmetrical refractive index distribution [2,3]. The birefringence results in polarization dependencies such as polarization dependent loss or polarization dependent shift of the mode-coupling wavelength. To use LPFGs as optical signal processing device, it is important to reduce the polarization dependencies, especially in applications for high-speed communications.

In this paper, a simple birefringence reduction method, by side loading on LPFGs, is proposed. Both the numerical and experimental results clearly show that the proposed method can drastically reduce the polarization dependencies of LPFGs regardless of its simplicity.

2 Polarization dependency reduction by side loading

A mode-coupling wavelength λ_p of an LPFG is given as follows,

$$\lambda_p = \Delta n_{ave}\Lambda, \qquad (1)$$

where $\Delta n_{ave} = n_{co} - n_{cl}$ is the average effective index difference between the core and cladding modes, Λ is the grating period. In general, LPFG writing process, an UV beam has been exposed to one side of a photosensitive fiber and it results in the asymmetrical refractive index distribution in the fiber core [2]. Here, it is assumed that the UV beam comes from the x axial direction. The UV-induced index change is the greatest at the core-cladding interface on the x-axis and it decreases exponentially toward the opposite side of the fiber core. Therefore, the core index n_{co} for the x-polarized light is greater than that for the y-polarized light, resulting in the previously mentioned polarization dependencies.

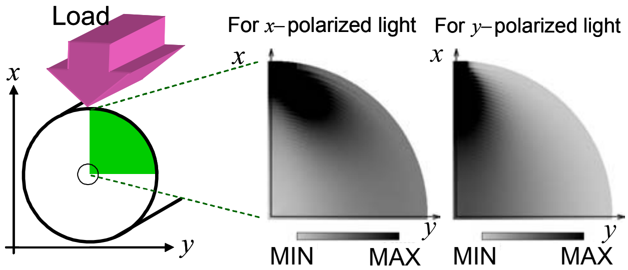

Fig.1 Refractive index change induced by side loading for two orthogonally (x- and y-) polarized lights.

Fig.1 shows refractive index changes induced by side loading for both x- and y-polarized lights. Because they are symmetrical from side to side and up and down, only quarters of them are shown here. As you can see in Fig.1, when a side loading is applied on the LPFG from the x axial direction, the refractive index change in the cladding for the x-polarized light is greater than that for the y-polarized light. Namely, the side loading relatively increases the cladding index n_{cl} for the x-polarized light, and Δn_{ave} for two orthogonally polarized lights approach each other, thus resulting in the reduced polarization dependencies.

3 Numerical analysis

The refractive index distributions in the optical fiber under the presence of the side loading were numerically analyzed by FEM. Fig.2 shows the index distributions for the x- and y- polarized lights. To obtain n_{co} and n_{cl} for two orthogonally polarized lights, the refractive index distributions on the two orthogonal axes, x- and y-axis, are averaged geometrically. Those averaged core and

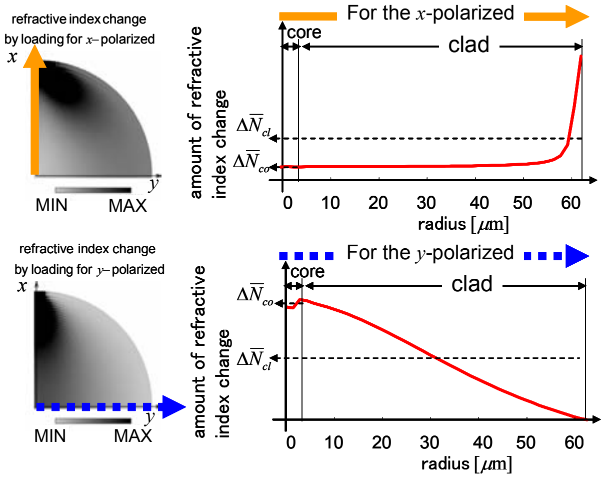

Fig.2. Index distribution for *x*- and *y*-polarized light.

cladding indices are used in the coupled mode analysis of LPFGs. By solving the coupled mode equations, the changes in the coupling wavelength between the core and cladding modes by side loading were numerically analyzed.

4 Proof-in-principle experiment

To demonstrate the validity of the proposed method experimentally, a proof-in-principle experiment was performed. Fig.3 shows the experimental setup.

The LPFG used, in the experiments, was made by one-side exposure of the Kr-F excimer laser, and it is loaded by some sash weights as shown in Fig.3. To load from immediately above the LFPG, a piece of the SMF was put in parallel to the LPFG. The LPFG and the SMF were sandwiched by two aluminum plates and the sash weights were put on the upper aluminum plate. The upper aluminum plate was 200g in weight and the sash weight was changed in every 500g from 0g to 2,500g. The polarization state of the linearly polarized ASE was controlled by the polarization controller so that the ASE having different polarization angle could be launched into the DUT. Then, the transmission spectra for the two orthogonally polarized lights were measured using the OSA.

Fig.4 shows the mode-coupling wavelength difference for two orthogonally polarized lights vs. weight on the LPFG. In the figure, the solid line shows the numerical result and the symbols show the experimental results. The tendency of both the numerical and experimental results is almost the same. It has almost 1.5nm difference without any weight. According to the increasing weight, the wavelength difference is reduced. It is almost zero at 1.2kg and increases again for more weight.

The insets show the spectra, (a) without any loading and (b) 1.2kg loading, for every 5 degree of the polarization angle. In the inset (b), there is still some amount (0.2nm) of the polarization dependency regardless of the zero wavelength difference for two orthogonally polarized lights. By the 1.2kg loading, Δn_{ave} becomes the same only for the two orthogonally polarized lights. For other polarization angles, there is still small amount of Δn_{ave} difference, thus resulting in the polarization dependency. It is clearly found that the amount of the polarization dependency, however, is drastically reduced compared with the inset (a).

5 Conclusion

The polarization dependency reduction method on LPFG by a side loading was proposed. Although the tested LPFG had a 1.5nm of the mode-coupling wavelength difference in the load free condition, it was reduced to 0.2nm by the side loading. Applications of this technique for gain flattening filters are further works

References

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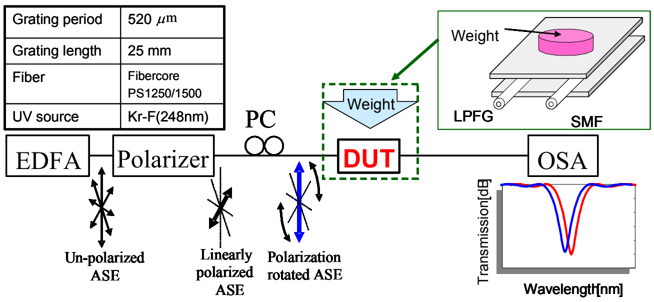

Fig.3. Experimental setup.

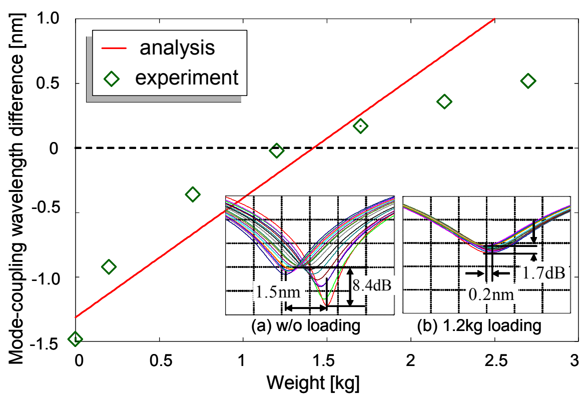

Fig.4. Changes in mode-coupling wavelength difference for two orthogonally polarized lights for side loading. Insets: (a) spectra without any loading, (b) spectra at 1.2kg loading.