12th Optoelectronics and Communications Conference/16th International Conference on Integrated Optics and Optical Fiber Communication (OECC/IOOC2007)
Technical Digest, July 2007, Pacifico Yokohama

11P-17

All-optical Variable Optical Attenuator Based on Nonlinear Optical Fiber with Fiber Bragg Grating

Seongmin Ju, Pramod R. Watekar[1], Yune Hyoun Kim[2], Taekjung Kim, and Won-Taek Han[1]

Research Center for Specialty Optical Fibers, OptoNest
958-6 Daechon-dong, Buk-gu, Gwangju, 500-470, South Korea

[1]Department of Information and Communications, Gwangju Institute of Science and Technology
1 Oryong-dong, Buk-gu, Gwangju, 500-712, South Korea

[2]Industrial Materials R&D, LG Chem. Ltd.,
Research Park, 104-1 Moonji, Yuseong, Daejeon 305-380, South Korea

Tel: 82-62-970-2215, Fax: 82-62-970-2204, E-mail: wthan@gist.ac.kr

Abstract
A novel all-optical variable optical attenuator based on a nonlinear optical fiber with fiber Bragg grating was developed with more than 35 dB variation controlled by a laser diode.

Introduction

Variable optical attenuator (VOA) in the optical communication system is a key component for gain control of optical amplifiers in dense wavelength division multiplexing (DWDM) systems and for dynamic channel power regulation and equalization in the cross-connected nodes. Also, VOA plays an important role for dynamic optical networks that perform protection and restoration the functions of the high-priced optical communication devices such as repeaters through decreasing power periodically or continuously. However, several types of the VOAs in the market suffer from disadvantages of complicated fabrication, high price, and response time. [1-5]

In the current communication, we have proposed and demonstrated, for the first time, the all-optical variable optical attenuator (AVOA) operating in the 1550 nm wavelength region based on the highly nonlinear optical (NLO) fiber, the Yb^{3+}/Al^{3+} co-doped fiber, with the fiber Bragg grating (FBG).

Experimental

A nonlinear optical fiber doped with Yb^{3+}/Al^{3+} ions was fabricated by the modified chemical vapor deposition (MCVD) and the doping solution method. The resonant optical nonlinearity of the fiber was measured using the method proposed by our group earlier and it was found to be ~ 7.5×10^{-15} m^2/W. [6]

A FBG with ~ 45dB around 1550 nm was written on the hydrogen loaded Yb^{3+}/Al^{3+} co-doped fiber by using a phase mask with the KrF excimer laser (248 nm). The maximum attenuation level, center wavelength, grating length, and bandwidth of the fabricated FBG are about 45 dB, 1549.84 nm, 1 cm, and 0.35 nm, respectively.

The experimental setup for all-optical variable attenuator is shown in Fig. 1, where the Yb^{3+}/Al^{3+} co-doped nonlinear optical fiber with FBG was spliced between two 980 nm/1550 nm wavelength division multiplexers (WDM). An ASE source was used as a signal at 1550 nm and a 980 nm laser diode (LD) as the pumping source. The total length, L_1, between two WDM couplers was 10 cm, where the length, L_2, of FBG was 1 cm. The attenuation at required wavelength was monitored using the optical spectrum analyzer (OSA, Ando AQ6317B).

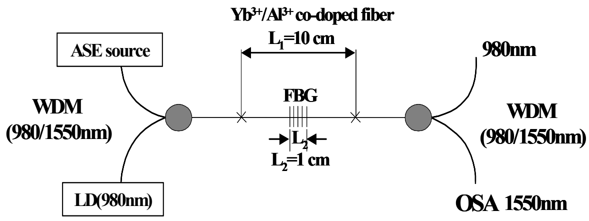

Fig. 1. Schematic diagram of the setup for all-optical variable optical attenuator.

Results and discussion

Optical transmission of the Yb^{3+}/Al^{3+} co-doped NLO fiber with FBG was measured by increasing the 980 nm LD pump power and the results are shown in Fig. 2. The transmission spectrum at the resonance wavelength formed by the FBG was found to shift towards the longer-wavelength side with the increase of the pump power. Since the transmission near 1550 nm decreased with the increase of the pump power, the maximum attenuation of about 35 dB

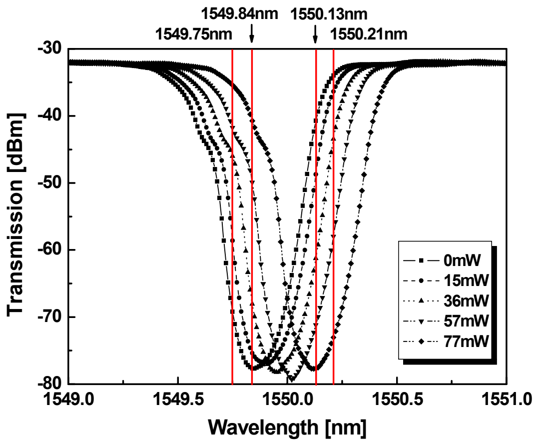

Fig. 2. Typical transmission spectra of the AVOA made by the Yb^{3+}/Al^{3+} co-doped nonlinear optical fiber with the FGB upon pumping with the LD at 980nm.

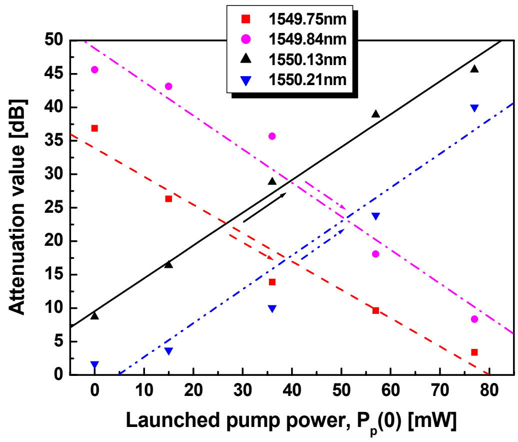

Fig. 3. Attenuation value of the AVOA made by Yb^{3+}/Al^{3+} co-doped nonlinear optical fiber with the FBG upon pumping with the LD at 980 nm.

decreased continuously to 0 dB upon pumping with the LD at 980 nm from 0 mW to 77 mW. Note that the bandwidth of reflection fringe of the FBG was maintained constant with 0.35 nm regardless of pump power. Fig. 3 shows the change in optical attenuation at different wavelengths upon LD pumping from 0 to 77 mW. The attenuation variation was found almost linear. The spectral attenuation before and after pumping is listed in Table I.

Table. 1. Variable optical attenuation at different wavelengths

Attenuation wavelength [nm]	$A/P_p(0)$		Attenuation range [dB]
	Min. $A/P_p(0)$	Max. $A/P_p(0)$	
1549.75	3.35/77	36.88/0	33.53
1549.84	8.32/77	45.62/0	37.30
1550.13	8.69/0	45.62/77	36.93
1550.21	1.67/0	40.03/77	38.36

A : Attenuation value [dB], $P_p(0)$: Launched pump power [mW]

It is easily noticed that the usable range of the present AVOA depends on the selected wavelength and the optical attenuation level depends on the LD pump power. The attenuation range of the present AVOA at 1549.75 nm was 33.53 dB from Max. 45.62 dB (0 mW) to Min. 8.32 dB (77 mW) and the attenuation range at 1549.84 nm was 37.30 dB from Max. 45.62 dB (0 mW) to Min. 8.32 dB (77 mW). On the other hand, in the case of the FBG bands located at longer wavelength, the attenuation increased with the increase of the pump power. The attenuation range at 1550.13 nm was 36.93 dB from Min. 8.69 dB (0 mW) to Max. 45.62 dB (77 mW) and that at 1550.21 nm was 38.36 dB from Min. 1.67 dB (0 mW) to Max. 40.03 dB (77 mW).

The proposed AVOA using the NLO fiber with FBG can be extended to use at various wavelength by changing the position of the FBG reflection band. In addition, the control power of the LD can be decreased by increasing the nonlinearity of the optical fiber and by decreasing the bandwidth of the FBG.

Conclusion

We have developed the novel AVOA by using the Yb^{3+}/Al^{3+} co-doped NLO fiber with the FBG. The attenuation was found to vary by pumping with the LD at 980nm and the total optical attenuation range of about 35dB was obtained near 1550nm pumped from 0 to 77 mW.

Acknowledgment

The authors are grateful to OptoNest Corporation, South Korea. This work has been supported by the GIST Technology Initiative (GTI), South Korea.

References

[1] A. Benner, H. M. Presby, and N. Amitay, J. of Lightwave Tech., Vol. 8, No. 1, pp. 7-10 (1990).
[2] K. Hirabayashi, M. Wada, and C. Amano, Appl. Opt., Vol. 40, No. 21, pp. 3509-3517 (2001).
[3] N. A. Riza and Z. Yaqoob, IEEE Photon. Tech. Lett., Vol. 13, No. 7, pp. 693-695 (2001).
[4] R. A. Soref and D. H. McMahon, Opt. Lett., Vol. 5, pp. 147-149 (1980).
[5] B. Barber, C. R. Giles, V. Askyuk, R. Ruel, L. Stulz, and D. Bishop, IEEE Photo. Tech. Lett., Vol. 10, No. 9, pp. 1262-1264 (1998).
[6] Y.H. Kim, B.H. Lee, Y. Chung, U.C. Paek, and W.-T. Han, Opt. Lett., vol. 27, no. 8, pp. 580-582 (2002).