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

12P-19

Asymmetrical Raman resonator for multi-wavelength Raman fiber laser

Young-Eun Im [(1),(2)], Swook Hann[(2)], Dong-Hwan Kim[(2)] , and Chang-Soo Park [(1)]
[(1)] School of Information and Mechatronics, GIST, Gwangju, 500-712 , South Korea
Tel: +82-62-970-3145 Fax: +82-62-970-2237, *csp@gist.ac.kr*
[(2)] Strategic technology group, Korea Photonics Technology Institute (KOPTI), Gwangju, South Korea, *swookhann@yahoo.com*

Abstract

A novel Raman fiber laser emitting three output wavelengths has been implemented using an asymmetrical Raman resonator of broadband chirped fiber Bragg grating (CFBG) and Germano-silicate Raman fiber. It is a promising solution of cost-effective and user-friendly technique to flexibly manipulate as many as output wavelengths.

Introduction

Multi-wavelength Raman fiber lasers (RFLs) for Raman amplification is a significant technique to achieve a broad and flat amplification in the long-haul wavelength-division-multiplexing (WDM) transmission systems [1]. Stimulated Raman scattering (SRS) in optical fibers shows a powerful solution to amplify optical signals and to generated new laser wavelengths, multi-wavelength RFLs using Germano-silicate fiber (GDF) or Phosphor-silicate fiber (PDF) have attracted considerable interest. Several schemes of multi-wavelength Raman lasers have been presented so far: nested cavities with six output wavelengths [2,3], cascaded fiber end reflector [4]. These methods, however, require not only a number of reflectors but also a sophisticated skill to align components in free space for achieving a multi-wavelength RFL. We chose the broadband CFBG as a wideband reflector to construct simple Raman resonator and eventually to reduce a unit cost of RFL so it would be a significant advantage to have high power RFL with well-proven reliability and mass-productivity.

In this paper, a novel and cost-effective technique has been proposed to enhance the multi-wavelength RFL in the long-wavelength spectral range of 1400 nm band by using the broadband CFBG reflector, for the first time to the best knowledge of the authors.

Experiment result and Discussions

The three-output asymmetrical RFL is shown schematically in Fig. 1. Ytterbium double-clad fiber laser (Yb-DCFL) with the maximum power of 17.6 W at 1070.8 nm is used as a pump source. The gain medium, GDF has a 23 mol % of GeO_2, the Raman cross section of the fiber yields a high Raman gain coefficient of 22 dB/kmW at 1310 nm. The fiber has a refractive index difference, $\Delta n \approx 0.032$, LP_{11} mode has a cutoff around 900 nm, and a background loss of 1 dB/km at 1480 nm. Considering the Stokes shift of GDF, to build the triple RFL in 14xx nm, fourteen FBGs are needed. In Fig. 1, discrete FBGs (DFBGs) with high reflection values are a function of threshold power reduction for Raman stokes shift. Four successive Raman shifts, 1124, 1184, 1247, and 1320 nm are generated.

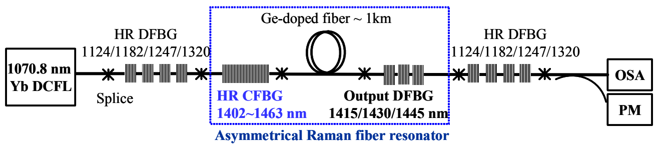

Fig. 1 *Asymmetrical Raman fiber resonator for three-wavelength RFL, DFBG: discrete FBG, CFBG: chirped FBG.*

In order to reduce the number of reflectors, we configured asymmetrical Raman resonator using the broadband CFBG instead of HR DFBG in the reflection part. A fabricated CFBG is a role of assembly DFBGs, whose reflection and transmission spectra are shown in Fig. 2. The CFBG was written in the SMF-28 in this experiment over high reflectivity, 99.9% in the wavelength range, 1402 to 1463 nm. We have designed

CFBG which is equal to the center wavelength of fifth stokes wave and the output wavelength of RFL is aimed at the S and C band for telecommunications. The maximum gain for the last Stokes (at 1320 nm) is at 1400 nm. Consequently, 1400 nm can transfer efficiently part of its energy to the last output wavelength (at 1460 nm).

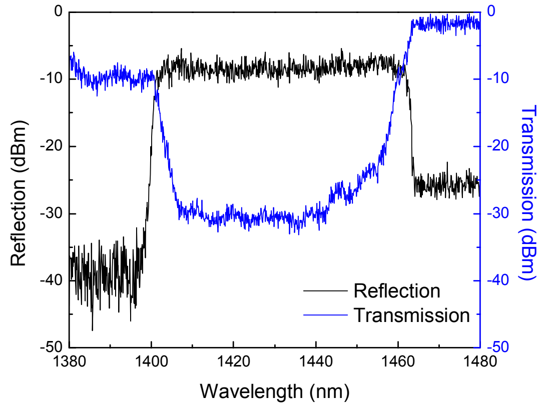

Fig. 2 *Measured reflection and transmission spectra of broadband CFBG.*

Based on above results, asymmetrical Raman resonators with three wavelength outputs RFL were experimented. Output wavelengths have been chosen for 1415, 1430, and 1445 nm, their relative reflection values are 35, 70, and 30 %, respectively. The measured RFL spectra are shown in Fig. 3 (a) by adjusting pump power of 9.98 W at 1400 nm. Three lasers, 1415, 1430, and 1445 nm were sequentially generated at a threshold power of 3.93, 4.47, and 8.36 W, respectively. A total output power of about 1.02 W at 1400 nm with 15.5 % of slope efficiency. Note that the output spectrum is a little different ASE level in the center of 1400 nm compared to the symmetrical Raman fiber laser due to the unbalanced reflection of broadband CFBG. Three lasers are competed with each other in the fixed cavities with dissimilar reflection in their output reflectors. Output characteristics of RFL with respect to the input pump power are presented in Fig. 3 (b). Note that 1430 and 1445 nm outputs are higher than that of the 1415 nm including slope efficiencies. Although this laser showed lower output and efficiency compared to the symmetrical Raman resonator, we are convinced that it will be improved the efficiency of laser through the refinement of CFBG.

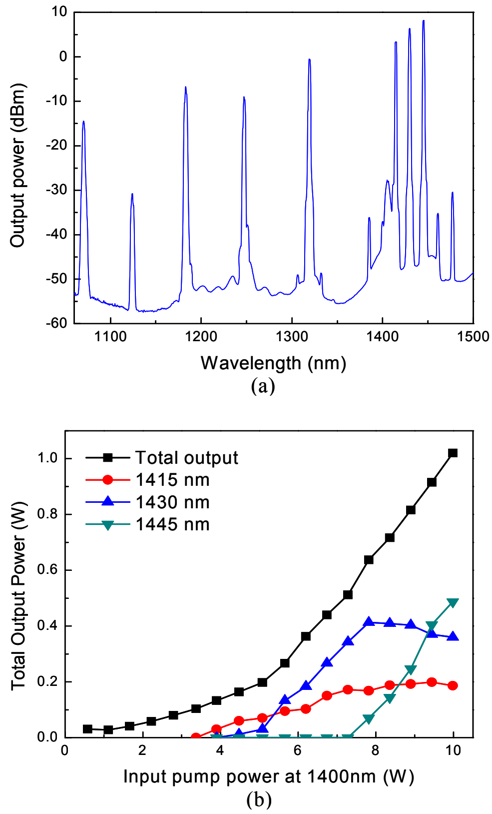

Fig. 3 *(a) Asymmetrical three-wavelength RFL spectra at input pump power 9.98 W at 1400 nm (b) RFL characteristics.*

Conclusions

In summary, we proposed a novel asymmetrical Raman resonator to enhance the multi-wavelength RFL in the spectral range 1402 nm to 1463 nm by using the broadband CFBG. Total output power of laser can be obtained 1.02 W and the pump conversion efficiency of laser is calculated about 15.5 %. The proposed method can provide a strong potential to inherently enhance the laser characteristics and expand its applications.

References

[1] Agrawal, Fiber Optic communication systems, Jon Wiley, New York.

[2] M. D. Mermelstein, et al, "Six wavelength Raman fiber laser for C+L band Raman amplification," CLEO 2002, CThJ1.

[3] F. Leplingard, et al, "Six output wavelength Raman fiber laser for Raman amplification," ECOC 2002, paper 4.1.2.

[4] Y. Zhao, et al, "Grating-free nth order Raman fiber lasers using Ge-doped highly Ge-doped low loss fiber," Vol. 12, No. 17, Optics Express, Aug. 23, 2004.