A C- or C+L-Band Selectable ASE Source Using the Backward Feedback Technique with an Optical Switch

Wang Xiulin[1]　Huang Wencai[2]　Cai Zhiping[2]

([1] *Department of Physics, Jimei University, Xiamen, Fujian* 361021, *China*
[2] *Department of Electronic Engineering, Xiamen University, Xiamen, Fujian* 361005, *China*)

Abstract　A band selectable amplified spontaneous emission (ASE) source of an erbium-doped fiber (EDF) which can operate in either the C- or the C+L-band region is proposed and demonstrated. The band selectable ASE source is realized using the backward feedback technique with a 1×2 optical switch in a bi-directional pumping configuration. The 25.9 mW C-band and 22.5 mW C+L-band ASE spectra are alternately obtained merely by controlling the state of the optical switch.

Key words　fiber optics; fiber light sources and detectors; amplified spontaneous emission source; erbium-doped fiber

OCIS codes　060.2380; 140.6630; 060.2410

基于光开关和后向反馈技术的C或C+L波段可选择的ASE光源

王秀琳[1]　黄文财[2]　蔡志平[2]

([1] 集美大学物理系，福建 厦门 361021
[2] 厦门大学电子工程系，福建 厦门 361005)

摘要　研究了一种能够工作在C波段或C+L波段的带宽可选择的掺铒光纤放大自发辐射(ASE)光源。该光源采用双向抽运结构，并通过利用后向反馈技术结合光开关来实现波段选择。实验表明仅通过控制光开关的工作状态就可以交替获得25.9 mW的C波段和22.5 mW的C+L波段ASE谱。

关键词　光纤光学；光纤光源与探测器；放大自发辐射光源；掺铒光纤

中图分类号　TN253　　**文献标识码**　A　　**doi**：10.3788/LOP49.120601

1　Introduction

The amplified spontaneous emission (ASE) incoherent broadband light source based on erbium-doped fiber (EDF) has been the best alternative to the component testing and spectrum sliced sources in dense wavelength division multiplexing (DWDM) systems[1]. The use of ASE source for erbium-doped fiber amplifier (EDFA) characterization, optical sensing and fiber optic gyroscope[2~4] has further emphasized its importance. In the past decades, various configurations of ASE source based on EDF have been proposed and investigated with the aim to improve its performance parameters such as operating bandwidth, mean wavelength stability, power density and conversion efficiency to meet the application requirements. The ASE sources operating at C-, L-, and C+L-band have achieved much success[5~9]. To extend the application for selectable upstream or downstream spectrum-sliced coarse wavelength devision multiplexing (CWDM) transceivers in emerging metro networks, the C- or L-band selectable ASE source by using optical switch was recently proposed[10,12]. In Ref. [13], a band selectable broadband loop ASE source was demonstrated operating in C-, L-, or C+L-band using seed signal injection. In this paper, we propose and demonstrate an ASE source configuration that utilizes the backward ASE feedback technique to enable it

收稿日期：2012-06-27；**收到修改稿日期**：2012-07-11；**网络出版日期**：2012-10-19

基金项目：福建省自然科学基金(2011J01368)资助课题。。

作者简介：王秀琳(1974—)，女，博士，副教授，主要从事光纤通信器件与技术等方面的研究。
E-mail：wanxl@jmu.edu.cn

to operate in a selectable C- or C+L-band region with the use of a 1×2 optical switch and a fiber loop mirror. This band selection using ASE feedback technique provides users the necessary C- or C+L-band ASE source with nearly equal output powers and it is very easy to realize as well because no upgrading or additional module attachment is required.

2 Experimental setup

The schematic diagram of the band selectable ASE source design is shown in Fig. 1. The configuration consists of a piece of EDF bi-directionally pumped by two 980-nm laser diodes (LD) via two 980/1590 wavelength division multiplexers (WDMs), and a 1 × 2 optical switch that switches the backward ASE_1^- generated by LD1 to either a fiber loop mirror or to the 50:50 power coupler, which also couples the ASE_2^- to the output port of the source. The fiber mirror is self-made from a broadband 3-dB fiber coupler that can feedback the whole spectrum of ASE_1^-. An optical isolator at the output port is used to prevent any backward reflection that might cause undesired oscillation within the gain medium (EDF).

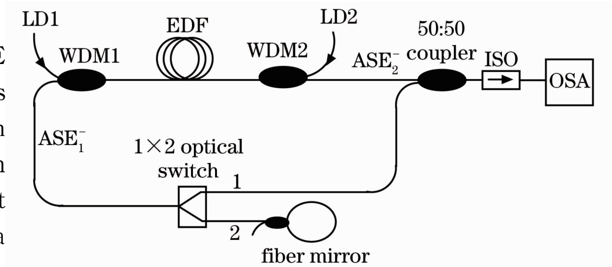

Fig. 1 Schematic of the selectable C- or C+L-band ASE source; 1,2: optical-switch ports; ISO: isolator; OSA: optical spectrum analyzer

Therefore, the ASE source can operate at two selectable band regions, namely, the C-band and the C+L-band. The operating band at the output of the ASE source is merely determined by the operation state of the 1×2 optical switch. The principle of the band selection can be described as follows. When the optical switch is switched to port 1 (termed the non-feedback system), the output of the design is then a combination of the two backward ASEs (ASE_1^- and ASE_2^-). In this state, the output spectrum is expected to be operated in C-band region. Whereas, when the optical switch is switched to port 2 (termed the feedback system), the backward ASE_1^- generated by the LD1 pump is reflected back by a fiber mirror to the EDF. Namely, the ASE configuration becomes a double-pass bi-directional pumping configuration which is expected to be operated in the C+L-band. That is to say, by switching the optical switch from port 1 to port 2, the operational band of the ASE source will be selected between C-band and C+L-band. Namely, the C-band ASE is obtained without backward ASE feedback while the C+L-band ASE is obtained with the backward ASE feedback.

3 Results and discussions

As mentioned above, the ASE source operates in C-band with the switch at port 1 and in C+L-band with the switch at port 2, as shown in Fig. 1. Therefore, in order to let the configuration operate in either C-band or C + L-band by controlling the state of optical switch, the pump powers of LD1, LD2, and the fiber length of EDF should be chosen properly. In this configuration, the Lucent LRL EDF with a peak absorption of 27～33 dB/m at 1530 nm, mode field radius of 5.2 μm, cutoff wavelength of 1100～1400 nm, and numerical aperture of 0.25 is used in experiment. The OASIX software is firstly used to optimize the parameters of pump powers of LD1, LD2, and the fiber length of EDF. The aim of the simulation is to achieve a flat C+L-band ASE spectrum with the switch at port 2. Furthermore, the pump power of LD1 is as low as possible. The EDF length of 18 m, $P_{LD1}=13$ mW and $P_{LD2}=80$ mW are chosen for the ASE configuration by the simulation. Figure 2 shows the calculated output C-band (curve a) and C+L-band (curve b) ASE spectra with the switch at port 1 and port 2, respectively.

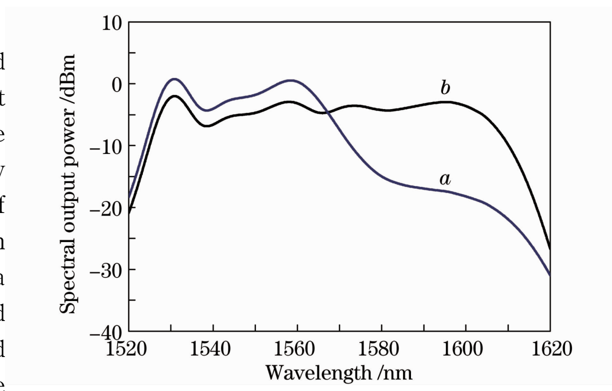

Fig. 2 Calculated C-band and C+L-band ASE spectra

The optical switch was firstly set at port 2 and the power of LD2 was fixed at 80 mW in the experiment. The power of LD1 was adjusted to 15 mW to achieve a flatest output ASE spectrum in C+L-band. The measured output spectrum of the selectable ASE source is shown in Fig. 3. When there is no feedback (i.e., the optical switch is switched to port 1), the output ASE is in the C-band region, as most of the output spectrum power is from ASE_2^-. As a comparison, to observe the ASE_1^- for the non-feedback system, the output for this system was measured with the switch at port 1 and the connection between the 50∶50 coupler and the switch disconnected, thus enabling ASE_1^- monitoring. The measured spectrum of ASE_1^- is also shown as curve b in Fig. 3. Since the power of LD1 is only 15 mW, the power density of the ASE_1^- is low, so that there is no significant effect on the C-band ASE output generated by the backward ASE (ASE_2^-). The overall ASE output of the non-feedback system is then on C-band, as shown as curve a in Fig. 3. The output power of the C-band ASE was measured to be 25.9 mW.

When the optical switch is switched to port 2, the ASE_1^- is fedback to the gain medium (EDF). The measured result of the output spectrum is shown as curve a in Fig. 4. We can see that the output ASE spectrum falls on C + L-band. With regard to the feedback system, we measured the output ASE spectrum with the switch at port 2 and the pump of LD2 is disconnected, as shown as curve b in Fig. 4. Since the length of EDF is 18 m and the power of LD1 is only 15 mW, the output spectrum falls on the L-band and is weak because of low average inversion level of erbium ions. With the pump of LD2 of 80 mW simultaneously, the weak L-band ASE is substantially amplified and the C-band ASE will be slightly reduced. Thus, the overall output of the feedback system is a result of a balance of C-band and L-band ASE, as shown as curve a in Fig. 4. The output power of the flat C + L-band ASE was measured to be 22.5 mW.

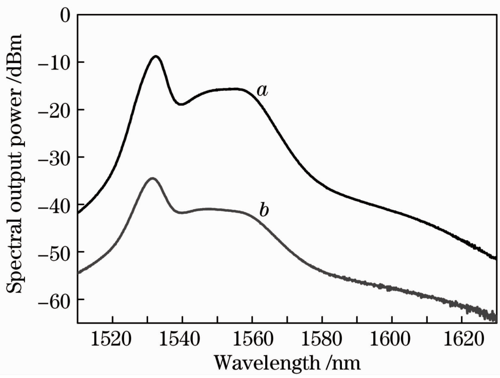

Fig. 3 Measured output ASE spectra for different conditions with the switch at port 1

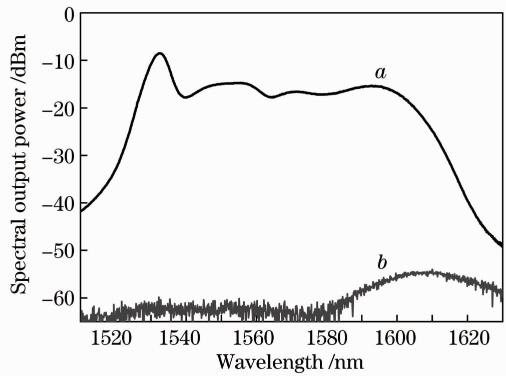

Fig. 4 Measured output ASE spectra for different conditions with the switch at port 2

As compared with the ASE source demonstrated in Ref. [11], the EDF is bi-directionally pumped by two 980-nm pump lasers in our design instead of merely pumped by one 980-nm pump laser with forward configuration. Since the one-stage bi-directionally pumping configuration has the good efficiency and simple structure to achieve a flat C + L-band ASE, the ASE source we propose here can provide a better ASE spectrum operation either in C-band or C + L-band region. We believe that it is useful for DWDM device characterization and for selectable upstream or downstream spectrum-sliced CWDM transceivers in the emerging metro networks.

4 Conclusion

In conclusion, we have experimentally demonstrated a band-selectable ASE source that is able to operate in either the C- or C + L-band region using the backward feedback technique. The operational band of the ASE source depends on the state of a 1 × 2 optical switch. C-band operation is obtained without backward ASE feedback, whereas C + L-band operation is obtained with backward ASE feedback. The C-band ASE spectrum of 25.9 mW and C + L-band ASE spectrum of 22.5 mW are obtained with simple control of the state of the optical switch, respectively.

References

1 J. S. Lee, Y. C. Chung, D. J. Digiovanni. Spectrum-sliced fiber amplifier light source for multichannel WDM applications [J]. *IEEE Photon. Technol. Lett.*, 1993, **5**(12): 1458～1461

2 M. E. Bray, R. T. Elliot, K. P. Jones. Comparison of erbium amplifier measurement using a high power amplified spontaneous emission source or using an ITU grid [C]. OFC, 2001. WI2

3 P. F. Wysocki, M. J. F. Digonnet, B. Y. Kim. Characteristics of erbium-doped superfluorescent fiber sources for interferometric sensor applications [J]. *J. Lightwave Technol.*, 1994, **12**(3): 550～567

4 C. D. Su, L. A. Wang. Multiwavelength fiber sources based on double-pass superfluorescent fiber sources [J]. *J. Lightwave Technol.*, 2000, **18**(5): 708～714

5 L. A. Wang, C. D. Chen. Stable and broadband Er-doped superfluorescent fiber sources using double-pass backward

configuration [J]. *Electron. Lett.*, 1996, **32**(19): 1815～1817
6 J. H. Lee, U. C. Ryu, N. Park. Passive erbium-doped fiber seed photon generator for high power Er^{3+}-doped fiber fluorescent sources with an 80 nm bandwidth [J]. *Opt. Lett.*, 1999, **24**(5): 279～281
7 R. P. Espindola, G. Ales, J. Park. 80 nm spectrally flattened high power erbium amplified spontaneous emission fiber source [J]. *Electron. Lett.*, 2000, **36**(5): 1263～1265
8 W. C. Huang, H. Y. Tam, P. K. A. Wai. A novel conventional/long-band erbium-doped fiber ASE source with 80 nm bandwidth [J]. *Chin. Phys. Lett.*, 2002, **19**(9): 1037～1038
9 S. C. Tsai, T. C. Tsai, P. C. Law. High pumping-efficiency L-band erbium-doped fiber ASE source using double-pass bidirectional-pumping configuration [J]. *IEEE Photon. Technol. Lett.*, 2003, **15**(2): 197～199
10 W. C. Huang, H. Ming, Z. P. Cai. A selective C and L-band amplified spontaneous emission source using a 1×2 optical switch [J]. *Chin. Phys. Lett.*, 2005, **22**(4): 887～888
11 V. Sinivasagam, K. Dimyati, R. D. Singh. Band selection in an amplified spontaneous emission source using the backward-feedback technique [J]. *Microwave and Optical Technology Lett.*, 2005, **46**(3): 218～220
12 X. L. Wang, W. C. Huang. Band-selective C- or L-band erbium-doped fiber amplified spontaneous emission source [J]. *Opt. Eng.*, 2006, **45**(2): 020501
13 A. Altuncu. Band selection in broadband loop ASE source using seed signal injection [J]. *IEEE Photon. Technol. Lett.*, 2006, **18**(9): 1043～1045