Multi-wavelength Tunable Optical Amplifier and Filter

by Electrical Pulse Signal Modulation into Laser Pumping of EDFA

การขยายและกรองสัญญาณทางแสงหลายย่านความยาวคลื่นด้วยเส้นใยแก้วนำแสงที่เจือด้วยเออร์เบียม
โดยการมอดูเลตสัญญาณพัลส์ให้กับเลเซอร์ปั๊ม

ปรเมษฐ์ จันทร์เพ็ง และ เสกสรร สุขะเสนา

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Abstract

งานวิจัยนี้เป็นการศึกษาและพัฒนาการขยายและกรองความยาวคลื่นแสงแบบหลายย่านความยาวคลื่นด้วยเส้นใยแก้วนำแสงที่เจือด้วยเออร์เบียม โดยการศึกษานี้ใช้อุปกรณ์เพียงน้อยชิ้นเพื่อทำการสืบสาวถึงผลกระทบของการนำสัญญาณพัลซ์มาทำการมอดูเลตให้กับเลเซอร์ที่ใช้ปั๊มให้กับเส้นใยแก้วนำแสงที่เจือด้วยเออร์เบียม จากการทดลองพบว่าสัญญาณแสงที่ผ่านเข้ามาในเส้นใยแก้วนำแสงนี้สามารถจะเลือกให้มีการส่งผ่านสัญญาณหรือลดทอนช่วงสัญญาณทางแสงได้ด้วยการควบคุมความถี่ที่มอดูเลตให้กับเลเซอร์ปั๊ม ผลที่ได้จากการศึกษานี้จะมีค่าที่สามารถปรับจูนได้อยู่ในช่วง 1-5 นาโนเมตร โดยการมอดูเลตความถี่ในช่วง 0-100 เฮิร์ตซ์ มีค่ากำลังขยายสัญญาณทางแสงสูงสุดที่ 0.63 มิลลิวัตต์ ที่กำลังเลเซอร์ที่ใช้ปั๊ม 50 มิลลิวัตต์ และสามารถลดกำลังแสงลงได้ถึง -43 เดซิเบล

We set up an experiment with a minimal number of equipment, to investigate the available properties of optical amplifier and filter by using the Erbium Doped Fiber Amplifier (***EDFA***) to modulate pulse signal into the laser pumping. The channels of light can be chosen to transmit or distort the optical signal by using frequency modulated light source to pump the ***EDF***. The wavelength spacing could be tuned to be about 1-5 nm by adjusting the range of frequencies from 0-100 Hz. The maximum optical output power with amplifier is 0.63 mW at the pumping power of 50 mW while the distortion of the light after passing through ***EDF*** is -43 dB.

KEYWORDS: Erbium-Doped Fiber Amplifier (***EDFA***), ***WDM***, Multi Wavelength Laser.

คำสำคัญ : เส้นใยที่เจือด้วยเออร์เบียม, การแบ่งคลื่นเป็นช่วงๆ, เลเซอร์หลายความยาวคลื่น

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Introduction

The **E**rbium **D**oped **F**iber **A**mplifier (**EDFA)** has been actively used in many applications, especially in the field of communication, optical fiber laser or as a component of the measurement devices (Quan *et al*., 2015; Choia *et al*., 2002; Mahdi *et al*. 2001; Marques *et al*., 2012; Chen *et al*., 2003). There are many advantages, in the field together, i.e., it has low noises, high gain bandwidths and amplifying multi channels on different wavelengths (Singh *et al*., 2013). (This is because the **EDFA** wavelength ranges in the **C-Band** and **L-Band**). In some research the wavelengths are supposed to be amplified for particular wavelength. So creating such a tunable fiber laser source, the wavelength can be adjusted (Choi and Kwon, 2013; Qian *et al*., 2015; Mo *et al*., 2014) and it is a crucial part in present day experiments.

In this paper, there is a requirement to filtering and amplifying the wavelength signal. Therefore, it is necessary to use the device of selecting the filter as Mach-Zehnder Interferometer **(MZI)** optical grating or fiber optic ring resonator (Mo *et al*., 2014; Razak *et al*. 2015), and so on. In this research, we have taken the **EDFA** as an important part to be used in the design of the optical signal amplifying and filtering. The selective ability of the wavelength of the desired amplifying or filtering, by means of a modulation pulse signal, is applied to the laser pumping source providing the signal for the **EDFA**. This approach is to show that using a few optical devices, as a result [Figs.4 and 5], the lighting system is cheaper and easier to prepare and to manipulate [Fig.1].

Experimental setup and results

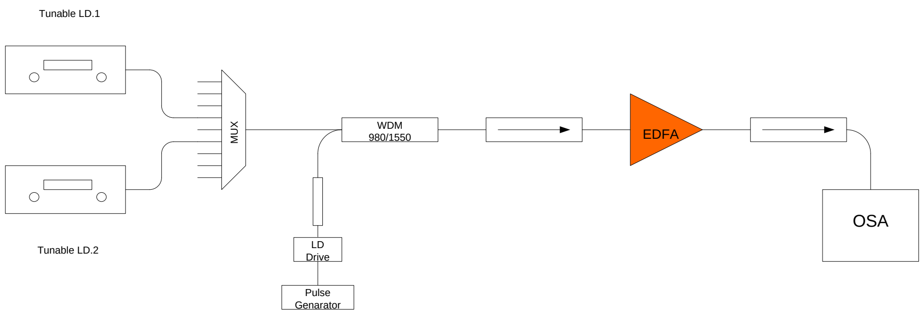


Fig.1 The Experimental setup of tunable amplifier and filter by modulation pulse signal into the laser pumping.

The experimental setup of the multi-wavelength tunable optical amplifier is illustrated in Fig. 1. The laser output of tunable laser diode 1 and 2 (Tunable LD.1, LD.2) are launched into the wavelength division multiplexer (**MUX**) by using Fiber-optic connector **(FC)** connector with the output power 0.16 mW and wavelength at 1,546 and 1,547.6 nm respectively. The output of **MUX** is fusion spliced to end arm of 1,550 nm at WDM 980/1550. The 980 input port of WDM 980/1550 is spliced to fiber pigtailed 980 nm laser diode to be a pumping source for the EDFA. At the output port of this WDM is spliced to optical isolator for improving the noise figure return to the laser diode (LD.1, LD.2 and LD. pump). The output port of optical isolator is also spliced to the **EDFA** provided a 20 meters long. At another end of **EDFA**, it is spliced to the optical isolator, again for protecting the noise return to **EDFA**. The output port of the second optical isolator is connected to the **O**ptical **S**pectrum **A**nalyzer (**OSA**.) by **FC** connector, for analyzing the optical output signal. The pumping laser (LD. pump) have been controlled by laser diode driving and modulation circuit (LD. Drive). In the part of modulation circuit, we used the electrical pulse generator to generate the modulation pulse signal into the laser pump.

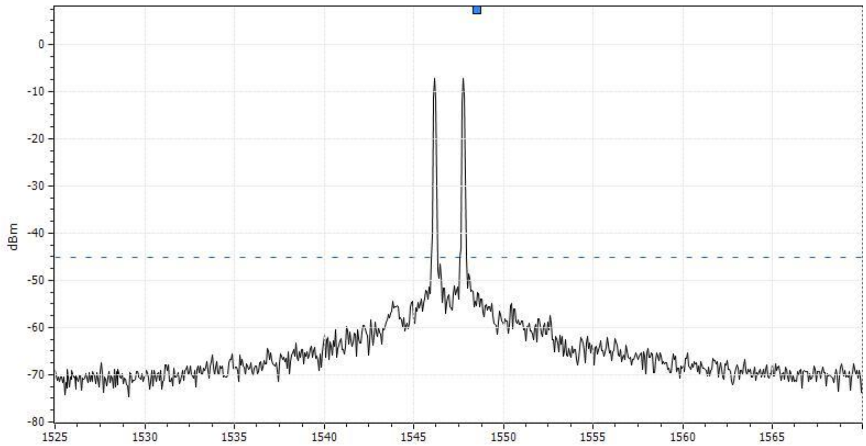


Fig. 2 Spectrum of tunable laser (LD1 and LD2) with multiplexing by MUX.

The modulator (**Mod**.) is used to modulate the pulse signal by using the pulse generator to control the current in laser diode with the frequency pulse varying from 10 Hz to 100 Hz in the step of 5 Hz.

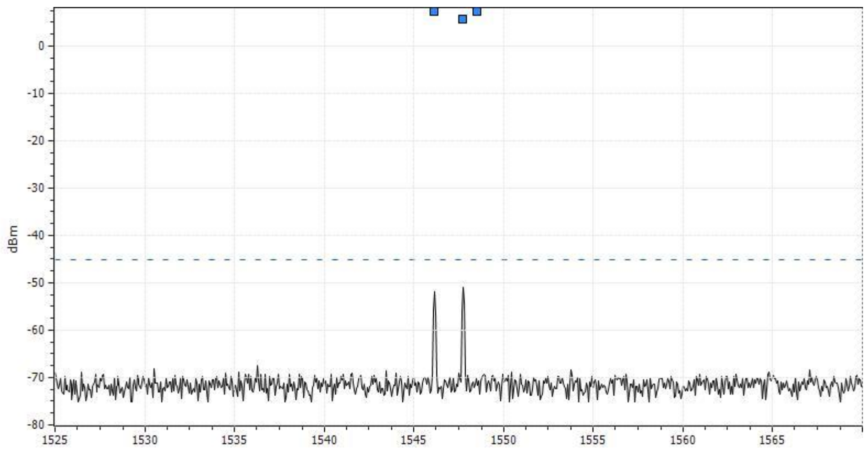


Fig.3 Result of spectrum after passing EDF without laser pumping.

The operational principle of tunable optical amplifier and filter by **EDFA** relies on the result of low frequency to modulation pulse signal into laser pumping at 0 to 100 Hz. First of all we measured the spectrum after LD.1 and LD.2 multiplexing by **MUX** and then measured at the output port of MUX by using the **OSA**. The result of multiplexing is illustrated in Fig. 2. The wavelength spacing of our experiment is 1.6 nm and the **maximum output power** is -7 dBm. After measuring the optical multiplexing, we spliced the **output port** of MUX into the EDFA system and then measure the output spectrum and its power at the output port of optical isolator 2^{nd} , the result is shown in Fig. 3. The results of this experiment showed that the optical fiber can filter with attenuation of optical signal at -43 dB.

For the next experiment, we modulate the electrical pulse signal into the laser pumping from 0 to 100 Hz by increasing the frequency in every 5 Hz at the output power of the laser 50 mW. Fig. 4 showed the output spectrum of non-modulation signal (0 Hz), the output power from LD.1 and the LD.2 is about -5 dBm.

The results of modulation signal into the laser pumping are shown in Fig. 5. Fig.5(a) illustrated the spectrum of the light source with modulation pulse signal at 30 Hz, from the LD.1, the light source is distorted to -33 dB and the LD.2 is amplified to 5.98 dB. The optical power with modulation at 45 Hz with amplifier at channel 1 (LD.1) and filter channel 2 (LD.2) is shown in Fig.5(b) where the amplifier is 6.90 dB and loss to -26 dB. Fig.5(c) showed the spectrum with frequency 80 Hz, in this frequency modulation the **EDFA** is filtering wavelength from LD.1 and LD.2 with distortion at -19.00 dB and -13.00 dB respectively. The modulation pulse signal at 95 Hz gives the output power and booth amplifier to 4.98 dB as shown in Fig.5(d).

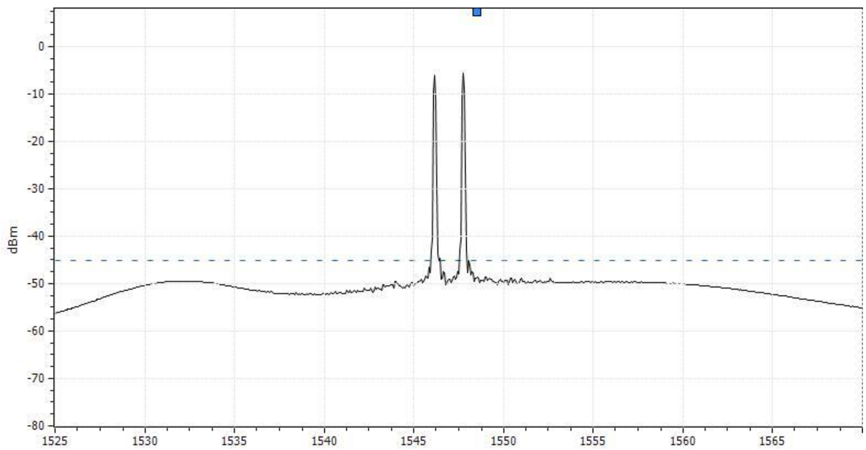
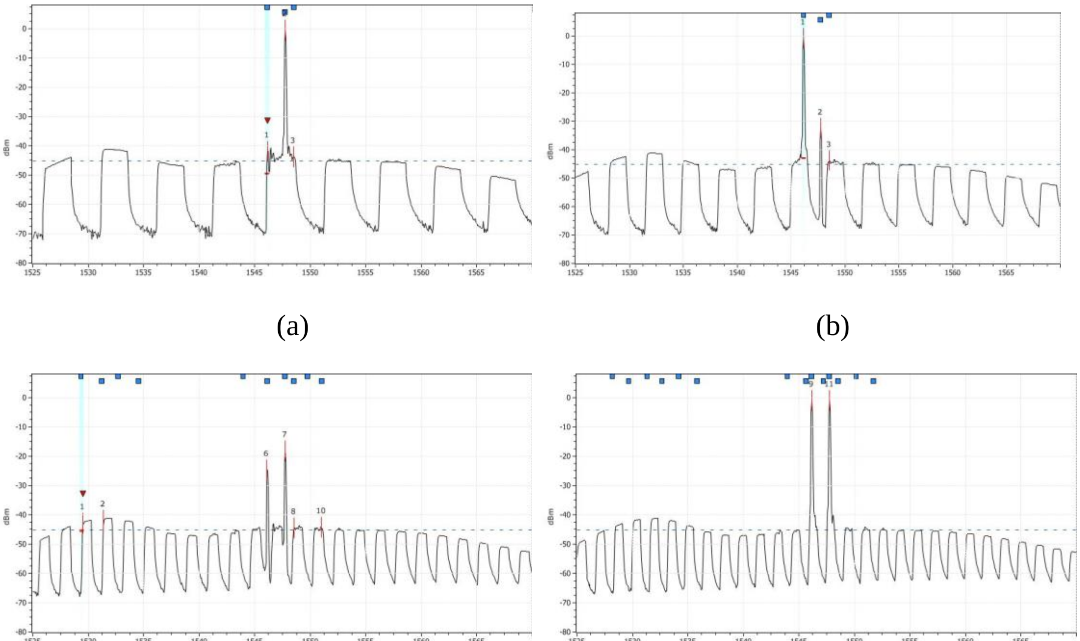


Fig.4 Spectrum of light signal with laser pumping at 50 mW with non-modulation pulse signal (0 Hz).



(a) (b)

(c) (d)

Fig 5. Spectral response of EDF with modulation pulse signal at frequencies (a) 30 Hz, (b) 45 Hz, (c) 80 Hz and (d) 95 Hz respectively.

The wavelength spacing of **EDFA** with modulation pulse signal is shown in Fig.6. This result shows the frequencies which are modulated and compared to the spectral range for being choices to selective range of amplifier and filter.

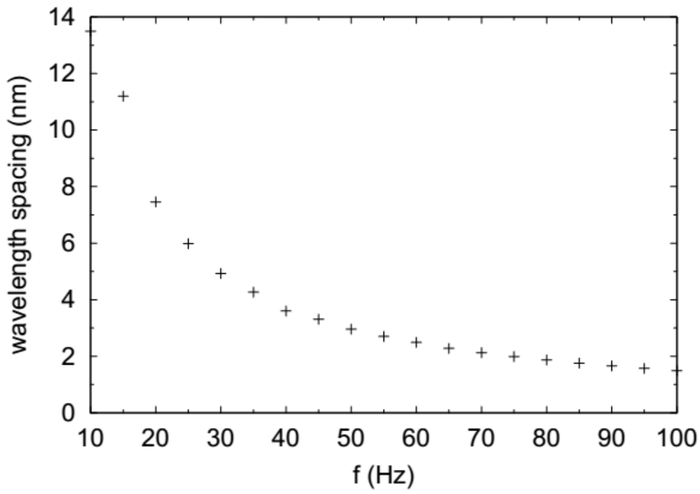


Fig.6. The wavelength spacing versus pulse signal with modulate in the laser pumping.

Discussion and Conclusion

The multi-wavelength tunable optical amplifier and filter by modulating pulse signal into the laser pumping is reported. The spectrum for amplifier and filter was tuned by adjusting the frequency modulation. The tuning range on this experiment of 1 nm is obtained. In future investigations, improvement in the range of tuning may be obtained by using High frequency laser diode driving and modulation circuits. The devices for demonstration in this research is simple for setting up. Moreover it is easy to select the group of wavelength for filtering and amplifying in all of the Erbium window (C-band).

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References

[1] Quan, M., Li, Y., Tiann, J., Yao, Y. 2015. Multifunctional tunable multiwavelength erbium-dopedfiber laser based on tunable combfilter and intensity-dependent loss modulation. Optics Communications 340, 63–68.

[2] Choia, H.B., Oh, J.M., Lee, D., Ahn, S.J., Park, B.S., Lee, S.B. 2002. Simple and efficient L-band erbium-doped fiber amplifiers for WDM networks. Optics Communications 213, 63–66.

[3] Mahdi, M.A., Mahamd Adikan, F.R., Poopalan, P., Selvakennedy, S., Ahmad, H. 2001. A novel design of bi-directional silica-based erbium-doped fiber amplifier for broadband WDM transmissions. Optics Communications 187, 389-394.

[4] Marques, C. A. F., Oliveira, R. A., Pohl, A A. P., Nogueira, R. N. 2012. Adjustable EDFA gain equalization filter for DWDM channels based on a single LPG excited by flexural acoustic waves. Optics Communications 285, 3770–3774.

[5] Chen, H., Leblanc, M., Schinn, G.W. 2003. Gain enhanced L-band optical fiber amplifiers and tunable fiber lasers with erbium-doped fibers. Optics Communications 216, 119–125.

[6] Singh, S., Singh, A., Kaler, R.S. 2013. Performance evaluation of EDFA, RAMAN and SOA optical amplifier for WDM systems. Optik 124, 95–101.

[7] Choi, B.-H., Kwon, Il-B. 2013. A wide tunable fiber laser for two independent C-band and L-band wavelengths. Optics Communications 286, 156–160.

[8] Qian, L., Fen, D., Xie, H., Sun, J. 2015. A novel tunable multi-wavelength Brillouin fiber laser with switchable frequency spacing. Optics Communications 340, 74–79.

[9] Mo, B., Zhong, R., Wan, Z. 2014. Line width analysis of a tunable optical filter based on free-space optics. Optik 125, 6488–6490.

[10] Razak, N.F., Ahmad, H. , Zulkifli, M.Z., Muhammad, F.D., Munajata, Y., Harun, S.W. 2015. Single mode EDF fiber laser using an ultra-narrow bandwidth tunable optical filter. Optik 126 179–183.