Journal of Engineering Research and Education
Vol. 7 (2013) 59-67

Characterize Raman amplification at L-band wavelength utilizing Non-Zero Dispersion Shifted Fiber LEAF ® optical fiber as gain medium

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ABSTRACT

In this project, the characterization of L-band Raman amplifier by utilizing Non Zero Dispersion Shifted Fibre LEAF ® optical fiber was studied. The effect of Stimulated Raman Scattering effect was observed upon injection of various Raman pump unit power and laser sources power to the system. Based on the experiment, it shows that at 1584.89 mW and 1778.27 mW, the RPU power at 1480 nm was oscillated to the L-band wavelength region at 1580 nm. Maximum output peak power was found at injected RPU power of 1584.89 mW. Meanwhile, at 1580 nm injected laser source power of 0.04 mW, 0.4 mW, 1.58 mW and 2. 51 mW, the amplified power was obtained at 0.36 mW, 2.54 mW, 3.0 mW and 3.65 mW. Furthermore, the variation of RPU power and laser power value affect the amplification of peak power whereby the maximum value of power led to the increment of peak power.

Keywords: *Raman, amplifier, Amplified Spontaneous Emission, Stimulated Raman scattering, Spontaneous Raman scattering, NZ-DSF LEAF ® optical fiber.*

INTRODUCTION

Recently, Raman amplification is the most practical type of light amplification [1, 2]. Raman amplification has several advantages such as self-phase matching between the pump and the signal, broad bandwidth or high speed response, improved noise figure and improved gain flatness [3]. The applications of Raman amplification is the broadband transmission using wavelength division multiplexing (WDM) and in a long haul optical telecommunications [4] had been widely study for several continues years.

Moreover, the employment of dense WDM in optical communication system has increased the demand for more bandwidth [4, 5]. The foremost option is the additional of the L-band transmission window, which is from 1567 nm to 1610 nm. The consumption of Raman amplifier in optical communication system by employing the L-band transmission window has eliminated few drawbacks of C-band region optical communication system especially four-wave mixing effects [6]. However, the performance of Raman amplification is based on Raman scattering in the optical fiber but depends on the glass materials [7]. Raman scattering is a very important non-linear effect whereby it will be dominant at high power. [8, 9, 10]. Raman Scattering process is caused by the light interaction with vibrational modes of molecules of lattice crystals [11]. This inelastic process occurs when a pump photon, excites a molecule up to a virtual level (intermediate state). A molecule finally drops to a lower energy level and emitting a photon signal. There are two types of Raman scattering: Spontaneous and Stimulated.

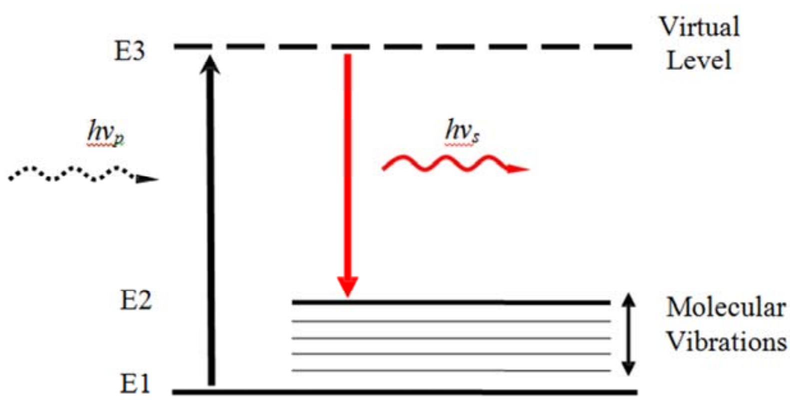

Figure 1: Energy diagram of Stimulated Raman Scattering [10]

Spontaneous Raman scattering occurs if the intensity of the incident field is below threshold level [12]. In this condition, photon are scattered randomly. In this situation, a photon signal reduced energy, created spontaneously when a pump photon of energy is lift to a virtual energy level [13,14]. Meanwhile, Stimulated Raman scattering (SRS) only occur when the pump power exceeds a certain threshold level. The process of Raman scattering is illustrated in Figure 1. This effect is due to a transition of incident photon energy by a molecule from ground energy level (E1) to the virtual energy level (E3), from which it immediately returns to a final energy level (E2) or molecular vibration level emitting a photon with different energy. The molecular vibration level is a vibration mode of the material. The energy difference between the ground energy level (E1) and the final level (E2) of the molecule is changed to a phonon which is a vibration mode of the material.

In this paper, the characteristics of Raman amplifier at L-band wavelength utilizing 20 km long of Non-Zero Dispersion Shifted Fiber (NZ-DSF) LEAF ® optical fiber as gain medium was investigated. NZ-DSF LEAF ® optical fiber have adaptability of a Raman amplifier, improvement of dispersion compensator, low dispersion slope and providing a tremendous performance for WDM with the ability to reduce non-linear effects [15, 16]. It is worthy to note that Raman signal has high efficiency with respect to gain medium. At injected laser sources power of 0.15 mW, 0.4 mW, 0.63 mW, 1mW, 1.58 mW and 1.99 mW, the peak power or amplification power was obtained at 2.05 mW, 2.54 mW, 2.75 mW, 3.0 mW and 3.27 mW, respectively. Since the length of NZ-DSF LEAF ® optical fiber is 20 km, we need high injected RPU power to produced amplification effects. Due to the lengthy size of NZ- DSF LEAF ® optical fiber , the high injected Raman pump unit (RPU) power is needed prior to produce high amplification effects.

CONFIGURATION

Figure 2 shows a Raman amplifier at L-band wavelength region which consists of 20 km long of NZ-DSF LEAF ® optical fiber, optical WDM coupler, isolator, Raman pump unit (RPU), tunable laser source (TLS), and optical spectrum analyzer (OSA). The amplification gain medium was provided by NZ-DSF LEAF ® optical fiber. An NZ-DSF LEAF ® optical fiber has affective group of 72 um^2, affective group index of refraction of 1469 and chromatic dispersion of 4 ps/nm*km. The optical WDM coupler is used in this configuration to combine RPU signal and laser source signal. The isolators are deployed to allow one-way direction of signal and blocked signal from opposite direction. A laser source signal from TLS at 1580 nm and Raman pump signal from RPU at 1480 nm was injected into the gain medium through optical WDM coupler. The laser source signal and RPU signal was guided into gain medium, which laser source signal was amplified. The output of the configuration was connected to an OSA that is used for observation and extracted in this experiment.

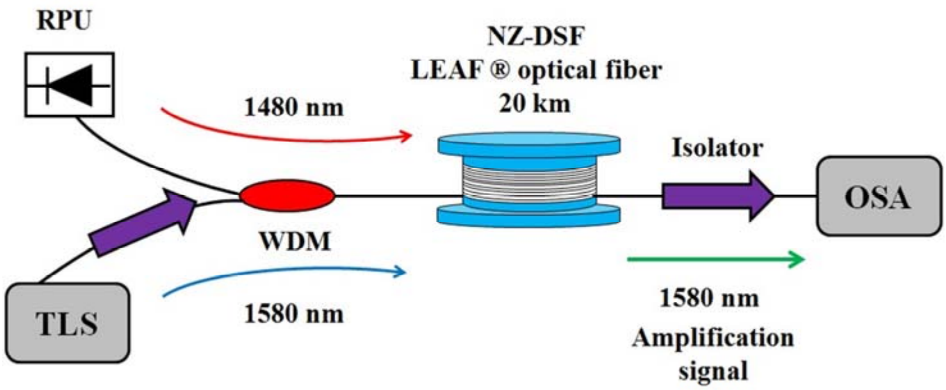

Figure 2: Raman amplification utilizing NZ-DSF as medium gain at 1580 nm amplification signal

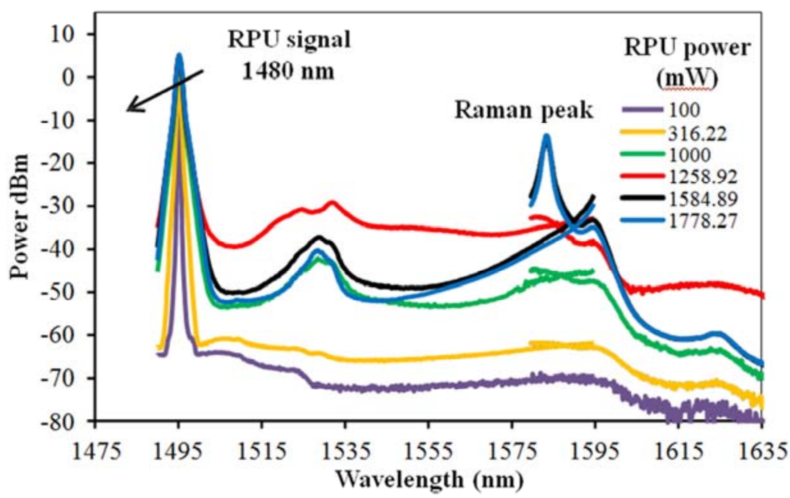

Figure 3: The output spectrum of the ASE at different injected Raman pump power

Without lunching the laser source signal, we investigated the contribution of Amplified Spontaneous Emission (ASE) with different injected RPU power into configuration. Practically, peak Raman wavelength will be oscillated about 100 nm away from injected RPU peak wavelength at 1480 nm [17] which is at 1580 nm. The output spectrum of the ASE at selected RPU powers are shown in Figure 3. It is seen that ASE power increased with increment injected RPU power. For RPU power of 1778.27 mW and 1584.89 mW, peak Raman wavelength was appeared around 1580 nm Thus, it is proved that the RPU power shifted to the L-band wavelength region.

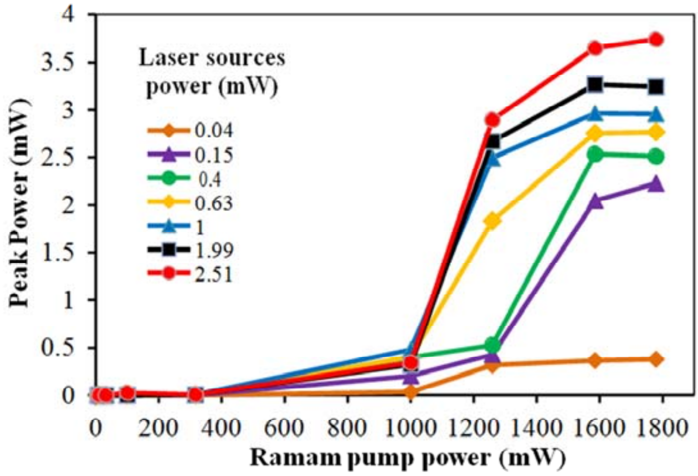

Figure 4: Amplify signal peak power against Raman pump signal power at 1480 nm with different laser sources power

To investigate the amplification peak power, the laser source signal was fixed at 1580 nm and its powers were varied from 0.04 mW to 2.51 mW. The 1480 RPU signal was injected from it minimum value of 0 mW to maximum value of 1778.28 mW. Meanwhile, the resolution bandwidth of OSA was set at 0.02 nm with 2 nm span. As shows in Figure 4, when input RPU power was increased, the output peak power was increased due to SRS effect upon it reaches a power level called threshold. The output peak power becomes significant when the injected RPU power reaches this value. As shows in Figure 4, as the laser sources power increased, the threshold power decreased. The lower threshold power was found around 300 mW of RPU power for injected laser sources power at 2.51 mW, 1.99 mW, 1 mW, 0.63 mW , and 0.4 mW respectively. It is worthy to note, higher input power from RPU is required due to the NZ-DSF length is too long to obtain sufficient gain. Experimental results have evidently shows that maximum output peak power was obtained at injected RPU power of 1585.89 mW. Above injected RPU power of 1585.89 mW, it is seen that saturated output peak power was obtained. This means that the maximum power Raman amplifier is able to generate, however it depends on the length of NZ-DSF LEAF ® optical fiber.

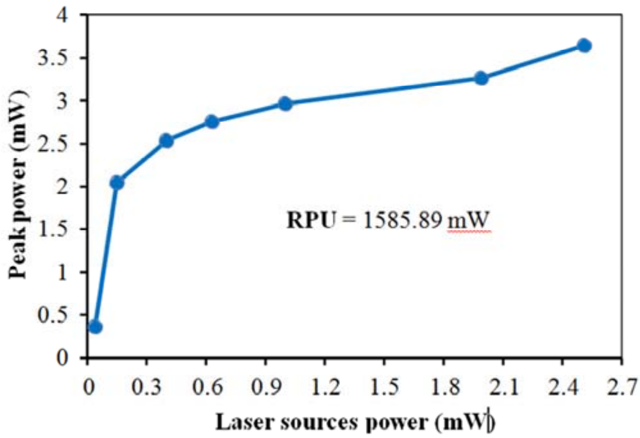

Figure 5: Amplify signal peak power against laser source power at RPU power of 1584.89 mW

In order to investigate the characteristics of maximum output peak power, RPU power was fixed at 1584.89 mW and peak power against laser source power was plotted as shown in Figure 5. The laser source signal was injected within 0.04 mW to 2.51 mW. At low laser source power of 0.04 mW, only 0.36 mW of peak power was obtained. At high laser source power of 2.51 mW, peak power was found to be 3.65 mW. For other case injected laser source power at 0.15 mW, 0.4 mW, 0.63 mW, 1mW, 1.58 mW and 1.99 mW, the peak power are 2.05 mW, 2.54 mW, 2.75 mW, 3.0 mW and 3.27 mW, respectively. It shows that, the increases of laser source power, will affect the increment of peak power. Additionally, Figure 6 shows the output spectrum of the L-band Raman amplification at various laser sources power and RPU power at 1584.89 mW.

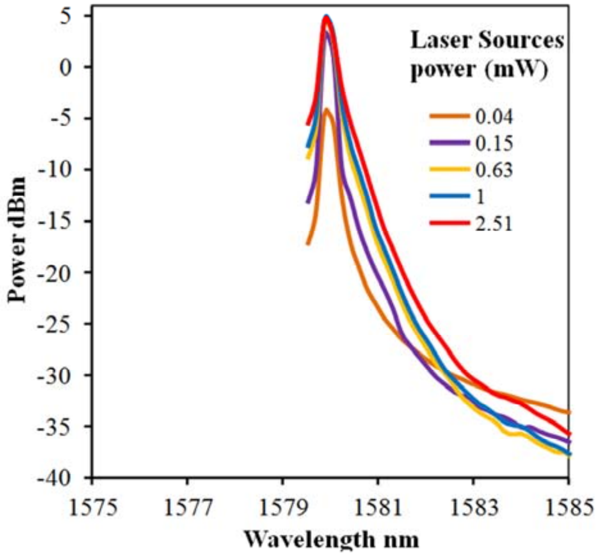

Figure 6: Output spectrum of L-band Raman amplification at different laser source power and RPU power at 1584.89 mW

CONCLUSION

We have successfully demonstrated the L-band Raman amplifier by utilizing NZ-DSF LEAF® optical fiber as gain medium. From the experimental, it shows that at 1584.89 mW and 1778.27 mW, the RPU power was oscillated to the L-band wavelength region from 1480 nm to 1580 nm due to the SRS effect. Further to that, the investigation of amplification of peak power was conducted by varies the laser power and RPU power. Based on the result, it is concluded that the higher value of laser source power led to the increment of peak power.
Future work can be carried out to reduce the length of the NZ-DSF LEAF ® optical fiber and investigate the amplification effect for each operating wavelength within 1567 mm to 1610 nm. The lower output power will produced if NZ-DSF LEAF ® optical fiber length is too long due to absorption from the long length of fiber.

ACKNOWLEDGMENTS

This work was fully supported by the Ministry of Higher Education, Malaysia under research grant # FRGS/9003-00362#.

REFERENCES

[1] Islam M. N. (2002). Raman amplifiers for telecommunications. *IEEE Journal of Selected Topics in Quantum Electronics*, *8*, 548.

[2] Singh. S. P, Gangwar. R., & Singh. N. (2007). Nonlinear Scattering effects in Optical Fibers. *Progress in Electromagnetics Research, PIER*, *74*, 379.

[3] Headley. C, & Agrawal. G. P. (2005). Raman Amplification in Fiber Optical Communication: Elsevier Academic Press.

[4] Kumar M, Singh. S, Singh. J, & Saxena. R. (2012). Performance Analysis of WDM/SCM System Using EDFA. *International Journal of Advanced Research in Computer Science and Software Engineering, 2*(6), 112.

[5] Mahdi. M. A, Thirumeni. S, Poopalan. P, Selvakennedy. S, Mahamd Adikan. F. R, Chan. W. Y, & Ahmad. H. (2000). Effects of self-saturation in an Erbium-doped fiber amplifier. *Optical Fiber Technology, 6*(3), 265.

[6] Mahdi. M. A, Poopalan. P, Selvakennedy. S, Ismail. N, & Ahmad. H. (1999). All optical gain-locking in Erbium doped fiber amplifiers using double-pass superfluorescence. *IEEE Photonics Technology Letters, 11*(12), 1581.

[7] Sing. S. P & Sing. N. (2007). Nonlinear effects in optical fiber: Origin management and Application. *Progress In Electromagnetics Research: PIER, 73*, 249.

[8] Boyd. R. W. (1992). Nonlinear Optics. Academic Press: San Diego, 8.

[9] Hecht. J. (2005). Understanding Fiber Optics. Prentice Hall, 112.

[10] Agrawal. G. P. (2001). Nonlinear Fiber Optics. Academic: San Diego.

[11] Haycraff. J. C. & Stevens. L. L. (2006). Single-crystal, polarized, Raman scattering study of the molecular and lattice vibrations for the energetic material cyclotrimethylene trinitramine. *Journal of Applied Physics, 100*, 1.

[12] Zhao. H. & Zhang. S, (2007). Spontaneous Raman scattering for simultaneous measurements of in-cylinder species. Third International Conference on Optical and Laser Diagnostics, 1.

[13] Aoki. Y. (1989). Fibre Raman amplifier properties for applications to long-distance optical communications. *Optical and Quantum Electronics, 21,* S89.

[14] Stolen. R. H, Lee. C, & Jain. R. K, (1984). Development of the stimulated Raman spectrum in single-mode fibers, *Journal of Optical Society of America B, 1*, 652.

[15] Kumano. N, Mukasa. K, Sakan. M, & Moridaira. H. (2002). Development of a Non-Zero Dispersion-Shifted Fiber with Ultra-low Dispersion Slope. *Furukawa Review, 22,* 1.

[16] Ooishi. T, Kato. T, Yokoyama. Y, Yoshida. M, Takahashi. Y, Makio. Y, & Nishimura, M. (2001). Optimum dispersion of non-zero dispersion shifted fiber for high bit rate DWDM systems. Optical Fiber Communication Conference and Exhibit, OFC, 2.

[17] Ahmad Hambali. N. A. M, Al-Mansoori. M. H, Ajiya. M, Bakar. A. A. A. Hitam. S. Hitam, & Mahdi. M. A. (2011). Multi-Wavelength Brillouin Raman Ring Cavity Fiber Laser with 22 GHz Spacing. *Laser Physics September, 21*(9), 1656.