EUROPEAN ACADEMIC RESEARCH
Vol. VII, Issue 1/ April 2019

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

ISSN 2286-4822
www.euacademic.org

Self Q-switched wavelength tunable Erbium-Ytterbium co-doped double clad fiber laser

I. M. BABAR[1]
Department of Physics, University of Karachi
Karachi, Pakistan
Photonics Research Centre, University of Malaya
Kuala Lumpur, Malaysia
M. YASIN
Department of Physics, Faculty of Science and Technology
Airlangga University, Surabaya, Indonesia

Abstract

An Erbium-Ytterbium co-doped double clad fiber Q-switch wavelength tunable laser based on self Q-switching principle is proposed in a simple ring cavity configuration. This laser doesn't employ any component like polarization controller, fiber bragg grating, un-pumped fiber section, Mach-Zehnder interferometer and saturable absorber as is usually used to produce Q-switch lasers. This laser is successfully tuned in the range 1535-1550nm by using OTF-320 manually tunable optical filter. We observe a stable Q-switch laser in the range 1535 to 1550nm, with pulse energy of 17nJ at 1445 nm. An increase in repetition rate is observed from 31.53 to 35.64 KHz with increase in the filter wavelength from 1535 to 1550 nm.

Keywords: Self Q-switch, tunable filter, double clad fiber, ring cavity.

INTRODUCTION:

Recently there has been growing interest in self Q-switch fiber lasers. Self-Q-switching (SQS) refers to the generation of a

[1] Corresponding author: ibabar@uok.edu.pk

periodic train of Q-switched pulses from a laser cavity containing only the gain medium. Since SQS does not require any additional elements such as saturable absorbers or active modulators, it is far simpler and lower cost in comparison with other Q-switching methods [1]. Q-switched fiber lasers are attractive optical sources for applications in remote sensing, medicine, and terahertz generation, among others. Tamayo et al presented a self-Q-switched Erbium-Ytterbium (Er-Yb) co-doped double clad fiber tunable ring laser with dual wavelength and single wavelength operations [2]. Zhang et al reported a self Q-switched and mode locked Er-Yb fiber laser incorporating saturable absorption in an un-pumped Erbium-Ytterbium doped fiber (EYDF) and Mach-Zhender interferometer [3]. Tsao et al proposed and demonstrated a compact, 980 nm continuous wave pumped Er–Tm all-fiber laser system where the thulium fiber was intra-cavity pumped by self-induced 1570 nm Q-switched resonance and self-mode-locked at 1950nm [4]. Several possible mechanisms such as ion-pairing acting as a saturable absorber, re-absorption of laser photons in the un-pumped part of the doped fibre, external perturbation such as pump noise, relaxation oscillations of the inversion and photon populations, interaction between laser signal and population inversion, distributed Rayleigh scattering, cascaded stimulated Brillouin scattering (SBS), and other nonlinear effects (stimulated Raman scattering (SRS), self-phase modulation (SPM), cross-phase modulation (XPM), and four-wave mixing (FWM)) as the sources of self-modulation and self-pulsing in different rare-earth-doped fibre lasers have been reported [5-7].

Although efforts were considerable to understand and control self-pulsing phenomenon in fibre lasers, there is plenty of scope for research and in-depth understanding of the physical parameters responsible for this phenomenon. Tunable lasers are unique physical systems that enjoy an abundance of applications ranging from physics to medicine. Given this utilitarian aspect, the sense of wonder in tunable lasers extends beyond beauty [8].

In this study we successfully demonstrated a self Q-switched tunable Er-Yb double clad fiber laser in the 1.5 micron range using an all fiber ring cavity configuration. A tunable filter is employed to tune the wavelength from 1535 to 1550 nm.

EXPERIMENTAL SETUP:

Experimental setup for the Erbium-Ytterbium (Er-Yb) co-doped fiber tunable laser is shown in fig. 1. It consists of a 5m long piece of CP1500Y double clad Erbium-Ytterbium doped fiber (EYDF) with core diameter of 5µm, inner cladding diameter of 105 µm and secondary cladding diameter of 125 µm as multi lobed pump guide as shown in fig. 1 (inset).

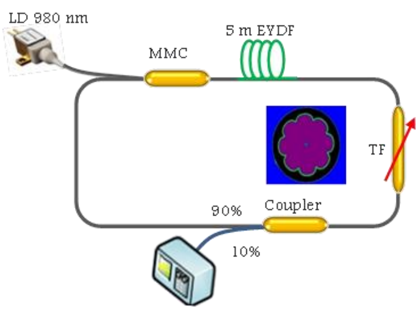

Fig. 1: Tunable EYDFL. Inset shows a cross-section image of the EYDF with a multi lobed pump guide structure.

The core has a numerical aperture 0.2-0.22 whereas the pump guide (inner cladding) has the NA 0.24-0.28 [9]. A multimode combiner (MMC), a 10dB coupler (90:10), a 980 nm multimode laser diode as the optical pump source and a tunable filter (OTF-320) are also used in the ring cavity configuration as shown in fig. 1. The amplified spontaneous emission (ASE) light oscillates in ring cavity to generate laser at 1.5µm region. Output of the EYDFL is tapped out using the 10% probe of the coupler and the 90% probe is used to oscillate light in the laser cavity. An optical spectrum analyzer (spectral resolution 0.01

nm) is used to analyze the output spectrum of laser. Moreover an oscilloscope is used to observe the output pulse train via a photo detector (Thor Lab, PDA50B-EC). Total cavity length of the ring resonator was equal to 10m.

Fig. 2: OTF-320 tunable filter.

The OTF-320 is a manually tunable optical filter that features an analog wavelength indicator as shown in fig. 3. It employs linear sliding method. Tuning is achieved by rotating a dial on side of the unit, and a meter on top of the unit provides wavelength reference. It is based on a thin film filter based tunable filter with 80nm tuning range starting from 1530nm to 1610nm.

RESULTS AND DISCUSSION:

In this study we don't use any extra component like saturable absorbers, polarization controllers, isolators etc. to produce Q-switched laser as shown in fig. 1. This fiber is itself capable of producing nonlinear effects like nonlinear polarization rotation (NPR) or four wave mixing thought to be the cause of the change of the Q-factor of the cavity. This is a unique ability of this fiber discovered for the first time to the best of our knowledge.

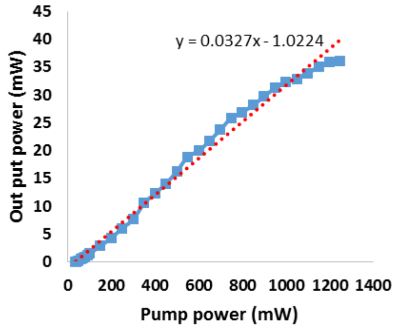

Fig. 3: Pump power vs output power

The efficiency of the laser is about 3.27% as is evident in fig. 3. The threshold pump power is about 40 mW without Tunable filter (TF) incorporated in the cavity. The highest power obtained is 36 mW with 1250 mW pumping, using 980nm multimode laser diode. The Q-switched pulse form is depicted in fig. 4 at different wavelengths (1535, 1545 and 1550nm) tuned on the tunable filter while providing a constant pump power of 100 mW. The laser is very stable and distinct Q-switch output is observed. When the filter is tuned at 1535 nm the observed repetition rate is 31.53 KHz whereas pulse width is 6.62 µs, pulse energy 5.57nJ and peak power 0.83 mW. With TF tuned at 1545 nm the repetition rate is 35.46 KHz and and pulse width 6.7 µs, pulse energy 16.92nJ and peak power 2.52 mW. Further TF is tuned at 1550 nm, repetition rate 35.64 kHz, pulse width 8.2 µs, pulse energy 11.62nJ and peak power 1.416 mW are observed. This shows that, there is a decrease in losses with increasing wavelength whereas Q-factor of the cavity switches rapidly to produce higher repetition rate pulses.

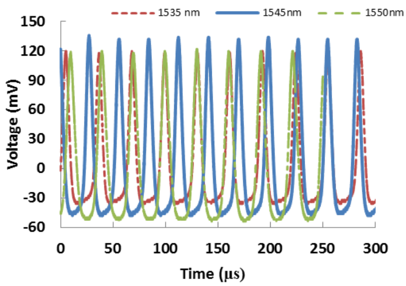

Fig. 4: Q-switch pulse forms at 1535, 1545 and 1550nm TF values with 100mW pump power.

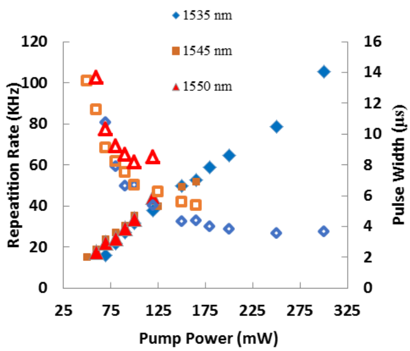

Fig. 5: Repetition rate (solid marker) and Pulse width (hollow marker) vs Pump Power.

We observe different threshold pump powers with different wavelengths tuned on TF. The threshold pump powers are 70, 45 and 50 mW at tuned wavelengths 1535, 1545 and 1550 nm respectively for producing Q-switch laser as shown in fig. 5. This also shows that the TF causes very little power loss in the cavity. There are also different power bands for different tuned wavelengths in which Q-switch pulses are observed. For 1535 nm the observed range is 70 mW – 300 mW, for 1545 nm, 45 mW – 180 mW and for 1550 nm is 50 mW – 120 mW. This shows that the pulse production range decreases with increasing filter wavelength. The fig. 5 shows the repetition rate and pulse width vs. pump power. We observe an increase in the repetition rate with increasing pump power whereas pulse width decreases with increasing pump power, which is a typical Q-switched laser phenomenon.

Optical spectrum with TF value fixed at 1545 nm providing pump power of 60 mW is shown in fig. 6. It is evident that the laser retains its wavelength that is set on the TF. It is also observed that with increasing pump power it maintains the wavelength set on TF at output. The fig. 7 shows the RF spectrum of the proposed Q-switch laser at 1535 nm TF value with 100 mW pump power. The signal to noise ratio is 31.48 dB which is an evidence of the stability of the laser.

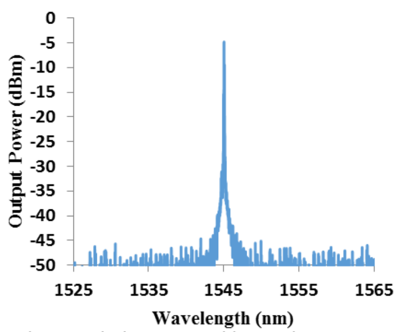

Fig. 6: Optical spectrum with TF value 1545nm at pump power 60 mW.

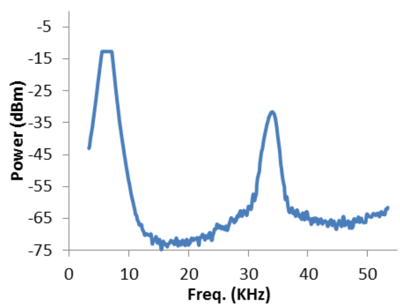

Fig. 7: Rf spectrum with TF at 1535nm at pump power of 100 mW.

Fig. 6: Optical spectrum with TF value 1545nm at pump power 60 mW.

Fig. 7: Rf spectrum with TF at 1535nm at pump power of 100 mW.

CONCLUSION:

We have successfully demonstrated a self Q-switch Er-Yb co doped double clad all fiber laser. This laser doesn't employed any extra component like polarization controller, Mach-zhender interferometer etc. In this study we use the commercially available CP1500Y Er-Yb fiber. We infer that the cause of self-pulsing is the simultaneously occurring non-linear polarization (NPR) effect and four wave mixing (FWM) or the reabsorption caused from the ineffectively pumped part of the fiber since we use a quite lengthy piece of fiber (5m). Further study is required to identify the cause exactly. To the best of our knowledge, the potential of CP1500Y to produce self- pulsing is first time discovered.

REFERENCES:

1) Ersen Beyatli, Alphan Sennaroglu, and Umit Demirbas, Self-*Q*-switched Cr:LiCAF laser, Journal of the Optical Society of America B, Vol. 30, Issue 4, pp. 914-921, 2013.
2) R I Álvarez-Tamayo, M Durán-Sánchez, O Pottiez, B Ibarra-Escamilla, M Bello-Jiménez and E A Kuzin, Self-Q-switched Er–Yb double clad fiber laser with dual wavelength or tunable single wavelength operation by a Sagnac interferometer, Laser Phys. 25, 075102, 2015.
3) Shu-min Zhang, Fu-yun Lu and Jian Wang, Self-Q-switching and mode-locking in an all-fiber Er/Yb co-doped fiber ring laser, Optics Communications, 263, 47-51, 2006.
4) Hong-Xi Tsao, Chun-Hsiang Chang, Shih-Ting Lin, Jinn-Kong Sheu, Tzong-Yow Tsai, Passively gain-switched and self mode-locked thulium fiber laser at1950nm , Optics & Laser Technology (56), 354–357, 2014.
5) B. Ortaç, A. Hideur, T. Chartier, M. Brunel, G. Martel, M. Salhi and F. Sanchez, Influence of cavity losses on stimulated Brillouin scattering in a self-pulsing side pumped Ytterbium-doped double clad fiber laser, Optics Communications, vol. 215, pp. 389-395 (2003).
6) A. Hideur, T. Chartier, C. Ozkul, F. Sanchez, Ynamics and stabilization of high power, side pumped Yb3+- doped double clad fiber ring laser, Opt. Communication, 186, 311-317, 2000.
7) Glas, P., Naumann, M., Schirrmacher, A., Däweritz, L., & Hey, R., Self pulsing versus self locking in a cw pumped neodymium doped double clad fiber laser, Optics communications, 161(4-6), 345-358, 1999.
8) Tunable Lasers Handbook, Edited by F. J. Duarte, Academic Press, Inc. California, USA, 1995.
9)http://www.docstoc.com/docs/72222060/CP1500Y-Fiber---CP1500Y-Cladding-Pump-Fiber.