PAPER • OPEN ACCESS

COPPER-BASED 3D PRINTER FILAMENT AS PASSIVE Q-SWITCHER

To cite this article: N. N. A. A. N Zain *et al* 2021 *J. Phys.: Conf. Ser.* **2075** 012003

COPPER-BASED 3D PRINTER FILAMENT AS PASSIVE Q-SWITCHER

N. N. A. A. N Zain [1], N. A. H. Jasni [1], W. M. F. W Nawawi [2] and F. Ahmad [1*]

[1] Malaysia- Japan International Institute of Technology, Universiti Teknologi Malaysia, Jalan Sultan Yahya Petra, 54100 Kuala Lumpur, Malaysia
[2] Department of Biotechnology Engineering, International Islamic University Malaysia, Kuala Lumpur, Malaysia

*Corresponding author's email: fauzan.kl@utm.my

Abstract. Using a copper-based saturable absorber (SA) and chitin as a biocompatible host polymer, this research effectively demonstrated the production of passive Q-switched in an erbium-doped fibre laser (EDFL). A Q-switched lasing was generated with a 100 kHz repetition rate and a pulse width of 4.60 µs. High pulse energy of 17.19 nJ was generated, with a respective instantaneous peak power of 3.51 mW.

1. Introduction

Researchers have recently become interested in metal nanoparticles, such as copper, for the next generation of SAs for use in passive Q-switching [1]. This is due to the Localized Surface Plasmon Resonance (LSPR) feature of metal nanomaterials, which is caused by the collective oscillation of conduction electrons in metal nanoparticles [8]. Copper has a broad saturable absorption range and a fast response time [2, 3]. Copper-based pulse laser generation are reported to operate at broad operating wavelength [9-12] with various source materials such as copper pellets [9], copper nanoparticles [10], copper oxide nano powder [11], and copper nanowires [12]. Using copper-based 3D printer filament as the starting material and Chitin biocompatible host polymer, this work provided an alternate method for developing copper-based passive Q-switchers. This method aims to investigate the use of metal-based 3D printer filament in optics. Because of the compatibility of the solvent used to dissolve the metal base, the chitin biocompatible polymer was chosen.

2. Methodology

2.1. Copper-chitin SA fabrication

3D Gadgets provided the copper-based 3D printer filament (Magma). The diameter of the 3D printer filament is 1.75mm +/- 0.03mm, the length is 155mm, the heated bed temperature is 0- 60°C, the printing temperature is 190°C - 210°C, the net weight is 0.50 kg, and the material is Polylactic Acid (PLA) with 15% copper powder. The size of 3D printer filament was red for easier construction. . The size of 3D printer filament was reduced from 1.75 mm to 400 m by extrusion at 210°C through a 0.4 mm extruder nozzle for easier fabrication process. To dissolve the copper-PLA 3D printer filament, 25 mg of reduced diameter copper filament was thoroughly combined with 1 ml tetrahydrofuran (THF) solvent, to produced copper-PLA-THF suspension. Wan Nawawi et al. [4] described the production of Chitin as a host polymer using oyster mushrooms as the source of chitin. To develop a copper-chitin-based passive saturable absorber, the copper-PLA-THF suspension was completely mixed with chitin suspension in a one-to-one ratio at room temperature trough ultrasonication. Around 5 mL of the copper-PLA-THF-Chitin homogeneous suspension was poured into a dish and dry for 36 hours at ambient, where the PLA-THF evaporated, leaving a copper-chitin-based film. The free-standing copper-chitin based film will be peeled off and divided into 1 mm x 1 mm squares before being integrated in ring laser cavity for pulsed laser generation.

2.2. Experimental setup

As illustrated in Figure 1, a 980 nm laser diode (LD) was utilised to pump the erbium-doped fibre laser (EDFL) ring cavity. A 980/1550 nm wavelength division multiplexer (WDM) pushed the laser towards the gain medium, which was a 1.7 m erbium-doped fibre gain medium. An isolator was installed in the cavity to ensure unidirectional light propagation. Before being integrated into the cavity as a passive Q-switcher, the free-standing copper chitin was sandwiched between two fibre ferrules with the help of index matching gel. For the output observation, the light passes via a 95/5 output coupler, with 95% of the signal remaining in the cavity and the remaining 5% tapped out as data gathering output. A Yokogawa AQ6370B Optical Spectrum Analyzer (OSA), an optical power meter (OPM), a Tektronix MDO3024 Mixed Domain Oscilloscope with Thorlabs DET01CFC 460 kHz bandwidth photodetector (PD) were used to monitor the signal.

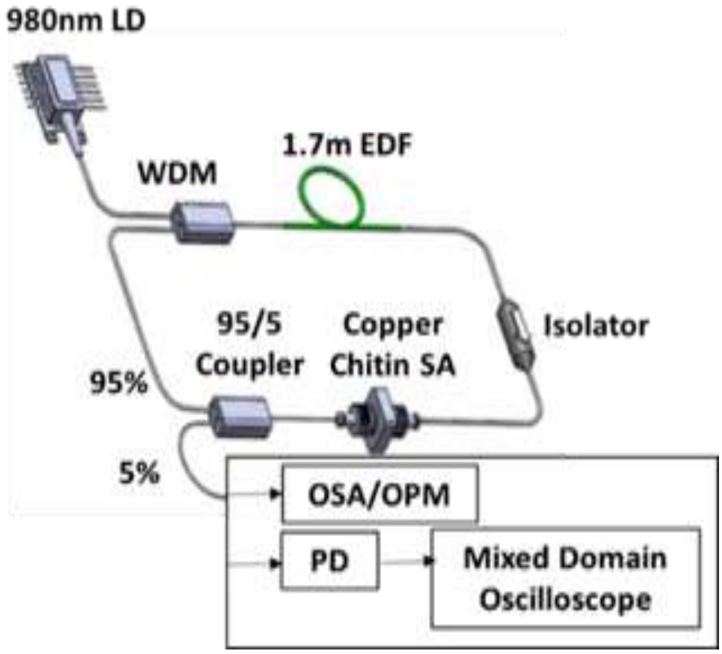

Figure 1 Integration of copper-chitin SA in ring laser cavity

3. Result and discussion

The Q-switching wavelengh of copper chitin SA in the laser cavity is 1559.316 nm, as illustrated in Figure 2. The threshold power of the Q-switched is at 38.7 mW and up maximum the pump power of 71.8 mW. Because the SAs have been saturated, Q-switched pulses cannot be created above 71.8 mW pump power, and only limited signal absorption can be achieved at higher pump power [5].

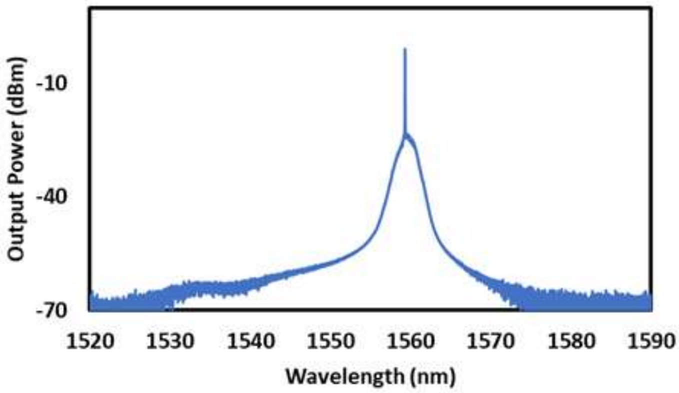

Figure 2 The optical spectrum at 71.8 mW of pump power.

A continuous Q-switching operation with no amplitude modulation was shown in Figure 3.Figure 3(a) depicts the Q-switching operation's pulse train repetition rates. At an input pump power of 71.8 mW, the copper chitin SA produced a pulse train with a 100 kHz repetition rate and a 10 μs pulse separation. Figure 3(b) illustrates a pulse width of 4.60 μs at the 71.8 mW.

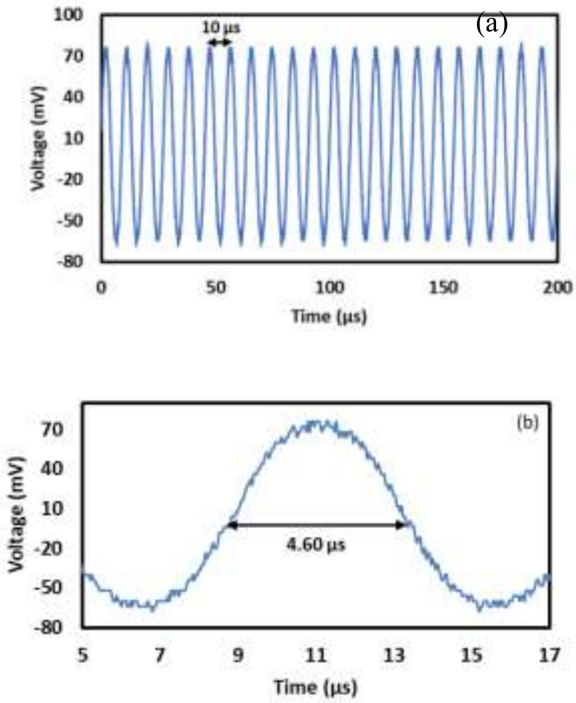

Figure 3 A continuous Q-switching operation (a) repetition rate (b) pulse width at 71.8mW.

Figure 4 illustrates that when the pump power increases, the repetition rate climbs almost linearly until it approaches 100 kHz, which is typical of Q-switched operations [6]. The pulse width decreased within input power from 38.7 mW to 71.8 mW, decreasing from 7.57 µs to 4.60 µs. Increasing pump power should theoretically provide more gain in producing SA saturation, resulting in a higher repetition rate and smaller pulse width [6][7].

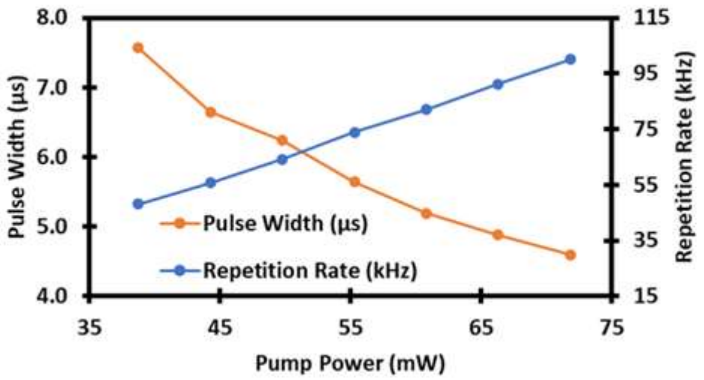

Figure 4 Pump power against repetition rate and pulse width.

Figure 5 illustrates how the instantaneous pulse energy and peak power were calculated using the observed repetition rate and pulse width [13]. Pumping power was raised from 38.7 to 71.8 mW, resulting in enhanced pulse energy and peak power.

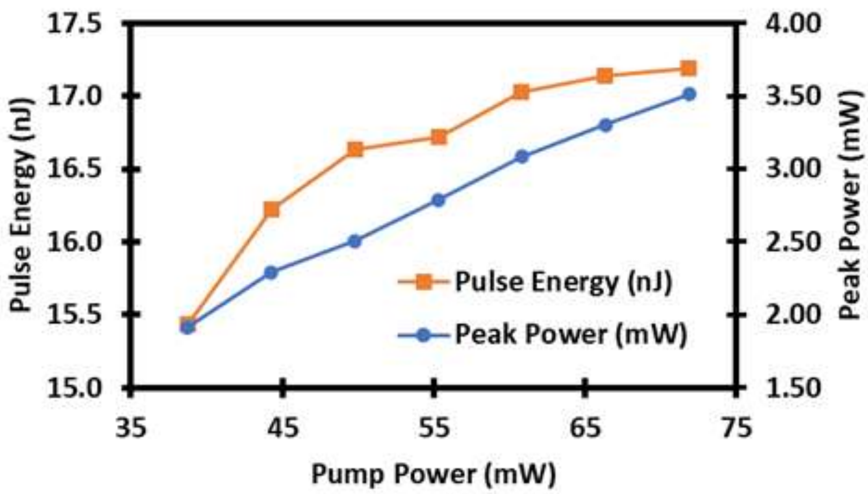

Figure 5 Instantaneous pulse energy and peak power versus input pump power.

Figure 6 shows how a mixed domain oscilloscope was used to verify the stability of the generated Q-switched pulse. At 71.8 mW, the initial beat note at 98 kHz was 80.18 dB, indicating good pulse stability. The signal-to-noise ratio (SNR) was higher than that of copper nanoparticles, which was 54 dB [3].

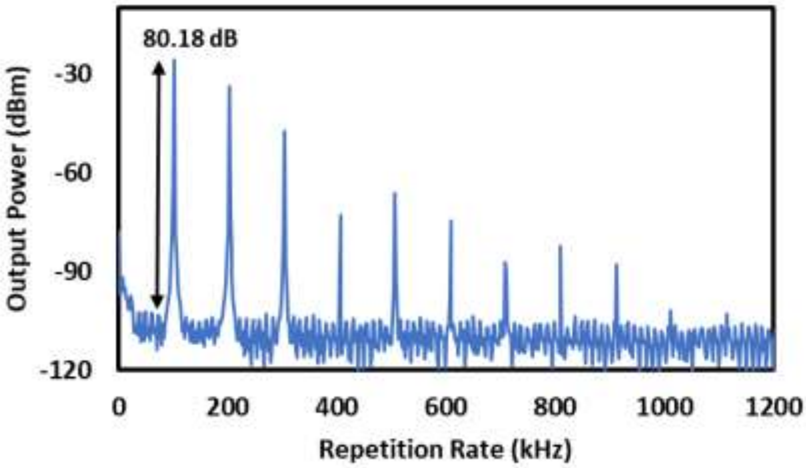

Figure 6 Signal-to-noise ratio

4. Conclusion

Copper-chitin SA was used to demonstrate a passively Q-switched EDFL with a highest repetition rate of 100 kHz, the shortest pulse width of 4.60 s, and a pulse energy of 17.19 nJ at input pump power of 71.8 mW. The pulse's stability can also be seen in the mixed domain oscilloscope with signal-to-noise ratio of around 80.18 dB. The copper-based 3D printer filament in chitin biocompatible host polymer revealed the ability to operate as a passive Q-switcher in this study.

References

[1] Ismail E, Ahmad F, Ambran S, Latiff A, Harun S. Q-switched erbium-doped fiber lasers based on copper nanoparticles saturable absorber. Journal of Physics: Conference Series. 2019;1371:012028.

[2] Lu S, Miao L, Guo Z, Qi X, Zhao C, Zhang H et al. Broadband nonlinear optical response in multi-layer black phosphorus: an emerging infrared and mid-infrared optical material. Optics Express. 2015;23(9):11183.

[3] Guo H, Feng M, Song F, Li H, Ren A, Wei X et al. Q-Switched Erbium-Doped Fiber Laser Based on Silver Nanoparticles as a Saturable Absorber. IEEE Photonics Technology Letters. 2016;28(2):135-138.

[4] Fazli Wan Nawawi W, Lee K, Kontturi E, Murphy R, Bismarck A. Chitin Nanopaper from Mushroom Extract: Natural Composite of Nanofibers and Glucan from a Single Biobased Source. ACS Sustainable Chemistry & Engineering. 2019;7(7):6492-6496.

[5] Kiat YY. Chemical Synthesis And Characterization of Graphene Oxide For Use As Saturable Absorber and Broadband Polarizer [dissertation].Kuala Lumpur, Malaysia : University of Malaya; 2015.

[6] Holzwarth A. Applications of ultrafast laser spectroscopy for the study of biological systems. Quarterly Reviews of Biophysics. 1989;22(3):239-326.

[7] Degnan J. Optimization of passively Q-switched lasers. IEEE Journal of Quantum Electronics. 1995;31(11):1890-1901.

[8] Murray, W. A., & Barnes, W. L. (2007). Plasmonic materials. Advanced materials, 19(22), 3771-3782.

[9] Muhammad, A.R, Ahmad, M., Zakaria, R., Rahim, H., Yusoff, S., Hamdan, K., Yusof, H., Arof, H., & Harun, S.W. (2017). Q-Switching Pulse Operation in 1.5-µm Region Using Copper Nanoparticles as Saturable Absorber. Chinese Physics Letters, 34(3), 034205.

[10] Muhammad, A.R, Ahmad, M., Zakaria, R., Yupapin, P., Harun, S.W., & Yasin, M. (2019). Mode-locked thulium doped fibre laser with copper thin film saturable absorber. Journal of Modern Optics, 66(13), 1381-1385.

[11] Sadeq, S. A., Al-Hayali, S. K., Harun, S. W., & Al-Janabi, A. (2018). Copper oxide nanomaterial saturable absorber as a new passive Q-switcher in erbium-doped fiber laser ring cavity configuration. Results in Physics, 10, 264-269.

[12] Ismail E, Ahmad F, Shafie S, Yahaya H, Latif A, Muhammad F. Copper nanowires based mode-locker for soliton nanosecond pulse generation in erbium-doped fiber laser. Results in Physics. 2020;18:103228.

[13] Zain N N A A N, Zuikafly S N F, Jasni N A H, Nawawi W M F W and Ahmad F. Passively Q-Switched Tri-Wavelength Erbium-Doped Fiber laser with Aluminium-Based Saturable Absorber. Results in IEEE International Conference on Semiconductor Electronics (ICSE). 2020:128-131