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

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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 produce copper-PLA-THF suspension. Wan Nawawi et al. [4] described the production of Chitin as the 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 through ultrasonication. Around 5 mL of the copper-PLA-THF-Chitin homogeneous suspension was poured into a dish and dried 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 into the 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](image-url)
3. Result and discussion
The Q-switching wavelength 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](image)

**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](image)

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

**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](image)

**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].
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.

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