

## Q-switched pulse fiber laser characterization in 2000 nm wavelength region with forward and backward laser pump system

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**Abstract:** A passively Q-switched thulium-doped fiber laser (TDFL) at 1.96  $\mu\text{m}$  region based on multi-walled carbon nanotubes (MWCNTs) as the saturable absorber (SA) by using a bi-directional pumping configuration has been demonstrated. The SA is fabricated by sandwiching the MWCNT embedded in polyvinyl alcohol (PVA) thin film between two fiber ferrules. The proposed laser utilizes a 4 m-long thulium-doped fiber by OFS (TmDF200) which is pumped by two laser diodes operating at 1550 nm with a maximum combined pump power of  $\sim 440$  mW. The bi-directional pumping scheme allows for a higher gain and lower noise performance of the TDFL. The resulting Q-switched is able to generate a wide range of repetition rate, starting from 11.39 kHz to 49.45 kHz, starting at the Q-switching threshold of 102.74 mW up to a maximum of 196.82 mW. The corresponding pulse width can be tuned from 6.51  $\mu\text{s}$  to 3.81  $\mu\text{s}$  by increasing the pump power. The maximum average output power and pulse energy of the Q switched TDFL is 1.28 mW and 25.93 nJ respectively. The proposed laser also generates a relatively high signal-to-noise ratio of 64.07 dB as measured from the radio frequency spectrum analyser, indicating a stable Q-switched pulsed operation.

**Keywords:** Thulium-Doped Fiber, Fiber Laser, Q-Switched Pulse, Saturable Absorber.

### INTRODUCTION

Two-micron fiber laser has become a highly interest topic among researchers in photonics field due to its ruggedness, compactness and reliability to satisfy a wide range of demands in the industry [1]. The thulium-doped fiber laser (TDFL) has a broad wavelength range from 1800 nm up to 2200 nm, which falls in the 'eye-safe' laser region due to its high absorbance of water or liquid [2]. For instance, the TDFL is applicable for ophthalmic medical technology specifically for laser eye surgery [3,4]. A significant interest has also emerged on Q-switched TDFL since their high pulse energies are particularly useful for application that does not require ultrafast pulse such as material processing and remote sensing. In this work we introduce a passively Q-switched TDFL at 2  $\mu\text{m}$  region based on bidirectional pumping scheme operating at 1550 nm with a maximum total pump power of  $\sim 440$  mW by incorporating MWCNT as the saturable absorber (SA). The Q-switched TDFL yields 11.39 kHz repetition rate at the Q-switching threshold of 102.74 mW and 49.45 kHz repetition rate at 196.82 mW pump power, with the corresponding pulse width of 6.51  $\mu\text{s}$  and 3.81  $\mu\text{s}$  respectively. The maximum average output power and pulse energy of the Q-switched TDFL is 1.24 mW and 37.45 nJ respectively.

## MATERIALS AND METHODS

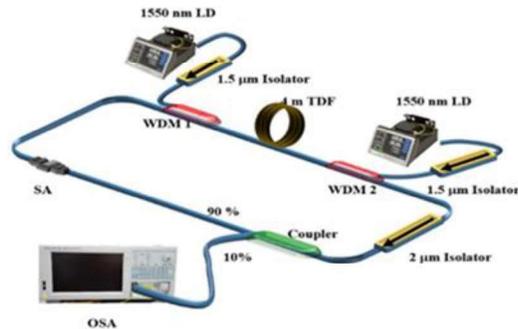


Fig. 1. Experimental setup of bidirectional-pumped Q-switched TDFL

## RESULTS AND DISCUSSION

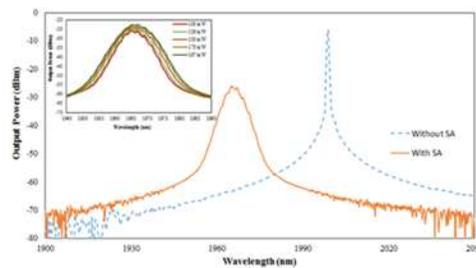


Fig. 2. Q-switched TDFL output spectrum

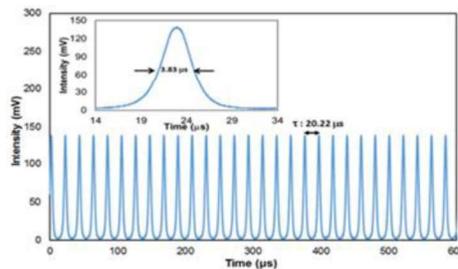


Fig. 3. Q-switched pulse train at 49.45 kHz

## CONCLUSIONS

A passively Q-switched TDFL at 1.96  $\mu\text{m}$  region utilizing bi-directional pumping scheme by incorporating MWCNT-PVA thin film as the SA has been demonstrated. The Q-switched TDFL exhibits high repetition rate, starting from 11.39 kHz to 49.45 kHz, with the corresponding pulse width of 6.51  $\mu\text{s}$  to 3.81  $\mu\text{s}$ . A broad 3-dB bandwidth of  $\sim 6$  nm is obtained. The high signal-to-noise ratio of 64.07 dB indicates a stable Q-switched pulsed operation. This proposed work with

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the bidirectional pumping scheme exhibits a better Q switched laser performance over the single pumping scheme, based on comparison with other works on Q-switched TDFL.

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