2μm widely tunable thulium-doped fiber laser seed oscillator

Peixin Hu1, Encai Ji2, Zilin Nie1, Jinchao Deng3, Lu Yao1, Zhengdi He1, *
1Key Laboratory of laser Intelligent manufacturing in digital dentistry, Shenzhen Technology University, Shenzhen, China
2MIL Medical Technology LLC, Shenzhen, China
3Shenzhen Key Laboratory of Laser Engineering, Shenzhen University, Shenzhen 518000, China
*Corresponding author: Hezhengdi@sztu.edu.cn

Abstract. 2μm band laser can be used in transparent plastic welding, soft tissue laser surgery, LiDAR, toxic hazard gas sensing and medium-and far-infrared parametric oscillation conversion. However, there are still many problems that need to be clarified on how to break through the peak power limit, realize pulse time domain programmable and laser wavelength wide range tuning in the nanosecond thulium fiber system. In this experiment, wide tuning laser at 2μm band was used to realize different laser wavelength, constant seed laser power output, and EOM was used to define laser pulse waveform and pulse frequency.

Keywords: Fiber laser seed oscillator, Wide tuning laser, Electro-optical modulation technology.

1. Introduction
Since the birth of lasers, in order to continuously adapt to the actual needs of higher-end scientific research, higher-quality laser processing or more precise laser surgery at each stage, multi-dimensional real-time control of lasers has always been the direction of laser research/development.

The 2μm-band thulium-doped fiber laser has also undergone laser control research in different dimensions since its first experimental report in 1988 at the University of Southampton [1] and achieved mode-locked nanosecond laser output in 1992 [2]. In 1993, the National Research Center of Canada [3] realized electro-optic Q-switched high-energy laser output, and MIT [4] realized tunable output of mode-locked femtosecond laser in 1995. In 2012, NP Photonics company [5] reported a laser system using electro-optic modulation + MOPA to realize all-fiber nanosecond laser output. In 2013, Turin polytechnic university [6] used semiconductor seed modulation way to realize frequency and pulse width control. In 2014, University of Southampton [7] integrated arbitrary waveform generator (AWG) to modulate semiconductor seeds to achieve pulse waveform control of MOPA system. However, up to now, there are still many problems that need to be clarified about how to break through the limit of peak power, realize pulse time domain programmable and laser wavelength large-range tuning in the nanosecond thulium fiber system.

In this work, we focus on the experimental research on how to realize the dynamic control of laser time domain and frequency domain while ensuring the high heavy frequency and peak value power output of the all-fiber nanosecond laser system. LiNbO3 EOM is mainly used to modulate the continuous
output seed laser at high speed. The tuning range of the final laser wavelength supported by the system is determined, and the change law of the impulse response function of the system under different emission wavelengths is compared to reveal the physical mechanism of the evolution law. The laser output could be tuned continuously in the range of 1924.3nm to 1972.2nm covering a total of 48nm. The output power can reach to nearly 300mW.

2. Material and method
Figures 1 shows the schematic diagram of the all-fiber tunable 2-µm fiber laser seed source. The fiber laser consists of a multimode 796-nm diode laser as the pump source, a fiber pump-signal combiner, a double-clad Tm-doped fiber with a 10-µm core diameter and a 130-µm cladding diameter. A library file is formed to calibrate the pump light power required by laser of different center wavelength when the output power is 300mW. The OUTPUT laser pulse waveform is controlled by LabVIEW software at the PC end to ensure the control sensitivity and precision.

3. Results and Discussion
To allow us to observe the wavelength tunability of the fibre laser with Sagnac loop interferometer in the experiment, we used an optical spectrum analyzer (NIR256, from Ocean Optics, USA) which is able to examine the wavelength range from 862.2nm to 2607.3nm. Figure 2 shows that the laser output could be tuned continuously in the range of 1924.3nm to 1972.2nm covering a total of 48nm.

Figure 1. The setup of tunable multi-wavelength Tm-doped fiber laser seed source

Figure 2. Spectrum of the laser output tuned from 1924.3nm to 1972.2nm
The pulsed seed laser could emit output power from about 4.4 mW to 298.7 mW. The maximum pulsed average output powers are 28.4, 62.4, 155.9 and 298.7 mW respectively at the duty cycles of 10%, 20%, 50% and 80% and repetition rate of 1 MHz, as shown in Figure 3.

![Figure 3. Pulsed laser output average powers in different duty cycle](image)

4. Conclusion

- A new concept of dynamic intermodulation between laser frequency domain and pulse time domain is proposed.
- In the area of 2 μm band thulium optical fiber system, explore the laser output wavelength, pulse width, pulse waveform and pulse repetition frequency, multi-parameter alignment technology route of spreading the can not only satisfy some spectrum application scenarios to the needs of different laser wavelength, also can satisfy the industrial material processing more scenes of pulse waveform, pulse frequency for the actual demand of dynamic adjustment.
- At the same time, the method of combining tunable fiber laser with high-speed electro-optic external modulation technology is proposed, which has high technical innovation.

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