L-band wavelength-tunable fiber laser mode-locked by all polarization-maintaining nonlinear polarization rotation

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ABSTRACT

We achieved the first demonstration of a wavelength-tunable mode-locked fiber laser in the L-band using all-polarization maintaining (all-PM) nonlinear polarization rotation (NPR). The all-PM configured laser features excellent repeatability and reliability. By increasing the pump power from 82.5 mW to 135 mW, a center wavelength-tunning from 1576.2 nm to 1592.2 nm is obtained. This non-mechanical tunning mechanism opens new possibilities for L-band wavelength-tunable lasers and their applications.

Keywords: Mode-locked, L-band, wavelength tunable, all-polarization maintaining, nonlinear polarization rotation

1. INTRODUCTION

Wavelength-tunable mode-locked fiber lasers have gained significant interest in the fields of optical spectroscopy, sensing, and communication [1]. Among them, L-band ultrafast lasers (1565 nm to 1625 nm) have shown great potential in applications such as optical sampling. Previous studies on L-band wavelength-tunable lasers have employed spectrum filters, intracavity loss control, or birefringence adjustment [2]. However, the non-PM configuration in these research makes the lasers susceptible to environmental perturbations, while the inclusion of a polarization controller (PC) in the cavity compromises reliability and repeatability. To address these issues, realizing NPR mode-locking in all PM fibers (all-PM NPR) offers an effective solution. As of now, there has no report of wavelength-tunable fiber lasers mode-locked by this technique. In this work, we present the first experimental demonstration of an all-PM NPR mode-locked fiber laser that generates wavelength-tunable pulses in the L-band. By increasing the pump power from 82.5 mW to 135 mW, the wavelength can be tuned from 1576.2 nm to 1592.2 nm.

2. EXPERIMENT SETUP AND RESULTS

The experiment setup of the laser is shown in Fig. 1, and all the components and fibers are the PM type. A

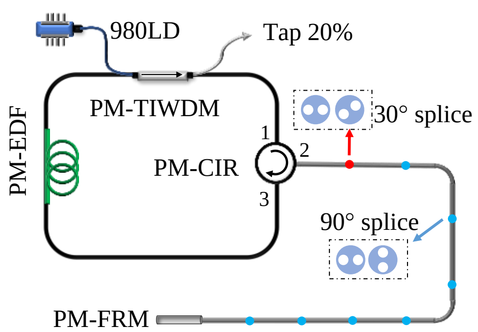

Fig. 1 Experiment setup of the all-PM NPR laser

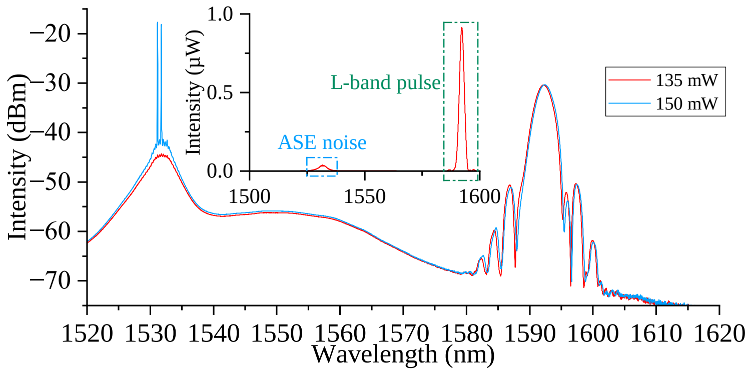

Fig. 2 Optical spectrum in logarithmic and linear scale (inset)

slow-axis working PM tap isolating wavelength-division multiplexing (PM-TIWDM) serves as a polarizer, WDM, isolator and 20% output coupler. A 1.5 m PM-EDF (Nufern ESF-7/125) works as the gain medium. The artificial saturable absorber (NPR section) consists of 21 m PMF (Fujikura SM15-PS-U25A) and a slow-axis working PM Faraday rotation mirror (PM-FRM). The 21 m PMF is segmented into 8 sections by 90° angle splicing (blue dots) between the 30° angle splicing (red dot) and the FRM. The slow-axis working PM circulator (PM-CIR) functions as a polarizer. The total cavity length is about 50 m, with a net group velocity dispersion (GVD) of -1.03ps^2 at 1550 nm, indicating the laser operates in the soliton regime.

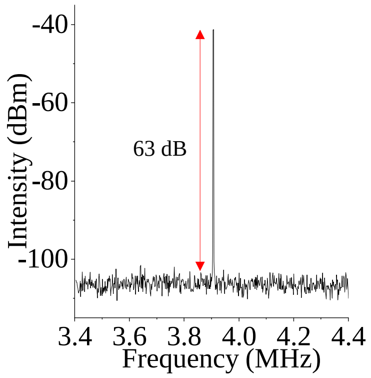

Fig. 3 RF spectrum

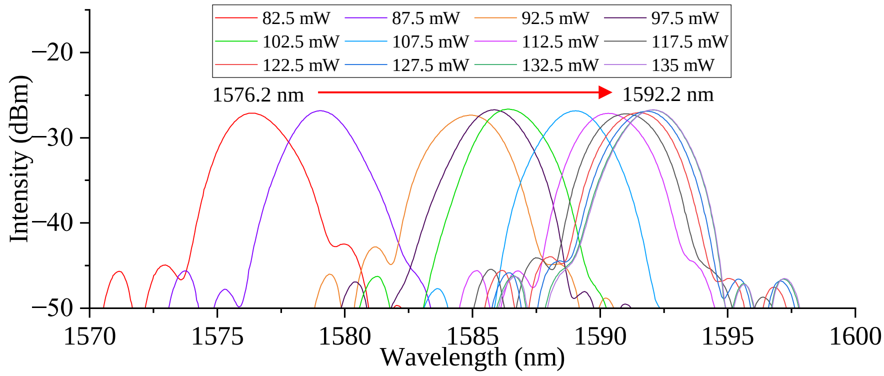

Fig. 4 Wavelength-tunning performance by increasing the pump power

At a pump power of 260 mW, the self-started laser exhibits unstable multi-pulses. However, by gradually reducing the pump power to 135 mW, stable single soliton pulsing is achieved with an output power of 120 μW and a center wavelength of 1592.2 nm. The overall spectrum in logarithmic scale (dBm) is presented in Fig. 2, with the inset showing the spectrum at 135 mW pump in logarithmic scale (μW). The estimated output power of the L-band soliton pulse is 108 μW, considering that the ASE noise contributes approximately 10% of the total power. Further increasing the pump power to 150 mW results in continuous wave (CW) lasing at 1530 nm, while the L-band soliton pulse remains unchanged. Fig. 3 illustrates the radio frequency (RF) spectrum with a resolution bandwidth (RBW) of 100 Hz, and a 63 dB signal-to-noise ratio (SNR) indicates a high pulse-to-pulse stability. The center frequency of 3.9 MHz aligns with the approximate 50 m cavity length.

The wavelength-tuning performance is depicted in Fig. 4, where the center wavelength can be tuned to 1576.2 nm by gradually reducing the pump power to 82.5 mW. Below 82 mW, the laser transitions from mode-locking to CW lasing. The 16 nm tuning range can be repeatedly achieved by increasing or reducing the pump power, and this has been tested multiple times. However, it is important to note that the pump power tuning mechanism is nonlinear, with the near L-band solitons exhibiting greater tuning range compared to the middle L-band solitons under the same 5 mW pump power change. This nonlinearity is likely due to the gain profile shift of the PM-EDF at different pump powers.

3. CONCLUSION

In summary, we have successfully reported the first all-PM NPR fiber laser capable of generating wavelength-tunable soliton pulses in the L-band. By increasing the pump power from 82.5 mW to 135 mW, we achieved a tuning range of 16 nm (1576.2 nm to 1592.2 nm). Our laser exhibits superior repeatability and reliability compared to non-PM and mechanically tunable L-band fiber lasers.

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