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Femtosecond Pulse Generation by Nonlinear Polarization Rotation in a Bismuth-Based Er-Doped Fiber Laser

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Abstract

We realize a femtosecond all-fiber passively mode-locked laser using polarization rotation in a single nonlinear/gain medium, bismuth-based Er-doped fiber that features broad gain bandwidth along with high nonlinearity. Analysis on the pulsed output is presented.

1. Introduction

Many schemes to realize mode-locked lasers have been developed with their own advantages to meet the specific needs of the state-of-the-art optical technologies. Among them, passive mode locking by nonlinear polarization rotation in a nonlinear intracavity component has been spotlighted with its attractions including the short pulse generation as well as the simplified laser cavity structure [1]. So far, many attempts for achieving better pulse quality hire highly nonlinear fiber (HNLF). However, they need a separated active gain medium in addition to the nonlinear medium, so that the realized structure of the laser cavity is voluminous and costly. Recently, even if a mode-locked laser based on phosphate-based fiber is demonstrated [2], it also has some drawbacks including the limited gain bandwidth. For an improved pulse quality, it is highly expected to have a novel intracavity component that has both the high nonlinearity and the broader gain bandwidth compared with the conventional gain medium. In this work, we employ a Bi-based Er-doped fiber (Bi-EDF) as combined gain and nonlinear medium for the passive pulse formation by the nonlinear polarization rotation. Resultant full width at half maximum (FWHM) of the pulsed output spectrum is 15.6 nm, and the repetition rate is 5.21 MHz. The average output power is 8.57 dBm.

2. Experiment

Fig. 1 shows the configuration of the passively mode-locked laser operated by the nonlinear polarization rotation in Bi-EDF for sub-picosecond pulsed output. The Bi-EDF was pumped by 1480 nm laser diodes that provide an optimum pumping condition for the Bi-based amplifiers [3]. The Er concentration and the nonlinear coefficient of the Bi-EDF are 6,500 ppm and 50 1/W/km, respectively. The length of the Bi-EDF is 75 cm. The Bi-EDF is fusion spliced to the silica fibers that have high numerical aperture (NA) in order for the mode field matching. The NA is 0.2. WDM-isolators guarantee the uni-directional operation of the laser as well as the pump coupling. Two polarization controllers (PCs) are employed to control the states of polarization (SOPs) with respect to the polarizer and the active gain medium. The polarizer used has the extinction ratio of 30 dB. For the intra-cavity dispersion management, 18m of single mode fiber is inserted. The laser output is given by the 90/10 coupler and the isolator that cuts out the deleterious reflection back from the end facet of the output port.

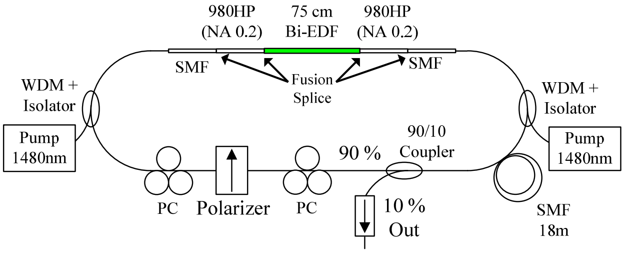

Fig. 1. Experimental setup.

3. Results and Discussion

As can be seen in Fig. 2, the Bi-EDF provides a wide gain bandwidth ranging from 1520 to 1580 nm, thereby ensures the shorter pulse realization as well as the wide tuning range of the center wavelength. With the optimized SOPs, the pulses start to be formed with the pump current of 300 mA.

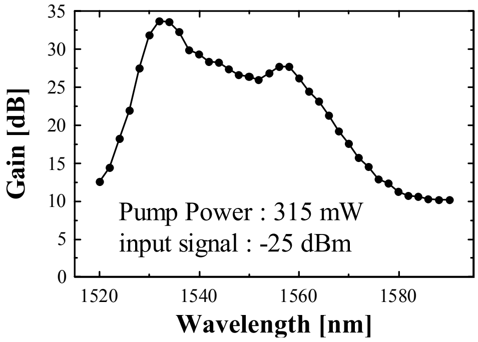

Fig. 2. Gain spectrum of Bi-EDF.

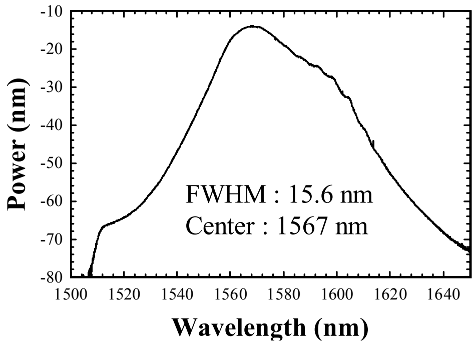

Fig. 3. Output spectrum of our pulsed laser with FWHM of 15.6 nm.

Fig. 3 illustrates the optical spectrum of our pulsed laser. FWHM is estimated to 15.6 nm. Assuming the sech^2 transform-limit pulse shape, the temporal pulse width calculated is 165 fs. However, the second-harmonic generation (SHG) autocorrelation trace measurement shows the actual pulse width of 260 fs meaning that our pulsed output is highly chirped (see Fig. 4) [4]. The time-bandwidth product of the laser output is 0.494. The center wavelength of our pulsed output is 1567 nm.

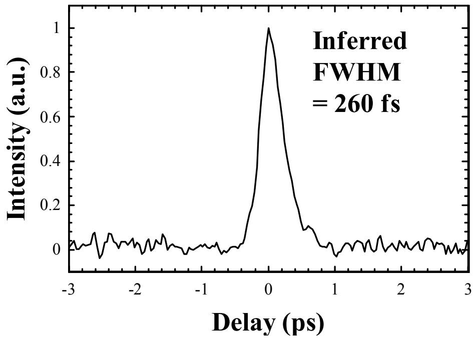

Fig. 4. Autocorrelation trace of our pulsed laser with inferred pulse width of 260 fs.

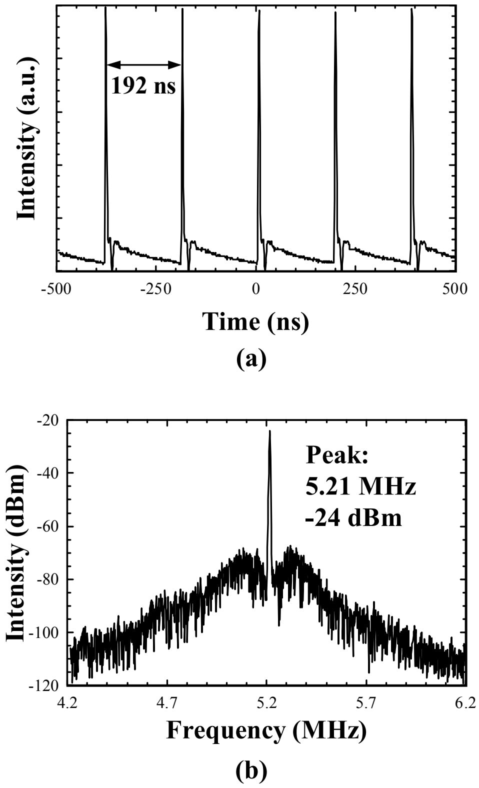

Fig. 5. (a) Output pulse train with repetition rate of 5.21MHz, (b) RF spectrum of the mode-locked laser.

Fig. 5 (a) depicts the periodic pulse train with the repetition rate of 5.21 MHz. Fig. 5 (b) shows RF spectrum of the pulsed output. The peak is located at the frequency of 5.21 MHz and the extinction ratio is higher than 40 dB.

In conclusion, we realized an enhanced femtosecond mode-locked laser passively operated by nonlinear polarization rotation in a high nonlinear gain medium. The combination of the nonlinear and gain media provides not only the structural simplification but also robust optical nonlinear functionality. Our scheme is expected to be one of the strong tools to generate the femtosecond optical pulses in the future competitive field.

References

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