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Generation of dual wavelength ultrashort pulse outputs from a passive mode locked fiber ring laser

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Abstract

By incorporating two sections of polarization maintaining fibers in the passive mode locked fiber ring laser cavity, dual wavelength ultrashort pulse outputs, around 1558 nm and 1570 nm, having the same direction of polarization and pulse widths of 2.4 ps and 2.1 ps, respectively, were observed simultaneously.

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Keywords: Optical fiber laser; Optical soliton; Optical polarization; Optical filter

1. Introduction

Ultrafast fiber optics has attracted great attention due to their potential applications in the field of telecommunication, medical, scientific research and Terahertz field generation. Ultrashort single wavelength ultrashort pulse output from passive mode locked fiber laser have been obtained through nonlinear polarization rotation (NPR), stretched pulse, additive pulse mode locking, Figure-8 switch techniques [1–5], etc. Bound-solitons were also observed by several research groups [6,7]. Further to these techniques, single-soliton, multi-solitons, and bound–solitons and noise-like pulses phenomena have been summarized and analyzed [5]. Recently, high repetition rate output (up to several hundreds Gigahertz) based on four wave mixing (FWM) effect from passive mode locked fiber ring laser has been reported, where the authors have used a sampled FBG [8] or biased modulator [9]. Multiwavelength outputs in continuous wave (CW) type and actively mode-locking type of Erbium fiber and SOA laser have been thoroughly investigated [10–13]. In the latter case, the necessary framework for the theoretical analysis of the relevant deployed technique has been also recently established [14]. But multiwavelength ultrashort pulse output in passive mode locked fiber ring laser has not yet been addressed so far.

In this paper, we present a passive mode locked fiber ring laser based on nonlinear polarization rotation technique. By incorporating two sections of polarization maintaining fibers, which forms a filter together with the polarizer in the cavity, we firstly observed dual wavelength ultrashort pulses outputs simultaneously around 1558 nm and 1570 nm. They have a pulse width of 2.4 ps and 2.1 ps, respectively, and they have the same direction of polarization.

2. Experiment and results

Fig. 1 shows the configuration of the dual wavelength passive mode locked fiber ultrashort pulse ring laser. The loop length of the laser cavity is about 22 m, which

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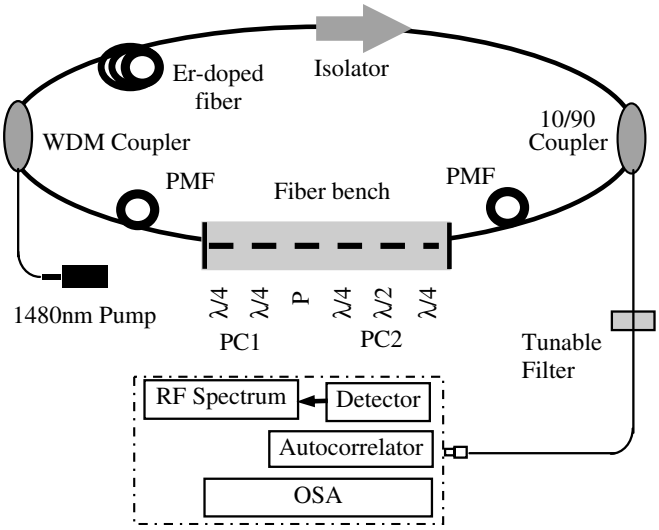

Fig. 1. The configuration of the dual wavelength passive mode locked fiber ring laser.

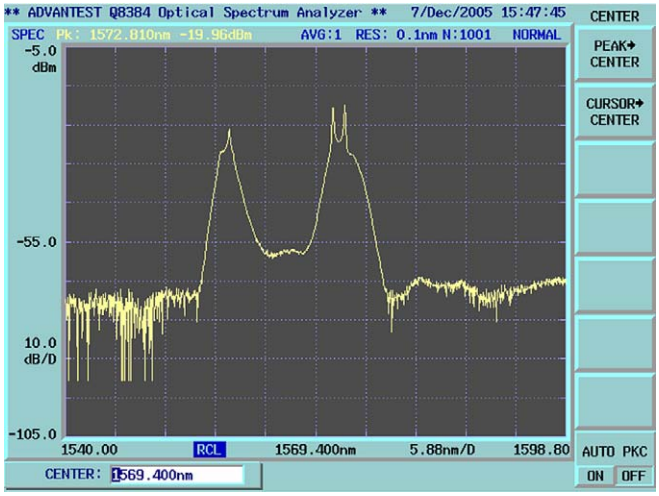

Fig. 2. The spectrum of dual wavelength ultrashort pulse.

comprises of about 8 m long high erbium-doped fiber (Fujikura). Total cavity loss is around 2.0 dB except Erbium-doped fiber. A Keopsys Raman Fiber Laser at 1480 nm is used to pump the laser. Unidirectional operation of the laser is enforced by the inclusion of a polarization-independent isolator in the cavity. There are two polarization controllers (PC) as shown in Fig. 1. PC1 consists of two quarter-wave plates; PC2 consists of two quarter-wave plates and one half-wave plate. All the waveplates are mounted on a Newport fiber bench. The combination of the negative dispersion value of the Erbium-doped fiber and the positive dispersion of the single mode fiber leads to a total cavity dispersion of around 20 fs/nm at 1550 nm wavelength. Two pieces of polarization maintaining fibers (PMF) with length of 113 cm and 67 cm, respectively, were inserted into the cavity as shown in Fig. 1. Our tested beat length of the PMF is around 1.2 cm. Different phase shifts work together with the polarizer in the cavity leading to a filter effect. The separation $\Delta\lambda$ between two peaks can be estimated by [15]:

$$\Delta\lambda \propto \frac{L_B}{L_1 \pm L_2} \tag{1}$$

where L_B is the beat length of the PMF while L_1, L_2 are the lengths of the PMFs in the cavity. Then here the estimated corresponding $\Delta\lambda$ are about 12 nm and 45 nm, respectively.

By careful adjustment of the waveplates, self-started dual wavelength mode locking was observed. Sometimes, only one of its wavelengths achieved mode locking while the other mode may still be lasing in CW if the PCs were not in the perfect positions. Fig. 2 shows the dual wavelength ultrashort pulse laser spectrum (Advantest Q8384) from the laser's direct output with a pump power of 200 mw. There are two simultaneous mode-locking wavelengths that have peak wavelengths around 1558 nm and 1570 nm, respectively. The approximate spectral bandwidths for each wavelength ultrashort pulse were 2 nm and 3 nm, respectively. Both these peak wavelengths can be shifted up to a maximum of 4 nm and the spectral widths can be varied a little by tuning the waveplates. Both these wavelength ultrashort pulses are accompanied by one or two strong CW components because of the high Raman pump power (minimal pump output power is 60 mw at start-up). If the pump power is lower than 180 mw, mode-locking of the dual wavelengths will be unstable.

We used a tunable filter, with a 3 dB bandwidth of 5.8 nm, to filter out shorter wavelength (Fig. 3). The output powers, after the filter, are 2.0 mw and 4.4 mw, respectively. They are quite strong due to the existence of the CW components. Later a 45 GHz Newfocus photodetector (Newfocus 1056) was used to detect the signal. A clear frequency component of 9.24 MHz with 50 dB signal noise ratio was seen on the spectral analyzer (Agilent E4404B). It was only the fundamental round trip frequency of the cavity. Fig. 4 shows the temporal domain profile from the wide band oscilloscope (Agilent Infinitum 86100A). It

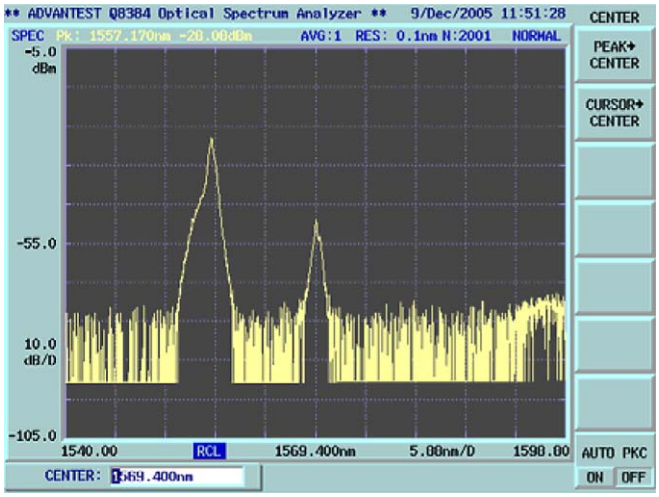

Fig. 3. Single wavelength ultrashort pulse spectrum after filter.