Linearly Polarized, 135-nm Bandwidth Pulse Generation in an Erbium-Doped Fiber Ring Laser

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Abstract: We present a linearly-polarized erbium-doped fiber laser generating 135-nm bandwidth pico-second pulses with excellent temporal and spectral stability. The pulse energy and width are readily reconfigurable via controlling the internal polarization state and pumping power.

OCIS Codes: (140.3500) Lasers, erbium, (140.3510) Lasers, fiber, (140.3560) Lasers, ring, (140.3538) Lasers, pulsed

1. Introduction

Ultrashort optical pulses have been generated with fiber lasers exploiting a variety of cavity configurations and mode-locking techniques. Passively mode-locked erbium-doped fiber (EDF) lasers can operate in both soliton and non-soliton regimes by controlling the group velocity dispersion (GVD) in the cavity [1]. Apart from these traditional pulse generation techniques, a passively mode-locked fiber laser can also generates very broad bandwidth (noise-like) pulses [2,3]. These pulses can be regarded as a bunch of ultrashort pulses with random pulse widths and peak powers that circulate in the cavity at the fundamental roundtrip frequency. These pulses eventually form a very broad spectral emission, which is sometimes even broader than the gain bandwidth [3]. Light sources with such a broadband spectrum are very useful in areas such as optical metrology or optical coherent tomography (OCT), where short coherence lengths are essential and ultimately required. In this work, we present a linearly polarized, all-fiber erbium doped fiber ring laser that generates 135-nm bandwidth pico-second pulses operating at an eye-safe wavelength range centered at 1570 nm with excellent temporal and spectral stability. The result is obtained by exploiting fiber birefringence and nonlinearity in the cavity. This result is, to the best of our knowledge, the broadest spectral bandwidth directly generated from an EDF laser [3]. Furthermore, we thoroughly characterize the source, also making a range of modifications to the main cavity as well as investigating the effects of the total group velocity dispersion GVD in the pulse and bandwidth characteristics.

2. Experimental setup

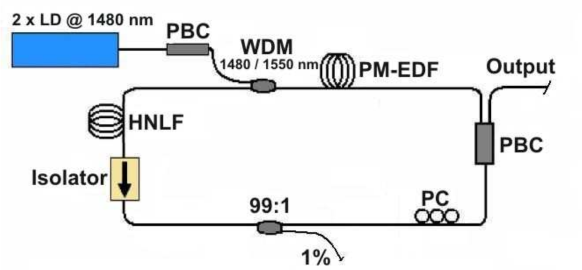

Fig. 1. Schematic diagram of the erbium-doped fiber ring laser. LD: laser diode, PBC: polarization beam combiner, PC: polarization controller, PM-EDF: polarization maintaining erbium doped fiber.

The experimental setup of the ring laser is depicted in Fig. 1. The laser cavity consists of 5-m polarization maintaining erbium doped fiber (PM EDF), a WDM coupler (1480 /1550 nm) that combines the laser signal and pump light from two laser diodes (LD) delivering a maximum power of 270-mW at 1480 nm. The other components include a 12-m Sumitomo highly nonlinear fiber (HNLF) with a nonlinear coefficient $\gamma = 10$ (W Km)$^{-1}$, a fiberized isolator to ensure unidirectional lasing, a 99/1 coupler to monitor the intracavity signal, and a polarization controller to adjust the state of polarization inside the cavity and to adjust the output-coupling ratio of the laser. Finally, a fiberized polarization beam splitter (PBS) is used to obtain linearly polarized output pulses and to excite only one of the polarization modes inside the PM EDF. In practice, a polarization beam combiner (PBC) is used by reversing its output port and input ports so that it can act in the same way as a PBS. The total length of the cavity is ~22 m.

3. Experimental results and discussion

A stable train of pulses with a fundamental repetition rate of 9.1 MHz was readily achieved by adjusting the polarization controller in the cavity for pump powers above 120 mW. In this regime, the laser's output presented square-shaped pulses with an average pulse width of ~90 ps measured with a 20 GHz bandwidth oscilloscope. The autocorrelation trace of these pulses showed a narrow spike with subpicosecond width located on the top of a broad asymmetric pedestal that covered the maximum scan range of the autocorrelator (30 ps) used. (Note that this autocorrelation trace is not shown in the paper.) By finely tuning the PC, the pulse width can be broadened up to ~ 220 ps. Fig. 2(a) shows the characteristics of the optical spectrum in this regime. As the average square-pulse width becomes broader, the optical bandwidth is reduced. [See bold trace in Fig. 2(a).] Fig. 2(b) shows the characteristics of the pulse width and energy as a function of the output power while adjusting the state of polarization in the cavity, thereby varying the coupling ratio of the cavity. By increasing the pump power with holding the PC at a fixed position, it was also possible to increase the pulse width as well as the average output power of the laser.

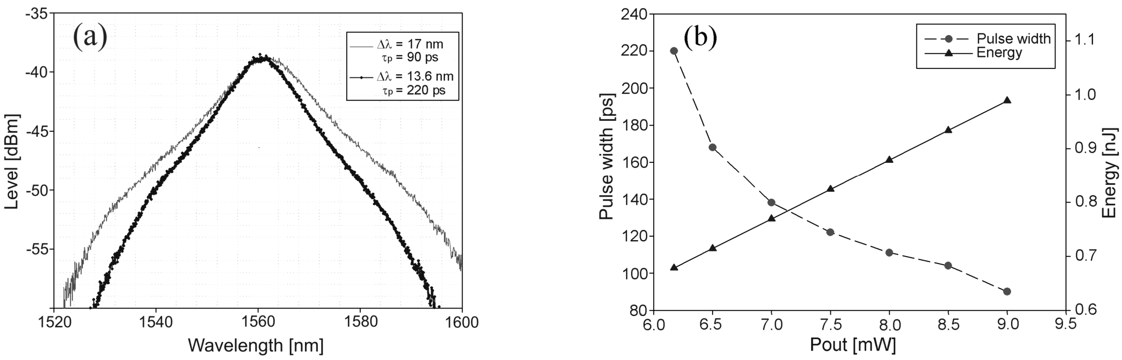

Fig. 2. (a) Optical spectrum of a bunched noise-like pulse and (b) pulse width and pulse energy as a function of the output power.

With increasing the pump power to the maximum (270 mW) as well as adjusting the internal polarization state we obtained a smooth and nearly flat spectral emission, the bandwidth of which was ~135 nm. [See Fig. 3(a).] The average output power of the laser was 6.9 mW. The autocorrelation trace of the output pulse is shown in Fig. 3(b), where a narrow spike of a sub-pico-second pulse sits on the top of a pedestal of ~6.5-ps width. This represents a feature of the complicated intensity pattern of the bunch of pulses, while we could obtain very stable pulses of a several-picosecond duration.

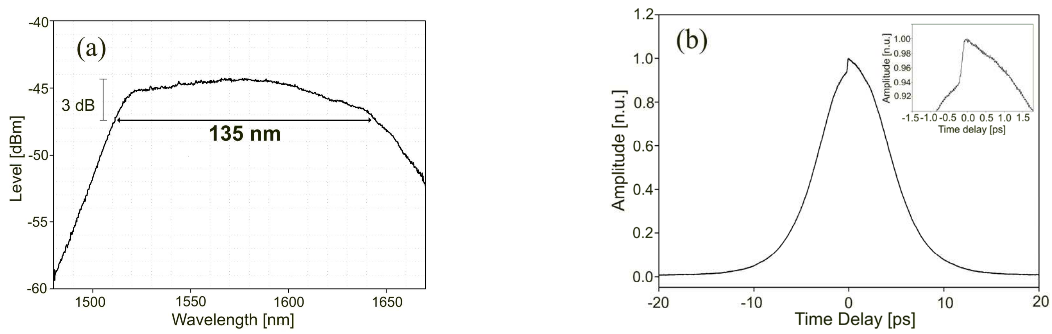

Fig. 3. (a) Optimized optical spectrum of a bunched noise-like pulse and (b) the corresponding autocorrelation trace of the laser output.

4. Conclusion

We have demonstrated a linearly polarized ultra broadband fiber laser source of 135-nm bandwidth by exploiting the birefringence and nonlinearity of the fiber in a ring cavity configuration. Further comprehensive investigation including the relative intensity noise (RIN) measurement of the source (in comparison with other broadband sources, e.g. fiber-based supercontinuum source, etc. and its applications to an OCT system are currently being carried out and will be presented at the conference.

5. Reference

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