1 GHz spaced Er:fiber frequency combs based on NPE mode-locked laser

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High-repetition-rate optical frequency combs (OFCs) have many applications in the fields of optical metrology, spectroscopy, astronomy etc. Especially, OFC is recognized as the most efficient and simple optical frequency measurement tool, which will be key components for optical atomic clocks. Notably, gigahertz frequency combs offer enhanced power per comb-mode compared to conventional megahertz frequency combs, leading to improved signal-to-noise ratios (SNR) in beat signals. In order to generate high repetition rates, semiconductor saturable absorber mirrors (SESAMs) are widely used in either solid-state or fiber lasers. However, such lasers are generally limited by low output power and broader pulse width. In addition, the SESAMs are subjected to optical damage.

The nonlinear polarization evolution (NPE) mode locked ring fiber laser can output a higher power and a shorter pulse to meet the requirements of spectrum expansion. Our group have generated GHz OFCs based Yb:fiber laser[1, 2]. However, limited by the low doping, the ring cavity Er-doped fiber laser is difficult to generate higher repetition rates.

The key to make an high-repetition-rater ring fiber laser is sufficiently short fiber and as well as compact free-space components. In the experiment, the total Er:fiber length is 190 mm and the free-space takes about 18 mm. Four laser diode modules are employed as pump sources, providing a total pump power of up to 3 W. By properly rotating the wave plates, the mode-locking is easily achieved with the standard NPE process. The fundamental repetition rate is estimated to be 1.006 GHz, and the signal-to-noise ratio is 70 dB at a resolution bandwidth of 30 kHz, which implies mode-locking status is stable. The maximum output power was 200 mW, which corresponds to a pulse energy of 200 pJ. The spectral width is 30 nm, and the direct output pulse duration is 81.8 fs. The output power was amplified to 280 mW and the pulse width was compressed to 69 fs. By sending the amplified pulses to a f-to-2f waveguide module based on a tantalum pentoxide (Octave Photonics, COSMO), a 32 dB f_{ceo} was achieved at a resolution band width of 100 kHz, which is sufficient for locking. The schematic diagram of the optical frequency comb is shown in Figure 1.

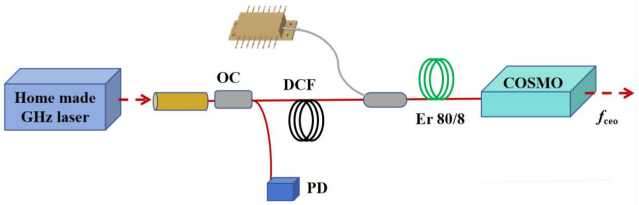

Fig. 1: Schematic diagram of the optical frequency comb based on NPE mode-locked laser.

[1] C Li, "1 GHz repetition rate femtosecond Yb:fiber laser for direct generation of carrier-envelope offset frequency", Appl. Opt., vol. 54, p. 8350-8353, 2015.

[2] B Xu, "Fully stabilized 750-MHz Yb: fiber frequency comb", Opt. Express, vol. 25, p. 11910-11918, 2017.