A 2cm-long fiber Fabry-Perot mode-locked laser incorporating carbon nanotubes

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Abstract: We demonstrate passive mode-locking of short-cavity (~2cm) fiber Fabry-Perot laser by incorporating carbon nanotubes as a saturable absorber. Stable pulses are generated with pulsewidth as short as 0.68ps and repetition rate as high as 5.18GHz.

OCIS codes: (000.0000) General

Passively mode-locked fiber lasers have been used in many applications due to their simplicity and their ability to generate transform-limited optical pulses in the sub-picosecond regimes. Such lasers, however, have not yet been applied to telecom sources because the cavity is long, typically from a few tens of meters to kilometers, as a result the repetition rate is low and unstable. In order to realize the telecom-grade pulse source, the cavity has to be shortened to a few tens of millimeters using the high-gain fiber, and small and fast SA. We have previously realized short-cavity (from a few hundred micrometers to a few centimeters) fiber Fabry-Perot lasers (FFPLs) using high-gain Er:Yb fibers to realize single-wavelength [1][2] and multi-wavelength [3] operations. As for a small and fast saturable absorber (SA), semiconductor SA mirrors (SESAMs) have been commonly used. Instead, we recently demonstrated a SA incorporating carbon nanotubes (SAINT) [4][5] which offers many advantages such as ultra-fast recovery time (<1ps), simplicity, robustness, etc. The SAINT can be directly formed onto the cleaved fiber end [6].

In this paper, we present stable generation of high-repetition pulses from a 2cm-long mode-locked FFPL using Er:Yb fiber and SAINT. This is the shortest cavity length and the highest repetition rate ever achieved in the passively mode-locked fiber lasers, to the best of our knowledge.

The passively mode-locked FFPL is illustrated in Fig.1. The laser consists of 2cm-long Er:Yb fiber, single-mode fibers with high-reflection (HR, ~99.87%) mirrors deposited on polished end-faces, and the SAINT between the left HR mirror and the Er:Yb fiber. The SAINT is a thin layer of single-wall nanotubes (SWNTs) with thickness of <1μm. The SWNTs are commercially available from Carbon Nanotechnologies Incorporated, having an absorption range from 1.1μm to 1.7μm. The Er:Yb fiber has absorption of 0.1dB/mm at 1535nm, and 2.4dB/mm at 976nm [2]. The laser is pumped from the right end with a 980nm laser diode (LD) through a wavelength-division multiplexed (WDM) coupler, and the rightward lasing light is output through the WDM coupler and an isolator.

At small pump power, the laser operates in unstable multimode, as is the case without SAINT. At a pump power of around 100mW, the laser self-starts to mode lock and produce stable pulses trains at a fundamental repetition rate of 5.18GHz. Once mode locked, the laser maintains the stable fundamental mode locking until the pump power is reduced to 25mW. The output spectrum and SHG autocorrelation trace at the pump power of 60mW are shown in Figs.2(a) and 2(b), respectively. Longitudinal mode structure is clearly seen in Fig.2(a) with the mode spacing of ~0.04nm. The average output power is about –7.6dBm. The 3dB spectral width is ~4.7nm, and inferred pulsewidth from Fig.2(b) is as short as 0.68psec.

We also measured the RF spectra after detection. Figure 3 shows the RF spectrum around fundamental repetition frequency of 5.18GHz. The fundamental line is narrower than the resolution (100Hz), indicating that the timing jitter is very small. The line frequency, however, slowly drifts within ±2.5kHz, due to the environmental change. We believe that the frequency can be locked to meet the telecom data rate with a feedback-control of the cavity length.

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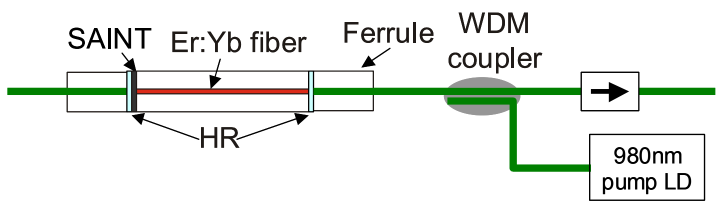

Fig. 1. Passively mode-locked FFPL with SAINT

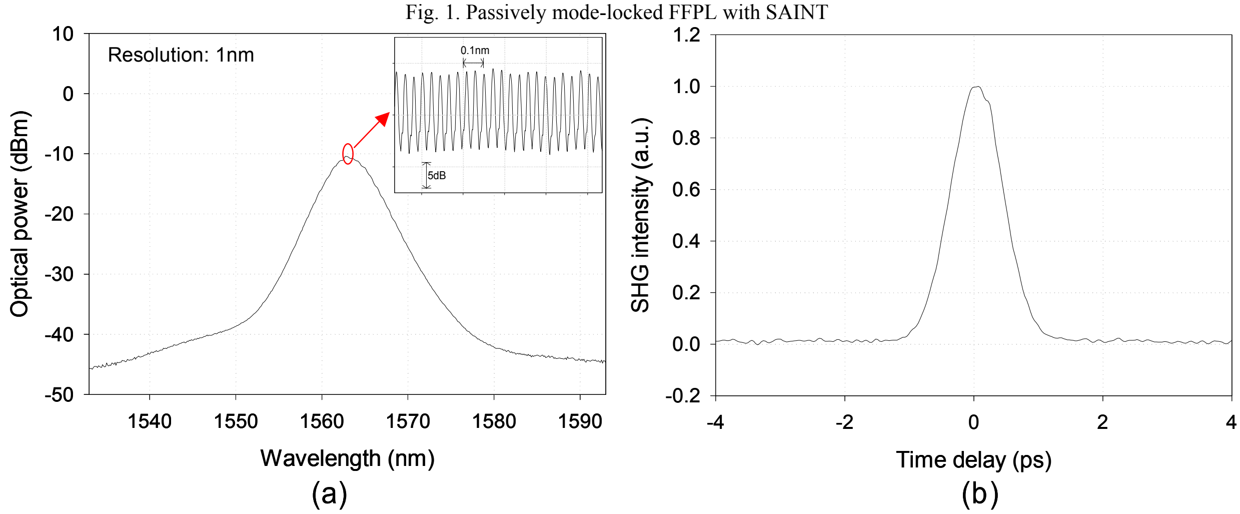

Fig. 2. (a) Output optical spectrum (b) SHG autocorrelation trace

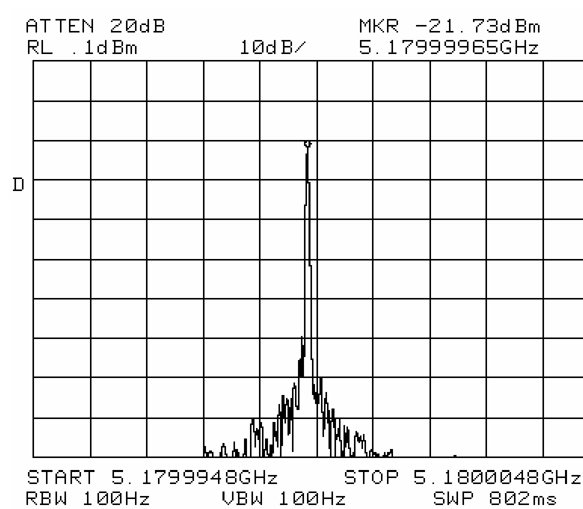

Fig. 3. RF spectrum around fundamental repetition frequency