The Characterization of a Simple, Smoothly Wavelength-Tunable Harmonically Mode-Locked Fiber Ring Laser

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Abstract: A very simple configuration of smoothly wavelength-tunable mode-locked fiber ring laser is characterized. It can directly generate 11-ps near transform-limited pulses with 1.7% amplitude noise and 0.7-ps timing jitter and achieve 12-nm smooth wavelength tuning.

OCIS codes: (140.4050) Mode-locked lasers, (140.3510) Fiber lasers, (250.5980) Semiconductor optical amplifiers

1. Introduction

Harmonically mode-locked fiber ring lasers (HMLFRLs) are able to generate high-speed, wavelength-tunable picosecond pulses with simple implementation. However, most configurations reported so far can not achieve wavelength tuning without interrupting the stable pulsing due to the multi-parameter nature of their tuning mechanisms [1, 2]. We have demonstrated a stable and smoothly wavelength-tunable HMLFRL by combining dispersion tuning and an intracavity SOA [2]. However, the laser requires external pulse compression and appears to produce strong asymmetric pulses with large nonlinear chirp due to the nonlinearity of the SOA. In this paper, we report a simplified but improved design, which properly combines the effects of dispersion and SOA to achieve better pulse quality while maintaining the unique features of smooth wavelength tuning and low amplitude noise.

2. Experiment

Fig. 1 shows the laser configuration. The EDFA is the major gain medium. Unlike the previous system, in which a $LiNbO_3$ modulator was used as the mode-locker and the SOA was used to suppress supermode noise, the SOA is directly modulated to achieve active mode locking so that the modulator can be removed. The intracavity group velocity dispersion is provided by 25-m dispersion compensating fiber, which has a normal dispersion parameter of -88 ps/(km·nm) at 1560 nm.

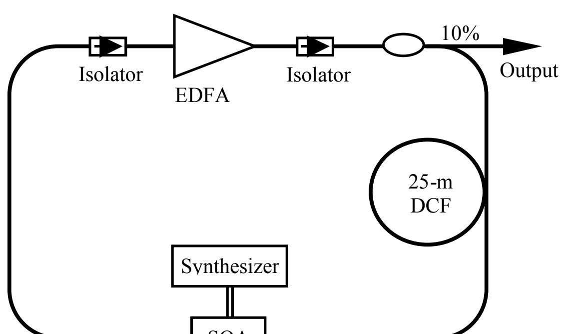
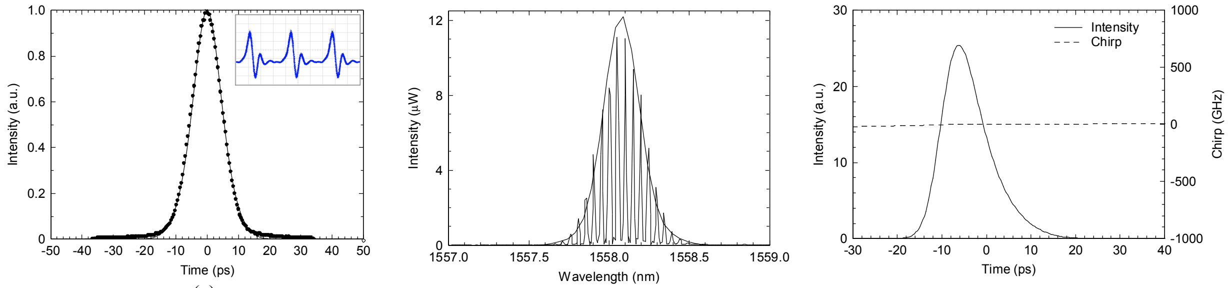


Fig. 1. Schematic of the laser configuration.

The experiment was conducted at repetition frequencies around 6 GHz. This value was limited by the RF coupling to the SOA. Stable pulsing was realized as evident from the oscilloscope trace (inset of Fig. 2 (a)). A FWHM pulsewidth of 11.4 ps and a 3-dB spectral width of 0.25 nm were measured at 1558 nm, leading to a time-bandwidth product of 0.35 with the assumption of $Sech^2$ pulses, which indicates that the pulses are near transform-limited even without pulse compression. Fig. 2 shows the normalized autocorrelation trace of the pulses and the optical spectrum.

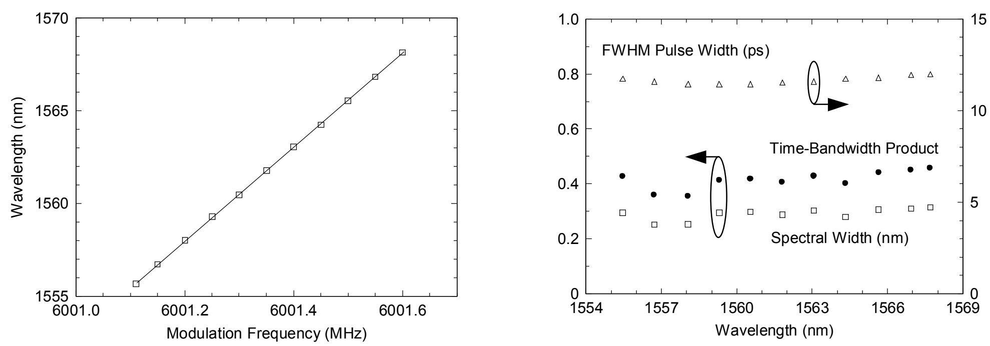


(a) (b) (c)

Fig. 2. Pulse characteristics: (a) oscilloscope trace (inset) and autocorrelation trace (dots – experiment, line – simulation); (b) optical spectrum (envelope is simulation result); (c) pulse shape and chirp from simu lation.

In order to study the combined effect of dispersion and SOA, numerical simulation was conducted. The algorism was similar to that described in [2], with the only exception that the SOA gain was varied sinusoidally. Experimental data used, the simulation result shows that the frequency chirp across the output pulse is flat and close to zero, as shown in Fig. 2 (c), which agrees with the experimental result. The calculated autocorrelation function and the spectrum also show good agreement with the experiment (Fig. 2 (a), (b)).

Smooth wavelength tuning over 12 nm was achieved by varying *only* the modulation frequency within 500 KHz. The spectral peak red-shifted when the frequency increased, indicting a normal total intracavity dispersion, and the oscilloscope trace remained still, indicating stable pulsing throughout the tuning process. The linear wavelength-frequency relation and the pulse characteristics at different wavelengths are shown in Fig. 3.



(a) (b)

Fig. 3. Smooth wavelength tuning: (a) wavelength vs. modulation frequency; (b) pulse characteristics at different wavelengths.

The noise properties of the laser were characterized using RF spectral method. Fig. 4 shows a typical power spectrum around one modulation harmonic (inset) and the ratios of the noise band integral over the harmonic peak at different harmonics. By fitting the curve quadratically, the amplitude noise and the timing jitter were determined to be 1.7% of the average output power and 0.7 ps, respectively.

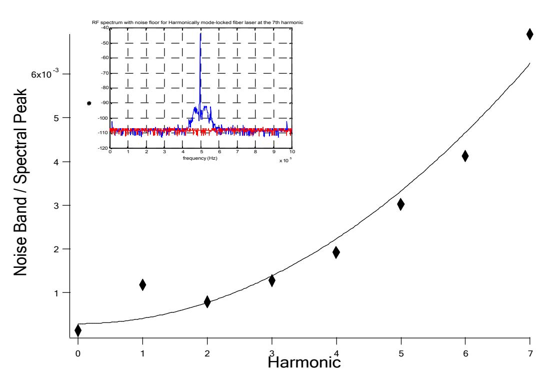


Fig. 4. Power spectrum at the 7th harmonic (inset) and the ratio of noise band integral over spectral peak vs. harmonics.

3. Conclusion

The proper combination of intracavity normal dispersion and a directly modulated SOA can generate near transform-limited picosecond pulses without pulse compression while retaining the smooth wavelength tunability of dispersion-tuned lasers. Amplitude and phase noises are found to be reasonably low even without special stabilization.

Reference

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