High power and high repetition rate pulse generation using self injection-locking in Fabry-Perot Laser diode

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Abstract: A 139.6 GHz transform limited pulse train with peak power of 120 mW is generated using self injection-locking of a Fabry-Perot Laser diode. The pulsedwidth is 1.6 ps and the time-bandwidth product is 0.34.

OCIS code: (140.3520) Laser, injection-locked, (190.7110) Ultrafast, nonlinear optics

1. Introduction

High bit-rate pulse trains have many important applications in ultrahigh-speed optical communication systems. Active mode locking [1] or modulation instability in erbium-doped fiber ring lasers (ED-FRL) [2-3] are attractive methods to generate high speed pulse trains, but the output power is not very high. High repetition pulse generation based on nonlinear propagation of a dual-frequency beat-signal within a long piece of dispersion decreasing fiber requires two DFB lasers [4]. In this paper, we report a simple method to generate high power and high repetition rate pulse train based on self injection-locking in a commercially available Fabry-Perot laser diode (FP-LD). Two-mode self injection-locking in a FP-LD is achieved by connecting a dc driven FP-LD externally with two uniform fiber Bragg gratings (FBGs). The two self injection-locked modes interfere and evolve into a high power high repetition rate pulse train through interplay between self-phase modulation and anomalous dispersion in a long piece of highly nonlinear fiber (HNLF). The repetition rate and peak power of the transformed-limited pulse train is 139.6 GHz and 120 mW respectively.

2. Experiment

Figure 1 shows the experimental setup for the proposed high repetition rate pulse generation based on a self injection-locking of a FP-LD. We used a commercially available FP-LD with center wavelength of 1550 nm and threshold current of 8 mA. The dc bias current is chosen to be 10.4 mA. The multimode output of the FP-LD is injected into two uniform FBGs through a 1:1 coupler. The Bragg wavelengths of the two FBGs are tuned to coincide with two different longitudinal modes of the FP-LD. The two FBGs therefore reflect the power of the two longitudinal modes back to FP-LD, thus forming a two-mode self injection-locked output. The self injection-locked output can be optimized by adjusting the polarization controllers PC1 and PC2.

The self injection-locked FP-LD output is obtained from Arm 1 of the coupler (see Fig. 1). The two self injection-locked modes have similar polarization and will therefore beat. The beating signal is amplified by an EDFA with maximum output power of ~340 mW, and then propagates through a 1146 m long HNLF. The dispersion coefficient of the HNLF is 2.6 ps/nm/km at ~1550 nm and the nonlinear coefficient is ~14 W⁻¹km⁻¹. Through interplay between four wave mixing and group velocity dispersion (GVD) in the HNLF, a high average power, high repetition pulse train is formed at the end of HNLF. The 10% output signal from a 1:9 coupler at the end of the HNLF is sent to an optical spectrum analyzer (OSA) with resolution of 0.01 nm. The 90% output power is sent to an auto-correlator for autocorrelation trace measurement.

3. Results and discussion

Figure 2(a) shows the free running spectrum of the FP-LD. The center wavelength is around 1546.5 nm. Figure 2(b) shows output spectrum of the two adjacent simultaneously self injection-locked longitudinal modes at Arm 1. The wavelengths of the two modes are

Fig. 1 Experiment setup for high repetition pulse generation based on self injection-locking in a FP-LD.

1550.91 nm and 1552.03 nm. The wavelength spacing is 1.12 nm. Side mode suppression ratio (SMSR) is ~ 38 dB and the output power is about -26.39 dBm

The two self injection-locked longitudinal modes have the same polarization at Arm 1 because the FP-LD output is TE-polarized. The two longitudinal modes beat and experience both four wave mixing and GVD in the HNLF after amplification by the EDFA. Figure 3(a) shows the output spectrum from the 10% arm of the 1:9 coupler. From the spectrum, side bands are generated on both sides of the two original FP-LD modes as a result of FWM. The wavelength spacing between these side modes is ~ 1.12 nm. The 3 dB bandwidth of the spectrum is about 1.7 nm. Figure 3(b) shows the corresponding autocorrelation trace of the pulse train. From Fig. 3(b), the peak-to-peak pulse spacing is 7.16 ps. This corresponds to a repetition rate of 139.6 Gb/s. The FWHM of the central pulse in the autocorrelation trace is ~ 2.3 ps. Assuming a Gaussian profile, the FWHM of the corresponding individual pulse in the train is about 1.6 ps. This gives a time-bandwidth product of ~ 0.34 indicating a transform-limited pulse train. The average output power is ~ 14.5 dBm. The peak power is therefore ~ 120 mW. The pulsewidth and time-bandwidth product can be varied by changing the pump power of EDFA. Figure 4 shows the pulsewidth (triangles) and time-bandwidth product (squares) versus the output power. From Fig. 4, the balance point of self-phase modulation and GVD is at output power of ~ 14 dBm, where the pulse width is ~ 1.6 ps and time-bandwidth product is ~ 0.34 .

Fig. 2 (a) Free running spectrum of FP LD and (b) two simultaneously self injection-locked FP-LD modes at wavelengths of 1550.91 nm and 1552.03 nm.

Fig. 3 (a) Output spectrum and (b) the corresponding autocorrelation trace after the HNLF.

Fig. 4 Pulsewidth (triangles) and time-bandwidth product (squares) versus output power.

4. Conclusion

We report a high output power, high repetition rate, and transform-limited optical pulse train generation based on simultaneously self injection-locking of two longitudinal modes of a FP-LD. The repetition rate is 139.6 GHz, the pulse width is ~ 1.6 ps and the time-bandwidth product is ~ 0.34 .

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6. Reference

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