Threshold condition for pulse generation from a DISC-loop-type pulse generator

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Abstract

We improved the quality of 5-ps, 10-GHz pulses from a DISC-loop-type pulse generator. Separately, we observed that the pulse power drastically increased when the pulse loop gain reached the threshold gain.

Introduction

Ultrashort pulses with repetition rates as high as 40 GHz are needed for the ultrafast optical time-division multiplexed (OTDM) systems which will operate at 160 Gb/s in the near future. To generate such pulses, various pulse sources, such as mode-locked-lasers, have been studied. Recently, 3.2-ps, 50-GHz and 11-ps, 10-GHz pulse generation [1,2] using mode-locked-lasers with a ring-cavity containing a semiconductor optical amplifier (SOA) have been demonstrated.

In a delayed-interference-signal-wavelength converter (DISC [3,4]) loop-type pulse generator, the pulse width is determined by the DISC-MZI's delay time Δt. So far, 5-ps, 10-GHz pulse generation from a DISC-loop-type pulse generator has been demonstrated [5,6]. However, asymmetric distortion was observed in the optical spectrum of the output pulse [6]. Also, the effect of pulse loop gain on the pulse power was not examined.

In this work, we built a 5-ps, 10-GHz DISC-loop-type pulse generator using a commercially available SOA, and examined the pulse loop gain when the pulse was generated.

Experimental setup

Figure 1 shows our experimental setup. The pulse generator consisted of a ring cavity and an external continuous-wave (CW) laser source. The ring cavity consisted of a DISC, a tunable delay, an energy-distribution (ED) Mach-Zehnder interferometer (MZI), Er-doped fiber amplifiers (EDFA), polarizers (P), and half- or quarter-wave plates (H or Q). The DISC consisted of a SOA (Avanex 1901, drive current = 150 mA) and a MZI. The MZI contained a birefringent calcite crystal (DGD, Δt = 5.0 ps). The ED-MZI was the same as that in Ref. 6. The ED-MZI delay time ΔT_{MZI} determined the output pulse repetition frequency.

The optical phase bias between the fast and slow CW components passing through the MZI was tuned by rotating the Q and P located after the calcite crystal. The polarization direction of the CW light (λ = 1554.92nm, +0.5 dBm) from the DFB-LD to the SOA input facet was aligned to either the TE or TM axis of the SOA. The polarization of the pulse after one round trip was made vertical to the polarization state of the CW light to prevent laser oscillation. The DISC performed polarization conversion of the pulse so that the pulse could continue to go around.

Low-distortion pulse generation and threshold gain

Figure 2(a) shows a typical output optical spectrum from the DISC-loop-type pulse generator. When the optical phase bias was slightly detuned from π, we observed a low-distortion optical spectrum. The peak wavelength was equal to the input CW wavelength, the spectral width was 0.75 nm, and the spectral spacing was approximately 85 pm (10 GHz). The spectral envelope was close to the calculated spectrum of a 3.5-ps sech pulse. Figure 2(b) shows a typical autocorrelation trace. The pulse extinction ratio was 16.6 dB. The estimated pulse width was 5.5ps, assuming a sech pulse shape. This time-bandwidth product was 1.6 times as broad as the transform limit. Figure 2(c) shows a typical output radio frequency (RF) spectrum. The peak frequency was 10.439GHz, and the spectral width was 40MHz. This peak frequency indicated the pulse-repetition frequency. The 4.4-MHz-spaced RF components were the harmonics of the ring cavity frequency.

Figure 3(a) shows the dependence of the power of the cross-phase modulation (XPM) components on the pulse loop gain. We defined the pulse loop gain as the sum of the DISC transmittance, the passive device losses, and the EDFA unsaturation gains. We estimated the DISC transmittance to be –14 dB when we input the 2-ps, 12.5-GHz pulse train into the DISC unit in a separate experiment. We defined the XPM component power as the total of the power from the third, second, and first blue components and the first, second, and third red components. The

XPM component power drastically increased by 12 dB when the pulse loop gain reached approximately +7 dB. This threshold gain was larger than the 0 dB that we had expected. We think this difference was because our estimation of the DISC transmittance was high.

Conclusion

We generated 5-ps, 10-GHz pulses with a low-distortion optical spectrum from a DISC-loop-type pulse generator. We examined the pulse-generation conditions and observed that the pulse power drastically increased when the pulse loop gain reached the threshold gain.

References

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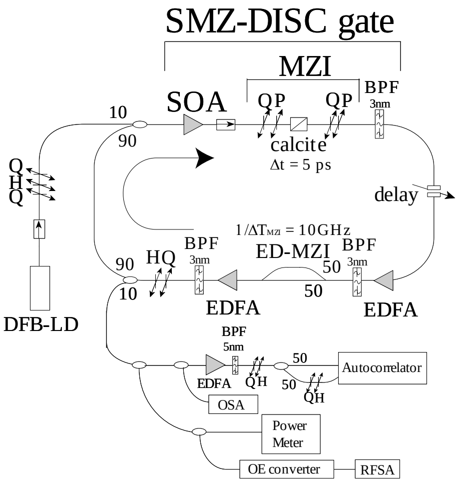

Fig. 1. Experimental DISC-loop-type pulse generator setup
SOA: semiconductor optical amplifier, BPF: band pass filter
ED-MZI: energy distribution Mach-Zehnder interferometer
H: half wave plate, Q: quarter wave plate, P: polarizer
EDFA: Er-doped fiber amplifier, OSA: optical spectrum Analyzer
RFSA: radio frequency spectrum analyzer

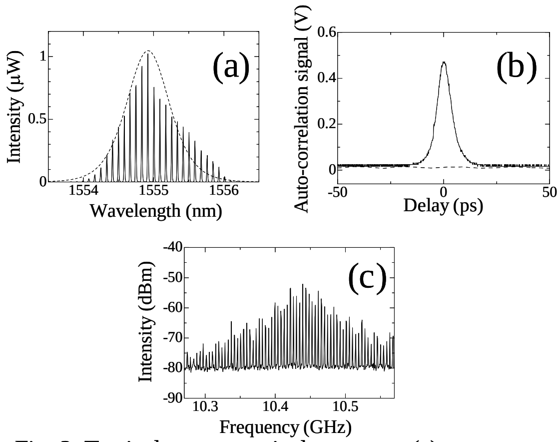

Fig. 2. Typical output optical spectrum (a), autocorrelation trace (b), and RF spectrum (c).
Pulse loop gain = +16.7 dB, CW wavelength =1554.92 nm.
The dashed curve in (a) is a 3.5-ps pulse's spectrum.
The dashed line in (b) is the background level.

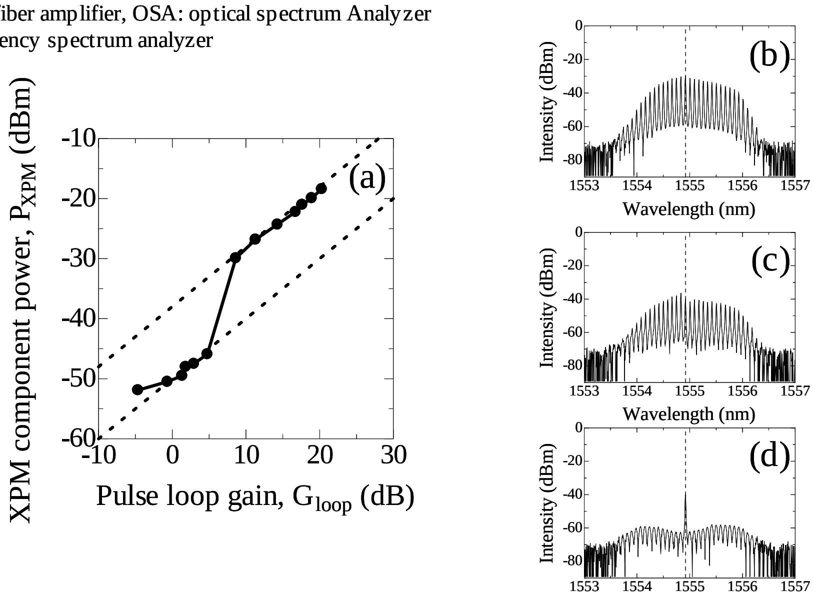

Fig. 3. Threshold conditions for pulse generation.
(a) XPM component power as the total of the power of the third, second, and first blue components and the first, second, and third red components.
The dashed line is for $G_{loop} = P_{XPM}$ as a reference.
Optical spectrum with a pulse loop gain of +16.7 dB (b), +8.63 dB (c), +4.76 dB (d)
The dashed line is the CW wavelength (1554.92nm) .