40-GHz mode-locked pulse generation with a new scheme of SOA-based pulse generators

Rei Suzuki, Takashi Ohira, Jun Sakaguchi, and Yoshiyasu Ueno

Univ. of Electro-Communications, Dept. of Electronic Engineering, 1-5-1 Chofugaoka, Chofu, Tokyo 182-8585, Japan

suzuki@ultrafast.ee.uec.ac.jp

Abstract: We have successfully demonstrated high-quality, 40-GHz, 4.5-ps, 1550-nm, passively-mode-locked pulse generation, with our original SOA-based pulse-generator scheme.

OCIS codes: (250.5980) Semiconductor optical amplifiers; (320.7080) Ultrafast devices; (060.2330) Fiber optics communications; (190.5970) Semiconductor nonlinear optics

1. Introduction

High-quality short-pulse optical sources with high-repetition rates are key elements for realizing ultrahigh-speed optical-communication systems that flexibly combine ultrafast TDM and WDM technologies. In addition to conventional mode-locked laser diodes (MLLD's), semiconductor-optical- amplifier (SOA) -based mode-locked ring lasers have recently been proposed because of their possible advantages in the long-term stability, mass-production, and large-scale integration in the near future [1, 2]. In contrast to the MLLD's, however, the mode-locking mechanism that determines the width of the output pulses of those SOA-based lasers has not been clearly studied, to the authors' knowledge. On the other hand, the present authors have proposed a new scheme of SOA-based mode-locked-pulse source that contains a delayed-interference signal-wavelength converter (DISC [3,4]), and have successfully demonstrated mode-locked 10-GHz, 5-ps pulse generations [5, 6]. It has been shown that the output-pulse's width (5 ps) in this scheme is strongly determined by an interference delay time (Δt= 5 ps) inside the DISC [5, 6].

In this work, we demonstrate 40-GHz pulse generation, for the first time to the authors' knowledge.

2. Experimental set up

Our experimental set up is shown in Fig. 1. The continuous-wave (cw) light at 1549.965nm was injected into the ring cavity at 0dBm. We adjusted the cw wavelength to the top of the transmission spectrum of the 40-GHz etalon inside the cavity. The DISC in this pulse-generation-scheme converts the polarization of the re-circulating pulses from TE to TM (or vice versa) [5]. The DISC in this work consisted of a commercial SOA (Avanex 1901, drive current = 150 mA) and a MZI. The polarization direction of the cw light at the SOA input facet was carefully aligned to either the TE or TM axis of the SOA, for preventing unexpected nonlinear polarization rotations. In the SOA, the phase of the cw light is cross-phase-modulated by the round-trip input pulses. In the birefringent calcite crystal in the asymmetric MZI, then, the phase-modulated cw light is split into fast and slow components, between which an optical delay time Δt is given. At the end of the MZI, the two-split cw components interfere with each other, and consequently Δt-long pulses are newly generated from the input cw in principle. The polarizer was carefully adjusted to strongly remove the orthogonally polarized old input pulses, while passing through the newly generated pulses. As a result, unwanted cw lasing of the ring cavity was strongly suppressed.

The EDFA inside the ring cavity was temporarily inserted in our present ring cavity, for compensating for our relatively high fiber-coupling losses (and the relatively low transmittance of the DISC).

3. Experimental results

Fig. 2 shows the autocorrelation trace of the 40-GHz pulse trains, when we used a 5.0-ps calcite crystal. The extinction ratio (15.9 dB) of the trace has indicated the high extinction ratio (i.e., high quality) of the generated 40-GHz pulses. The envelope of the autocorrelation trace was in better agreement with a sech^2 fit than gaussian fit. Assuming a sech^2 pulse shape, the pulse width was estimated to be 4.5 ps, which corresponded well with the DISC-MZI's delay time Δt =5.0 ps (the time-bandwidth product was 0.59). Fig. 3 (a) shows the power of the second-blue spectral component as a function of the pulse loop gain (which was defined in Ref. 6). The measured results with the 40-GHz etalon in Fig. 3 has matched well with the pulse-generation mechanism that the ring cavity starts generating mode-locked pulses when the pulse loop gain approximately exceeds 0 dB [6].

When we exchanged the 5.0-ps calcite crystal in DISC to a 2.2-ps calcite crystal, we observed 40-GHz mode-locked pulses, again (Fig. 4). The pulse width in this case was estimated to be 2.0ps, and its time-bandwidth product was 0.53. Figure 4 (b) shows nonlinear phase shifts in the SOA, which were systematically measured with the experimental method that was described in Ref. 4. The measured phase shift under the 5-ps condition in Fig. 4(a) was close to that under the 2-ps condition in Fig. 2(a).

4. Conclusion

In this work, we successfully generated high-extinction, nearly-transform-limited 40-GHz, 4.5-ps, 1550-nm pulses from the DISC-loop-type pulse generator. We also generated 40-GHz, 2-ps pulses. Those pulse widths have matched well with the interference delay time, Δt of the DISC polarization converter inside the ring cavity. The origin of the relatively poor extinction ratio in case of the 2-ps pulse generation is under study.

ACKNOWLEDGMENTS

The authors would like to thank Optoquest Co., Ltd. for providing the polarization controllers.

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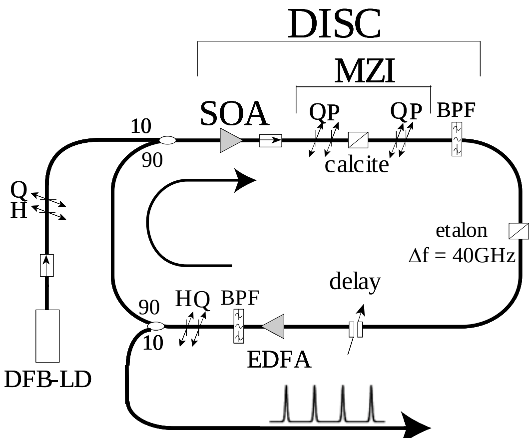

Fig.1. Experimental set up.
SOA : semiconductor optical amplifier,
MZI : Mach-Zehnder interferometer, BPF : band pass filter,
P : polarizer, H : half wave plate, Q : quarter wave plate.

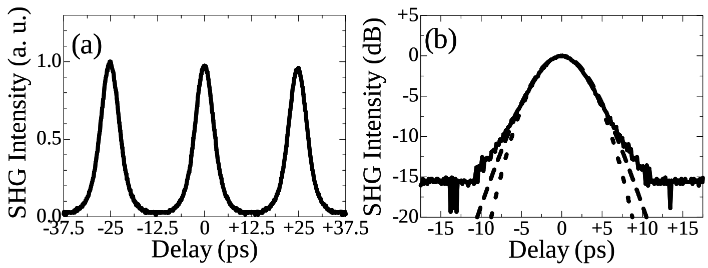

Fig.2. Autocorrelation trace of 40-GHz, 4.5-ps pulse train.
Solid curves : measured results,
Dashed curve : calculated sech^2 curve,
Dotted curve: calculated Gaussian curve.

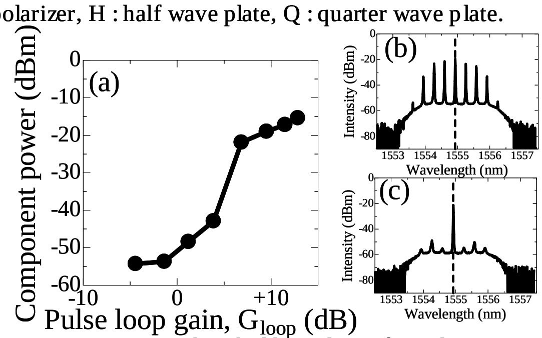

Fig.3. Threshold condition for pulse generation.
(a) The dependence of the second blue component power on pulse loop gain.
(b,c) Optical spectra with a pulse loop gain of +11.5 dB (b), +3.9 dB (c).
Dashed lines are the cw wavelength (1554.925 nm).

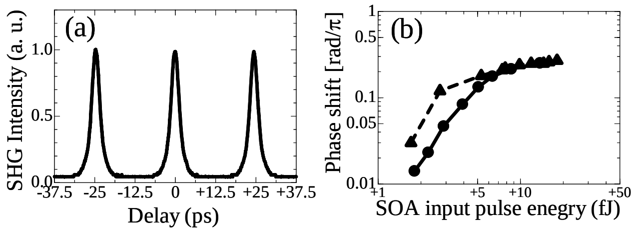

Fig.4. Measured results of 40-GHz, 2.0-ps pulse train.
(a) Autocorrelation trace. SOA input pulse enegry = 14 fJ.
(b) Nonlinear phase shifts (solid curve), in comparison with those of 40-GHz, 4.5-ps pulse train.