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500 GHz Optical Pulse Generation from a Short-Cavity GRIN-SCH-MQW Mode-Locked Laser Diode

Shin Arahira, Yukio Katoh, and Yoh Ogawa

Components Division, Oki Electric Industry Co., Ltd.,
550-1 Higashiasakawa, Hachioji, Tokyo 193-8550, Japan
Phone: +81-426-62-6767 Fax: +81-426-62-6770 e-mail: arahira335@oki.co.jp

1. Introduction

Ultrafast and ultrashort optical pulse generation is attractive for applications such as high bit rate optical communication systems, micrometer/millimeter-wave communications, and ultrafast data processing. Passively mode-locked laser diode (PML-LD) shows promise for this purpose because it needs no external modulation source for pulse generation in principle and the pulse characteristics suffers no electrical limitations [1]-[2].

Shortening absorption recovery time in the saturable absorber is one of the key parameters to achieve the mode-locking at very high (>100 GHz) repetition frequencies. When the pulse period is close to absorption recovery time, the absorption modulation depth in the absorber becomes shallow and the modulation waveform also becomes close to a sinusoidal one. These weaken pulse-shortening effect and the mode-locking process is prevented. Use of graded-index separated confinement heterostructure (GRIN-SCH) on the top and the bottom of multiple quantum well (MQW) is promising for this purpose because photo-generated carriers can be smoothly swept out from SCH layer due to reduction of pile up of photo-carriers at the hetero interface.

Colliding-pulse mode-locking (CPM) configuration by locating a saturable absorber in the center of the laser cavity [1] is also promising for increasing pulse repetition frequency because the pulse repetition frequency is twice of the cavity roundtrip frequency and also the absorber can be bleached at lower pulse energy than a conventional end-absorber configuration.

In this paper, we report on a 500 GHz optical pulse generation using a short-cavity GRIN-SCH-MQW CPM-LD. Pulse shortening by GRIN-SCH structure is experimentally investigated.

2. Pulse shortening by GRIN-SCH structure

We prepared two types of PML-LDs (Fig. 1). Device A has a SCH consisting of a uniform 1.3-μm bandgap-wavelength InGaAsP layer. Device B has a GRIN-SCH consisting of three InGaAsP layers. Total thickness of the SCH layers was 600 Å. The active layers consisted of an InGaAsP/InGaAsP compressively strained MQW structure. The lasers had buried heterostructure. The lasers were divided into two or three sections corresponding to a saturable absorber and gain sections by chemical etching of Au electrode and an InGaAs contact layer.

When the current was injected to the gain sections and the absorber was suitably reverse biased, passive mode-locking occurred. We compared the pulse characteristics between device A and B. Figure 2 shows the dependence of the pulse widths and the spectral widths on the absorber length for 930 μm-length end-absorber PML-LDs. The pulse widths decreased and the spectral widths increased with shortening the absorber length. This indicates that the resultant pulse width was influenced by the transit time of the optical pulse in the absorber section. The pulse widths of the device B were shorter than those of device A, and the spectral widths of device B were broader than those of device A. This indicates that the absorption recovery time is reduced and hence pulse shortening effect is enhanced for device B. Such pulse shortening was also observed in CPM-LDs. Figure 3 shows the comparison of SHG correlation traces of 160 GHz CPM-LD output. The pulse width was reduced from 1.15 ps to 930 fs by using GRIN-SCH structure.

3. Pulse generation from a short-cavity CPM-LD

Fast absorption recovery in GRIN-SCH structure is promising for increasing pulse repetition frequency of the PML-LDs as well as the pulse shortening. We succeeded in generating a 500 GHz optical pulses from a short-cavity (170 μm) GRIN-SCH CPM-LD. Figure 4 shows (a) the SHG correlation trace (dashed line) and (b) optical spectrum of the laser output. The pulse repetition frequency was 500 GHz, corresponding to twice of the cavity roundtrip frequency, indicating that the colliding-pulse effect occurred in the absorber. This was verified in the optical spectrum at which every other lasing mode was enhanced. The laser output was broadened due to frequency chirp. The pulses were compressed to 390 fs by chirp compensation using a 7-m standard single mode fiber. The spectral width was 9.7 nm and the time-bandwidth product for the compressed pulses was 0.47, close to the transform-limited value.

4. Summary

In summary, we have succeeded in generating a 500 GHz optical pulse train using a short-cavity GRIN-SCH MQW CPM-LD. GRIN-SCH has been found to be effective to pulse shortening and also to increasing the pulse repetition frequency due to the reduction of absorption recovery time.

Acknowledgements

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References

[1] Y. K. Chen et al., Appl. Phys. Lett. **58**, 1253 (1991).
[2] S. Arahira et al., IEEE-JQE, **32**, 1211 (1996).

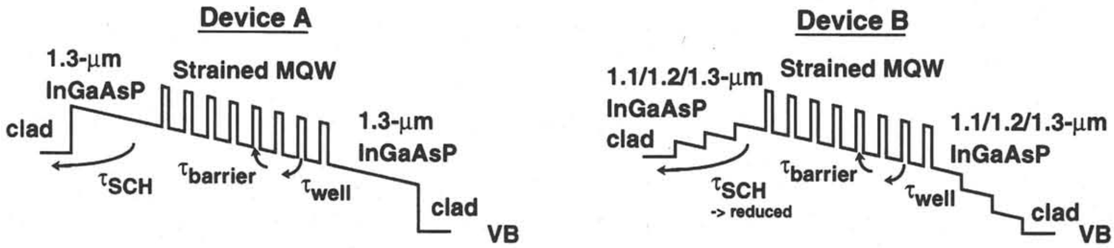

Fig. 1 Band diagrams of two types pf PML-LDs used in this work

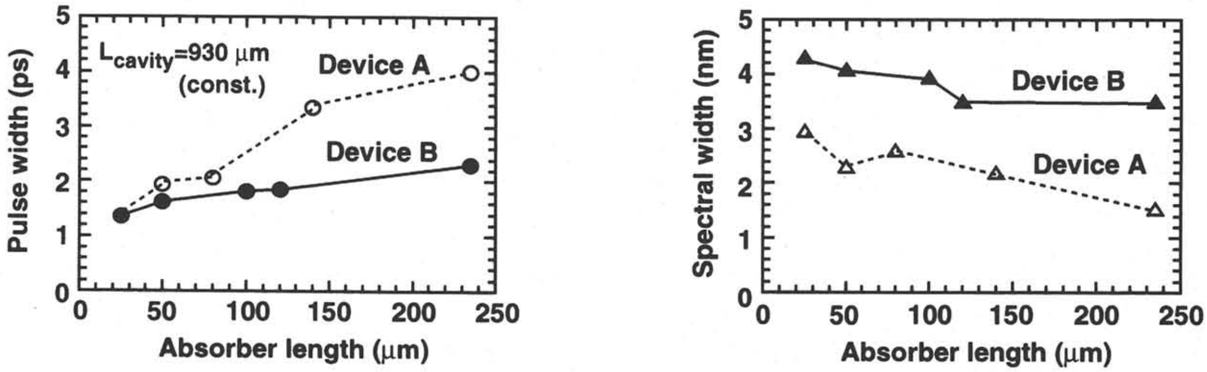

Fig. 2 Dependence of the pulse widths and spectral widths on the absorber length of 930-μm end-absorber PML-LDs

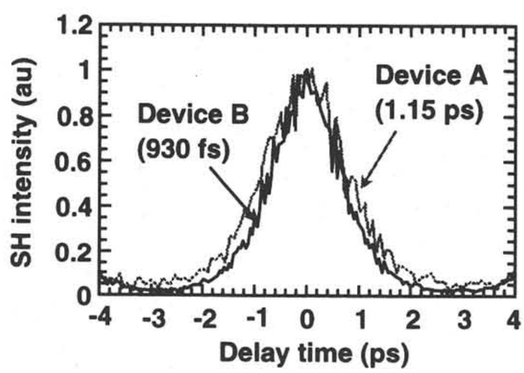

Fig. 3 Comparison of the SHG correlation traces of 160 GHz CPM-LDs

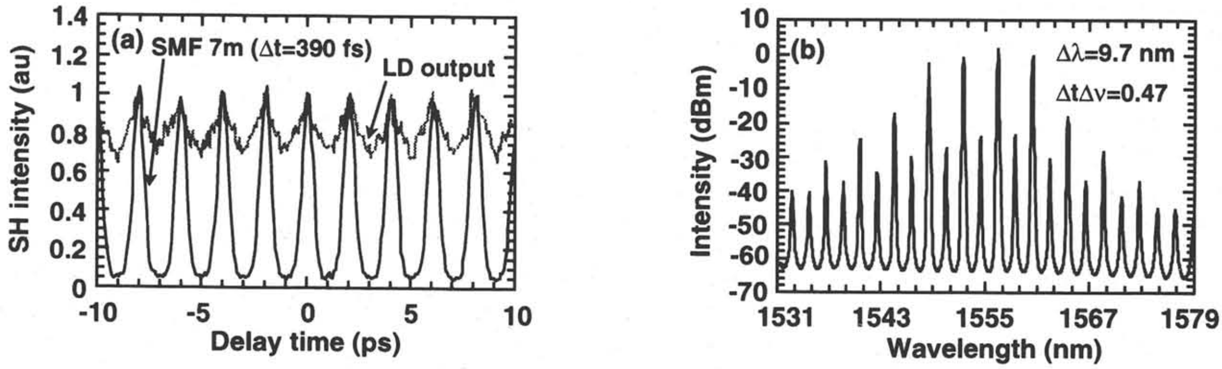

Fig. 4 (a) SHG correlation traces and (b) optical spectrum of a 500 GHz optical pulse train generated from a 170-μm GRIN-SCH CPM-LD