*Submitted to
the 9th OptoElectronics and Communications Conference,
July 12-16, 2004, Yokohama, Japan*

Suppression of pseudorandom timing jitters and wavelength chirping properties after optical 3R gating with a Symmetric-Mach-Zehnder gate

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Abstract: We studied how the random timing jitter is suppressed after optical 3R gating at 42 Gb/s with a Symmetric-Mach-Zehnder gate, for the first time. According to our SMZ-3R gating model, it is almost linearly suppressed by a factor of 4.6-7.3. We also report wavelength-chirping properties and an example of bit-error-rate assessment of the optical 3R gating.

1. Introduction

All-optical semiconductor gates are expected to be useful for optical 3R gating at ultrahigh bitrates, i.e. 40-160 Gb/s, because of their compactness and low power consumption. To date, optical 3R gating at 80-84 Gb/s with the Polarization-Discriminating Symmetric-Mach-Zehnder (PDSMZ) gates has been demonstrated [1-3]. Optical-3R loop experiments at 40 Gb/s with the PDSMZ gate have been demonstrated by three research teams [4-6]. In contrast, the maximum circulations in the latest optical-2R loop experiment was limited to 42 by accumulation of timing jitters [7].

For practical applications, it is easier to integrate the original Symmetric Mach Zehnder (SMZ) gate [8] than to integrate the PDSMZ gate. In fact, integrated SMZ gates have been fabricated by many global research teams [9-11]. The SMZ gate has been believed to possess similar 3R functionalities [12, 13].

Theoretical designs of the optical 3R gating performance had never been reported until recently. Very recently we have modeled the SMZ-3R gating by expanding our SMZ model in the periodical gating scheme [14] to that in the random gating scheme. With this model, we estimated the amplitude-noise-suppression performance, where the Q factors of eye diagrams were systematically improved [15]. Suppression of the input timing jitter after the 3R gating has, however, never been theoretically reported. (It has never been systematically demonstrated in previous SMZ nor PDSMZ experiments, either.) The regeneration-induced wavelength chirping was never been reported, either.

In this work, we have calculated how the timing jitter is suppressed by the SMZ-3R gate, for the first time. We also report other advances in our model calculation.

2. Suppression of input timing jitters

We calculated waveforms of the regenerated 42-Gb/s pseudorandom data pulses at the output of the SMZ-3R gate (Fig. 1). The delay time Δt in the gate structure was set to 11.9 ps. The input data pulse's width (FWHM) was set to either 2.0 or 4.0 ps. The clock pulse's width was set equal to the input data pulse, respectively. The gating conditions for the 2-ps data are described in Ref. 15. For the 4-ps data, some of the conditions were re-adjusted.

For assuming a specific amount of timing jitters, input pulse's positions were shifted by analogue pseudorandom numbers in a normal distribution. Figure 2 shows typical eye diagrams before and after the 3R gating, where the standard deviation of the input pulse positions (σ_{in}) was set to 0.57 ps. Figure 3 shows calculated standard deviation of the output pulse positions (σ_{out}) as a function of σ_{in}. It has indicated that the timing jitter was almost linearly suppressed by a factor of 7.3 (2-ps data) and 4.6 (4-ps data), respectively.

3. Other advances: wavelength chirping properties and bit-error-rate assessment

Figure 4 shows a typical wavelength-chirping profile of the 42-Gb/s regenerated pulses. Figure 5 shows the pulse width as a function of the transmission distance after the 3R gate. This result indicates that the width behaves irregularly in case of the positive-dispersion transmission lines. It was because the small sidelobe in the regenerated pulse's trailing edge is blue-shifted and it collides with the pulse's center component. Contributions from the 1st- and 2nd-order chirping coefficients of the center component were relatively small.

On the other hand, we started calculating bit error rates of the regenerated data pulses. To begin with, we evaluated the amplitude-noise-suppression performance via the calculated error rates (Fig. 6). In this analysis, pseudorandom amplitude noise was superimposed to the input '1' pulses, as those in Ref. 15. The minimum error rate was 3×10^{-7}, since we calculated 3×10^{6}-bit data pulses. Both of the analogue random-pattern length (2^{32}) for generating the amplitude noise and the digital random-pattern length (2^{31}-1) were set larger than 3×10^{6}. Figure 6 has indicated that the acceptable decision-level range was expanded by approximately a factor of 2.3 after the SMZ-3R gating.

4. Conclusion

We studied the suppression of input timing jitters by the SMZ-3R gating. According to our gating model, the timing jitter was significantly suppressed by a factor of 4.6-7.3. Two other advances in our model calculation were also reported. These design techniques will be useful for realizing practical optical-3R systems.

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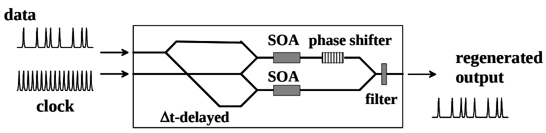

Fig. 1 SMZ-3R gate
SOA: semiconductor optical amplifier

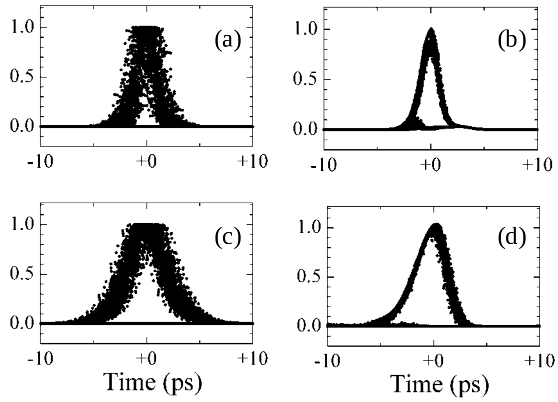

Fig. 2 Eye diagrams before and after the 3R gate (42 Gb/s)
(a) 2-ps input data (timing jitter, σ_{in}= 0.57 ps)
(b) Regenerated 2-ps data (timing jitter, σ_{out}= 0.09ps)
(c) 4-ps input data (σ_{in}= 0.57 ps)
(d) Regenerated 4-ps data (σ_{out}= 0.13 ps)
The horizontal thickness of each eye's envelope approximately corresponds to 4×σ_{in} or 4×σ_{out}.

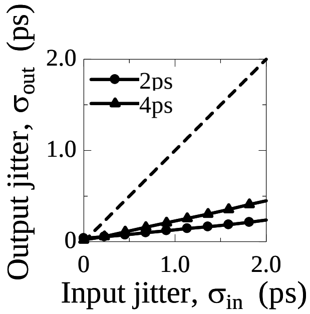

Fig. 3 Suppression of input timing jitters.
Dashed line: σ_{out}= σ_{in} as a reference.

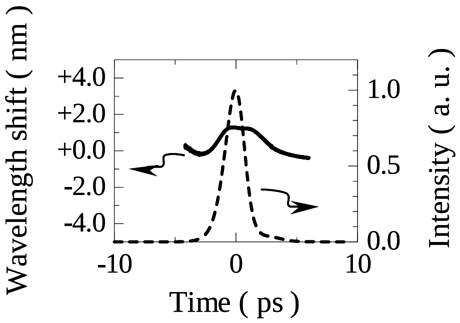

Fig. 4 Typical wavelength-chirping profile
Dashed curve: a regenerated 2-ps data pulse.

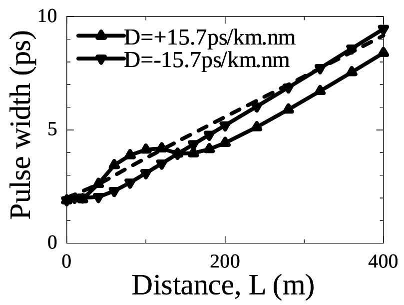

Fig. 5 Regenerated data pulse's width
as a function of transmission distance after the 3R gate.
Dashed curve: transmission of an unchirped pulse.

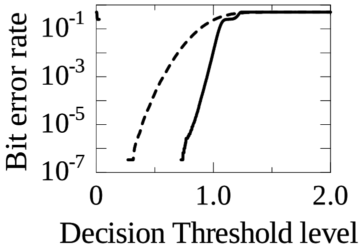

Fig. 6 Calculated bit-error rates
Solid curve: regenerated data pulses (Q^2= 23.2 dB).
Dashed curve: input data pulses with amplitude noise in a normal distribution (Q^2= 16.4 dB).
The decision threshold level is normalized by the respective averaged pulse height.