A Compact All-Optical 40Gb/s Clock Recovery Using a Traveling-wave Electroabsorption Modulator-Based Ring Oscillator With a Chip Coplanar Q-Filter

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Abstract: A compact, 40Gb/s all-optical clock recovery is demonstrated by utilizing filtered and actively amplified photocurrent in a traveling-wave electroabsorption modulator-based ring oscillator. The recovered 40GHz optical clock has 500fs timing jitter and 8ps pulsewidth.

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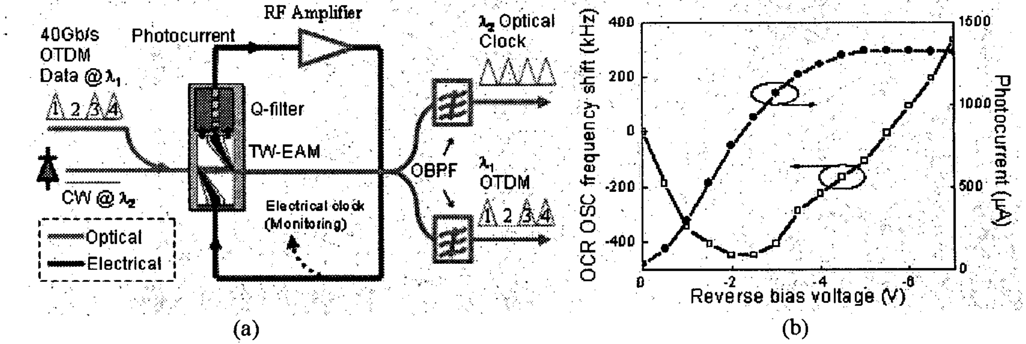
1. Introduction

All-optical clock recovery (OCR) is a crucial element to 3R (retiming, reshaping and reamplification) regeneration for the future high-speed all-optical networks. To date, various clock recovery schemes based on electro-optical phase-locked loop (PLL) or injection locking optoelectronic oscillator have been demonstrated [1-2]. However, a more compact device is preferable for practical use. Beating type self-pulsating distributed feedback (DFB) lasers have been extensively applied for the OCR [3], but subject to mode hopping due to internal reflections or spatial hole burning. In this paper, we demonstrate a compact all-optical 40Gb/s OCR using a traveling-wave electroabsorption modulator (TW-EAM)-based ring oscillator, which is shown in Fig.1 (a). The OCR is potentially monolithic integration. Details of the TW-EAM have been previously reported in [4]. The TW-EAM ribbon-bonded with a chip coplanar Q-filter is employed to detect and filter the clock component of the input optical signal. When the OCR's free-running oscillation frequency is tuned close to the clock frequency, the ring oscillator is injection phase locked. The TW-EAM simultaneously works as a photodetector by using photocurrent from upper electrical port and a pulsed optical clock generator by using the RF feed-back driving signal from the lower electrical port to modulate the CW at another wavelength [5]. A phase shifter is not employed in the ring oscillator due to the TW-EAM's photocurrent generation from nonlinear electroabsorption process so that TW-EAM's reverse bias adjustment can tune the loop phase. The OCR's free-running oscillation frequency was measured to shift up to ±400kHz by tuning the reverse bias voltage, which is shown as the square symbol curve in Fig. 2(b).



(a) (b)

Fig.1. (a) OCR configuration. OBPF: optical bandpass filter; (b) OCR's free-running oscillation frequency shift dependence on the TW-EAM's reverse bias voltage (square symbol curve). Circle symbol curve: TW-EAM's photocurrent.

2. Experimental results

A 10GHz gain-switched distributed Bragg reflector (DBR) laser was used to generate pulses at 1553.8nm (λ_1) and modulated with PRBS 2^{31}-1 pattern through a LiNbO3 modulator and then multiplexed to 40Gb/s optically. The CW light input for generating the recovered optical clock was 6dBm at 1558.7 nm (λ_2). The 40GHz coplanar chip Q-filter was fabricated on the semi-insulation InP substrate with a Q-factor of about 50 and a sideband suppression ratio of over 20dB. A 38GHz-40GHz RF amplifier with 26dB gain was used for compensating the loop loss and a bias-tee was used to provide the reverse bias for the TW-EAM. Without optical signal input, the OCR oscillated at the free-running oscillation frequency of 38.7961GHz which is determined by the peak frequency of Q-filter and the total loop delay. When around 40Gb/s OTDM signal input is applied, both 39.79629GHz clock component and the free-running mode exist in the loop, which is shown as the grey line in Fig. 2(a). Through adjusting the TW-EAM's reverse bias voltage to around 3V, the OCR oscillation was fine-tuned close to the clock frequency and immediately it was phase-locked at the clock frequency, which is shown as the dark line in Fig.2 (a).

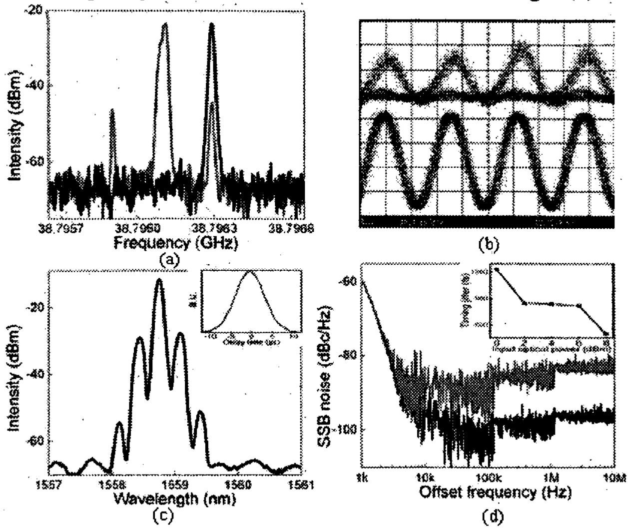


Fig.2. (a) RF spectra of un-injected locking (grey line) and injected-locking (dark line) OCR; (b) Eye diagram of around 40Gb/s input OTDM signal (upper) and corresponding generated optical clock (lower) (c) Optical clock's optical spectrum and autocorrelation curve (inset); (d) SSB noise spectra of the input OTDM signal and optical recovered clock. Inset: Timing jitter of optical recovered clock against input optical power.

Fig. 2(b) shows the eye diagram of around 40Gb/s input OTDM signal (upper part) and around 40GHz generated optical clock (lower part), respectively. The generated optical clock's optical spectrum is shown in Fig. 2(c) and its pulsewidth is about 8ps as shown in the inset of Fig. 2(c). Basing on the measured single sideband (SSB) noise spectra shown in Fig. 2(d), the timing jitter for the input OTDM signal and optical recovery clock (with EDFA amplification) are calculated as 830fs and 500fs, respectively. The timing jitter of the generated optical clock was also measured as a function of the input optical power in the inset of Fig. 2(d). When the input power was increased from 0dBm to 8dBm, the timing jitter decreased monotonously.

3. Summary

We have demonstrated a compact 40Gb/s OCR using a TW-EAM-based ring oscillator. The generated optical clock has 500fs timing jitter and 8ps pulsewidth. The compact structure consisting of a TW-EAM, a coplanar Q-filter and a RF amplifier is promising for fast OCR through further monolithic integration so as to allow the minimized loop length corresponding to the shortest capture time for synchronization to the data stream. The authors would like to acknowledge funding for this project under KDDI grant 442530-59406 and a State of California UC Discovery grant 597095-19929.

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