All-optical clock recovery using erbium-doped fiber ring laser incorporating an electro-absorption modulator and a linear optical amplifier

Lixin Xu,1,2 L. F. K. Lui,1 P. K. A. Wai,1 and H. Y. Tam,3
1Photonics Research Centre and Department of Electronic and Information Engineering, The Hong Kong Polytechnic University, Hung Hom, Hong Kong
Phone: +852 2766-6231, fax: +852 2362-8439, email: enwai@polyu.edu.hk
2Department of Physics, University of Science and Technology of China, Hefei, 230026, China
3Photonics Research Centre and Department of Electrical Engineering, The Hong Kong Polytechnic University, Hung Hom, Hong Kong

Abstract
We demonstrated 10-GHz all-optical clock recovery using an erbium-doped fiber laser incorporating an electro-absorption modulator and linear optical amplifier. Stable clock pulses with peak power of 200 mW and pulsewidth of 6 ps are obtained.

1 Introduction
All-optical clock recovery circuit is a key component for system synchronization in all-optical communication systems. Several technologies including tank circuit, injection locking, all-optical phase-locked loop have been proposed to address this issue [1]. Among these technologies, injection locking in a fiber ring laser is a promising approach because of its capability to generate high-intensity ultrashort optical pulses [2]. Recently, we have implemented a novel 10 GHz mode-locked fiber laser that incorporates an electro-absorption modulator (EAM), a linear optical amplifier (LOA), and an Er-doped fiber amplifier (EDFA) [3]. The mode-locked fiber laser can have stable output pulses at very high peak power with pulse duration of 2.4 ps [3]. In this paper, we use the fiber laser demonstrated in [3] to implement ultra-fast all-optical clock recovery. Stable clock pulse at 10 GHz with peak power of 200 mW and pulsewidth of 6 ps are obtained. The timing jitter is less than 1 ps.

2 Experimental results and discussion
Figure 1 shows the configuration for all-optical clock recovery which composes of an EAM, an LOA, a 12 meter long erbium-doped fiber, a bandpass filter, a circulator, two isolators, a 980 nm/1550 nm WDM coupler, a 1550 nm band 90:10 coupler, and a polarization controller (PC). The EAM is biased at a DC voltage of −1.015 V. A 10 Gb/s data stream is injected into the EAM through the circulator (C) in the direction opposite to the circulating direction of the laser cavity. The fiber laser could be mode-locked and output the optical clock of the data stream if the parameters of the laser are chosen properly. The data stream is generated by modulating a 10 GHz mode-locked laser source, which has a pulsewidth of ~1.8 ps, using an M-Z modulator. The laser gain is provided by the LOA and EDFA. The LOA operates at a current of 233 mA with a gain of ~13.5 dB, and a saturation output power of 13 dBm. The linearity of the LOA gain renders the laser system less susceptible to the transients due to the variations in the ambient conditions. Amplitude jitter of the mode-locked fiber ring laser output is therefore reduced. The EDFA was pumped at 980 nm through the 980 nm/1550 nm WDM coupler. The bandpass filter is centered at 1555 nm with a bandwidth of 6 nm and side mode suppression of 20 dB. The PC is used to optimize the polarization states of the cavity modes because the EAM has a small polarization dependent loss. Ten percent of the cavity energy was coupled to output through the 90:10 coupler.

The output pulses were measured using a YOKOGAWA Optical Sampling Oscilloscope (OSO)
Figure 2(a) shows the 10 Gb/s input data pattern 1001001010. Figure 2(b) shows a 10 Gb/s pseudorandom binary sequence (PRBS) input signal. Figure 2(c) is the recovered 10 GHz optical clock when the input data is the fixed data pattern shown in Figure 2(a). The output peak power and the pulselength of the optical clock are 150 mW (1.5 W inside the cavity) and 10 ps respectively. Figure 2(d) shows the 10 GHz recovered optical clock corresponding to the PRBS input data shown in Figure 2(b). The output peak power and the pulselength of the optical clock are 200 mW (2 W inside the cavity) and 6 ps respectively. Figure 2 show that the optical clock is recovered successfully. The timing jitter of the output clock is measured to be less than 1 ps. Stable optical clock output can still be observed when the input data rate varies within 3 MHz (60% of the fundamental frequency which is about 5 MHz in our setup). Figure 3(a) is the output spectrum when the input data rate is 9.9580 GHz. The wavelength of the optical clock is 1556.19 nm while the wavelength of the input data stream is 1546.64 nm. The bandwidth of the optical spectrum is measured to be 1.87 nm. The pulselength measured from the OSO is 6 ps. The output clock pulses were significantly chirped. Figure 3(b) gives the corresponding RF spectrum with a resolution bandwidth of 10 kHz. The sidemode suppression ratio is beyond 48 dB.

3 Summary
We demonstrated 10-GHz all-optical clock recovery using an erbium-doped fiber laser that incorporates an EAM and an LOA. Stable pulses with peak power of 200 mW and pulselength of 6 ps are obtained. The timing jitter is less than 1 ps. The external data stream is used to optically drive the EAM and actively mode-lock the fiber laser. Since no electronic components are involved, our configuration can potentially operate at clock rate beyond 10 GHz.

4 References