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All-optical pseudorandom bit sequences generator based on TOADs

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ABSTRACT

A scheme for all-optical pseudorandom bit sequences (PRBS) generator is demonstrated with optical logic gate 'XNOR' and all-optical wavelength converter based on cascaded Tera-Hertz Optical Asymmetric Demultiplexer (TOADs). Its feasibility is verified by generation of return-to-zero on–off keying (RZ-OOK) 2^{63}-1 PRBS at the speed of 1 Gb/s with 10% duty radio. The high randomness of ultra-long cycle PRBS is validated by successfully passing the standard benchmark test.

1. Introduction

Pseudorandom bit sequences (PRBS) is widely applied in optical transmission systems and optical communication networks, for example, for the purpose of error rate measurements [1–4], encoding/decoding (scrambler, perturbation solution) [5–7], encryptions/decryptions (secure communications) [8], simulations of white noises [9], spread spectrum modulations (code division multiple access) [10], and so on. As the rates of both the communication system and network transmission are growing increasingly faster because of the rapid development of optical communication technologies, the requirements for the testing rate are promoted accordingly. Presently, hero experiments were being performed at 160 Gb/s and up to 640 Gb/s [11]. However, the structure of a high-speed PRBS generator is very complicated with a high cost in the electric field. This problem is significant for a bit rate over 40 Gb/s. Though several methods of all-optical pseudorandom bit sequence (PRBS) generation have been shown recently [12–15], there are a number of problems in these solutions. For instance, Wagemans Silvia has proposed a scheme of PRBS generator based on double-loop flip-flop with a complex structure and a low rate at 10 Kb/s. K.E. Zoiros has proposed a PRBS generator by the TOAD-based D flip-flops with a complex structure, and S. Ma also has proposed a PRBS generation based on quantum-dot semiconductor optical amplifiers. They were both just realized by theoretical simulation without any experimental result. In the meantime, an optical PRBS generator using a Dual-Drive Mach–Zehnder modulator was proposed by Louis Christen, however, the rate upper limit of PRBS data stream obtained by this scheme would be restricted by 'electronic bottleneck' for the introduction of photovoltaic conversion.

In this paper, we proposed a scheme for optical PRBS generation using an optical logic gate 'XNOR' and an all-optical wavelength converter based on cascaded Tera-Hertz Optical Asymmetric Demultiplexer (TOADs). This scheme abandons the interference structure and an assistant light is introduced in the all-optical logic to improve the quality of the signal compared with the system presented by Poustie A.J. in 1999 [16]. Its feasibility is verified by generation of return-to-zero on–off keying (RZ-OOK) 2^{63}-1 PRBS at the speed of 1 Gb/s with a 10% duty radio. The high randomness of ultra-long cycle PRBS is validated by successfully passing the standard benchmark test.

2. Principle

A typical method for generating a PRBS data stream is to use a linear feedback shift register (LFSR) [17]. Fig. 1 illustrated the principle of a characteristic example of PRBS electronic generation with a cycle of 2^4-1.The level-4 LFSR is cascaded by 4 D flip-flops which are controlled by a common clock. According to a primitive polynomial such as $f(x) = x^4 + x^3 + 1$, the output of the 3'rd D flip-flop and 4'th D flip-flop are XOR'ed and fed back to the 1'st D flip-flop as the input signal.

However, the implementation of the LFSR requires cascading multiple triggers, which significantly increases the complexity of the system for long cycle PRBS generation. Especially, the integration technology of trigger is imperfect in optical domain, this

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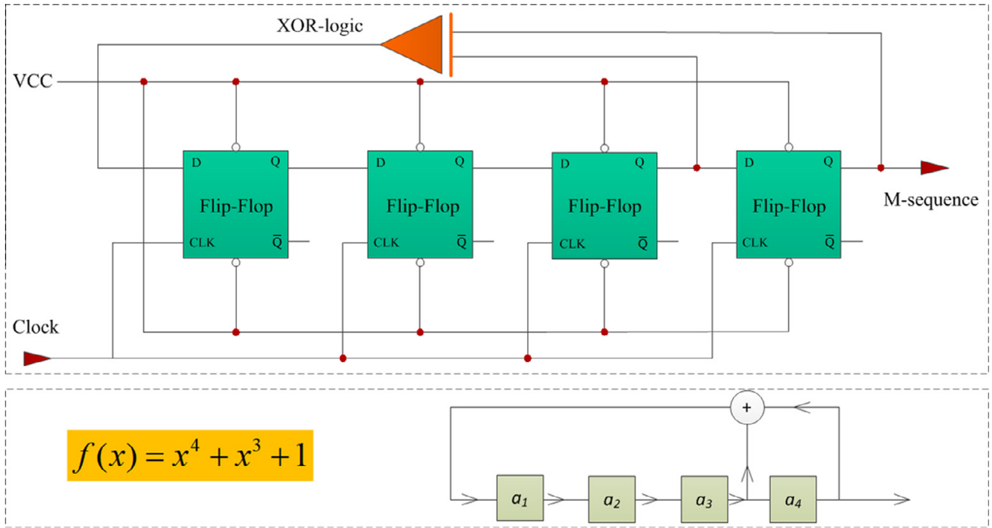

Fig. 1. The principle of a characteristic example of PRBS electronic generation with a cycle of 2^4-1.

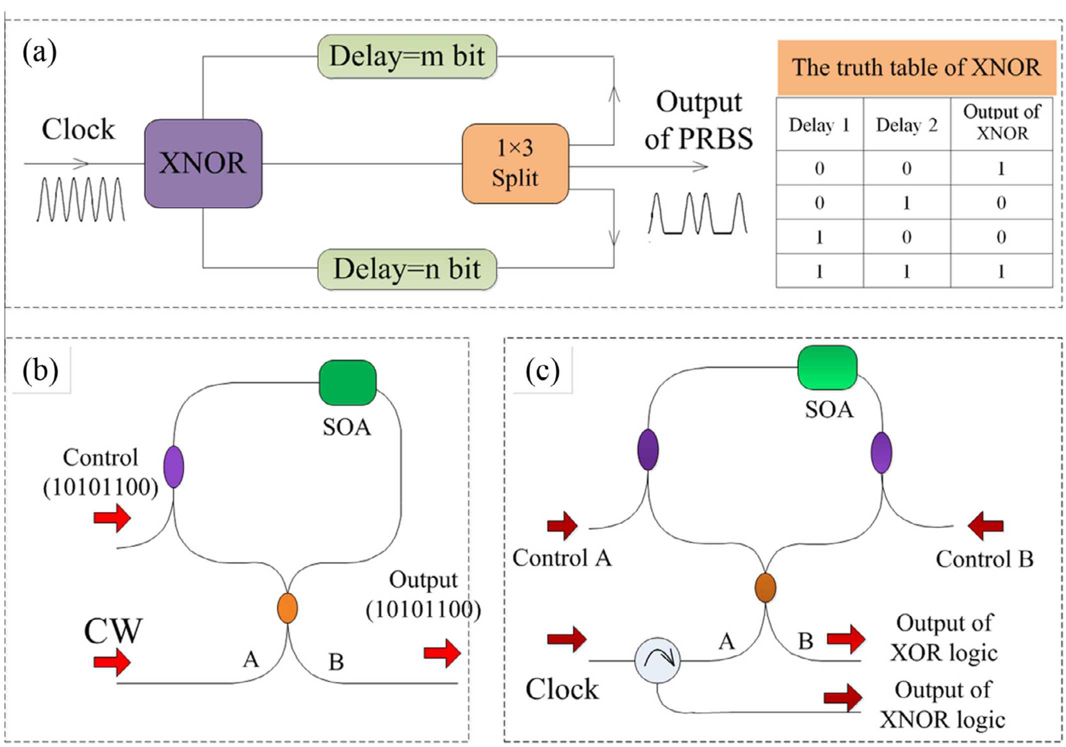

Fig. 2. (a) Principle of all-optical PRBS generator and the truth table of XNOR-logic, (b) Wavelength conversion based on TOAD, (c) XNOR-logic based on TOAD.

problem is striking. For instance, a typical PRBS generator with a cycle of 2^{31}-1 needs 31 cascaded triggers in the part of LFSR. We propose here the generation of an optical PRBS data stream using a optical XNOR logic configured as shown in Fig. 2(a). An optical clock pulse train serves as the input signal of the XNOR logic. The output pulses stream of the logic is split into 3 paths. Two of the outputs are amplified and fed back as the two control signal of the logic, while the third output serves as the pattern generator output. The two feedback paths include tunable delay lines to adjust the tap delays to desired values. For example, the feedback path with tap delays of m and n bits has a characteristic polynomial equal to $f(x) = x^m + x^n + 1$.

This all-optical scheme requires two key techniques, one of which is high-speed all-optical XNOR-logic operation, and the other one of which is high-speed all-optical wavelength conversion. The structure of wavelength conversion by TOAD [18] is shown in Fig. 2(b), where the continuous-wave (CW) is injected into Port A, and the switch operates in the bar or cross state depending on the control signal at another wavelength. In the absence of a control pulse, both inputs are mirrored out to their