UWB monocycle pulse generation by optical polarisation time delay method

H. Chen, M. Chen, C. Qiu, J. Zhang and S. Xie

A novel method to generate ultra-wideband (UWB) monocycle pulses based on birefringence time delay in polarisation-maintaining fibre (PMF) is proposed and experimentally demonstrated. Two polarity-reverse pulses are generated by polarisation modulation using a single phase modulator. They are delayed in PMF with enough time to generate monocycle pulse.

Introduction: Ultra-wideband (UWB) is emerging as a solution for future wideband personal access networks (PAN) [1]. It has more advantages than traditional wireless communication technologies, such as low power consumption, high bit rate, immunity to multipath fading and so on [2–4]. In UWB systems, one of the most used modulation techniques is impulse radio (IR) direct-sequence code-division multiplexing. And carrier-free impulse modulation attracts more attention which not only does not need a complicated frequency mixer, intermediate frequency, and filter circuits, but also has good pass-through performance due to base-band transmission. The Gaussian monocycle pulse has a better bit error rate and multipath performance and wider bandwidth than the other impulse signals [5]. With the radio-over-fibre technology improvement, UWB over fibre can be a candidate solution for future wideband access networks [6]. So there are many schemes to optically generate and distribute monocycle pulses. In [7] and [8], optical pulses are transmitted by fibre and monocycle pulses are obtained by a microwave differentiator in the electrical domain. Recently, Yao's group gave some attractive methods to optically generate monocycle pulses. One is to generate a monocycle pulse signal by cross-phase modulation in nonlinear fibre and an optical frequency discriminator [9]. The other utilised cross-gain modulation in a semiconductor optical amplifier (SOA) and a pair of fibre Bragg gratings (FBG) to generate polarity-reversed optical pulses and combined them together [10]. However, these two approaches both use two laser sources which may increase the system complexity.

In this Letter, a simple method to optically generate monocycle pulses based on birefringence time delay is proposed and experimentally demonstrated. An electrical pulse is used to modulate optical signal so as to get two polarity-reverse optical pulses in orthogonal polarisation orientation. The optical signal is then fed into a section of polarisation-maintaining fibre (PMF). When the two polarity-reverse optical pulses are launched along two principle axes respectively, the birefringence time delay will help to generate monocycle pulses. Furthermore, with different time delay, 0 or π phase shift monocycle pulses can be obtained. In our experiment, we get monocycle pulses with central frequency of 4.1 GHz and fractional bandwidth of 150%.

Principle and experiment: The principle of the proposed scheme is shown in Fig. 1. An electrical pulse is used to drive an optical phase modulator (PM) and keep the peak level to V_π of the PM. For linearly-polarised light launching at 45° relative to a principal axis of the PM, the phase shift between the two principal axes will depend on the driving voltage. If the driving voltage is set to V_π, the signal polarisation will rotate to the orthogonal direction at the output of the PM [11]. So at the input orientation there is a negative pulse, while at the orthogonal orientation there is a positive pulse. Then the optical signal is sent into a differential group delay (DGD) component with two polarisation orientations along the principal axes. Thanks to the birefringence time delay, the two inverse polarity pulses can be suitably delayed. After the O/E converter, monocycle pulses can be obtained by this method.

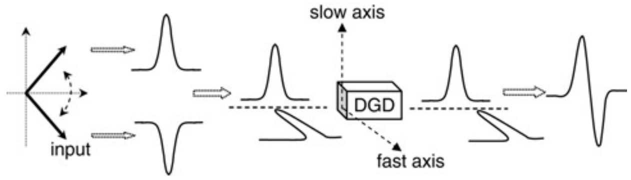

Fig. 1 *Principle of proposed scheme*

The experimental setup is shown in Fig. 2. The optical signal from the laser is tuned by the polarisation controller (PC) and then fed into an optical phase modulator driven by the electrical pulse generator. The phase modulator does not have an internal polariser so as to allow the two axes light to pass through it with similar loss. An electrical pulse is generated by a BER tester (BERT, Advantest D3186). The electrical signal is of fixed pattern '1000 0000 0000 0000' (one '1' every 16 bits) with a bit rate of 8.2 GHz, so the repetition rate of the pulse pattern is about 512 MHz. The electrical pulse FWHM is about 122 ps which is shown in Fig. 3. The output orientation of the phase modulator is adjusted by a PC and fed into a section of polarisation-maintaining fibre with length of 90 m. The beat length of the PMF is 3.8 mm and the time delay of the two principal states of polarisation (PSP) is about 122 ps. Then the optical signal is amplified to the O/E converter and measured by a digital sampling oscillator (DSO, Tektronix TDS8200).

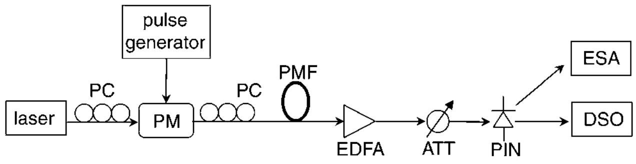

Fig. 2 *Experimental setup*

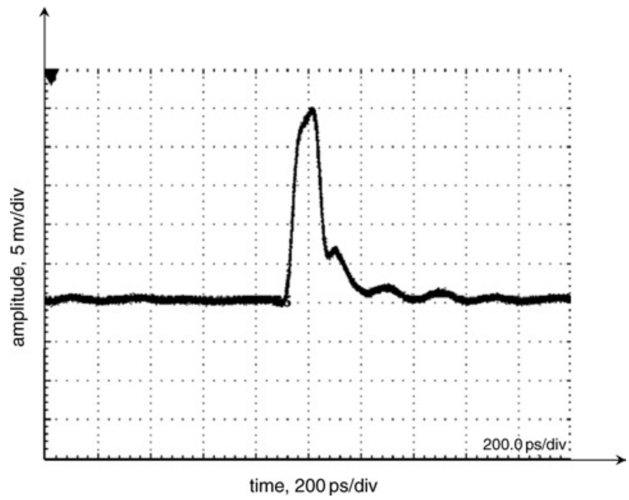

Fig. 3 *Electrical pulse*

Fig. 4 shows the generated monocycle pulse. The pulse width is almost the same as the input electrical pulse, and there is no power fluctuation at the DC level compared with the result of [10]. The optical signal orientation into the PMF can be easily tuned, and the two polarity-reversed pulses can pass along different principal axes of the PMF. So it is very easy to get an inverted monocycle pulse by turning the input signal polarisation to 90°as shown in Fig. 5 which can be used in biphase modulation format for UWB systems.

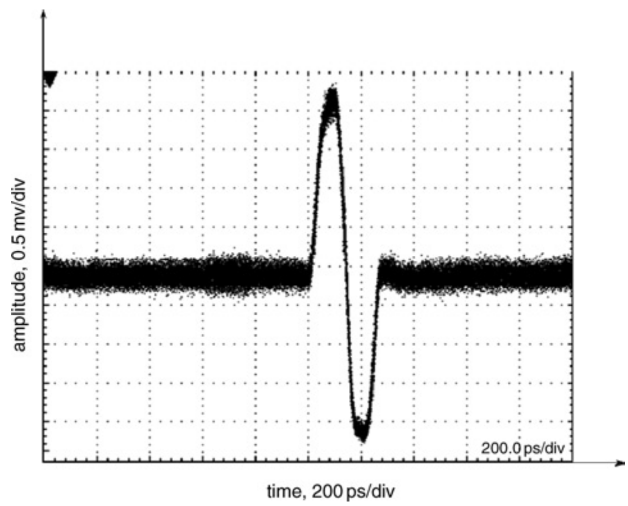

Fig. 4 *Generated monocycle pulse with positive polarity*

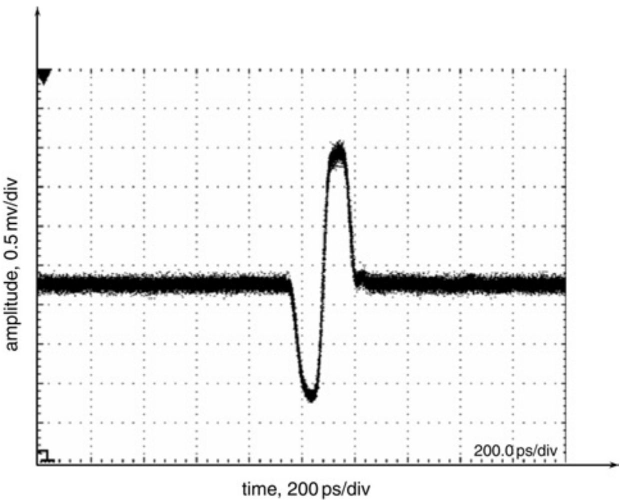

Fig. 5 *Generated monocycle pulse with negative polarity*

The spectrum of the generated monocycle pulse is measured by an electrical spectrum analyser (ESA, Agilent E4446A) and shown in Fig. 6. The repetition rate of the electrical pulse sequence from BERT is about 512 MHz which is equal to the interval of discrete frequency parts in the spectrum. The central frequency is about 4.1 GHz and the −10 dB bandwidth is nearly 6.15 GHz which corresponds to a fractional bandwidth of 150% due to the definition of UWB. The discrete spectrum envelope is just like the spectrum of a single monocycle pulse.

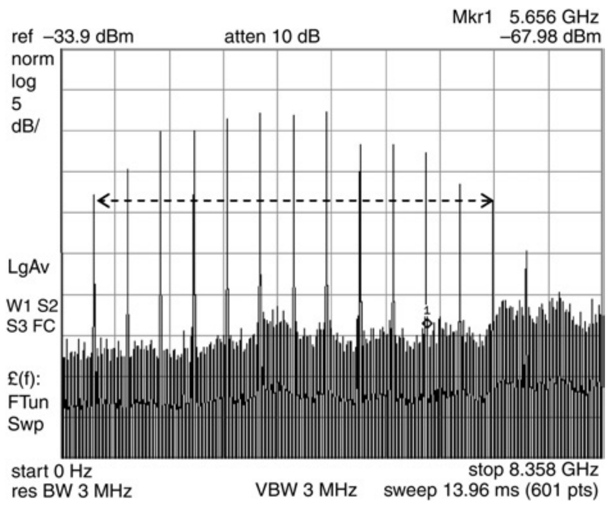

Fig. 6 *Spectrum of generated monocycle pulse*

Conclusion: A novel method is proposed to generate UWB monocycle pulses by birefringence time delay in PMF. This method has a simple structure to be realised. The polarity of the generated monocycle pulses can be easily changed by adjusting the input signal polarisation orientation of the PMF. The fractional bandwidth of the generated monocycle signal is near 150% which can satisfy the needs of a UWB over fibre system.

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H. Chen, M. Chen, C. Qiu, J. Zhang and S. Xie (*Department of Electronic Engineering, Tsinghua University, Beijing 100084, People's Republic of China*)

E-mail: chenhw@tsinghua.edu.cn

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