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A UWB pulse generation based on a phase modulator and programmable filter

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ABSTRACT

A simple scheme for the ultra-wideband (UWB) pulse generation based on a phase modulator and programmable filter is proposed and experimentally demonstrated. By locating the center wavelength of two tunable lasers at left and right linear slope of the filter, polarity-reversed monocycle pluses are generated. A section of single mode fiber is utilized to introduce proper time delay between the pair of UWB monocycle pulses. By switching the programmable filter between bandpass filter and notch filter, positive and negative doublet pulse can be obtained additionally. The generated UWB pulses are measured in both time and frequency domain.

1. Introduction

Ultra-Wideband (UWB) is considered as a promising technology for short range indoor wireless communication, due to its high data rate, low spectral density and immunity to multipath fading [1–3]. In 2002, the US Federal Communications Commission (FCC) approved the unlicensed use of the UWB spectrum from 3.1 to 10.6 GHz, with a power spectral density lower than −41.3 dBm/MHz [1,2]. Based on the definition of FCC, a UWB signal should have a spectral bandwidth greater than 500 MHz or a fractional bandwidth greater than 20% [2]. In order to the FCC-specified spectrum mask, the implementation of the first- or second-order derivatives of a Gaussian pulse, to generate Gaussian monocycle or doublet pulse, is considered as a simple and efficient technique for UWB pulse generation [3].

Compared to the electrical techniques using electrical circuitry, UWB signals generation in optical domain is more flexible, which enables the UWB pulses with different shapes and switchable polarity. In recent years, many UWB pulse generation techniques have been proposed. These techniques can be concluded as: 1. Microwave delay-line filter. Gaussian monocycle and doublet pulse can be realized by microwave delay-line filter with tap coefficients of (1, −1) and (1, −2, 1) respectively [4,5]. 2. Nonlinear effects [6,7]. 3. Optical spectrum shaping followed by frequency-to-time mapping [8,9]. 4. Phase modulation to intensity modulation (PM–IM) conversion [10–14].

Among them, UWB pulse generation through PM–IM conversion is an important way. By incoherent summation of multiple monocycle pulses with inverse polarities, proper time delays and weight coefficients, high-order UWB pulses can be constructed additionally. However, many proposed approaches are complex or of high cost, such as utilizing two pulse pattern generators to introduce time delay in electrical domain [12], or dividing to two orthogonal paths through optical delay line [13,14], which will limit the order of UWB pulse. For practical application, UWB pulse generator based on simple structure which can generate many kinds of UWB pulses is more desirable for different modulation format.

In this letter, we propose and demonstrate a simple method to generate UWB pulses that only use a phase modulator and programmable optical filter. The proposed UWB signal generation scheme utilizes PM–IM conversion to generate basic monocycle pulses and fiber dispersion for introducing delay between optical taps. Moreover, this approach is extensible for high-order UWB pulse generation.

2. Experimental setup and principle

The configuration of the proposed UWB pulse generation is shown in Fig. 1. Two tunable laser source (TLS, ID PHOTONICS) with typical line-width of 150 kHz are employed as the light source and these two lasers are combined through a 3-dB optical coupler. The electrical Gaussian-liked pulse train is generated by a bit-error-rate tester (Tektronix, BSA125C). The Gaussian pulse train has a data rate of 12.5 Gb/s with a fixed pattern of "1000………"

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(one “1” in every 32 bit), which is equivalent to a pulse train with a repetition rate of 390.625 MHz. The full width at half maximum (FWHM) of Gaussian pulse is measured about 76 ps and the peak amplitude of the input pulse is 2 V. The Gaussian pulse train is then applied to a phase modulator (EOspace PMP-DV5-40-PFU) via its RF input port. The phase modulator has a half wave voltage of 4.2 V. A programmable optical filter (Finisar WaveShaper 4000S) is used as the frequency discriminator, which has a minimum filter bandwidth of 10 GHz and a maximum filter bandwidth of 5 THz. A section of 6.23 km single mode fiber (SMF) acts as dispersion media to introduce time delay between two taps. A photodetector (PD Picometrix AD-10) is used to achieve optical to electrical conversion. The PD has a bandwidth of 43 GHz and output offset voltage of −0.7 V. The generated UWB signal at the output of the PD is then measured in time and frequency domain by use of a high speed sampling oscilloscope (Tektronix DSA 8200) and an electrical spectrum analyzer (Agilent E4447A) Fig. 2.

The working principle can be described as follows. The fundamental principle is based on PM–IM conversion. The center wavelength of two tunable lasers are defined λ_1 and $\lambda_2(\lambda_1 < \lambda_2)$. First, the programmable filter is implemented as a bandpass filter and the center wavelength λ_1,λ_2 are respectively located at positive and negative linear slope. Based on the PM–IM conversion, two reversed polarity monocycle pulses loaded on each wavelength are generated. Due to dispersion of SMF, the time delay between two signals will be introduced. By choosing proper time delay, positive doublet pulse can be generated at the end of PD. Similarly, negative doublet pulse can also be generated when the programmable filter is implemented as a notch filter. In this case, λ_1 is located at the negative linear slope and λ_2 is located at the positive linear slope, which is different from the bandpass filter.

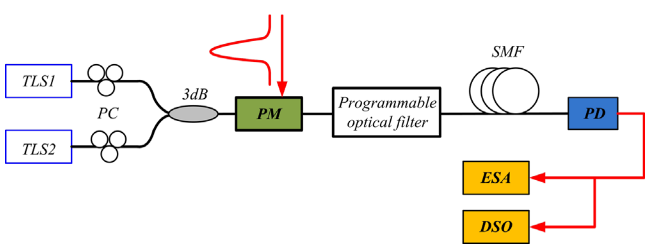

Fig. 1. Schematic of the proposed UWB pulse generator. PD, photodector; PM, phase modulator; PD, photodetector.

3. Experimental result and discussion

An experiment is then carried out to verify the proposed scheme for UWB pulse generation. The setup is based on the structure, shown in Fig. 1. The center wavelengths of two tunable laser sources are set at 1550.00 nm and 1550.70 nm respectively. The channel spacing is 0.70 nm. The two lasers output powers are set at 10 dBm. The total dispersion value of SMF is 105.7 ps/nm, corresponding to a time delay about 74 ps between two taps. The programmable filter is specified as a bandpass filter initially. In order to make that two tunable laser sources are located at left and right linear slope of the bandpass filter, the central wavelength and bandwidth are specified at 1550.35 nm and 0.70 nm. We measure the transmission spectrum of the bandpass filter using board band light source and an optical spectrum analyzer (YOKOGAWA AQ6370). The transmission spectrum of the bandpass filter is shown in Fig. 3, where the center wavelengths of two tunable lasers are marked.

At first, the tunable laser source1 (TLS_1) is on and tunable laser source 2 (TLS_2) is off, which equal to two taps coefficients (1, 0). The central wavelength of the TLS_1 is located at the positive slope of the bandpass filter. Based on PM–IM conversion, we obtain the

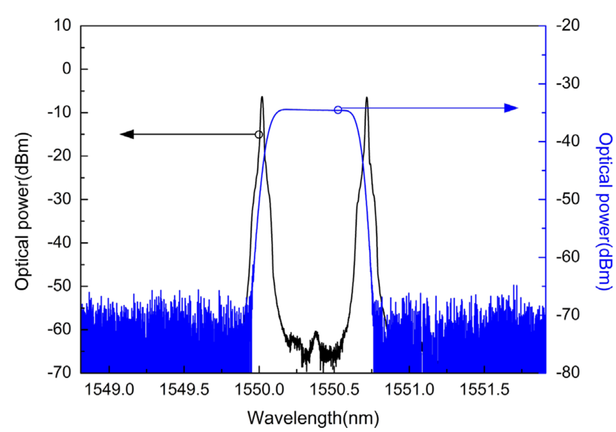

Fig. 3. The transmission spectrum of optical bandpass filter.

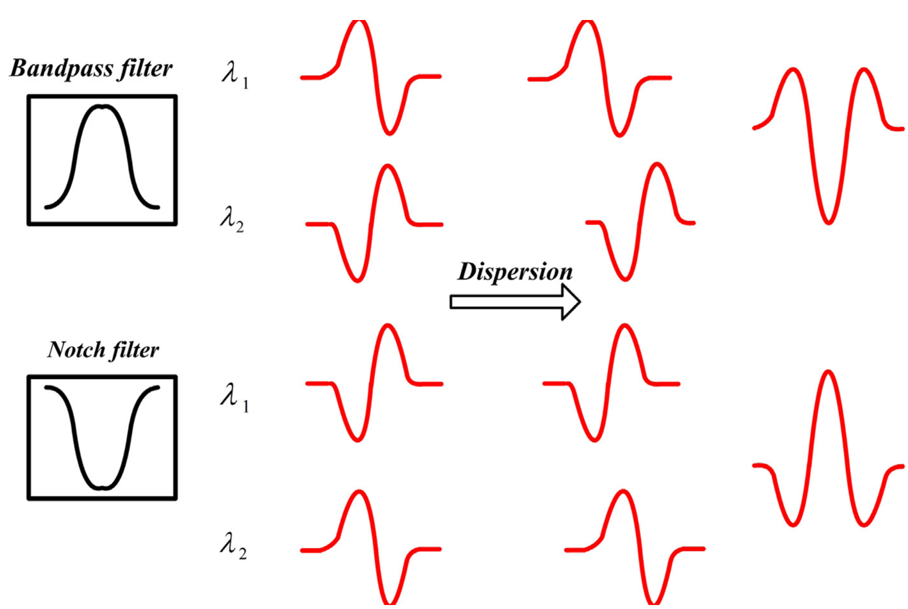

Fig. 2. Illustration of the scheme working principle.