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Multi-channel Ultrawideband Monocycle Pulse Generation via Cross Phase Modulation and Spectral Filtering

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Abstract

We demonstrate a novel technique for multi-channel ultrawideband monocycle pulse generation by using cross phase modulation and spectral filtering. High quality monocycle pulse on three WDM channels has been successfully generated.

1. Introduction

Ultrawideband (UWB) technology, which has been demonstrated to be able to provide high speed data link with low power consumption [1], has received great interest as a wireless replacement for short distance wired connections. Traditionally, the RF sources for UWB devices, which are in form of monocycle or doublet pulse train, are generated and transmitted in electrical domain. Until recently, UWB-over-fiber technology has been introduced to extend the reach of UWB radio service by taking advantage of low loss transmission over optical fiber. Therefore UWB pulse generation in optical domain would be an attractive alternative over electrical means for UWB-over-fiber service. Previously single channel optical UWB pulse generation has been demonstrated using specialized modulator [2], cross gain modulation (XGM) in optical parametric amplifier (OPA) [3], and phase-modulation to intensity modulation conversion through dispersion in single mode fiber and fiber Bragg grating [4-5]. However, simultaneous multiple channel UWB pulse generation has never been realized to the best of our knowledge. In this paper, multiple channel UWB impulse generation by using cross phase modulation (XPM) in optical fiber and spectral filtering in arrayed waveguide grating (AWG) is demonstrated.

2. Principle

The principle of multi-channel monocycle pulse generation is shown in figure 1. When a pulsed pump propagates with continuous-wave signals in a nonlinear medium with third order susceptibility (e.g. highly nonlinear fiber), the signal waves will be phase modulated according to the instantaneous intensity of pump due to XPM effect. Such phase modulation then causes the frequency of the signal waves to down-shift on the rising edge and up-shift on the falling edge of pump pulse. Mathematically, when dispersion and fiber loss are ignored, the frequency shift can be expressed as:

$$\delta f = -\gamma L \frac{d}{dt}\left(P_p(t)\right)$$

where δf is the frequency shift of the signal waves due to XPM, γ and L are the nonlinear coefficient and length of the medium, and P_p is the power of pump pulse. Thus if the pulse shape of the pump follows a Gaussian function, the frequency variation of the signals will follow the shape of a Gaussian monocycle pulse, which is the first order derivative of a Gaussian function.

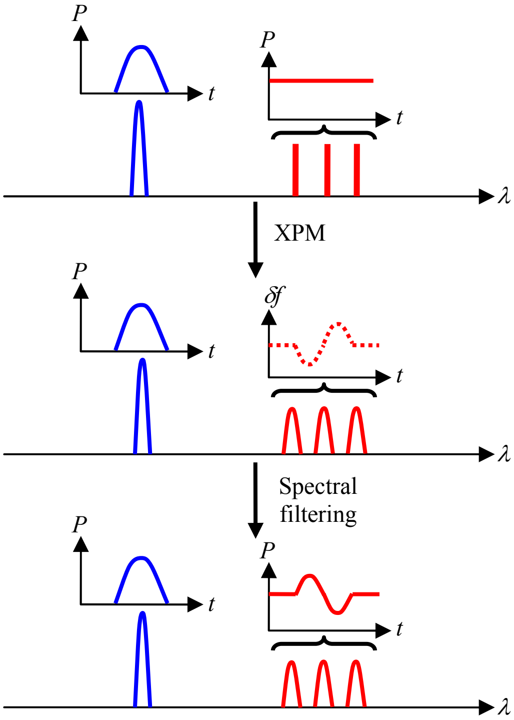

Fig. 1. Schematic diagram showing the principle of monocycle pulse generation.

When the phase modulated signal waves pass through an AWG with the pass-bands center wavelengths being slightly detuned from the signals wavelengths, the AWG converts the temporal frequency deviation of the signals into intensity variation because of pseudo-linear relationship between frequency and transmittivity at pass-band edges i.e. transmittivity $T \approx -k\delta f$ on the blue edge while $T \approx k\delta f$ on the red edge of AWG pass-bands. Monocycle pulse trains are thus generated simultaneously on the input signal waves.

3. Experimental Setup

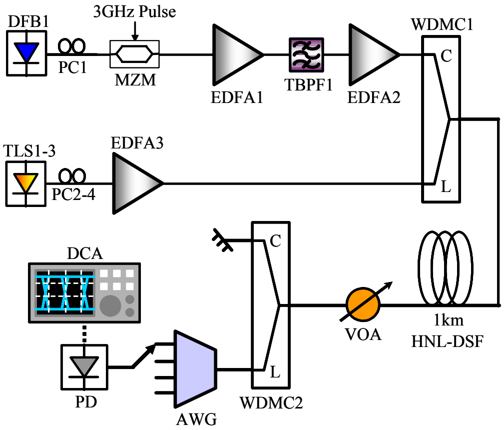

Fig. 2. Experimental setup for multi-channel monocycle pulse generation.

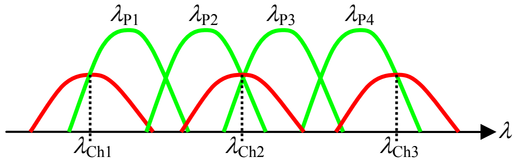

Fig. 3. Wavelength allocation of signals and AWG pass-bands. Red: Signal spectrums after XPM; Green: AWG pass-band spectrums.

The experimental setup for multi-channel monocycle pulse generation is shown in figure 2. The nonlinear medium used for XPM was a spool of 1km highly nonlinear dispersion shifted fiber (HNL-DSF) with nonlinear coefficient $\gamma \approx 14W^{-1}km^{-1}$ and zero-dispersion wavelength $\lambda_0 \approx 1560nm$. A DFB laser (DFB1) with emission wavelength λ_{Pump} at 1557.1nm was used as pump source. The pump wave was intensity modulated with 3GHz electrical pulse train at 25% duty cycle through an intensity modulator MZM. The pump was then amplified to 17dBm by two stages of EDFAs (EDFA1 and EDFA2) with a tunable band-pass filter TBPF1 inserted in between to reduce ASE noise level at EDFA2 input. On the other hand, three tunable laser sources TLS1-3 with wavelengths λ_{Ch1}, λ_{Ch2} and λ_{Ch3} at 1569.4nm, 1571.0nm and 1572.6nm respectively were served as signal sources and subsequently boosted to total power of 14dBm by EDFA3. The pump and signals were then combined using a WDM band combiner WDMC1 and launched into the HNL-DSF. After propagating through the HNL-DSF, the output waves were attenuated by a variable optical attenuator (VOA) and passed through WDMC2 to decouple signal waves from pump pulse. The L-band signal waves were launched into an AWG with 0.8nm channel spacing for spectral filtering of signal waves. The pass-bands center wavelengths λ_{P1}, λ_{P2}, λ_{P3} and λ_{P4} for output ports 1-4 were adjusted according to the allocation scheme shown in figure 3 so that only one channel was present at each output port. The polarization controllers PC2-4 were adjusted to obtain best pulse quality. The signals at AWG output ports were monitored by a photodetector (PD) and a digital communication analyzer (DCA).

4. Results and Discussions

The waveforms of monocycle pulse generated in three different channels at output ports 1, 3 and 4 are shown in figure 4. As seen from the diagrams, the waveforms resembled an ideal Gaussian monocycle pulse well, except that slight overshoot was observed at the trailing edge of the pulse. This was due to non-ideal electrical response of the modulator and driving electronics which gave rise to the overshoot at the trailing edge of pump pulse. Besides, the polarity of pulse generated in channel 3 was inversed with respect to channel 1 and 2 as the signal wavelength of channel 3 was on the red edge of pass-band of output port 4, which the frequency-loss relationship was reversed in this case. This also shows the possibility of pulse polarity modulation (PPM) by placing signal at the blue edge and red edge arbitrarily or switching between adjacent output ports when the signal is in between the pass-bands of the ports. Moreover, although in this work simultaneous pulse generation was demonstrated only on three channels, the maximum number of channel that the proposed method could support was only limited by the number of output port of the AWG used, and so could be increased by using AWGs with more output ports.

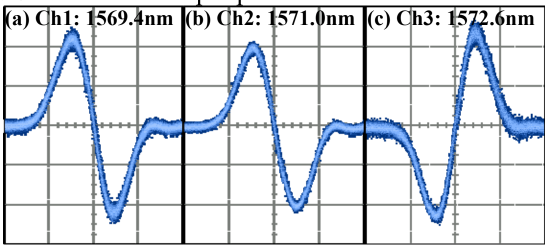

Fig. 4. Monocycle pulse waveforms at three different channels. The wavelength of channels are denoted at the top of diagrams.

5. Conclusion

We have demonstrated a multi-channel monocycle pulse generation technique based on XPM and spectral filtering. This technique would be helpful in providing cost-effective solution for generation and distribution of UWB signals to multiple access points.

6. Acknowledgement

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7. Reference

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