High Order UWB Pulses Generation based on a Scalable Phase-to-intensity Technique

Abstract *In this work, a scheme that relies on phase-to-intensity (PM-IM) conversion for high order UWB pulses generation is proposed and demonstrated by using a customized optical filter. The obtained triplet pulse reveals high efficiency and proper fitting for FCC standards.*

Introduction

Current trends in wireless networks technologies demand low complexity, low cost, low power consumption and high data-rate connectivity within the operational space. Under this background, ultra wideband (UWB) has emerged as an interesting topic of research supported for its capacity of sharing existing radio spectrum resources rather than demanding new spectral bands[1]. Nevertheless, due to the low power spectral density (PSD) value of ≤ 41.3 dB/MHz of the transmitted signal settled by FCC regulations[2], there is a trade-off between data rate and communication distance.

Several techniques to generate modulate and distribute UWB pulses have been proposed[3], not only to increase the scope of coverage area but also to provide undisrupted service across different networks. Generating directly in the optical domain avoids any extra electrical to optical conversion. In addition, the combination of UWB and Microwave photonics (MWP) techniques offers numerous beneficial features such as light weight, small size, tunability and immunity to electromagnetic interference[4]. Among the standard UWB pulses employed in modern literature, we can find monocycles and doublets. However, these pulses adapt poorly to the FCC spectral mask[5]. In this context, generation of high-order pulses stands as a fundamental niche to fully comply FCC regulations.

Different MWP techniques for UWB generation of low and high order pulses have been reported in the last years including solutions based on optical spectral shaping and dispersion-induced frequency-to-time mapping[6], microwave photonic filtering[7] and SOA nonlinear operation[8]. All these proposals even though effective do not represent entirely optimized schemes, since for each Gaussian base pulse generated only one coefficient is inserted to the system and into the generated waveform. In this way, an alternative technique was recently proposed for obtaining UWB high order signals consisting on the merge of various low order UWB pulses, such as monocycles and doublets to create triplets or quadruplets[9, 10].

In this letter, we present a proposal for generation of UWB high order pulses, which is focused on the merge of various low order UWB pulses. The principle of operation relies on the combination of a phase modulator with a customized FBG array for a simultaneous process of PM-IM conversion and pulse shaping. The notion of combining phase modulation with optical filters has been approached previously[11, 12]. However, high order pulses have not been experimentally reported with this promising technique. In the first one[11], the PM-IM conversion takes place in a single FBG, constraining any possibility of high-order pulses generation. In the other one[12], the design shows a complex receiver due to the presence of a balanced photodetector (BPD). Therefore, the bulky architecture limits the possibilities of an integrated optics approach. The remaining of the paper is organized as follows: firstly, the operation principles is presented and analysed. Secondly, experimental measurements of the generated UWB pulse, in both time and frequency domain, are presented revealing efficiency and a proper fit in terms of FCC settled standards. Apart from the generation of pulses with an efficient compliance of the FCC spectral mask, this optical UWB system holds the possibility of pulse codification, implementing different modulation formats such as Pulse Position Modulation (PPM) and Bi-Phase Modulation (BPM), which will be addressed at the end of the experimental section. Finally, conclusions are addressed.

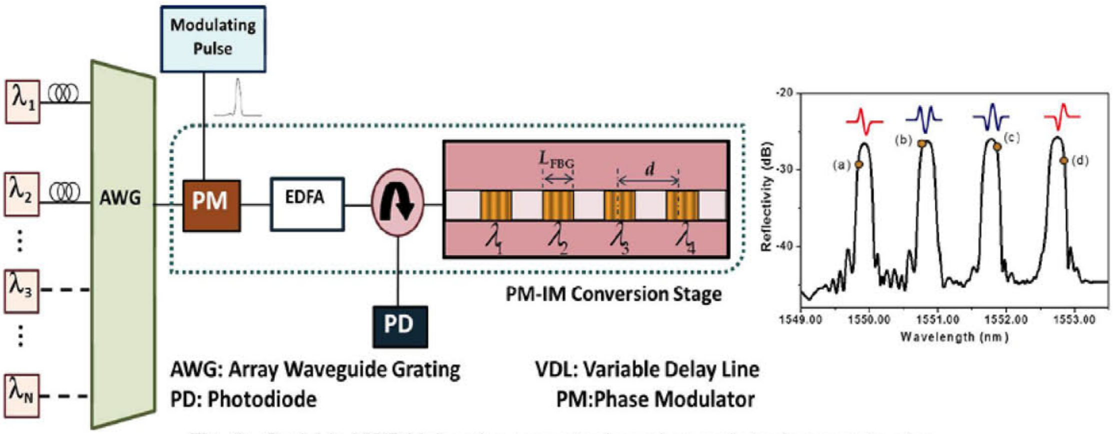

Fig. 1: Scalable UWB high order generator based on a photonic superstructure.

Principle of Operation

Figure 1 depicts in detailed the proposed photonic architecture. In the first contemplated segment, light from a set of N optical sources is launched to a phase modulator (PM) by means an array waveguide grating (AWG). The PM is modulated by Gaussian like pulses coming from an electrical pulse generator providing an OOK data sequence to be transmitted. In this implementation, we expand the concept of PM-IM conversion with a single fiber Bragg grating (FBG) operating as a frequency discriminator [13] by introducing high order pulses generation and modulation capacities through a FBG superstructure. In this context, by locating the optical carrier at the linear or the quadrature slope of the FBG reflection spectrum, the base monocycle or doublet pulses can be obtained. Deriving in operational points "A" (positive monocycle), "B" (positive doublet) "C" (negative doublet) and "D" (positive monocycle).

The design of a suitable FBG array is a significant matter since the quality of the reflected spectrum and the distance between each one will determine the quality of the high-order pulse to be produced. First of all, when designing the array, we had to consider a specific apodized profile to reduce the secondary lobes of the FBG spectrum in order to minimize the crosstalk between channels. Secondly, there is the separation factor *d*, this parameter holds a direct relation with the optical delay between taps ($\Delta\tau = 2n_0 d / c$).In order to be working with a FSR/2 around 6.45 GHz, in agreement with the central frequency of the UWB spectral band we require a FSR ($1/\tau$) of approximately 12.9 GHz and an optical delay ($\Delta\tau$) of 77ps. Therefore, *d* must hold a value around to 8mm. Finally, there is the length factor *l*. A 7 mm length is considered an optimal value for each FBG within the array in order to avoid overlapping between adjacent gratings in the fabrication process. In this specific solution, the phase modulated pulse is introduced to a FBG based superstructure through an optical circulator which will operate in function of the optical wavelength selected for each optical source.

Experimental Results

To demonstrate and validate the capabilities of generation in the scheme of Fig. 1, the generation of UWB high order pulses was accomplished by combining several low-order signals. For this experiment, we employed two lasers with an optical power value of 5.5 dBm each and wavelengths located at 1549.837 nm and 1550.683 nm. Activation of such optical sources is proportional to the number of lower order pulses to be reconfigured in the outcome signal and their values are directly related with the base UWB waveforms to be employed and hence the PM-IM conversion working point. In this case the triplet was accomplished by means of the lineal sum of two inverted doublet pulses, corresponding to the "C" and "B" operational points. Fig. 2(a) exhibits the obtained UWB triplet waveform, where the blue line corresponds to the theoretical simulation and Fig. 2(b) plots its corresponding spectral representation.

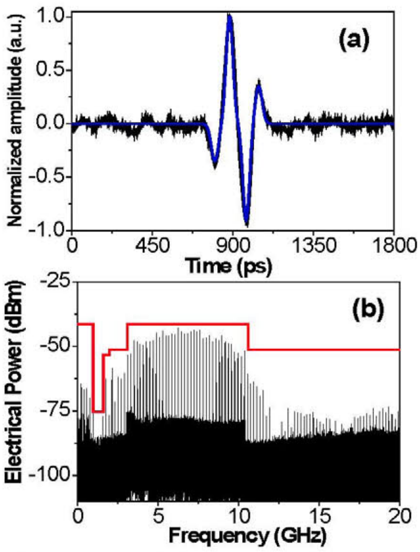

Fig. 2: (a) Generated UWB (b) corresponding spectrum. FCC mask is plotted in red line.

In order to maximize the functionalities of the proposed system, along with high-order waveforms generation, implementation of diverse modulation formats such as Pulse Position Modulation (PPM) and Bi-Phase Modulation (BPM) is also feasible. In the case of PPM modulation, it can be achieved by employing the entire FBGs array and tuning the proper wavelength in each FBG. Such wavelengths can be tagged as λ_{1A}, λ_{2A}, λ_{3A} and λ_{4A} with corresponding values of 1549.721 nm, 1550.631 nm, 1551.568 nm and 1552.561 nm. Figure 3(a) depicts the generated pulses for PPM modulation, with a separation between the original pulse and the delayed ones of approximately 77 ps, 154 ps and 231 ps. In the case of BPM, this format was achieved by the juxtaposition of two inverted pulses, setting up one FBG and two optical sources. The FBG1 works as the optical filter for this measurement with a Bragg wavelength of 1549.808 nm. The first tuned configuration corresponds to the "A" working point, which produces a positive monocycle and the inverted pulse is related to the "D" working point and thus to a negative monocycle. Figure 3(b) shows the two low-order UWB pulses obtained for BPM by switching the optical wavelength around values λ_{1A}= 1549.721 nm (red line) and λ_{1D} = 1549.871 (black line) nm.

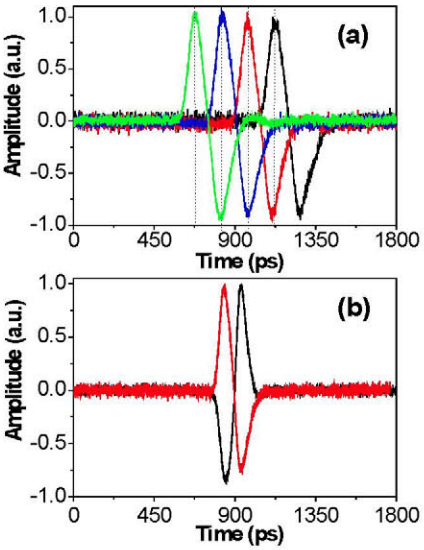

Fig. 3: BPM and PPM modulation for the generated UWB pulses. (a) PPM with a separation of 77 ps (b) For BPM, original pulse (red line) and inverted pulse (black line).

Conclusions

We have proposed an efficient, reconfigurable and scalable UWB generator based on a customized photonic superstructure. Feasibility of this concept was experimentally proved by the generation of an UWB triplet pulse. Results reveal an improvement in terms of spectral efficiency from 23 % to 65 % when contrasting the base lower order doublet employed and the generated UWB triplet. Parallel to this, the system portraits an interesting flexibility to perform standard modulation formats such as BPM and PPM.

Acknowledgements

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