UWB-over-Multimode-Fiber Technology for Short-Range Communication Networks

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Ultra-wideband (UWB)-over-fiber is an attractive technique to extend the reach of UWB systems and to consolidate wireless personal access networks with fiber-to-the-customer-premises (FTTCP). In this scenario, simple ways to generate UWB signals by photonic means is highly desired. Moreover, detection techniques of UWB signals that simplify the transceivers are of crucial importance. In this paper, we present experimental results for the photonic generation of UWB signals complying with the Federal Communication Committee (FCC) mask by using an uncooled distributed feedback laser (DFB). We also show examples of the use of digital signal processing (DSP) to assist the detection of UWB signal over multi-mode fiber links for short range communication networks.

Introduction

Ultrawide-band (UWB) is a promising short range communication technology due to its extremely low radiation power, very low operation signal-to-noise ratio (SNR), and wide bandwidth under unlicensed spectrum (3.1-10.6 GHz) specified by the Federal Communications Commission (FCC) [1]. However, this technique is limited to short range applications (up to 10 m or 30 feet). Therefore, the extension of its access range is an important issue. On the other hand, fiber optical access based technology such as fiber-to-the-customer-premises (FTTCP) has the well-known advantages of large bandwidth, long reach and is being deploying worldwide. Thus UWB-over-fiber is attractive and is a promising approach to extend the reach of UWB systems and to consolidate wireless personal access networks with FTTCP. In this scenario, simple ways to generate UWB signals by photonic means is highly desired as well as its distribution over fiber links. Recently, more and more researchers are focusing on the photonic generation and transport of FCC compliant UWB signals [2, 3]. Moreover, detection techniques of UWB signals that simplify the transceivers are of crucial importance.

In this paper, we present experimental results for the photonic generation of UWB signals complying with FCC mask by using an uncooled distributed feedback laser (DFB). We also demonstrate the use of digital signal processing (DSP) to assist the detection of a 781.25Mbps UWB signal over multimode fiber (MMF) links. Most importantly, UWB-over-MMF system is promising in the scenario of high-speed short range communication networks.

UWB Photonic Generator

The experimental setup is shown in Fig.1. A 12.5Gbps pattern generator is employed to generate programmable bit pattern, which is used to drive a Mach-Zehnder modulator (MZM). The modulated continuous lightwave then injects into a distributed feedback laser (DFB). Due to the polarization-dependence, the injection light is polarization controlled by a polarization controller (PC). At the output of the DFB, an optical filter is used to reject one wavelength from continuous wave laser (CW) and suppress noise from an Erbium-doped fiber amplifier (EDFA).

In the experiment, in order to increase cross gain modulation between DFB and CW lightwaves, the wavelength of CW is chosen to correspond with one side mode of DFB lasing, as displayed in Fig.2(a). When we apply a 12.5Gbps 16-bit programmable sequence ‘1010 0000 0000 0000’ to the MZM, thanks to the overshooting of DFB lasing, we can obtain UWB pulses at the output of filter. The generated UWB pulse is shown in Fig.2(b).

It is noticed that all components in this photonic UWB signals generator are single mode fiber based, and the generated UWB signals is on-off keying modulated. In other words, one pulse (data bit ‘1’) will be obtained if the original 16-bit sequence is ‘1010 0000 0000 0000’, and then no pulse (data bit ‘0’) will be achieved if we apply 16-bit sequence ‘0000 0000 0000 0000’. In this way, we can program an PRBS pattern with bit rate of 781.25Mbps.

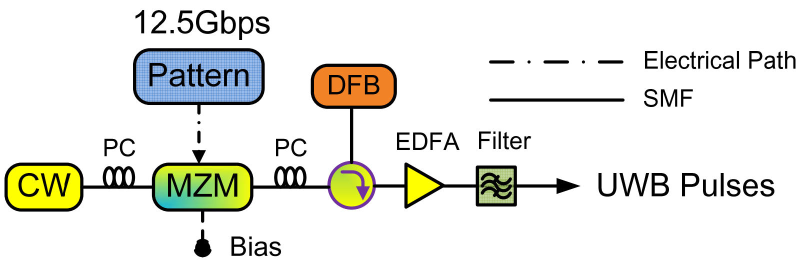
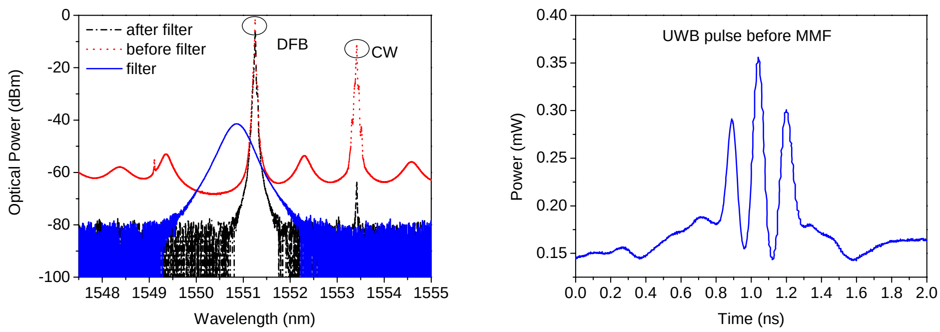


Fig.1. Photonic generation of UWB pulses based on external injection of an uncooled DFB laser. CW: continuous wave, MZM: Mach-Zehnder modulator, PC: polarization controller, DFB: distributed feedback laser, SMF: Single mode fiber, EDFA: Erbium-doped fiber amplifier.



(a) (b)

Fig.2. (a) optical spectra before and after optical filter, as well as transfer function of optical filter, (b) generated UWB pulse in time domain.

UWB-over-MMF and DSP Detection

In the past years, most efforts have been focused on the development of single mode fibre (SMF) transmission for long-distance networks or subscriber networks. MMF however offers the advantage of less stringent alignment tolerances thanks to its larger core diameter. For the last mile access networks, and in particular for in-building scenarios, MMF has thus very high penetration in already installed fiber infrastructure

[4, 5]. Therefore, MMF is an important transmission medium in short range communication networks.

In this paper, we demonstrate a UWB-over-MMF transmission system, as shown in Fig.3. The generated UWB signals by using SMF based components are launched into a 5.1 km MMF. Limited by the MMF based devices, SMF based attenuator and photodiode (PD) are used to receive the transmitted signals. In the electrical domain, a real-time sampling scope with sample rate of 40GSamples/s is employed to convert the analogue signals into digital signals. Finally, the bit-error-rate (BER) performance of this transmission system is processed offline in the digital domain by using digital signal processing (DSP) technology.

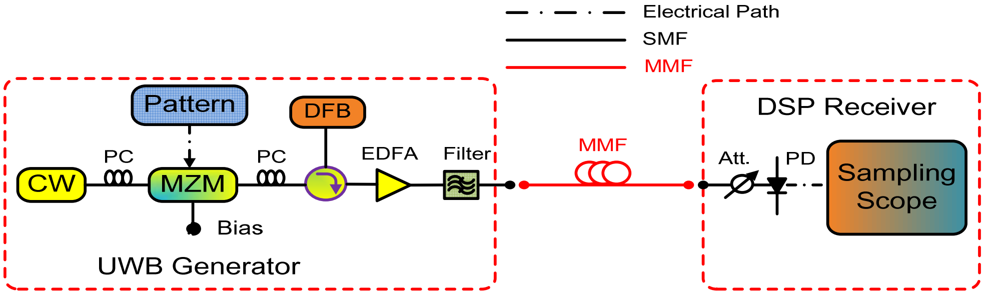
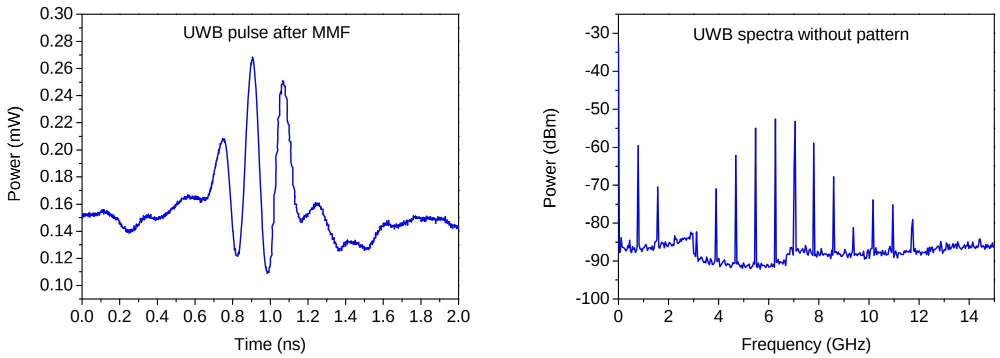


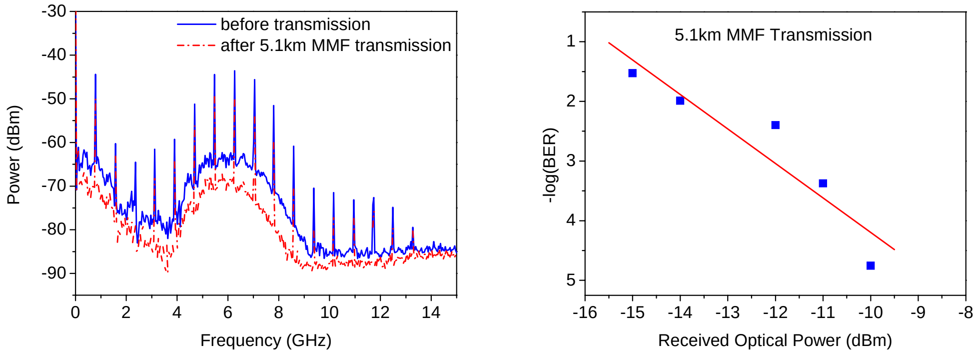
Fig.3. Transmission of UWB pulses over MMF and DSP detection. MMF: multimode fiber, Att.: attenuator, PD: photodiode, DSP: digital signal processing.

Compared to the pulse before transmission in Fig.2(b), the shape of the pulse after MMF transmission in Fig.4(a) does not change considerably. However, we can observe many small peaks because of the coupling efficiency between SMF and MMF, as well as the interaction of multi-modes within the MMF [6]. Regarding the spectra of UWB signals in the frequency domain in Fig.4(b), it is compliant with the FCC mask [1].

As mentioned above, when a 781.25Mbps PRBS with length of 2^7-1 is programmed, the spectra in frequency domain is shown in Fig.4(c), and we can observe the continuous envelope of digital pattern. Furthermore, the spectra are not significantly altered after 5.1 km MMF transmission. In the experiment, 57,000 data bits are sampled and stored to be processed offline. By counting the error bits, a BER curve is obtained, as displayed in Fig.4(d). There is only one error bit in the case of -10 dBm received optical power.



(a) (b)



(c) (d)

Fig.4. (a) UWB pulse without data pattern after 5.1km MMF transmission, (b) UWB signals in frequency domain, (c) UWB signals with 781.25Mbps data pattern in frequency domain before and after 5.1km MMF transmission, (d) measured BER performance by using DSP technology.

Conclusions

We propose and experimentally demonstrate a simple way to generate FCC compatible UWB pulses in optical domain by using an uncooled DFB. For the reception of the generated UWB signals, DSP technology is employed to obtain BER performance in the digital domain. The experimental results of 781.25Mbps UWB bit rate over 5.1 km MMF transmission system have been presented. Furthermore, our proposed UWB-over-MMF system has potential application in high-speed short range communication networks.

Acknowledgments

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