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### 3.125 Gb/s Impulse Radio UWB over Fiber Transmission

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#### Abstract

We demonstrate 3.125 Gb/s photonic impulse radio UWB generation using an uncooled distributed feedback laser. After 50km fiber transmission the signal is recovered without errors using a digital signal processing receiver.

#### Introduction

Current requirement from short-range wireless communication systems include low power consumption, radiating low power levels into the environment, and capability of supporting bandwidth intensive applications such as high definition TV. Impulse ultra-wideband (UWB) radio is a promising technology for meeting these requirements. At radiation below  $-41.3$  dBm/MHz wireless UWB signals can however at best only propagate several meters. Photonic UWB is thus invaluable for distributing UWB signals through fiber transmission in converged optical wireless access networks. The challenge to date has been high speed photonic impulse radio UWB (IR-UWB) generation. Previous demonstrations include 500 Mb/s with pulse shaping<sup>1</sup>, 625 Mb/s with frequency up-conversion<sup>2</sup>, 781.25 Mb/s<sup>3</sup>, and 1.025 Gb/s<sup>4</sup> and 1.625 Gb/s<sup>5</sup> featuring wireless transmission.

In this paper we demonstrate 3.125 Gb/s photonic impulse radio (IR) UWB signal generation based on incoherent optical field summation resulting from cross gain modulation (XGM) of an uncooled distributed feedback (DFB) laser injected with a 12.5 Gb/s modulated external cavity laser (ECL). The UWB signal is transmitted over 50 km of fiber and subsequently recovered without errors using a digital signal processing (DSP) receiver.

#### Experimental setup

Fig. 1(a) shows the experimental setup. A 1552.8 nm ECL intensity modulated at 12.5 Gb/s is injected into an uncooled DFB laser with a central wavelength of 1551.5 nm. A polarization controller (PC) placed before the circulator is used to adjust the state of polarization of the modulated ECL to ensure the XGM introduced within the DFB laser is maximized. The IR-UWB signal exiting the UWB generator after the circulator is launched into 25 km of single mode fiber (SMF) followed by 25 km of matching inverse dispersion fiber (IDF). The IR-UWB pulse is subsequently detected by a photodiode (PD). The electrical spectrum is measured and compared to the US Federal Communications Commission (FCC) requirement at

the photodiode. The bit error rate (BER) is also determined using an Agilent 40 GSa/s Digital Storage Oscilloscope and custom offline DSP algorithm. In addition to the high bit rate that is achieved, our scheme avoids the use of complex mode-locked lasers, custom fiber Bragg gratings, spectral shaping components, and nonlinear elements as in many previously reported optical IR-UWB generation techniques.

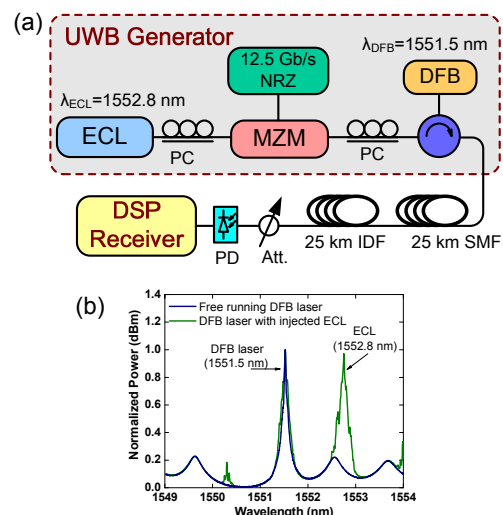
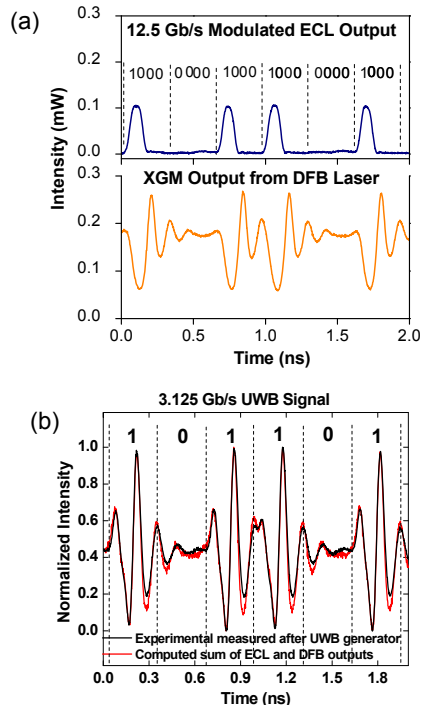


Fig. 1: (a) Experimental setup. (b) Optical spectra measured at the output of the UWB Generator.

#### Photonic UWB signal generation

Fig. 1(b) shows the optical spectra measured directly after the circulator. The ECL wavelength is chosen to correspond with a first-order DFB laser sidemode, thus ensuring strong XGM transfer to the 1551.5 nm DFB laser wavelength. Fig. 2 illustrates the generation principle for a 101101 UWB bit sequences. The ECL modulated at 12.5 Gb/s with the sequence 1000 0000 1000 1000 0000 1000 produces the XGM output of the DFB laser as shown in Fig. 2 (a). Noticeable are the overshoot and relaxation oscillations of the DFB laser<sup>6</sup>. UWB bits are subsequently created from the incoherent sum of the ECL and DFB signals<sup>7</sup> as shown in Fig. 2 (b). The 12.5 Gb/s modulation sequences 1000 and 0000 of the ECL correspond to 1 and 0 UWB

bits respectively, at an effective UWB bit rate of 3.125 Gb/s. The UWB pulse shape can be altered by slightly tuning the ECL wavelength about the first-order DFB wavelength. This alters the relative delay between the ECL and DFB laser signals caused by chromatic dispersion.



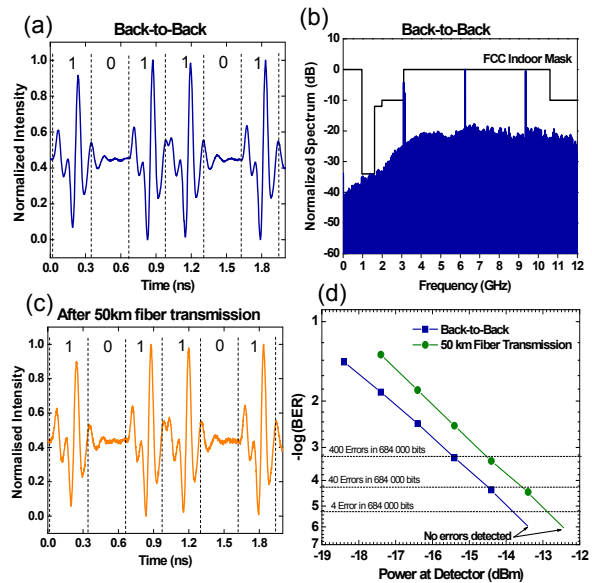
**Fig. 2:** (a) The ECL and DFB laser signals measured individually using a 0.4 nm FWHM filter at the output of the UWB generator. (b) The IR-UWB signal resulting from the incoherent summation of the ECL and DFB signals.

**Photonic UWB signal transmission**

The photonic back-to-back IR-UWB pulse shape shown in Fig. 3(a) was selected for the fiber transmission demonstration to obtain a high fractional bandwidth and good agreement to the FCC mask, as shown in Fig. 3(b). The -10 dB fractional bandwidth about the central frequency of 7.6 GHz is around 145%. For the transmission demonstration IDF was chosen as an option to compensate the SMF dispersion. IDF has the added benefit compared to dispersion compensating fiber of being used as transmission fibre, thus extending network reach. Inter- and intra-channel dispersion issues of the two wavelengths used in our IR-UWB have yet to be thoughtfully investigated.

Comparison between Fig. 3(a) and (c) shows that transmission does not alter the pulse shape. After fibre transmission the electrical spectrum was found to be practically identical to the back-to-back electrical spectrum and still comply with the FCC requirements. Fig. 3(d) shows the BER results for back-to-back and 50 km fiber transmission of the photonic IR-UWB signal. For each BER measurement point,  $6.84 \times 10^5$  UWB bits following a  $2^7-1$  PRBS pattern are transmitted and recorded

using a 40 GSa/s Digital Storage Oscilloscope. The BER is subsequently computed using a DSP algorithm in a bit-for-bit comparison between the transmitted and received bits. The DSP algorithm distinguished between “1” and “0” UWB bits by comparing the average power within the central window of each bit slot to an optimally determined decision threshold. Transmission over the 50 km link is seen to introduce a 1 dB penalty. Transmission without error in  $6.84 \times 10^5$  UWB bits occurs at receiver sensitivities of -13.4 dBm and -12.4 dBm for back-to-back and fiber transmission respectively.



**Fig. 3:** (a)-(c) The 3.125 Gb/s IR-UWB pulse in the time and electrical domains, before and after transmission over the 50 km fiber link. The spikes with 3.125 GHz spacing in (b) originate from the PRBS pattern repetition rate. (d) BER results for back-to-back and fiber transmission of the photonic IR-UWB signal.

**Conclusions**

We demonstrate 3.125 Gb/s photonic IR-UWB signal generation based on incoherent optical field summation for an uncooled DFB laser injected by a modulated ECL. The penalty was found to be 1 dB for transmission of the IR-UWB signal over 50 km of fiber. This first ever to our knowledge demonstration of photonic IR-UWB signal generation beyond 3 Gb/s paves the way for high speed converged optical wireless access networks supporting short-range wireless.

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