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Beyond 100Gbit/s wireless connectivity enabled by THz Photonics (Invited)

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ABSTRACT

Beyond 100Gbit/s wireless connectivity is appreciated in many scenarios, such as big data wireless cloud, ultrafast wireless download, large volume data transfer, etc. In this paper, we will present our recent achievements on beyond 100Gbit/s ultrafast terahertz (THz) wireless links enabled by THz photonics.

Keywords: THz photonics, THz wireless communication, photomixing, uni-travelling carrier photodiode (UTC-PD).

1. INTRODUCTION

THz band (>300GHz) features ultrabroad radio frequency bandwidth available, which makes it very attractive in many application scenarios, e.g. ultrafast short range wireless communication, nondestructive spectroscopic detection, telescope, etc. From the prospect of communication, THz technologies have been widely recognized as the ‘Next Frontier’ for supporting ultrafast datarates of up to Terabit-per-second (Tbps), which is and far beyond the capacity of microwave and millimeter-wave [1][2][3] and is foreseeable to be highly desirable in accommodating, for example, big data wireless cloud, ultrafast wireless download, large volume data transfer, etc. Recently, exploring sub-THz and THz bands for delivering very high datarates has been invested a lot of research efforts, and many communication systems have been demonstrated [4]-[19]. Amongst them, benefited from ultrafast photoresponse of uni-travelling carrier photodiodes (UTC-PDs) and hence extremely large bandwidth in the THz frequency bands, opto-electronic-based approach has exhibited advantageous potentials in supporting large throughput [20].

We have recently also demonstrated some high speed THz wireless communication systems in the frequency range of 300GHz-500GHz, at data rates of 60Gbit/s, 160Gbit/s and up to 260Gbit/s [14]-[17]. As we know, high speed data signals are very sensitive to the nonlinearity and phase noise in the transmission systems, in turn highly pure THz signals with low phase noise are needed, which is one of the challenging aspects in developing ultrafast THz wireless communication systems. In our system, we develop the technology to generate THz signals with low phase noise by using coherent photonics, and based on that, THz wireless transmission of beyond 100Gbit/s is realized.

In this paper, we will technically present coherent photonics-enabled THz generation with high quality and THz wireless transmission of 160Gbit/s in the 400GHz band. In addition, THz phase noise and its impact on the bit-error rate performance will be analyzed.

2. THZ PHOTONICS ENABLED HIGH SPEED WIRELESS LINKS

2.1 Photonics-enabled THz generation with high purity

The experimental configuration for generating THz tones and measuring THz phase noise is shown in Fig. 1. We first optically create a frequency comb based on two concatenated phase modulators (PMs), both of which are driven by an amplified 25 GHz sinusoidal signal. An optical tunable delay line in-between is used to match the phase of the two-stage modulation, in order to improve the signal-to-noise ratio (SNR) of the optical tones in the comb needed for the 300-500 GHz carrier generation. Subsequently, a programmable wavelength selective switch (WSS-1, Finisar 4000S) is employed to extract for photo-mixing generation of THz signals. We generate a 400 GHz beat note by photomixing two wavelengths in different schemes. Fig. 1(a) depicts the configuration of extracting two wavelengths without splitting them after the WSS-1, so called *coherent beating without optical splitting*, for phase noise performance comparison. Fig. 1(b) is the system configuration to test THz phase noise performance based on the complete system used for communication in Section 2.2, in order to obtain the best THz quality for communication by compensating phase decorrelation after the WSS-1. We measure phase noise of the generated 400 GHz tone when the optical local oscillator (λ_{LO}) path is compensated with a piece of matched fiber (50 m), called *with compensation fiber after WSS-1*. The THz purity is investigated by measuring the phase noise of down-converted intermediate frequency component in a spectrum analyzer.

Fig. 2(a) shows the measured phase noise of 400 GHz beat note in different cases. For comparison purpose, the phase noise by coherent beating two optical lines without splitting (in Fig.2(a)) is also displayed. It can be seen from Fig.2(a) that when path length difference (PLD) is 0 m, meaning the LO path is accurately compensated by a piece of matched fiber, the phase noise performance of THz carrier is same as that in coherent beating. However, the phase noise of 400 GHz signal is becoming worse and worse when 1 m, 2 m, 3 m and 5 m path-length difference are introduced. In addition, we investigate the influence of phase noise on communication system performance by modulating a 10 Gbit/s OOK baseband data and analyzing the BER of the received signal after a 50 cm free space transmission in the scope. The measured BER results are shown in Fig.2(b). We can observe that the BER performance in the cases *without optical splitting* and with the beating of two free-running lasers is the best and worst, respectively. In between the BER gets worse when path length difference increases from 0 m to 5 m. Therefore, the path-length difference caused optical phase de-correlation has significant influence on the communication system performance, due to the phase noise degradation of generated THz beat-notes.

Fig. 1. Experimental configuration for measuring 350 GHz phase noise generated in the cases of (a) coherent beating of two comb lines and (b) with compensation fiber after WSS-1.

Fig. 2. (a) Phase noise of the generated 400 GHz carrier with different path length difference. (b) BER performance of OOK modulation at 400 GHz with different path length difference.

2.2 160Gbit/s THz wireless connectivity

The THz communication experimental configuration is based on the system in Fig.1(b) when the path length difference is accurately compensated, as shown in Fig. 3(a). In this experiment, we modulate 25GHz-spaced 8 comb lines with Nyquist quadrature phase shift keying (QPSK) pseudorandom binary sequence (PRBS) 2^7-1 signals at an in-phase (I) and quadrature (Q) modulator. The digital baseband data signal is generated and shaped by using an arbitrary waveform generator (AWG). The 25 GHz spaced optical frequency comb and the combined 8-channel optical spectrum is shown in Fig. 3(a) and Fig. 3(b), the data modulated 8 WDM channels are used with the optical LO to generate the THz signal around 400 GHz. At the receiver side, a subharmonic THz Scottky mixer operating in the frequency range of 300-500 GHz is used to down-convert the received THz signal into an intermediate frequency signal. The mixer is fed by a 36-order frequency multiplier driven by an 8.3-13.9 GHz tunable electrical LO signal. The IF output is amplified by a chain of electrical amplifiers with 42 dB gain, and is finally demodulated and analyzed by a broadband real time sampling oscilloscope (63 GHz Keysight DSOZ634A Infiniium).

10Gbaud QPSK per channel is used in the experiment, resulting in a total bitrate of 160Gbit/s. The measured BER performance after wireless propagation is shown in Fig. 4(a). We can see that the 375 GHz and 500 GHz channels in Fig. 4(a) are slightly worse than the 325-, 350-, 425- and 450 GHz channels with a penalty of less than 1 dB. This penalty is mainly caused by the fluctuated conversion loss of the Schottky mixer based receiver, as shown in Fig. 4(b). In the 300-500 GHz frequency range, 375 GHz and 500 GHz bands exhibit the largest conversion loss and 400 GHz least, which comply well with the BER performance observation and is also reflected in the 8-channel electrical spectrum in Fig. 4(b). The BER performance in the experiment is evaluated from the error-vector magnitude (EVM) of the processed constellations.

Fig. 3. (a) Experimental configuration of the 300-500 GHz photonics-wireless communication system. (b) Generated 25 GHz spaced frequency comb spectrum and optical tones for THz generation. (c) WSS-prepared 8 WDM channels 25 GHz apart and centered 400 GHz from the LO before the UTC-PD.

Fig. 4. (a) Measured BER performance after 50 cm wireless transmission for 8 channels in the 300-500 GHz band, (b) 8-channel electrical spectrum and frequency dependent conversion loss of the receiver.

3. CONCLUSIONS

We have successfully generate THz signals with low phase noise in the 400GHz band based on photonics means. The phase noise of the 400 GHz signal is severely influenced by the beating path-length difference, and consequently significantly affects THz wireless communication performance. By compensating the length difference, highly pure THz signals can be achieved, which leads to enable the development of beyond 100Gbit/s THz photonic wireless transmission links.

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