# Wireless Terahertz Communications Using Optoelectronic Techniques

## Abstract:

Mobile data traffic has grown 18-fold over the past 5 years and will continue to grow exponentially. Sustaining this trend requires high-performance wireless infrastructures with carrier frequencies above 275 GHz, exploiting atmospheric transmission windows of low attenuation at frequencies which have not yet been allocated to specific services. To access these frequency ranges, optoelectronic signal processing is particularly promising [1]. For the transmitter (Tx), the tremendous potential of such concepts has been shown, leading to the first demonstration of coherent THz transmission at line rates of 100 Gbit/s [2]. For the receiver (Rx), optoelectronics offers similar advantages and enables broadband coherent reception without the need of an electronic local THz oscillator. However, up to now, these receiver technologies are not well explored in the context of THz communication systems. In this talk, we show two methods for optoelectronic coherent THz data reception, and we demonstrate their functionality in transmission experiments. In both set of experiments, the THz transmitter employs optical-to-terahertz (O/T) conversion in a high-speed photodetector, see Fig. 1(a).

Our first version of a THz receiver, Fig 1(b), relies on down-converting the THz signal directly to the baseband (T/E - conversion [3–5]). In this configuration, the beating of two detuned CW laser tones serves as a local oscillator, and the receiver can be tuned by frequency-shifting one of these CW laser tones. We show coherent data reception at wireless carrier frequencies in a range 25 GHz up to 0.34 THz, demonstrating the flexibility of the optoelectronic approach. We receive quadrature phase shift keying (QPSK) data with line rates up to 6 Gbit/s, transmitted at a carrier with frequency 0.295 THz and at a bit error ratio (BER) below the threshold of forward-error correction (FEC) with 7 % overhead. The bit rate of a single-carrier transmission is limited by the baseband electronics. We also investigate the receiver in a multi-carrier transmission experiment. A THz signal with 12 channels each carrying a 1.5 Gbit/s QPSK bit stream, was received with a BER below the 7% FEC limit for all the channels. This leads to a line rate of 18 Gbit/s. In both experiments, we span a transmission distance of more than 15 m.

In our second version of a THz reveiver, Fig 1(c), we modulate the THz data onto an optical carrier (T/O conversion [6]). This is achieved by a high-speed plasmonic organic hybrid modulator having an unprecedented bandwidth of at least 0.325 THz. Such a direct T/O conversion enables seamless integration of a THz wireless link into the existing fiber-optic infrastructure. In a back-to-back configuration, we receive a line rate of 16 Gbit/s with a QPSK signal transmitted on a 0.294 THz carrier for a BER below the 7 %-FEC limit, and a 30 Gbit/s QPSK signal below the 20 % FEC limit. The drop in the signal quality for higher line rates is due to the decrease in received THz power and does not reflect the performance of the plasmonic modulator.

In summary, we demonstrate down-conversion (T/E) and up-conversion (T/O) of a received THz data signal. Depending on the application, it might be advantageous to further process the data as an electrical signal, or to continue the transmission in the optical domain. We show that both reception schemes are useful for a frequency-tunable and high-capacity wireless link.

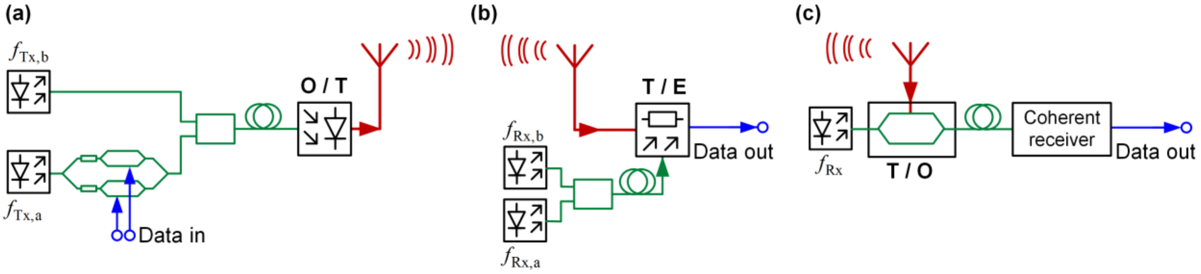

**Figure 1** Wireless terahertz communication system using optoelectronics. **(a)** THz transmitter. An IQ-modulator modulates an optical continuous-wave (CW) carrier with frequency $f_{\mathrm{Tx,a}}$. The modulated signal is superimposed with an unmodulated CW tone $f_{\mathrm{Tx,b}}$ and converted to the THz domain by photomixing in a high-speed photodiode (optical-to-terahertz conversion, O/T). The frequency of the THz carrier corresponds to the frequency difference of the lasers, $f_{\mathrm{Tx,THz}} = \left| f_{\mathrm{Tx,a}} - f_{\mathrm{Tx,b}} \right|$. **(b)** THz reception by optoelectronic down-conversion. The THz data signal is coupled to a photoconductive antenna, which leads to a voltage $u(t)$ across the photoconductor. Its conductance $G(t)$ is modulated by the power beat of two unmodulated optical CW tones with difference frequency $f_{\mathrm{Rx,THz}} = \left| f_{\mathrm{Rx,a}} - f_{\mathrm{Rx,b}} \right|$. The resulting THz current $i_{\mathrm{B}}(t) = \left\langle u(t) G(t) \right\rangle$, averaged over a THz period, contains the down-converted THz data signal (terahertz-to-electrical conversion, T/E) and is processed with baseband electronics. **(c)** THz reception by electro-optic up-conversion. The THz data signal is modulated onto an optical carrier $f_{\mathrm{Rx}}$ using an ultra-broadband plasmonic organic hybrid modulator (terahertz-to-optical conversion, T/O) for further optical transport.

## References

1. T. Nagatsuma, G. Ducournau and C. C. Renaud „Advances in terahertz communications accelerated by photonics," *Nature Photon.* **10**, 371–379 (2016).
2. S. Koenig et al. „Wireless sub-THz communication system with high data rate," *Nature Photon.* **7**, 977–981 (2013).
3. T. Harter et al. „Silicon-plasmonic integrated circuits for terahertz signal generation and coherent detection," *arXiv:*1802.08506 (2018).
4. T. Harter et al. „Wireless multi-subcarrier THz communications using mixing in a photoconductor for coherent reception," in *IEEE Photon. Conf.* 147 – 148 (2017).
5. T. Harter et al. „Wireless THz Communications Using Optoelectronic Techniques for Signal Generation and Coherent Reception," in *Conf. on Lasers & Electro-Optics* SM3J.2 (2017).
6. S. Ummethala *et al.* „Terahertz-to-Optical Conversion Using a Plasmonic Modulator," in *Conf. on Lasers & Electro-Optics* (2018).