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Free-Space Optical Communications using Terahertz Lasers at Gbit/s Data Rates

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High-speed free-space optical (FSO) communication in the terahertz (THz) spectrum is gaining attention as a solution to the rising demand for wireless data. THz frequencies (0.1–10 THz) offer ample bandwidth and can deliver fiber-equivalent data rates wirelessly, making them suitable for beyond-5G backhaul [1]. Terahertz quantum cascade lasers (THz QCLs) offer multi-gigabit modulation speed in FSO links. The THz FSO communication systems >1 THz remain largely unexplored due to limitations in source and photodetector limitations. However, significant progress in sources, modulators, and receivers has improved output power, bandwidth, and sensitivity. [2]. A THz QCL link at 20 Mbit/s was demonstrated [3], and a recent link achieved 1 Mbit/s with a room-temperature graphene receiver [4]. However, achieving higher data rates in a THz FSO communication link remains a significant goal.

Here, we report a THz FSO communication link achieving a Gbit/s data rate for the first time. Our system uses a QCL transmitter and a room-temperature Schottky diode receiver, investigating NRZ-OOK data format over 0.5 m distance. Fig. 1a shows the experimental setup, where a 2.4 THz QCL enables an FSO link that transmits digital data at 1 Gbit/s. The THz QCL produces with an optical power of 75 μW at 300 mA driving current. The QCL was modulated by an NRZ-OOK electrical data signal with 19 dBm power, and a Schottky barrier diode served as a direct detector for demodulating the received signal. Fig. 1b shows the measured BER, obtained by offline processing of the real-time oscilloscope samples lasting 1 ms, as a function of driving current of the QCL. The BER significantly decreases as the driving current increases above 260 mA, meeting the hard-decision forward error correction (HD-FEC) limit (3.8×10^{-3}). Below 260 mA, the BER is high, reflecting insufficient optical power and low signal-to-noise ratio (SNR), and above 260 mA, the BER stabilizes at around 10^{-6}, demonstrating a reliable data transmission. Figs. 1c and 1d show eye diagrams for driving currents of 245 mA and 300 mA, respectively.

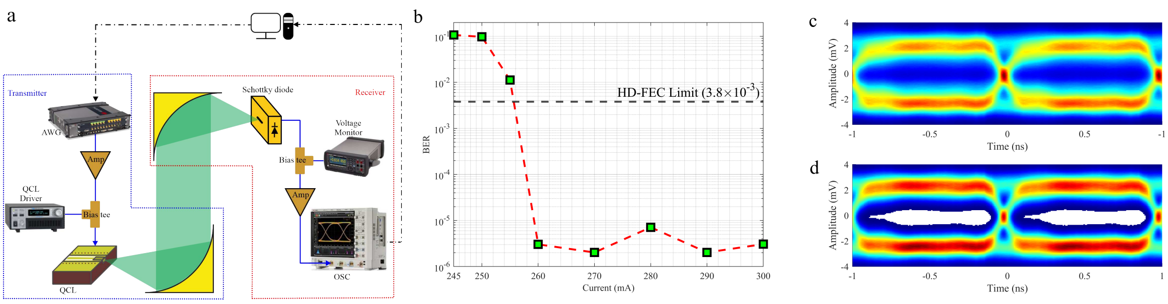

Figure 1: (a) Experimental arrangements of the THz FSO communication system, (b) BER as a function of the driving current of the QCL for NRZ-OOK at 1 Gbit/s, and eye diagrams of the demodulated signal for (c) 255 mA and (d) 300 mA.

At 245 mA, the eye diagram is greatly distorted, indicating high BER. In contrast, 300 mA presents a clear eye with defined transitions between "0" and "1" reflecting minimal distortion. This improvement at higher currents highlights the impact of QCL driving current on the transmission performance of the system.

Our experimental demonstration of Gbit/s data transmission using a terahertz laser provides proof of concept that such high data-rate links are feasible. Further data on multi-Gbit/s data transmission and optimization of the THz communications link is presented in Ref. [5].

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