Advances in Cryogen-Free QCL-based THz Wireless Communication

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The growing need for multi-hundred-Gbps to Tbps data rates and low latency (less then 10 ms) is driving communication systems toward the terahertz (THz) band. THz waves, less sensitive to Rayleigh scattering then infrared (IR) and visible waves, are well suited for harsh environments and industrial applications. Despite of this favorable feature, the absorption of water vapor in the atmosphere limits terrestrial THz wireless communication (TWC) distances. However, this could even represent an advantage in terms of security for intersatellite links (ISLs) [1]. Free space optical communication FSOC links in the 2–5 THz range have been enabled by high-power QCLs, but both transmitters and receivers still require strong cryogenic cooling [2].

We present a THz-FSOC link based on a 2.83 THz QCL [3] hosted in a compact closed-cycle cryostat. The receiver is a solid-state graphene-based field effect transistor (GFET) operating at room temperature. This marks the first experimental realization of a cryogen-free QCL-based TWC link, offering a portable solution for practical applications. Our TWC link is divided into a transmitter block (TX), an optical free-space channel, and a receiver block (RX).

A digital board generates a stream of packets at various bit rates, with the digital information encoded by modulating the Terahertz Quantum Cascade Laser (QCL) intensity, using an On-Off Keying (OOK) scheme with Manchester encoding. The 2.83 THz QCL of approximately 1 mW maximum power, is hosted in a compact K353 Stirling cryocooler by Ricor, stabilized at 38.4 K while the QCL is driven by a current of 570 mA.

The modulated THz beam is received by the RX stage, where it is converted into an electric signal by the GFET [4]. A variable-gain transimpedance amplifier (TIA) boosts the signal. A software-defined radio (SDR) digital filter removes excess noise before the digitizer/decoder stage on a second RX digital board [5]. This unit determines the received packets, comparing each with a reference message pre-stored on the board, and calculates the Packet Error Rate (PER). The system bandwidth is limited by the current driver at 1.4 MHz, thus we set the gain of the Femto DHPCA-100 TIA considering a trade-off between RX sensitivity and ultimate bandwidth, allowing error-free communication at 1 Mbps. By choosing higher amplification at the cost of lower bandwidth, we test the TWC for 115 kbps, demonstrating error-free communication up to approximately 3 m of distance. To assess the potential of this TWC system, we conducted simulations of the PER versus distance, assuming a QCL emitting in a frequency window with reduced water absorption. Our simulations show that longer distances can be achieved with our communication link. This novel cryogen-free TWC system represents a major advancement, being the first with no need of strong liquid-helium cooling at both TX and RX stages. This achievement opens the door to portable, field-ready, and satellite-compatible THz links above 2 THz.

References

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