

# Demonstration of a Transportable QCL-Based Free-Space link for Reliable THz Communications

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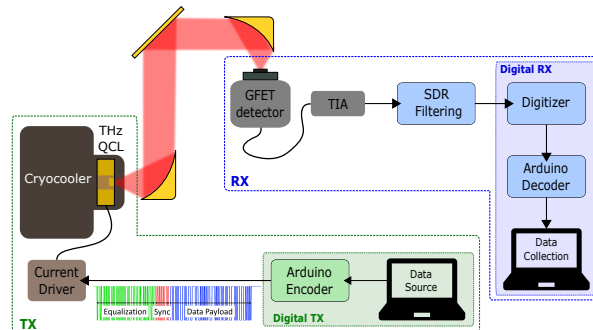
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**Abstract:** THz frequencies would enable Tbps links and robust free-space optical communication (FSOC) in harsh environments. We demonstrate the first cryogen-free THz FSOC link, based on a QCL and a graphene-based field effect transistor as the room-temperature detector.

The growing need for multi-hundred-Gbps to Tbps data rates and low latency (less than 10 ms) is driving communication systems toward the terahertz (THz) band. THz waves, less sensitive to Rayleigh scattering than 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 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), as depicted in Fig.1.



**Fig.1** | Schematic of experimental set-up: The lower panel shows TX block diagram, with an ArduinoDUE board depicted to encode the signal. TX block generates a stream of packets,

which are sent through the optical free-space channel that includes a QCL hosted in a Stirling cryocooler, and a room-temperature GFET detector. The upper panel shows the RX block diagram with digital decoding. The output of the GFET detector after passing through a variable-gain TIA, is digitized through a single-threshold Schmitt comparator, and decoded through a second Arduino DUE board, also performing a byte-wise comparison for PER calculation.

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 [3]. 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 [4]. 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 DHPKA-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 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.

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