# Free-space video broadcasting with a packaged, air-cooled, mid-infrared quantum cascade laser

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**Pierre Didier**,[1,+] **Olivier Spitz**,[1] **Frédéric Grillot**[1,2]

[1] *LTCI Télécom Paris, Institut Polytechnique de Paris, 19 place Marguerite Perey, Palaiseau, 91120, France*

[2] *Center for High Technology Materials, University of New-Mexico, Albuquerque, NM 87106, USA*

[+] *pierre.didier@telecom-paris.fr*

**Abstract:** In this work, we describe a free-space transmission at mid-infrared wavelength using off-the-shelf quantum cascade laser. The high modulation speed we can achieve with our setup allows us broadcasting a live video with data rate of 270 Mbits/s over a few meters. We also briefly compare the performance of a free-space transmission in the case of a near-infrared laser and this is of paramount interest for our future real-field experiments. Our proof-of-concept, combined with the high output power of quantum cascade lasers, is promising for long-range free-space transmissions that require beam shaping to limit beam wandering.

## 1. Introduction

Free-space communication has long been considered and the mid-infrared domain drew attention in the early efforts, back in the 70ies [1]. The first experiments were based on $CO_2$ lasers but these optical systems remained bulky and expensive, thus hindering the development of such technology. With the development of optical fiber networks, free-space optical systems were long forsook but recent years have seen a renewed interest in domains as varied as LIDAR technology or communication in areas where fiber deployment is expensive or sometimes impossible. Among the optical sources of interest, quantum cascade lasers (QCLs) are highly desirable because on the one hand, QCLs are semiconductor lasers emitting in the mid-infrared domain where the atmosphere is highly transparent [2] and, on the other hand, QCLs are characterized by the absence of relaxation oscillation resonance which is promising for high-speed direct modulation [3]. This experimental work reports on a free-space live video broadcasting with a room-temperature packaged QCL emitting at 4 µm. The video file is encoded in uncompressed 576i format and this corresponds to a data rate of 270 Mbits/s with on-off keying scheme. The modulated optical signal from the QCL is retrieved with a mid-infrared detector three meters away and the resulting electrical signal is sent to a TV monitor where the video can be watched in live. This experimental demonstration paves the way for further free-space studies, such as comparison between near-infrared lasers and mid-infrared lasers when weather conditions degrade.

## 2. Experimental setup

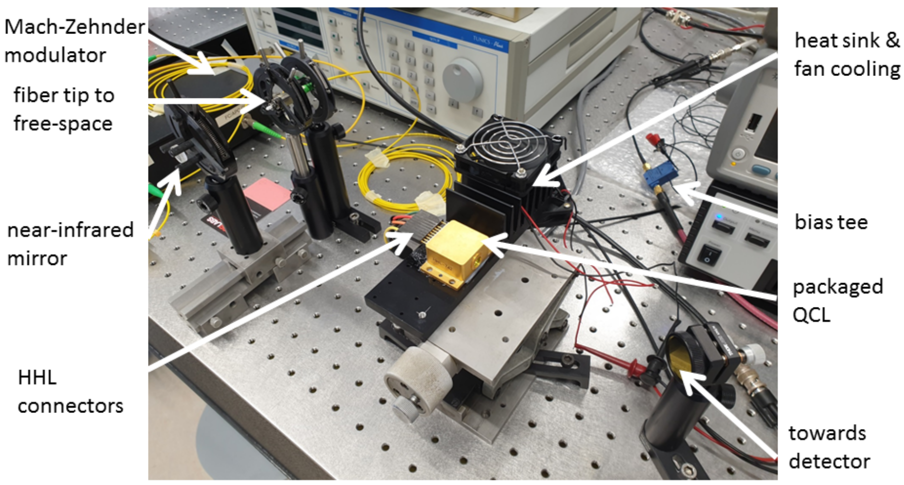


Figure 1: Experimental setup for both the mid-infrared free-space communication with QCL and the near-infrared free-space communication with telecom fiber exposed to air. The detectors are not shown in this picture and are placed on another table, 3 meters away.

The Fabry-Perot QCL under study emits up to 125 mW at 20°C and this is suitable for long-range transmission. This condition corresponds to a bias current of 750 mA and a voltage of 16 V. Cooling is achieved with a large heat sink and air cooling, as shown in Fig. 1. The video signal is converted from a 720p HDMI input to a 576i SDI (which is 75 Ohm BNC connector) output with a MD-HX Decimator board. This signal, which is 800 mV peak-to-peak, is attenuated with a 10-dB electrical attenuator before being injected in the AC port of a Pasternack bias tee with 12-GHz bandwidth. The DC port of this bias tee is connected to a low-noise current source and the combined electrical signal is sent to the HHL connector to bias the QCL. The mid-infrared beam is sent towards a Mecrury-Cadmium-Telluride (MCT) detector with 700 MHz bandwidth and this is suitable for analysis of the 576i signal at 270 Mbits/s. The MCT electrical signal is sent towards an oscilloscope with 500 MHz bandwidth and towards another MD-HX Decimator board to be converted back into HDMI and watched live on a TV screen. For comparison, we also study a free-space transmission at near-infrared wavelength. For this 1550 nm beam, we only have a free-space detector with 13 MHz bandwidth (Thorlabs PDA10CS2) so we cannot analyze an uncompressed video signal. We thus replace the MD-HX Decimator board by an arbitrary waveform generator (AWG) that produces a 15 Mbits/s on-off keying signal. This electrical signal is sent towards a Mach-Zehnder interferometer (MZI – modulation bandwidth of 5 GHz) for signal modulation. Our 1550 nm laser diode with 10 mW optical power is connected to the fiber input of MZI, while the fiber output of MZI is placed behind a free-space lens, as depicted in Fig. 1. In this configuration, the second output of the AWG is connected to the aforementioned bias tee so that we can display mid-infrared and near-infrared signals at 15 Mbits/s simultaneously on the oscilloscope.

## 3. Results and discussion

Figure 2 shows the eye diagrams for the two configurations we mentioned in the previous paragraph. The top left curve is the 576i signal coming from the MD-HX Decimator board at 270 Mbits/s. One can see that the signal is extremely well defined, with no jitter. The signal that is retrieved after transmission at mid-infrared wavelength is the bottom left curve. Because of the limited bandwidth of the packaged QCL [4], the electrical signal coming from the MD-HX Decimator board is degraded and a strong jitter can be seen. However, the transmission remains error-free, as assessed by the open eye, and the retrieved electrical signal can be converted back into a 576i video signal and displayed on a TV screen (not shown here). The right part of Fig. 2 shows the comparison between the mid-infrared transmission (top curve) and the near-infrared transmission (bottom curve), both at 15 Mbits/s. Eye diagrams are wide opened and the conclusion is that the transmission is error-free for both cases. It is relevant to note that the near-infrared signal is a more degraded than the mid-infrared signal, and this comes from the limited bandwidth of the free-space detector. High-speed near-infrared detector should allow us achieving multi-Gbits/s data speed in the future. This communication result is the first step towards the comparison of free-space mid- and near-infrared schemes for long-haul transmission, especially for various conditions of fog or precipitation where the size of the particles influences scattering and attenuation [5].

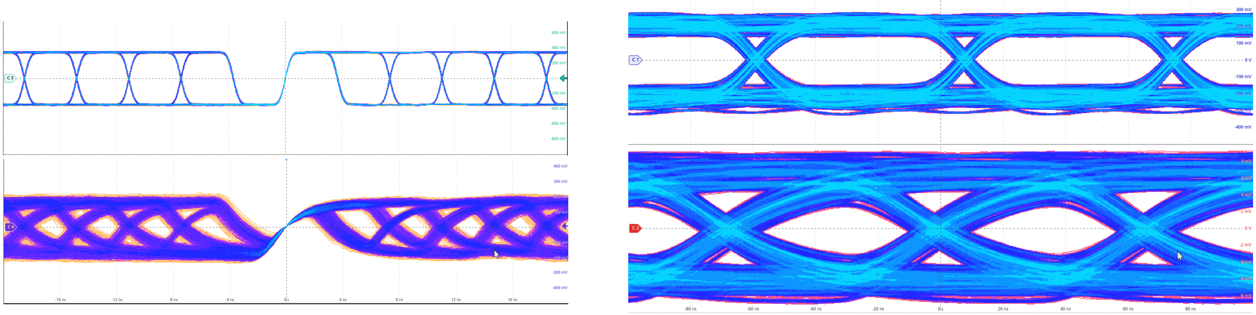

Figure 2: Experimental time traces for a video transmission (left), with the seed signal on top and the received signal on bottom; even if degraded, the received signal can be translated for live video broadcasting. The right traces are for the 15 Mbits/s transmissions at mid (top) and near (bottom) infrared wavelength.

## 5. References


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