Private free-space transmission based on chaos synchronisation in the 8-14 µm atmospheric transparency window

Pierre Didier[1,2], **Sara Zaminga**[1], **Olivier Spitz**[1,4], **Elie Awwad**[1], **Gregory Maison**[2], **Mathieu Carras**[2], **Frederic Grillot**[1,3]

1. *LTCI Télécom Paris, Institut Polytechnique de Paris, 19 place Marguerite Perey, Palaiseau, 91120, France*
2. *mirSense, Centre d'intégration NanoInnov, 8 avenue de la Vauve, Palaiseau, 91120, France*
3. *Center for High Technology Materials, University of New-Mexico, 1313 Goddard SE, Albuquerque, NM 87106, USA*
4. *now with CREOL, College of Optics and Photonics, University of Central Florida, Orlando, Florida 32816, USA*

With the emergence of Internet Of Things (IOT), the fast increment of users and the space development has opened the research towards free-space optics (FSO) using mid-infrared (MIR) wavelengths. Despite promising results have already been achieved in the 1.5 µm wavelength range, the mid-infrared domain offers several other advantages in particular a strong resistance to various atmospheric impairments [1]. Specifically, the 8-14 µm range has a high atmospheric transparency, strong resistance to degraded atmospheric conditions including turbulence [2]. For an eavesdropper, intercepting the beam through the atmosphere is more difficult because of significant thermal radiation in this range of wavelength. As MIR technology becomes more and more mature with recently demonstrated data transfers of several tens of Gbps it also becomes urgent to focus on the security and to innovative alternatives to ensure data privacy [3].

In this work, we demonstrated a private data transfer of a 5 Mbit/s 2 level PRBS message by using photonic chaos between two Distributed Feed-Back (DFB) 9.3 µm Quantum Cascade Lasers (QCLs). The chaos is obtained by self-external optical feedback at the transmitter side. The message is modulated with a very low-amplitude message (~mV) and dwelled within the chaotic carrier. To guarantee a high level of unpredictability, we also studied the complexity of the master signal's generated chaos. Among the different studies, we evaluated its Lyapunov exponent (LE) of the generated chaotic signal and obtained 3 positive ones. (7.5, 14 and 24 μs^{-1})

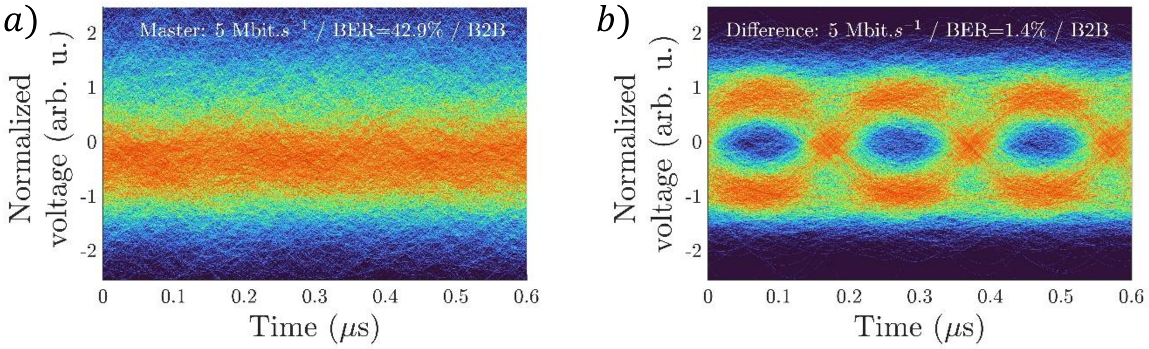

Fig. 1 Eye diagrams of the transmission after a free-space propagation of approximately 2 meters for 5 Mbit/s transmission: a) master signal exhibits an error rate of 42.9%, b) difference signal exhibits an error rate of 1.4%.

After 2 meters of free-space optical propagation, the master signal is injected into the slave laser, causing it to synchronize with the chaotic carrier of the master laser. The output signals of both lasers are then simultaneously detected. By filtering the received signal and taking the difference between the signals of the two lasers, the hidden message can be efficiently recovered. Figure 1.a) displays the eye diagram for the master signal. We estimate that an eavesdropper attempting to intercept the message will have a bit error rate (BER) of 42.9%, making it impossible to recover the message. However, for a legitimate user, the message can be recovered with a BER of less than 4% (Figure 1.b), allowing for error-free transmission after applying forward error correction (FEC). This private communication system is suitable for data transmission where the concealment of the message is a priority higher than the transmission speed which is of paramount importance for data transmission in unfavorable or even very degraded weather conditions, for example in the case of secure communication between ground vehicles, communication between two satellites, or for emergency communication after a natural disaster, or for secure and stealthy communication in areas without any infrastructure.

References

[1] E. Ciaramella, et al. "1.28 Terabit/s (32x40 Gbit/s) WDM transmission system for free space optical communications." IEEE Journal on selected areas in communications 27.9 (2009): 1639-1645.

[2] P. Corrigan, et al. "Quantum cascade lasers and the Kruse model in free space optical communication." Optics Express 17.6 (2009): 4355-4359.

[3] P. Didier, et al. "High-capacity free-space optical link in the midinfrared thermal atmospheric windows using unipolar quantum devices." Advanced Photonics 4.5 (2022): 056004.

[4] O. Spitz, et al. "Private communication with quantum cascade laser photonic chaos." Nature Communications 12 (2021): 3327.

979-8-3503-4599-5/23/$31.00 ©2023 IEEE