A world first: researchers open up a new avenue in the field of photonics.

The very first observation of chaos in mid-infrared optical radiation has been performed in Paris, France by Prof. F. Grillot and collaborators. Prof. F. Grillot is an Associate Professor at Télécom ParisTech and also a Research Professor at the University of New-Mexico. People involved in this pioneering work are L. Jumpertz (Télécom ParisTech), Dr. K. Schires (Télécom ParisTech), Dr. M. Carras (mirSense) and Prof. M. Sciamanna (CentraleSupélec). This result makes a significant breakthrough for the photonic community working at these wavelengths. The discovery has just been published [1] in the journal *Light: Sciences and Applications*, published by *Nature Publishing Group* and classified as the second highest impact journal in optics by Thomson Reuters. Major industrial applications are expected in the field of optical communications and sensing.

Close-up of this discovery.
Semi-conductor lasers were invented in 1962 and are largely used in our daily life. They generate optical impulses carrying information in fibre-optic networks and enable us to transmit over distances and at ever larger data rates.

Owing to a more mature technology, quantum cascade laser (QCL) can nowadays operate under continuous wave mode, at room temperature, in single- or multi-mode operation and with high output powers; up to a few watts for mid-IR devices. The spectacular development of QCLs. and their increasing use in practical applications also raise multiple urgent questions related to their stability and dynamical properties.

"Unlike conventional diode lasers, a quantum cascade laser behaves like a unipolar structure for which emission is achieved directly through inter-sub-band transition of a quantum confinement structure, combined with a multitude of heterostructures which allows efficient electron "recycling" said Prof.. Grillot

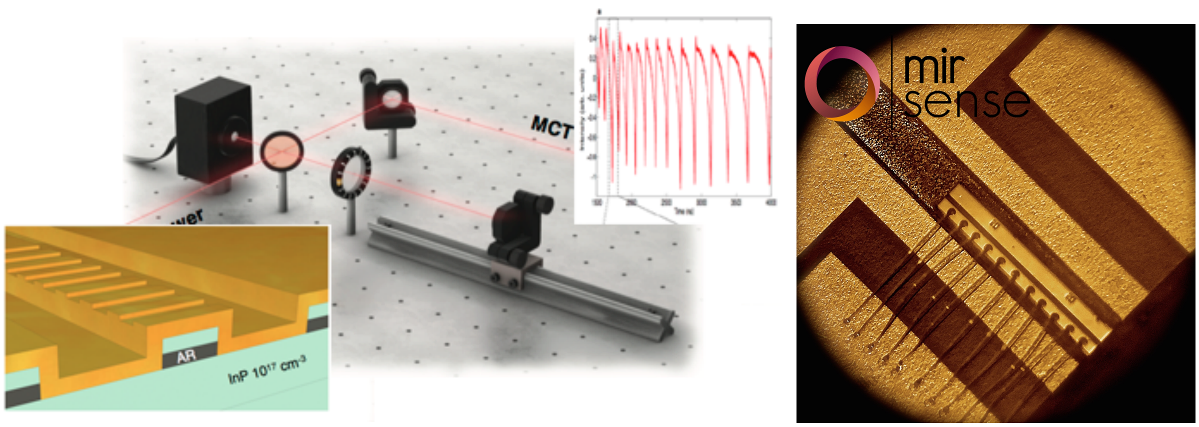
In this work, Prof. Grillot et al. show the very first observation of nonlinear dynamics and the underlying sequence of bifurcations to chaos in a quantum cascade laser (QCL), hence providing the first ever source of deterministic temporal chaos at mid-infrared wavelength. Authors also contradict the 35-years knowledge of laser diode destabilization to chaos from optical feedback, by demonstrating a sequence of bifurcations to chaos that does not involve Hopf bifurcation to undamped laser relaxation oscillations but rather self-pulsation at the external cavity frequency, a scenario so far only observed in gas lasers.

The observation of a chaotic dynamic was achieved by subjecting a quantum cascade laser (developed by mirSense) to optical feedback that is to say a part of the emitted light was reinjected into the laser. Although these properties normally provide these lasers with a very high stability, the reinjection of only a small percentage of the emitted energy back into the laser was sufficient to destabilise the quantum cascade laser to chaos. The laser emission is then formed of chaotic pulses, which are therefore irregular in time and unpredictable.

"This work would not have been possible without the high degree of maturity of the quantum engineering technology developed at mirSense", said Dr. F. Grillot.

Key industrial applications in the field of communications are therefore revealed
The permanent use of laser sources in the mid-infrared field (MIR) or the use of chaotic optical transmission in free-space communications is now possible. This will facilitate the security of data transmitted directly and the development of non-predictable sources for optical countermeasures. It is a paradigm shift in the understanding of light sources operating at these wavelengths.

This is a discovery which opens up a wide range of possibilities since the mid-infrared domain (MIR) combined with the transparent atmospheric window (3-μm and 10-μm) is involved in a very large number of applications: in direct optical communications, gas analysis (for the control of air pollution and for monitoring of industrial processes), in medicine (for assistance in diagnosis and for reconstructive surgery), as well as in the military field (in laser radar and countermeasures).



Left : schematics of the QCL, the optical feedback experiment and the time trace showing the chaotic oscillations at the output of the QCL ; Right: picture of the QCL fabricated by mirSense and used for the experiments (courtesy of Dr. Mathieu Carras).

[1] **Chaotic Light at Mid-Infrared Wavelength -** Louise Jumpertz, Kevin Schires, Mathieu Carras, Marc Sciamanna & Frédéric Grillot – *Light: Science & Applications* (2016) **5**, e16088; doi: 10.1038/lsa.2016.88.