Investigations of Coherence Collapse scenarios of Quantum Cascade Lasers

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Abstract: Different regimes of a Quantum Cascade Laser (QCL) operating at a wavelength of 8.6 μm and subject to a delayed optical feedback are measured and mapped according to critical parameters.

1. Introduction

The characteristic effects observed in semiconductor lasers (SLs) under optical feedback have attracted a lot of attention, as their chaotic behaviour provides an ideal physical model for investigations of nonlinear dynamic systems. From a technological point of view, feedback-induced instabilities in SLs are important to study for noise reduction, and are also a promising way of implementing cryptographic communication.[1]

Quantum Cascade Lasers (QCLs), on the other hand, made their appearance in 1994.[2] Unlike classical SLs, light in QCLs is emitted by electrons making transitions between confined states created by quantum confinement in a multilayer semiconductor quantum-well structure. This makes it possible to build lasers emitting in the mid- and far-infrared ranges—ranges that cannot be reached with classical SLs. In fact, QCLs with emitting wavelengths of 3 μm to 300 μm have been achieved. For communication purposes, QCLs are of particular interest, as their emitted wavelengths make it possible to build free space communication with virtually no quality losses by using the transmission window of the atmosphere in the mid-infrared region.

In this work, we will depict different phenomena occurring in QCLs under optical feedback with differing parameters, leading to the well-known coherence collapse.

2. Experimental Setup

Figure 1 shows the experimental setup used for measuring the resulting emission of a Quantum Cascade Laser (8.6 μm) submitted to an optical feedback signal. A characteristic criterion for verifying the strength of the feedback is by measuring the reduction of the threshold current of the laser as depicted in figure 2.

![Figure 1: Experimental Setup](image1)

![Figure 2: Reduction of threshold current](image2)

Critical parameters of the feedback setup are, in addition to the injection current, the strength of the feedback and the length of the external cavity. By varying these parameters, we mapped the different regimes of dynamical behaviour encountered by the QCL, very similar to prior works conducted by our group on classical semiconductor lasers in the NIR.[3]

3. Conclusions

Optical feedback in a Quantum Cascade Laser has been demonstrated. We also depicted the dynamic behaviour of a QCL subject to delayed optical feedback by varying critical parameters.

The results presented show a first approach to the use of Quantum Cascade Lasers as sources for encrypted communication channel in a free space context. Future experiments by our group should now enquire how chaos synchronization of two similar QCLs can be achieved.

4. References