Preface

Quantum cascade lasers are unipolar semiconductor lasers offering access to wavelengths from the mid-infrared to the terahertz domain and promising impact on various applications such as free-space communications, high-resolution spectroscopy, LIDAR remote sensing, or optical countermeasures. Unlike bipolar semiconductor lasers, stimulated emission in quantum cascade lasers is obtained via electronic transitions between discrete energy states inside the conduction band. Recent technological progress has led to quantum cascade lasers operating in pulsed or continuous-wave mode, at room temperature in single- or multimode operation, with high powers up to a few watts for mid-infrared devices.

Mid-infrared applications require sources with extremely high performances, in terms of output power, modulation bandwidth, single-mode emission, or narrow linewidth. In interband laser diodes, these properties can usually be significantly improved using external control, either optical injection or optical feedback. The former consists in injecting the light emitted by a first master laser into a second slave laser, whereas in the latter configuration, the light from a single laser is reinjected in its own active region. In the case of optical feedback, depending on the external cavity length and the feedback ratio, i.e., the ratio between reinjected and emitted light, the emission characteristics can either be greatly improved or significantly deteriorated. The dynamical behavior of the laser will also be impacted, leading to stable, periodic, or chaotic emission. Furthermore, optical feedback can reduce the complex spatial nonlinearities occurring in broad-area lasers, such as beam steering or filamentation.

The carrier lifetime of quantum cascade lasers is three orders of magnitude faster than that of interband lasers, and the α-factor is expected to be much smaller, the dynamical response of these structures to optical feedback would therefore be different from that of laser diodes. However, this phenomenon has almost never been studied in quantum cascade lasers, and it is worth verifying whether optical feedback can improve the emission properties of such devices. Furthermore, since parasitic optical feedback may arise from the experimental setups, it is also of prime importance to see whether a quantum cascade laser can destabilize and eventually become chaotic when subjected to this effect. Finally, optical injection might be able to improve the laser properties much more than optical feedback.

Therefore, the objective of this thesis is to study the nonlinear dynamics of quantum cascade lasers subject to optical feedback or optical injection. This work is a collaboration between Télécom ParisTech, mirSense, and the Direction Générale de l'Armement (DGA), to make the most of the expertise of each structure.

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