For a flute to emit a pure tone, the flutist must blow air with a certain strength and in a certain way, which the flutist learns over years of a musical career. If the flutist attempted to play the flute louder than usually, the sound would lose its purity. Thus, flutist would stir up other tones that interfere with the pure sound. The frequency of the flute sound can be mathematically determined by a wave equation describing the oscilations of air particles resonating within the flute. A very similar equation describes the frequencies of an electromagnetic wave resonating in a laser. Hence similar behaviour of the flute and the laser. When a laser is excited with a small amount of electrical power emits electromagnetic radiation at a single specific frequency. However, when excited with greater power, other frequencies of electromagnetic waves become involved, causing the emission spectrum of the laser to broaden, which is analogous to the false sound emitted by a flute. In practice, the broadening of a laser's emission spectrum limits its range of applications.

In the case of edge-emitting semiconductor lasers, single resonant modes in the longitudinal and vertical directions can be obtained using known laser structuring methods, while it is still a fundamental challenge to obtain a single lateral mode that would simultaneously enable high emitted power.

In this project we propose to adopt supersymmetry (SUSY) theory in a context of nitride-based lasers to boost their fundamental mode emission. SUSY enables widening the laser ridge and sustaining fundamental mode emission simultaneously, that will contribute to enhancement of optical power with high quality of the laser beam emitted by electrically driven devices. The project consists of three main scientific objectives. First two are related to designing and realisation the SUSY-lasers operating under the pulse regime and at continuous-wave CW operation. Both aims require different designs of SUSY-lasers that will be investigated in the project. Third aim is related to experimental characterisation of the SUSY-lasers unveiling reach physics responsible for stable single mode operation.

This new electrically driven laser configuration, that has never been studied experimentally nor theoretically, is a fascinating example of non-Hermitian physics that brings great promise for the enhancement of lasing properties not only of the configuration considered in the project, but also other in-plane lasers fabricated in all semiconductor material configurations including interband-cascade and quantum-cascade lasers, as well as vertical-cavity surface emitting lasers (VCSELs), fiber lasers etc. Therefore in this project we focus not only on improvement of nitride-based edge-emitting lasers properties but also on a thorough understanding of the fundamental physical phenomena occurring in SUSY-lasers concerning the role of the exceptional points and parity-time symmetry breaking, that are expected to play a key role in understanding the operational principles of SUSY-lasers.