Si/SiGe Quantum Cascades – from Electroluminescence to Lasing?

L. Diehl, S. Tsujino, S. Mentese, H. Sigg, D. Grützmacher, E. Müller, U. Gennser, I. Sagnes, Y. Campidelli, O. Kermarrec, D. Bensahel, and J. Faist
Paul Scherrer Institut and Univ. de Neuchâtel, Switzerland and *CNRS-LPN and STMicroelectronics, France*

Quantum cascade (QC) lasers emitting in the infrared or far infrared, and with continuous wave room temperature operation, are very interesting devices for niche applications such as chemical sensors or medical imaging. Its potential for use as a free space optical data link has also been demonstrated. Of special distinction, the QC laser design, exploiting intersubband transitions instead of band-to-band recombination, does not *a priori* limit itself to direct bandgap materials, and the possibility of realising a silicon-based intersubband laser has recently attracted much interest.

Si/SiGe QC structures have been realised, exhibiting electroluminescence in the 9 μm range, and with non-radiative lifetimes comparable to the best values measured in InGaAs/InAlAs based QC light emitting diodes. Furthermore, using SiGe pseudosubstrates, strain compensated Si/SiGe QC structures with a more sophisticated band engineering and up to 30 cascades have been realised. Relying on a "bound-to-continuum" design to have a rapid extraction of the carriers through a superlattice, electroluminescence in the 7 μm range has been demonstrated.

With these results, it may be an opportune moment to take stock what obstacles remain for the realisation of a Si based QC laser. A major complication in these structures is the use of the valence band, where the Si/SiGe heterostructures have their main band offset. As a consequence, in between the heavy hole states that are used for the intersubband transitions in most designs, light hole states are interspersed, reducing the non-radiative lifetime. Two approaches can be envisaged: the design of structures that avoid any intermediate light hole states, or the optimisation of the extraction of holes from the lower state combined with a reduction of all optical losses. We will discuss the injection into heavy and light hole states, as well as the different loss mechanisms, in relation to recent experiments.