Paper 12131-18

Frequency comb operation induced by a giant Kerr nonlinearity in quantum cascade lasers

In person: 4 April 2022 • 16:00 - 16:30 CEST | Curie A, Niveau/Level 1

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Abstract **Authors**

Optical nonlinearities are known to coherently couple the amplitude and the phase of light, which can lead to the formation of perfectly periodic waveforms – known as frequency combs. Recently, self-starting frequency combs that do not rely on the emission of short pulses are appearing in numerous semiconductor laser types, among which is the quantum cascade laser. This novel type of combs is gaining vast attention from researchers due to their self-starting nature and compactness, making them an ideal platform for further development of spectroscopic applications. Their spontaneous formation was explained through an interplay of phenomenological nonlinearity and dispersion in the laser active region, although the actual physical processes remained unclear until now. Here we show that Bloch gain – a phenomenon described by Bloch and Zener in the 1930s – plays an essential role in their formation. We demonstrate that a Bloch gain contribution is present in any quantum cascade laser and becomes particularly dominant under saturation. Bloch gain in QCLs with ultrafast gain recovery induces a giant Kerr nonlinearity, which is two orders of magnitude larger than the bulk values. The resonant Kerr nonlinearity provides coherent coupling between the amplitude and the phase of the laser field, which serves as a locking mechanism for frequency comb operation. We show that in Fabry-Pérot QCLs this results in frequency-modulated combs with a linear frequency chirp. In ring cavity QCLs, the Bloch gain is able to induce a single-mode instability by tuning the laser in the phase turbulence regime. This can lead to the formation of locked spatial patterns that are related to dissipative Kerr solitons, paving the way towards electrically pumped Kerr combs.

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