THz Quantum cascade lasers: from FM combs to pulses and back

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Recently, quantum cascade laser (QCL) proved to be an extremely interesting platform for frequency combs both in Mid-IR and THz frequency ranges [1,2]. The fast gain recovery time and the strong intrinsic non-linearity enable the locking of the modes with non-trivial relative phases giving rise to FM states [3,4]. I will discuss some peculiar aspects of these devices arising from the combination of ultrafast gain, strong RF modulation and different kind of cavities. The THz QCLs are capable of octave-spanning operation [5] and operate in ultra-broadband metallic waveguides and this offers the opportunity to fully exploit the hybridization with microwave technology. I will discuss an integrated photonic platform we recently developed based on active and passive elements integrated in a double-metal, high confinement waveguide layout planarized with a low-loss polymer [6]. An extended top metallization keeps waveguide losses low while improving dispersion, thermal and RF properties. Free-running on-chip quantum cascade laser combs spanning 800 GHz at 3 THz, harmonic states with over 1.1 THz bandwidth and RF-injected broadband incoherent states spanning over nearly 1.6 THz are observed using a homogeneous quantum-cascade active core. With a strong external RF drive, actively mode-locked pulses as short as 4.4 ps can be obtained. Despite the ultrafast nature of the gain medium, by properly engineering dispersion we demonstrate dissipative Kerr solitons both in Mid-IR and THz , with pulse durations of 3.7 ps in the Mid-IR and 10 ps in the THz [7]. Then, by RF modulating a circular cavity, we demonstrate a quantum walk comb in synthetic frequency space. The initially ballistic quantum walk does not dissipate into low supermode states of the synthetic lattice; instead, the state stabilizes in a broadand frequency comb, unlocking the full potential of the synthetic frequency lattice. Combs as broad as 100 cm^{-1} in the Mid-IR with flat top profile are reported [8]; I will discuss some preliminary quantum walk results in the THz range.

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