Sub-THz Chaos Generation in Semiconductor Superlattices

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High-frequency chaotic generators are currently in strong demand in a number of modern key technologies including fast random-number generation (see W. Li, I. Reidler et al, Phys. Rev. Lett. 111, 2013, 044102 and references therein) and chaos-based communication systems (F. C.M. Lau and C.K. Tse, Chaos-Based Digital Communication Systems: Operating Principles, Analysis Methods, and Performance Evaluation, Springer, New York, 2003). However, in contrast to the optical frequency range, chaotic sub- and terahertz generators are still underdeveloped.

We study theoretically and experimentally high-frequency generation originating from electron miniband transport in a semiconductor superlattice (SL) coupled to a resonator system. We show, counter-intuitively, that even a linear resonator can drive regular oscillations chaotic, when the oscillations originate from negative differential conductance (NDC). To address this question, we theoretically and experimentally investigate, how the eigenfrequency and the quality factor of a resonator affect the collective electron dynamics and the resulting high-frequency current oscillations in a SL. We show that the resonator can transform both the current-voltage characteristics and the current oscillations. By changing the voltage applied to the coupled SL and resonator system one can switch between periodic, quasi-periodic and chaotic current oscillations in SLs that exhibit only periodic oscillations in the absence of a resonator. Our theoretical analysis and experiments are in good quantitative agreement. The phenomena that we identify suggest applications for new resonant control of dynamics in systems with NDC and provide a new way to design tunable generators for chaos-based communication systems including wireless communication (H.-P. Ren et al., Phys. Rev. Lett. 110, 2013, 184101).