Towards intersubband polaritonics: how fast can light and electrons mate?

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Controlling the way light interacts with material excitations is at the heart of cavity quantum electrodynamics (cavity QED). In the strong coupling regime, quantum emitters inside a microresonator coherently absorb and reemit a photon many times before dissipation becomes effective. The resulting mixed light-matter states (polaritons) are studied in a broad context ranging from atomic [1] to solid state systems [2, 3] and inspire next-generation optoelectronic devices [4]. Thanks to intersubband transitions, we have recently demonstrated that semiconductor microcavities can reach a new limit of ultrastrong coupling, where light-matter exchange occurs on a time scale comparable with the oscillation period of light itself [5]. Remarkably, the anti-resonant and A square terms of the interaction Hamiltonian produce observable anomalies of the polariton dispersion even in a few photon experiment performed at room temperature. In this regime, ultrafast modulation of the coupling strength is predicted to reveal unprecedented QED phenomena [6] reminiscent of the dynamical Casimir effect [7] or Unruh-Hawking radiation of black holes [8]. Yet, up to now, QED devices switchable on sufficiently short times have not been available. Exploiting a semiconductor quantum well waveguide structure we experimentally show how to optically tune light-matter interaction from weak to ultrastrong and turn on maximum coupling within less than one cycle of light [9]. Using electro-optic detection one can also directly monitor, in the time domain, how a coherent photon population converts to cavity polaritons during abrupt switching. This system represents then a first promising laboratory for a new class of non-adiabatic QED effects and provides an efficient room-temperature switching device at the ultimate speed.

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