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

A. Tredicucci
CNR-INFM and Scuola Normale Superiore, Pisa, Italy

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.

The work was performed together with G. Günter, A. A. Anappara, J. Hees, G. Biasiol, L. Sorba, S. De Liberato, C. Ciuti, A. Leitenstorfer, and R. Huber.

1. F. Brennecke, T. Donner, S. Ritter, T. Bourdel, M. Köhl, and T. Esslinger, *Nature* **450**, 268 (2007).
2. K. Hennessy, A. Badolato, M. Winger, D. Gerace, M. Atatüre, S. Gulde, S. Fält, E. L. Hu, and A. Imamoglu, *Nature* **445**, 896 (2007).
3. D. I. Schuster *et al*, *Nature* **445**, 515 (2007).
4. S. I. Tsintzos, N. T. Pelekanos, G. Konstantinidis, Z. Hatzopoulos, and P. G. Savvidis, *Nature* **453**, 372 (2008).
5. A. A. Anappara, S. De Liberato, A. Tredicucci, C. Ciuti, G. Biasiol, L. Sorba, and F. Beltram, "Light-matter excitations in the ultra-strong coupling regime", to be published (2009).
6. S. De Liberato, C. Ciuti, and I. Carusotto, *Phys. Rev. Lett.* **98**, 103602 (2007).
7. E. Yablonovitch, *Phys. Rev. Lett.* **62**, 1742 (1989).
8. S. W. Hawking, *Nature* **248**, 30 (1974).
9. G. Günter *et al*, "Sub-cycle switch-on of ultrastrong light-matter interaction", *Nature,* in press (2009).