Max-Planck-Institut für Struktur und Dynamik der Materie

Max Planck Institute for the Structure and Dynamics of Matter

Tuesday, May 21st, 2019 – 10:30 pm
CFEL Seminar room I&II (Bldg. 99 ground floor)

Jérôme Faist
Institute of Quantum Electronics, ETH Zurich

Engineering with vacuum fields

When a collection of electronic excitations are strongly coupled to a single mode cavity, mixed light-matter excitations called polaritons are created. The situation is especially interesting when the strength of the light-matter coupling WR is such that the coupling energy becomes close to the one of the bare matter resonance w0. For this value of parameters, the system enters the so-called ultra-strong coupling regime, in which a number of very interesting physical effects were predicted. Using metamaterial coupled to two-dimensional electron gases[1], we have demonstrated that a ratio WR/w0 close to[2] or above unity can be reached.

We also demonstrated that such ultra-strong light-matter coupling can be achieved using special geometries where the only less than 100 electrons are effectively coupled to the resonator[3]. One very intriguing feature of the ultra-strong light-matter coupled system is the prediction that photon pairs will be emitted through non-adiabatic modulation of the coupling. To this end, we have realized metamaterials based on high Tc superconductors that retain a high quality factor resonance for magnetic field up to 9T and coupled them to two-dimensional electron gases[5].

We have also used transport to probe the ultra-strong light-matter coupling[6]. In these experiments, we have used transport samples engineered with cavities and studied them under very weak THz irradiation and now irradiation at all, showing an influence of the cavity in both cases.

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We have constructed a electro-optic based setup[7] that, we demonstrated recently, enables the probing of the vacuum field in free space and retrieve its first order correlation function in both space and time. Such experiment can be used also to probe the unconventional ground state of the ultra-strongly coupled systems[8].

[1] G. Scalari et al., "Ultrastrong Coupling of the Cyclotron Transition of a 2D Electron Gas to a THz
Metamaterial," (in English), Science, vol. 335, no. 6074, pp. 1323-1326, Apr 15 2012.
[2] C. Maissen et al., "Ultrastrong coupling in the near field of complementary split-ring resonators," (in English), Physical Review B, vol. 90, no. 20, p. 205309, Nov 24 2014.
[3] J. Keller et al., "Few-Electron Ultrastrong Light-Matter Coupling at 300 GHz with Nanogap Hybrid LC
Microcavities," Nano Letters, vol. 17, no. 12, pp. 7410-7415, Dec 2017.
[4] J. Keller et al., "Coupling Surface Plasmon Polariton Modes to Complementary THz Metasurfaces Tuned by Inter Meta-Atom Distance," (in English), Advanced Optical Materials, vol. 5, no. 6, p. 1600884, Mar 01 2017.
[5] J. Keller et al., "High Tc Superconducting THz Metamaterial for Ultrastrong Coupling in a Magnetic Field," ACS Photonics, rapid-communication pp. 1-7, Oct 04 2018.
[6] G. L. Paravicini-Bagliani et al., "Magneto-transport controlled by Landau polariton states," (in English),
Nature Physics, OriginalPaper vol. 15, no. 2, pp. 186-+, Feb 2019.
[7] I.-C. Benea-Chelmus, C. Bonzon, C. Maissen, G. Scalari, M. Beck, and J. Faist, "Subcycle measurement of intensity correlations in the terahertz frequency range," (in English), Physical Review A, vol. 93, no. 4, pp. 043812-9, Apr 07 2016.
[8] I.-C. Benea-Chelmus, F. F. Settembrini, G. Scalari, and J. Faist, "Electric field correlation measurements on the electromagnetic vacuum state," Nature, pp. 1-6, Apr 03 2019.

Host: Angel Rubio