Department of Physics
Condensed Matter Physics
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UNIVERSITY OF OXFORD

CONDENSED MATTER SEMINAR

Thursday 9 May at 2.15pm

"Extreme interaction between light and matter in solid-state devices"

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The interaction of light with matter is usually described in terms of photons absorbed, emitted, or scattered by massive objects.
The conceptual simplicity of such a framework rests upon the small strength of the electromagnetic force, which allows us to describe most electromagnetic interactions in terms of first order (absorption, emission) and second order (scattering) processes.
In carefully designed nanostructures it is nevertheless possible to increase interactions between light and matter, to the point that photons and matter excitations hybridise. The properties of the resulting hybrid entities, usually called polaritons, can thus be engineered by coupling different kinds of photonic resonators and optically active materials. This allows us to effectively design quasiparticles with tailored linear and non-linear features.

In this talk I will initially introduce polariton physics, then present my efforts to use the unique properties of polaritons to engineer mid-infrared non-linear optical devices, using either phonons in nanostructured polar dielectrics [1], or semiconductor heterostructures [2]. I will then discuss how, when the interaction between light and matter becomes large enough, electromagnetism can enter into the non-perturbative regime, leading to a completely novel phenomenology [3].
In such a non-perturbative regime the interaction modifies the system's ground state, leading to the creation of a population of bound photons [4]. Moreover, for large enough couplings, the Purcell effect dramatically breaks down and light and matter effectively decouple, posing an ultimate quantum limit to the working frequency of optoelectronic devices [5]. Finally, I will demonstrate how non-perturbative light-matter interaction can be exploited to engineer novel quantum materials with unique electronic and optical properties [6].

[1] Hybrid Longitudinal-Transverse Phonon Polaritons C. R. Gubbin, R. Berte, M. A. Meeker, A. J. Giles, C. T. Ellis, J. G.Tischler, V. D. Wheeler, S. A. Maier, J. D. Caldwell, and S. De Liberato Nature Communications 10, 1682 (2019)
[2] Resonant intersubband polariton-LO phonon scattering in an optically pumped polaritonic device J-M. Manceau, L. Tran, G.Biasiol, T. Laurent, I Sagnes, G. Beaudoin, S. De Liberato, I. Carusotto, and R. Colombelli Appl. Phys. Lett. 112, 191106 (2018)
[3] Ultrastrong coupling between light and matter A. F. Kockum, A. Miranowicz, S. De Liberato, S. Savasta, and F. Nori Nature Reviews Physics 1, 19 (2019)
[4] Virtual photon in the ground state of a dissipative system S. De Liberato Nature Communications 8, 1465 (2017)
[5] Light-matter decoupling in the deep strong coupling regime: The breakdown of the Purcell effect S. De Liberato Phys. Rev. Lett. 112, 016401 (2014)
[6] Strong coupling of ionising transitions E. Cortese, I. Carusotto, R. Colombelli, and S. De Liberato Optica 6, 354 (2019)

Host: Prof Robert Taylor

Simpkins Lee Room, Beecroft Building