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Slow-light polaritons in Rydberg gases

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Slow-light polaritons are quasi-particles generated in the interaction of photons with laser-driven atoms with a Λ- or ladder-type coupling scheme under conditions of electromagnetically induced transparency (EIT). They are a superposition of electromagnetic and collective spin excitations. If one of the states making up the atomic spin is a high lying Rydberg level, the polaritons are subject to a strong and non-local interaction mediated by a dipole-dipole or van-der Waals coupling between excited Rydberg atoms. I will present and discuss an effective many-body model for these Rydberg polaritons. Depending on the detuning of the control laser the interaction potential between the polaritons can be repulsive or attractive and can have a large imaginary component for distances less than the so-called blockade radius. The non-local effective interaction gives rize to interesting many-body phenomena such as the generation of photons with an avoided volume, visible in stronlgy suppressed two-particle correlations inside the blockade volume. Moreover the long-range, power-law scaling of the interaction can in the repulsive case give rize to the formation of quasi-crystalline structures of photons. In a one dimensional system the low-energy dynamics of the polaritons can be described in terms of a Luttinger liquid. Using DMRG simulations the Luttinger K parameter is calculated and conditions for the formation of a quasi-crystal are derived. When confined to a two-dimensional geometry, e.g. using a resonator with quasi-degenerate transversal mode spectrum, Rydberg polaritons are an interesting candidate to study the bosonic fractional quantum Hall effect. I will argue that the formation of photons with an avoided volume is essential for explaining recent experiments on stationary EIT in Rydberg gases [1,2].

[1] J.D. Pritchard et al., Phys. Rev. Lett. 105, 193603 (2010).
[2] D. Petrosyan, J. Otterbach, and M. Fleischhauer, arXiv:1106.1360