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Two-photon bound states in Rydberg gases MATTHIAS MOOS, RAZMIK UNANYAN, MICHAEL FLEISCHHAUER, Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — We consider the propagation of photons in a gas of Rydberg atoms under conditions of electromagnetically induced transparency. Here the photons form strongly interacting massive particles, termed Rydberg polaritons. Recent experiments have realized strong interactions between Rydberg polaritons and shown photon blockade [1] as well as pronounced bunching [2] under off-resonant coupling conditions. We derive an effective Hamiltonian for Rydberg polaritons in one spatial dimension for off-resonant coupling. We show that in addition to repulsive polaritons bound pair-states of photons exist. For strong interactions, quantified in terms of optical depth per blockade distance, these states are deeply bound and cannot be prepared under typical experimental conditions. For small optical depth per blockade bound pair-states can, however, be excited near the threshold of the scattering continuum. Using numerical wave-function simulations we analyze the dynamics of the formation of bound states in a pulsed experiment and analyze their properties and time-evolution inside the medium. Furthermore we discuss the interaction between Rydberg polaritons and bound pairs and the pair-pair interaction.

[1] Peyronel et al. Nature 488, 57 (2012)
[2] Firstenberg et al. Nature 502, 71 (2013)

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