Non-local nonlinear optics with Rydberg gases

Photons do not easily interact with each other and nonlinear processes on the few-photon level can usually be realized only under very special conditions. Recently it was shown that coupling of weak light fields to atoms involving Rydberg states may change this picture. Under conditions of electromagnetically induced transparency (EIT) such a coupling leads to the formation of Rydberg polaritons which are quasi-particles with tunable composition and effective mass, and strong, non-local interactions. The latter can turn photons into hard-sphere objects with a finite avoided volume in two particle correlations or lead to bound states of photon pairs, i.e. photonic molecules. I will explain the physics of Rydberg polaritons, review the experimental status and discuss interesting many-body effects arising from the long-range interaction such as the formation of Wigner crystals of individual photons.