Rydberg quantum optics in dense ultracold gases.

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Mapping the strong interaction between Rydberg excitations in ultracold atomic ensembles onto single photons via electromagnetically induced transparency enables manipulaion of light on the single photon level. We report the realization of a free-space single-photon transistor exploiting the interaction between Rydberg excitations with different principal quantum numbers. We also present our investigation of Rydberg-groundstate atom interaction in dense systems, which leads to the formation of Rydberg molecules. We show that spectra of discrete molecular lines observed at low prinicipal quantum numbers and low density turn into density-dependent shifts of the Rydberg line at large principle quantum numbers or high background density. We discuss the implications of this effect on quantum optics experiments based on Rydberg EIT.