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Multiple photon scattering and blockade in a dense dissipative Sr Rydberg gas

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Cooperative quantum optics has been one of the main research topics to emerge in the field of cold Rydberg gases. The first observations of optical nonlinearity at the single-photon level, and more recent demonstrations of single-photon transistors use a resonant two-photon excitation scheme. A key figure of merit is the optical depth per blockade sphere, which must be very high to ensure that all unwanted photons are scattered. Using a cold ($\sim 10\ \mu$K), dense (up to $\sim 10^{12}$ cm^{-3}) gas of strontium atoms we show that in this regime, a significant Rydberg population can be created by photons that are multiply scattered before leaving the cloud. The re-scattered field is density-dependent and has quite different spectral properties from the incident laser light. A careful analysis reveals that multiple scattering co-exists with signatures of the Rydberg blockade in this strongly dissipative regime. Our technique also provides a probe of the spectral distribution of the re-scattered light within the cloud, which may be qualitatively different from that of the transmitted light.

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