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Few-Body and Many-Body Quantum Optics in Rydberg Media

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We theoretically describe the propagation of quantized light under the conditions of electromagnetically induced transparency (EIT) in systems involving Rydberg states. In these systems, EIT enables the mapping of strong interactions between Rydberg atoms onto strong interactions between photons. We show how to make photons massive and how to introduce attractive, repulsive, and dissipative interactions between them. We also find and study the propagation of solitonic bound states of photons in such a medium. Finally, we determine the peculiar spatiotemporal structure of the output of two complementary Rydberg-EIT-based light-processing modules: the recently demonstrated single-photon filter and the recently proposed single-photon subtractor, which, respectively, let through and absorb a single photon. Our approach paves the way for the generation of a variety of nonclassical states of light, the implementation of photon-photon quantum gates, and the study of many-body phenomena with strongly correlated photons.