“Strongly interacting photons.”

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Photons are massless particles which do not interact with one another in vacuum. There exist nonlinear media in which light fields affect each other, but in conventional materials, optical nonlinearities are typically negligible at the single photon level. Media exhibiting strong photon-photon interactions are a long-standing goal of quantum optical science due to their important impact for all-optical quantum information and their ability to generate new exotic states of light.

In this talk, I will present the first realization of a single-pass quantum nonlinear medium. This medium consists in a vapor of cold atoms in which slowly propagating photons coherently couple to strongly interacting atomic states (Rydberg states) [1]. As a result, photons experience a blockade effect preventing their simultaneous propagation in an otherwise transparent medium. We can tune these interactions to a coherent regime, enabling co-propagating photons to acquire a large mutual phase-shift and to become entangled [2]. Under these conditions, the photons behave as massive particles exerting an attractive force onto each other and they can bind into molecular states.

I will also present an alternative approach to generate photon-photon interactions using cold atoms strongly coupled to photonic crystals [3]. A nanofabricated optical cavity enhances the coupling of a trapped atom to the light field, resulting in nonlinear effects at the single photon level. I will finally discuss how the scalable nature of this approach paves the way for increasingly complex systems of interacting photons, long-range atom-atom interactions and on-chip quantum networks.