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Spin Exchange in Rydberg EIT TRAVIS NICHOLSON, JEFF THOMPSON, QIYU LIANG, SERGIO CANTU, ADITYA VENKATRAMANI, Massachusetts Institute of Technology, THOMAS POHL, Max Planck Institute for the Physics of Complex Systems, SOONWON CHOI, MIKHAIL LUKIN, Harvard University, VLADAN VULETIC, Massachusetts Institute of Technology — The realization of strong optical nonlinearities between two photons has been a longstanding goal in quantum science. We achieve large single-photon-level nonlinearities with Rydberg EIT, which combines slow light techniques with strongly interacting Rydberg states. For two Rydberg atoms in the same state, a Van der Waals interaction is the dominant coupling mechanism. Inherently stronger dipole-dipole interactions are also possible between atoms in different Rydberg states. Using light storage and microwave resonances, we study the effect of dipole-dipole interactions in Rydberg EIT. We observe a coherent spin exchange effect for pairs of states dominated by dipole-dipole interactions. Spin exchange manifests as an increase in optical transmission through a cold Rubidium gas that is highly dissipative in the presence of Van der Waals interactions. We also observe a controlled $\pi/2$ phase shift due to this effect, which paves the way for robust, universal all-optical quantum gates.

Travis Nicholson
MIT Center for Ultracold Atoms

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