From Dipolar to Rydberg Photonics

Hadiseh Alaeian

Elmore Family School of Electrical & Computer Engineering, Department of Physics & Astronomy, Purdue Quantum Science & Engineering Institute, Purdue University

Strong light-induced interactions between atoms are known to cause nonlinearities at a few-photon level which are crucial for applications in quantum information processing. At densities higher than 1 atom per cubic wavelength, such interactions give rise to density shifts and broadenings, and when confined to less than a wavelength size, such dipolar interaction leads to collective blockade phenomena, which mostly have been studied in the context of strongly interacting Rydberg states.

Here we study these phenomena for low-lying excited atomic states confined in thin atomic clouds that are generated via the pulsed Light-Induced Atomic Desorption (LIAD) technique. For the first few nanoseconds, the transient light-induced dipolar interaction of the low-lying lines of Rubidium leads to shifts and broadenings well beyond the well-known Lorentz-Lorenz limit. In the second experiment, we combine the high densities achievable in thermal atomic vapors with an efficient coupling to a slot waveguide. In contrast to free-space interactions, atoms aligned within the slot exhibit repulsive interactions that are further enhanced by a factor of 8 due to the Purcell effect. The corresponding blueshift of the transition frequency of atoms arranged in the essentially one-dimensional geometry vanishes above the saturation, providing a controllable nonlinearity at the few-photon level.

Towards the end of my talk, I will introduce our novel platform in thin-film cuprous oxide, which allows us to realize strongly interacting Rydberg excitons in a solid-state system that is inherently suitable for scalability and integration. The results of these studies pave the way towards a robust scalable platform for quantum nonlinear chiral optics and all-optical quantum information processing in an integrable and scalable platform, and potentially at elevated temperatures.