A weakly-interacting many-body system of Rydberg polaritons — A new platform for BEC and quantum simulators

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Abstract

We proposed utilizing a medium with a high optical depth (OD) and a Rydberg state of low principal quantum number, *n*, to create a weakly-interacting many-body system of Rydberg polaritons, based on the effect of electromagnetically induced transparency (EIT). We experimentally verified the mean field approach to weakly-interacting Rydberg polaritons, and observed the phase shift and attenuation induced by the dipole-dipole interaction (DDI). The DDI-induced phase shift or attenuation can be viewed as a consequence of the elastic or inelastic collisions among the Rydberg polaritons [1,2]. Using a weakly-interacting system, we varied the DDI strength via the input photon flux and measured the transverse momentum distribution of the Rydberg polaritons. A larger DDI strength caused the width of the momentum distribution to become notably smaller, indicating the thermalization process and cooling effect was driven by elastic collisions [2]. The combination of the μs-long interaction time due to the high-OD EIT medium and the μm^2-size collision cross section due to the DDI suggests a new and feasible platform for the Bose-Einstein condensation (BEC) of the Rydberg polaritons.

[1] S.-S. Hsiao, K.-T. Chen, and I. A. Yu, "Mean field theory of weakly-interacting Rydberg polaritons in the EIT system based on the nearest-neighbor distribution," **Opt. Express** 28, 28414 (2020).

[2] B. Kim, K.-T. Chen, S.-S. Hsiao, S.-Y. Wang, K.-B. Li, J. Ruseckas, G. Juzeliūnas, T. Kirova, M. Auzinsh, Y.-C. Chen, Y.-F. Chen, and I. A. Yu, "A weakly-interacting many-body system of Rydberg polaritons based on electromagnetically induced transparency," **Commun. Phys.** 4, 110 (2021).