Neutral Atoms with Rydberg Interactions for Many-Body Physics and Quantum Simulations

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Abstract

Neutral atoms have emerged as a promising platform for quantum computing and quantum simulation. A key advantage lies in the ability to induce controllable long-range interactions by exciting the atoms to Rydberg states. In this talk, I will present our theoretical research focusing on the pivotal role of Rydberg interactions in a variety of atomic systems, enabling the study of exotic many-body physics and quantum simulations. For bosonic atoms in optical lattices [1], we show that Rydberg-dressing can lead to the emergence of density wave and supersolid states. The profile of these interactions can be characterized by examining the structure of density correlations and studying quench dynamics. In the case of degenerate Fermi gases [2], we show that Rydberg-dressed interactions can induce anisotropic Fermi surface deformation and Cooper pairs that reflect the characteristics of the target Rydberg state. Moreover, we recently proposed to investigate many-body effects in Rydberg atom arrays, where the exchange interactions of Rydberg atoms can be harnessed to tune the dynamics and phase transitions. These findings pave the way for further exploration of quantum simulation and computation using neutral Rydberg atoms.

References

[1] Y. Zhou, Y. Li, R. Nath, and W. Li, Phys. Rev. A 101, 013427 (2020).

[2] Y. Zhou, R. Nath, H. Wu, I. Lesanovsky, and W. Li, Phys. Rev. A 104, L061302 (2021).