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Progress Towards Quantum Many-Body Physics Experiments with a Metastable Helium Bose–Einstein Condensate.

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We present our ongoing efforts toward the preparation of Bose–Einstein condensate (BEC) of metastable helium [1], which enables several atomic quantum experiments.

To achieve a high phase-space density for BEC, the sequence starts with the atomic source and Low velocity intense source (LVIS), followed by MOT, compressed MOT, magnetic trap, 1D Doppler cooling, and ends with transfer to an optical dipole trap for final evaporative cooling to reach BEC.

Beyond BEC production, we outline future experiments, including the study of (i) superradiance in extended atomic ensembles, where cooperative light emission can reveal collective coherence properties; correlation function measurements at the single-particle and single-photon level, enabling detailed insight into coherence and quantum statistics [2]. Previous superradiance studies focused on photon–photon second-order correlations to probe the emitted light’s coherence [3]. In contrast, our work will probe into atom–photon second-order correlations, providing direct insight into the coupled dynamics of the atoms and scattered light; and (ii) quench dynamics, in which sudden parameter changes drive the system far from equilibrium, providing a powerful platform for investigating nonlinear dynamics, thermalization pathways, and relaxation processes in many-body systems [4]. Our research employs correlation functions as powerful probes of many-body dynamics during the non-equilibrium formation of a Bose–Einstein condensate. While previous work has primarily focused on first-order properties such as the correlation length [5], condensate atom number [6], and defect count, We extend this approach to second and higher order correlations, revealing deeper insights into the underlying many-body phenomena.

References

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