Spin- and momentum-correlated atom pairs mediated by photon exchange and seeded by vacuum fluctuations

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Engineering pairs of massive particles that are simultaneously correlated in their external and internal degrees of freedom is a major challenge, yet essential for advancing fundamental tests of physics and quantum technologies. In this work [1], we experimentally demonstrate a mechanism for generating pairs of atoms in well-defined spin and momentum modes. This mechanism couples atoms from a degenerate Bose gas via a superradiant photon-exchange process in an optical cavity, producing pairs via a single or two discernible channels. The scheme is independent of collisional interactions, fast and tunable. We observe a collectively enhanced production of pairs and probe inter-spin correlations in momentum space. We characterize the emergent pair statistics, and find that the observed dynamics is consistent with being primarily seeded by vacuum fluctuations in the corresponding atomic modes. Together with our observations of coherent many-body oscillations involving well-defined momentum modes, our results offer promising prospects for quantum-enhanced interferometry and quantum simulation experiments using entangled matter waves.

References

[1] F. Finger, R. Rosa-Medina, N. Reiter, P. Christodoulou, T. Donner, T. Esslinger, *arXiv:* 2303.11326.

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