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Precision measurement based on quantum matter

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The progress of optical lattice clock to the accuracy of 2 x 10^{-18} has benefited greatly from the understanding of atomic interactions [1,2]. The precision of clock spectroscopy greatly facilitates the exploration of many-body spin interactions [3], including SU(N) symmetry [4] and spin-orbit coupling [5]. Building on this combined front of quantum metrology and many-body physics, we have realized a Fermi degenerate three-dimensional optical lattice clock, which represents a scalable solution with a high, correlated density of a degenerate Fermi gas guarding against on-site interaction-related clock shifts [6]. We demonstrate atom-light coherence time of 10 s and clock measurement precision at 3 x 10^{-19}. [1] B. J. Bloom, *et al.*, An optical lattice clock with accuracy and stability at the 10^{-18} level. Nature **506**, 71 (2014). [2] T. L. Nicholson, *et al.*, Systematic evaluation of an atomic clock at 2 10^{-18} total uncertainty. Nature Comm. **6**, 6896 (2015). [3] M. J. Martin, *et al.*, A quantum many-body spin system in an optical lattice clock. Science **341**, 632 (2013). [4] X. Zhang, *et al.*, Spectroscopic observation of SU(N)-symmetric interactions in Sr orbital magnetism. Science **345**, 1467 (2014). [5] S. Kolkowitz, *et al.*, Spin-orbit coupled fermions in an optical lattice clock, Nature **542**, 66 (2017). [6] S. L. Campbell, *et al.*, A Fermi-degenerate 3D optical lattice clock, Science, in press (2017).