One-minute coherence in an optical-lattice based atom interferometer

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In quantum metrology and quantum information processing, a nonclassical state must undergo a quantum process before unwanted interactions with the environment lead to decoherence. In atom interferometry, the nonclassical state is a coherent spatial superposition of partial wave packets and the process might be, e.g., accumulation of sufficient phase shift to allow detection of extremely weak interactions, such as the gravitational field of a small proof mass. The coherence in atomic fountains is limited by the available free-fall time in Earth's gravitational field. This can be overcome by suspending the wave packets in an optical lattice, which has so far reached up to 20 s of coherence, but the fundamental influences limiting this time have not been understood [1]. Here, we realize atom interferometry with a spatial superposition state held by an optical lattice for as long as one minute and describe our experiments exploring the sources of decoherence. This can be used to further increase coherence and sensitivity, which may enable gravimetric measurements, searches for fifth forces, or fundamental probes into the non-classical nature of gravity.

[1] Victoria Xu, Matt Jaffe, Cristian D. Panda, Sofus L. Kristensen, Logan W. Clark, Holger Müller, "Probing gravity by holding atoms for 20 seconds." Science **366,** 745-749 (2019).