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Long-lived quantum coherence in a 1D optical lattice investigated using 2D pump-probe spectroscopy LUCIANO S. CRUZ, SAMANSA MANESHI, CHAO ZHUANG, CHRISTOPHER R. PAUL, AEPHRAIM M. STEINBERG, CQIQC, IOS and Department of Physics, University of Toronto — We observe a surprising plateau in the decay of pulse-echo amplitude measured for quantum vibrational states in a 1D optical lattice, indicating a long-lived component of the coherence. We present a hypothesis for the origin of the plateau in the decay, and develop a 2D pump-probe spectroscopy technique to test this model. In our 1D lattice, atoms are free to move in the transverse directions with thermal velocities about 3 cm/s. Although the intrinsic decoherence time is expected to be of the order of 50 ms, this transverse drift through the spatially inhomogeneous laser beam leads to a finite frequency decorrelation time, degrading the echo in about 1 ms. Modeling suggests that initial position-velocity correlations, which build up during state preparation, can lead to echo amplitude which plateaus after an initial fast decay. To probe the atoms' frequency drift directly, we have developed a pump-probe spectroscopy technique, essentially a version of spectral hole-burning for these vibrational states. This allows us to directly measure the frequency-frequency correlation as function of time, which can be used to make predictions about the echo decay and develop techniques to better preserve coherence.

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