DAMOP17-2017-020020

Abstract for an Invited Paper
for the DAMOP17 Meeting of
the American Physical Society

Multi-component quantum gases: Entanglement and Phononic Lamb shift

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Mixtures of quantum gases have been investigated in many different contexts. Here I will present recent results addressing two distinct topics. In the context of spinor condensates I will describe the realization of an atomic SU(1,1) interferometer [1]. With these experiments we show that time reversal of nonlinear dynamics can be used to utilize many particle entanglement at the Heisenberg limit even in the limit of a noisy atom detector. This opens an alternative route for accessing quantum resources even with limited detection capabilities. As second topic I will report on the first observation of the phononic Lamb shift. It has been predicted in the context of the Fröhlich hamiltonian which describes a particle coupling to excitations of a bosonic system. For the realization we use trapped lithium atoms immersed in a sodium Bose Einstein condensate forming the synthetic vacuum. A precise determination of the self energies with motional Ramsey spectroscopy reveal additional energy shifts to the expected mass renormalization [2]. The minute energyshifts become accessible since the atomic model system allows the direct comparison between quantum vacuum and truely empty space.

[1]D. Linnemann et al. **Phys.Rev.Lett** 117, 013001 (2016)
[2]T. Rentrop, et al. **Phys.Rev.X** 6, 041041 (2016)