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Vibrational state control of BECs using stochastic webs

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It has previously been shown that non-KAM chaotic motion can be exhibited in a range of systems, from semi-conductors to tokamak fusion reactors. We show that using this particular type of motion, we can controllably excite both non-interacting and repulsive Bose-Einstein condensates (BEC) with a travelling wave optical lattice (OL). We then show that the magnitude of this excitation is dictated by the spatial form of the OL whilst the depth of the OL controls its rate. This classical chaotic motion then enters the quantum regime when the magnitude of the excitation is set to only a few quanta of the quantum harmonic oscillator (QHO) level spacing. In this regime, we see a departure from the classical results and instead we see that for a set of key OL wavelengths, we can cause population transfer between different QHO states with unprecedented precision, as shown in figure. Further, we show that whilst superpositions of states are difficult to achieve, due to coupling between differing level populations, excitation schemes can be found which create desired superpositions of these semi-classical QHO Fock states. We show this by creating a range of cat states in a large number of atoms, which previously have only been achieved on such a scale in photonic and phononic systems. All of our theoretical models are based on experimentally achievable systems and so could be utilized in a wide range of applications from quantum computation, superpositions of large ensembles and the coupling of atoms to macroscopic objects.

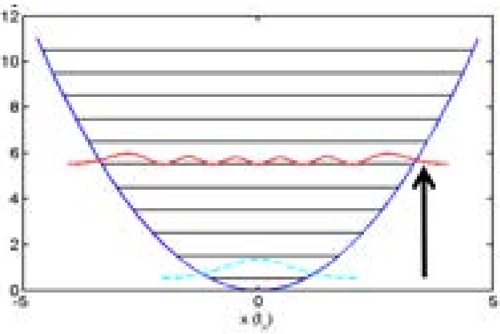

Figure: *The spatial density distribution of a ground state BEC (light-blue dashed) in a harmonic trap (dark blue) excited into the 5th QHO level (red dashed) using a travelling wave optical lattice of specific wavelength and frequency.*

Biography

Nathan Welch is a Research Fellow in Quantum Technologies at the University of Nottingham. His research focus is the design and optimisation of experimental quantum systems, including magnetic fields, optics and atom-surface coupling. Part of his PhD research involved modelling and optimising complex multi-component electromagnetic systems, which included integrating the optical and magnetic sensitivity of atomic gases across the classical and quantum regimes. His work also included analysing phenomena such as chaotic atom motion in laser beams and Casimir attraction between atoms and condensed matter surfaces, including electronic control chips. He is particularly interested in using this insight to improve on previous system design and allowing new physical paradigms to be explored and exploited in new industry capabilities and products.

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