

Diverse Classical Walking of a Single Atom in an Amplitude-Modulated Standing Wave Lattice

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The classical walking behavior of a single atom in an amplitude-modulated standing wave lattice is investigated. Based on a simple effective model, we identify a diversity of dynamical regimes of atomic motion by periodically adjusting the lattice depth. Harmonic oscillation or pendulum rotation with classical step-jumping, random scattering walking, chaotic transportation, quasi-periodic trapped motion, and roughly ballistic free flying are found in this simple model within different parametric regions. Our study demonstrates a complex motion of single atom in a modulating optical lattice beyond the quantum description.

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I. INTRODUCTION

Nowadays, fabrication technology steps more and more towards the atomic scale, and the detection of one single molecule or atom is now a promising technique [1, 2]. Controlling one atom in cavity quantum electrodynamics has now nearly met this step [3–5]. Based on optical techniques, the motion of one single atom in a controlled 1-dimensional (1D) optical lattice becomes a hot topic with continuous interests for its basic theoretical value and potential applications in quantum information processing [6], atomic lithography [7], solid state physics [8], quantum walking algorithm [9, 10], plasmonic application [11, 12], quantum-to-classical transition [13], and molecular dynamics. In an optical lattice, the atom can be accelerated [14] or decelerated [15] by an optical force for the purpose of precise control. However, on the atomic scale, quantum effects start to play a tricky role in atomic dynamics. For example, under a deterministic linear force, the atomic motion is still beyond definite prediction in quantum theory because of an intrinsic uncertain fluctuation. That a quantum motion is distinguished from a classical trajectory motion is actually due to the superposition of the atomic wave packet, which induces interference effects such as dynamical localization [16]. But, just for one single atom, the external wave superposition will be excluded [17] and the motion at different times also will not interfere, unless a long memory imprinted on the optical field can feed back to the atomic motion along the classical trajectory. However this memory will be cut down by a definite external optical control. Therefore the quantum motion and the classical motion meet at this single atomic scale.

According to the quantum descriptions, by including the internal quantum transitions, many kinds of motional behavior were found for this single atomic system, such as