Orbital dynamics of bosons in the second Bloch band of an optical lattice

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Introduction

We experimentally and theoretically explore Josephson-like oscillations of a Bose-Einstein condensate populating the second Bloch band of a bipartite optical square lattice [1]. Initially, the atomic sample is transferred from the Γ –point to one of the two inequivalent $X_{\pm}$-points in the lowest band via Bloch oscillations. Subsequently, the atoms are loaded into the first excited energy band via population swapping technique [2]. An oscillation of the relative population difference between the two energy minima of the second band is observed (see fig. (1), (b)) . The oscillation frequency depends on the ratio of two distinct collisions processes: the on-site collision term of atoms in either of the three local orbitals s, p_x, p_y in the shallow and deep wells of the lattice, respectively, and a flavour changing collision, where two atoms in the same p_x – orbital upon colliding are both transferred to the p_y – orbital or viceversa. The observations are compared to the predictions given by a full quantum model limited to only two single-particle modes neglecting dissipation, which reproduces the measured oscillations and show the correct dependency of the oscillation frequency on the ratio among the strenght of the aforementioned collision terms (see fig (1), (c)).

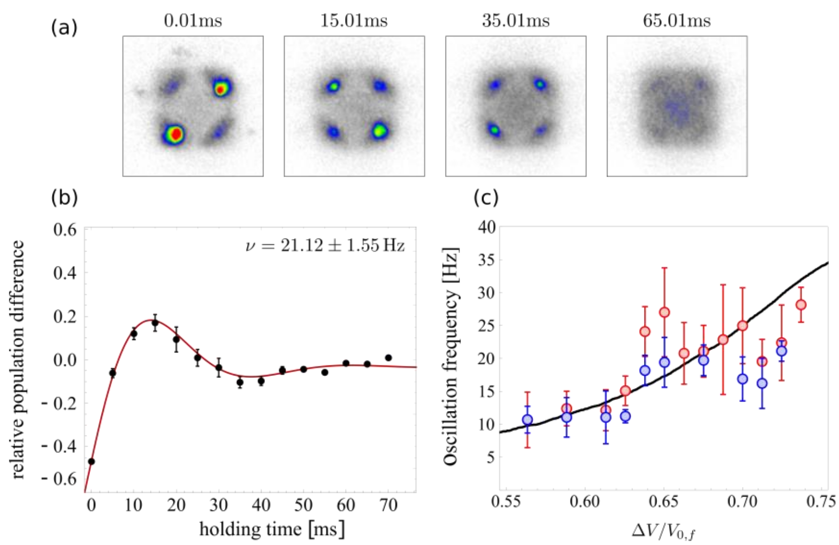

Figura 1: Observation of Josephson-like dynamics in the second band of an optical lattice. (a) Absorption images of the atoms by using band-mapping technique for a lattice of $V_0 = 7.2E_{rec}$, and ΔV= 0.73 V_0 (potential energy difference between two sublattices A, and B). (b) The temporal evolution of the relative population different shown for a fixed ΔV= 0.73 V_0. Error bars show the standard deviation with respect to the mean of a set of ten measurements. (c) The observed oscillation frequencies obtained from fitting data as in (b) are plotted versus ΔV. The solid-black line shows a calculation using a two-mode model.

References

[1] J. Vargas et al. 2021, Phys. Rev. Lett. 126, 200402.
[2] T. Kock et al 2016, J. Phys. B: At. Mol. Opt. Phys. 49 042001.