How to characterize the dynamics of cold atoms in non dissipative optical lattices?

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Cold atoms are a tremendous tool to study the transition between the classical and the quantum world. Numerous approaches have been followed, as e.g. the realization of quantum logical gates [1,2], or the study of the properties of a Bose-Einstein condensate. The dynamics of classical cold atoms have also been investigated, mainly through instabilities of the disordered cloud produced by a magneto-optical trap [3-6]. However, the richer dynamics is expected in ordered potential, as those obtained with optical lattices. In such potentials, atoms, in their travel from site to site, can exhibit a very complex dynamics, including chaos. Up to now, the experimental works in this domain are very limited. Quantum chaos has been studied for atoms in the wells of a 1D kicked potential [7,8], and some works described the diffusion of atoms in optical lattices [9].

Our aim is to study experimentally the dynamics of atoms in various 2D or 3D optical potentials. In particular, we would like to be able to detect the existence of chaotic individual trajectories. As experimentally, we have not access to the individual trajectories, we need to find in the collective behavior, signatures of the individual dynamics. Presently, we are searching for these collective signatures through simulations of the atomic dynamics in different optical lattices: a standard square potential, which is either red or blue detuned, and a lattice developed in our group, made of a stack of ring traps [10].

Chaotic behaviors are predicted in all cases, though with great differences: for example, chaos appears inside the wells for the blue detuned square potential, while it appears only for multi-sites dynamics in the ring potential and in the red detuned square potential. Even the chaotic multi-sites dynamics show differences. For example, chaos is associated with ballistic trajectories only in the red detuned potential.

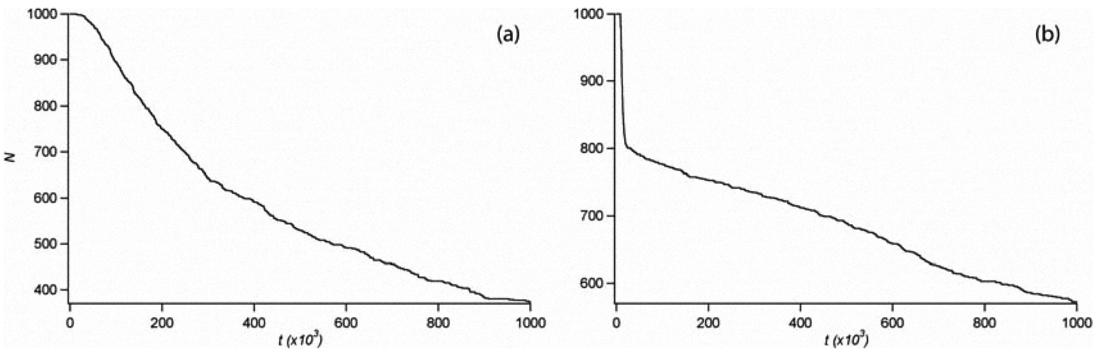

Fig. 1 Number of atoms versus time for the (a) blue and (b) red detuned square potentials.

A detailed analysis shows that these differences have consequences on the way the atoms escape the lattice. Fig. 1 shows that if on looks at the number of atoms in the lattice as a function of time, several different life times appear, and even the decreasing function shapes differ. Thus the lifetime of the atoms inside the lattice could play the role of a collective signature of the individual dynamics

The aim is to use these results to characterize the atomic dynamics in experiments. A next step should be to transpose these results to the quantum world, in order to study the quantum mechanism at the base of chaos.

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978-1-4244-4080-1/09/$25.00 ©2009 IEEE