Ultracold atoms in many-level systems

Ultracold atoms (temperatures about few, few tens of billionth of a degree) can be forced to move in the so-called optical lattice potential. This potential is created by a laser standing wave. Regions where the intensity of the laser is maximal are avoided by atoms, which vibrate around intensity minima. This in way resembles an egg placed inside a cardboard egg box.

It is evident that one cannot create in this ways potentials with details of size much below a single wavelength. One of new developments in few last years was new method of potential construction, also using lasers, which however allow to break the resolution limit. The comb potential (see figure below) was created for ytterbium atoms.

The project aim is to study new possibilities that exist due to new potential creation method, as well as studying some underlying fundamental problems. As far as the latter goes, one should address the question of which atoms are suitable to be used in the new construction. This question is motivated by relatively short system lifetime in the ytterbium experiment. Another problem to be solved is to give a correct description of interaction in the comb potential. Experiments with Ytterbium were in a very convenient setup – for a fermionic isotope. Ultracold fermions cease to collide each other due to the Pauli exclusion principle. Generalization to ultracold bosons would allow to simulate much more behaviors of quantum particles, but the description of collision has to be provided.

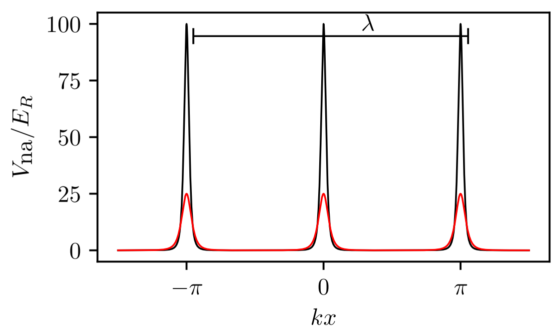

Figure 1: The comb potential. The distance λ marks a single wavelength.

In the systems considered here, the atoms fill a system of a few atomic levels (in case of the the potential in the Figure – three) which are coupled by laser radiation. Among many choices of these atomic levels, laser polarizations, in case of so-called "double-Λ" system, where 5 levels are coupled, a potential similar to the comb potential for the Figure may be created, but it will contain randomness in peaks placement and/or height (the randomness strength maybe controlled). Such systems would open up new possibilities to study the motion of quantum particles in the random, disordered environment. Random peaks would model simulate atoms in the modeled substance, while the free electron gas would be modeled by ultracold atoms. Random potentials allow to study the Anderson localization phenomenon, which renders some real material insulators in low temperatures. Such a research until now has been carried out theoretically or numerically, or in systems where the electrons are simulated by microwave radiation. No interaction between particles was possible however in such arrangement, which is natural for ultracold atoms, where interaction strength can even be altered with magnetic field amplitude.