Many-body localization - cold atoms approach

Jakub Zakrzewski

The scientific aim of this project is the analysis of many-body localization in nontrivial models based on cold atomic systems placed in optical lattice potential. Such a potential results from a nonresonant interaction of laser light with atoms. Using counterpropagating laser beams one creates light standing wave resulting in a periodic potential in which atoms move. This resembles the situation of electrons in crystals, except that atoms are electrically neutral. Electron transport in metals is very effective - metals are good conductors. Still in the pioneering work in the late fifties anderson have shown that randomly placed defects, modelled by addition of the disorder to the system may profoundly affect the transport properties when particles interact with external random potential (but not among themselves). This localization phenomenon is particularly effective in systems with reduced dimentionality (such as one-dimensional chains). This discovery had a profound impact in solid-state physics and was rewarded with Noble prize.

Anderson wanted to find out what happens for interacting particles – this problem remains, however, to large extend not solved up till now. This is based on inherent difficulty of the problem which is quite hard to be described by some simplified theories. Only in the last 10 years a significant progress has beeen made resulting in several theoretical papers as well as numerical simulations showing that in the presence of strong interactions and strong disorder the so called many-body loclaization may appear. Hundreds of papers per year appear on the subject - that shows an immense interest in this topic.

That broad interest may be understood realizing that the phenomenon discussed is fundamentally linked with the basis of equilibrium statistical mechanics. Many-body localization may lead to the fact that a small subsystem remembers, at least partially, its initial conditions despite interaction with the remaining parts of a given system. thus there is no thermalization due to the contact with the surroundings. The information is not only encoded in the global observables of the full system but also it is stored in local averages or correlations for a subsystem.

In the project we plan to perform a detailed analysis of the single existing experiment which has been reported this year and shows some signatures of many-body loclaization phenomenon. We plan also the anysis of other models based on cold atoms systems aiming at better understanding of the phenomenon and at proposing other experiments. We plan to test and develop numerical tools enabling analysis of excited quantum states of large systems, for which standard approaches fail.