Periodically driven many-body systems

The aim of this project is to construct and test propositions for many body models with unusual and interesting properties - the exotic quantum matter - obtained using periodic modulations of the parameters of a given setup (lattice depth, strength of the interactions). Sounds complicated?It is not, really. Ultra cold atoms form an intriguing atate of matter in which atoms must be treated as waves. Waves that may be steered using laser radiation which imposed effective forces on atoms. In the standing wave laser field atoms feel the periodic potential like electrons in a solid. For electrons their behaviour is determined by the crystal structure, for atoms we can freely modify this structure changing the orientation, frequency, intensity or polarisation of laser beams. Additionally using magnetic field and atomic structure properties we can change the interactions between atoms - it depends on us whether they attract or repel each other. Our control of atoms seems almost complete.

But this is not the whole truth. Electrons in a solid, as charged particles react to an external electric or magnetic field. Neutral atoms cannot do so. But the freedom we have in changing parameters of the system studied allows us to force the atoms to react as if they were charged - we are able to create artificial fields. This sounds like a miracle but it is not - for a number of years scientists model with cold atoms a number of phenomena observed/predicted to occur in different areas of physics from solid state to physics of strong interactions (including Higgs boson) and cosmology.

We want to control the atoms even better to be able to create newe exciting systems with unusual properties. The additional know to tune we can use, the knob addressed in this project, is a periodic in time change of system's parameters. Why this is essential?The period of parameters' change (be it laser frequency or phase to shake the lattice position, laser intensity to vary its depth, magnetic field to vary interactions) may be adjusted to complicated properties of many atoms in optical lattice creating resonance effects. Like the swing which has its characteristic swing frequency (depending on its length, moment of inertia). We can force it periodically. If the frequency of our force will not be adapted to the parameters of the swing - the effect will be negligible. for the frequency close to the swing characteristic frequency the oscillations of the wswing will beocme large. it will swing with the external frequency given by us. Resonant driving is efficient.

The same we can do will a large nesemble of cold atoms Resonant coupling may be induced not only with a single atom but also with the whole group modifying drastically properties of the ensemble. One of the interesting applications is the creation of systems with nontrivial topology. We say that the ball and the cube have the same topology, one can be deformed into the other by a smooth transformation. The topology of the torus (or Cracow's pretzel) is different - to deform the ball into the pretzel one must be drastic and make a whole in the middle of the ball. Small perturbations of the pretzel make some deformations - but still one hole remains - the object is stull equivalent topologically to a pretzel. The system is robust against local perturbations. We believe that periodic driving of atoms in lattices may create such interesting topologicall, robut systems. Such object are interesting for quantum computing - after all we do not want the results of the computations to depend on subtle perturbations. Still - to reach the true quantum computer there is still a long way to go.