Project objectives

Polar molecules can be encountered in everyday life. Our body consists mostly of them (water is dipolar). We frequently cope with crystals, for example salt or sugar. Light reaches us from all directions constantly (even at night, but with low intensity). Within the project we are going to analyze polar molecules interacting with light in some unusual conditions. We are going to investigate ultracold polar molecules trapped in crystals made of light, so called optical lattices. These pinned molecules in temperatures close to the absolute zero reveal their complex quantum nature. We can use them for example for quantum computations. In quantum computations quantum mechanics allows to accelerate the calculation speed beyond the boundaries of the classical physics. The second promising perspective is the simulation of other systems known from the quantum world, for example very complex high-temperature superconductors. The road towards quantum computers is still quite long. Interactions between polar molecules in optical lattices has not yet been described in a detailed manner.

Research

We would like to divide our research project into three stages. Within the first of them we are going to describe two colliding polar molecules trapped in separate harmonic potentials. These controlled collisions offer a good, nondesructive and relatively fast scheme for quantum information computing. In case of molecules the collision process depends on the internal state. Thus it allows for creation of quantum logic gates. After verifying the basic concepts with simplified model we plan to use more experimentally realistic description, in which two separate traps will be substituted by an optical lattice. The optical lattice is a standing laser light wave creating a perfect crystal for molecules. Molecules in such a field tend to occupy maxima or minima of the light intensity (depending on their polarizability). Particles in neighboring sites will feel each other thanks to the strong dipolar interactions. After comprehensive investigation of various aspects of molecular dynamics in lattices we are going to apply developed numerical and analytical methods to propose a quantum computation scheme involving ultracold polar molecules in optical lattices.

Motivation

There are various motivations towards investigation of ultracold molecules in optical lattices. First of all they are interesting from the fundamental point of view – they have not been studied theoretically enough yet and this motivates the need to deepen the human knowledge. What is more, the fascinating domain of ultracold collisions may help to realize the quantum computer. With the help of such a tool we could simulate other quantum systems, that are not easily studied by other methods. Moreover, such a computer would be much more efficient in certain computation tasks than classical ones. There are several quantum computation algorithms which are expected to be much faster than their classical counterparts. In order to use ultracold polar molecules for such purposes, first one has to completely understand their rather complicated dynamics in optical lattices .