Nondemolition quantum-state tomography and spin-interaction detection
Popular-science summary

One of the most promising topics of modern science is **quantum-information theory** and **quantum-state engineering**. Quantum mechanics, the theory underlying these subjects, is governed by laws strikingly different from those observed on the macro-scale. Theoretical analysis shows that exploring the theory effects unavailable for classical physics can be observed/achieved. For example, quantum mechanics guarantees that information transmitted between two parties cannot be undetectably eavesdropped. Thanks to this, the algorithm securing information becomes almost unbreakable (cryptographic key generation). On the other hand, however, a number of algorithmic problems practically unsolvable for classic computers could be relatively easy solved using quantum computers.

The basic unit of information of a quantum computer is the so-called **qubit**. It is a quantum object, which is governed by the **law of superposition** (unlike its classical counterpart, which can be either 0 or 1, it can also exist in a combination of these two states). However, to be able to carry out quantum calculations, it is necessary to combine qubits into so-called **quantum registers**. Unfortunately, working with the registers is challenging, as a **sudden reduction in the lifetime of such registers with increasing number of building qubits**. The process or **retrieving the information** contained in the register is also **challenging**.

One scheme **enabling transmission, storage or processing quantum information involves atoms interacting with light and magnetic field**. However, hitherto, all experiments allowing for implementation of these tasks are realized in **complex and difficult to miniaturize apparatus**. This complicates the practical application of the systems in the future. In contrast, **working with gases at room temperature does not require such elaborated equipment**, which makes them better suited for the job. It turns out, however, that there is a fundamental challenge with **application of hot gases for the task**, as no one knows if and to what extent they can be explored for quantum-information purposes. Within the project, we plan to **find the answer to this question, first tackling it theoretically**.

Independently from theoretical investigations envisioned within the project, we plan to **construct a dedicated experimental apparatus**, which, on one hand, will allow **generation of arbitrarily quantum states**, and on the other hand will **provide means for quantum-state tomography** (reconstruction of the state). This task will be carried out by containing the gas in a special glass cell and make it interact with light and magnetic fields. The field will modify the quantum state of atoms building the gas, which will manifest at the macro-scale by a change of optical properties of the medium. With this respect, detection of properties of light traversing the medium of interest will provide access to the quantum state of atoms.

This project combines theoretical and experimental research. On the one hand, the **studies are an interesting from scientific point of view**, while on the other they burden the **potential for practical applications**. While (most likely) they will not lead to the construction of a quantum computer right away, they may contribute to the development of such a device.