## 1. Research project objectives - WHAT?

Quantum memory is a device able to store and produce on demand the quantum states superposition. It is as neccessary during the quantum information proccessing as a classicial RAM memory for classical computer. Our realization of quantum memory is based on off-resonant Raman scattering in warm rubidium vapours. Its operation is as follows: in the write-in process we illuminate the atoms with a strong laser beam and as a result of the scattering process we obtain individual photons registered on the sensitive camera. Together with photons the so called spin wave - the collective excitation storing information about emitted photons is created inside the atomic ensamble. Information about excitations is stored and then in the reading process emitted in the form of photons which are also registered on the camera. The whole process has a multimode character meaning we are able to produce many independent groups of photons at the same time. Multimode character is classically equivalent to array of registers instead of a single register, which significantly increases the capacity of the memory.

In the project we want to show that it is possible to manipulate the quantum state of light through its interaction with the atomic ensemble. Using external magnetic fields, we intend to carry out measurements involving the selective addressing and manipulation of selected states. We plan to perform interference of coherences during the memory storage stage, selective state write-in and readout to/from quantum memory, as well as sequential readout of two modes being stored.

## 2. Research methodology - HOW?

Previous manipulations of light states stored in the quantum memories were performed for macroscopic light intensity - for experiments on the single-photons level an external source of photons was necessary. In addition, quantum memory devices used by other groups operate in a single spatial mode, which is a serious constraint on the capacity and the possibility of manipulating the various degrees of freedom. The built by us multimode photon generator system has a chance to expand the existing capabilities of quantum engineering of atomic states.

From the rich energy structure of the rubidium atom we are going to pick a few levels which will be addressed by laser beams, causing generation of multiple independent excitation stored in a controlled manner inside the memory. Then, using magnetic fields, laser beams and radio frequency waves, we will be able to make a coherences from one atomic state to another. Thanks to this it will be possible to observe i. a. sequential reproduction of two (or more) excitations stored inside the memory, as well as change the excitations parameters. Using the sCMOS camera with an image intensifier - a unique equipment constructed from components in our laboratory - which has been constructed by us from components, by the use o a system of atomic filters we are able to observe single photons coming form the distinct spatial modes of the memory.

To carry out the study, we will usequantum memory setup built by the Applicants in hot rubidium vapours which is in the laboratory of Faculty of Physics, University of Warsaw. In year 2016 we plan to build the magneto-optical trap (MOT), also based on rubiduim, which may provide additional opportunities for this project through the study of cold atoms. It will be a great opportunity to compare the capabilities of both warm and cold light-atoms interfaces, important from the point of view of future applications.

## 3. Research project impact - WHY?

Proposed ideas can be used to build quantum logic gates which is a first step towards quantum information processing science. Generation of N-photons states produced on demand during the readout process in the certain states will be easier than it is today. The development of multimode memory technology is important to increase the capacity of information channels used to transmit single photons over long distances (the quantum Internet idea). It will also find application in the field of quantum computation and possibly also in ultraprecise measurements. By controlled manipulation the entangled states of light can be prepared and in the case of using several different degrees of freedom the so-called hyperentanglement. As a result, information processing becomes easier and more efficient.