The goal of the project is to demonstrate the possibility of precise control of single photon holograms encoded in ultracold atomic ensemble by means of strong laser light .

Typical experimental scenario is presented in Fig. 1. The result is the entangled state of two photons, the very same that lead Einsetein, Podolski and Rosen[1] to formulate their critique of the quantum theory.

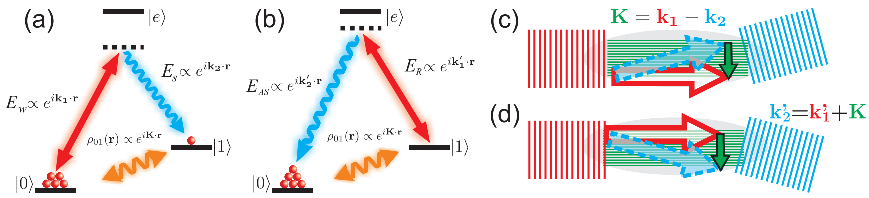

Figure 1: The ensemble of atoms is illuminated by a laser beam inducing Stokes scattering — a random emission of photon and creation of a corresponding atomic hologram, as the atoms are transferred to another state. The atoms store the hologram until we illuminate the ensemble using another laser beam. Then we observe emission of another photon, this time strictly dependent on the stored hologram, which constitutes a read-out process. The hologram is destroyed due to the no-cloning theorem.

We seek to demonstrate the modulation of stored atomic holograms as well as a new method to retrieve holograms unretrievable be means of typical Raman scattering scheme.

Effects of modulating the spin-wave can be analogous to the ones of prisms and lenses in classical optics, but also new possibilities arise due to the phase-matching condition.

Finally, we want to demonstrate the possibility to retrieve dark holograms. We will use 3 laser beams[2].

The research will be carried out using the magnetooptical trap allowing us to cool and trap an ultracold ($< 1mK$), elliptically shaped cloud of rubidium atoms. The trap has been operating in our laboratory since the beginning of May. We will also use a camera sensitive to single photons that was assembled in our group.

The proposed experiments will show that modulation of holograms stored in quantum memory leads to a vast range of new possibilities.

Read-out of dark holograms will be a significant advance in the rapidly developing scheme known as Gradient Echo Memory[3], in which an MRI-like magnetic field is used to store light pulses in the hologram of varying periodicity of domains. Their readout without using the magnetic field will allow to turn them back to the light side, allowing previously impossible interference of stored light pulses.

The proposed exploratory research is an important part of the lively field of quantum memory research. It is also one of very few that explores spatial properties of light and atomic ensembles. Development of holography-inspired methods and ways to manipulate stored holograms will lead to a processing scheme, in which we will be able to create, manipulate and retrieve holograms in a variety of new complex ways. Finally, we would be able to prepare photons and atoms in states precisely engineered for applications in quantum metrology, communication or computation.

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[1] A. Einstein, B. Podolsky, N. Rosen, Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?, Phys. Rev. 47, 777 (1935)

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[3] M. Hosseini et al., Coherent optical pulse sequencer for quantum applications, Nature 461, 241-245 (2009)