The influence of diffraction on the storage of quadrature-squeezed light in a thermal atomic ensemble

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Generally, in theoretical models of quantum memory, the cold atoms approximation is used. In framework of the approximation all atoms of the ensemble do not change their position throughout the entire memory cycle, which includes the stages of writing, storage, and read out a quantum light pulse. It allows to significantly simplify the mathematical description of the ongoing physical processes. However, one can experienced considerable difficulties with obtaining such an ensemble in a real-life experiment. This is due to the fact, that it is possible to suppress the thermal motion of atoms in the transverse direction and leave the atoms moving in the longitudinal direction, and vice versa [1]. In this regard, in our work, we examined the influence of the thermal motion of the atoms of the ensemble on the writing and read out of light in the memory cell for cases of longitudinal and transverse motion of atoms relative to the direction of light fields propagation.

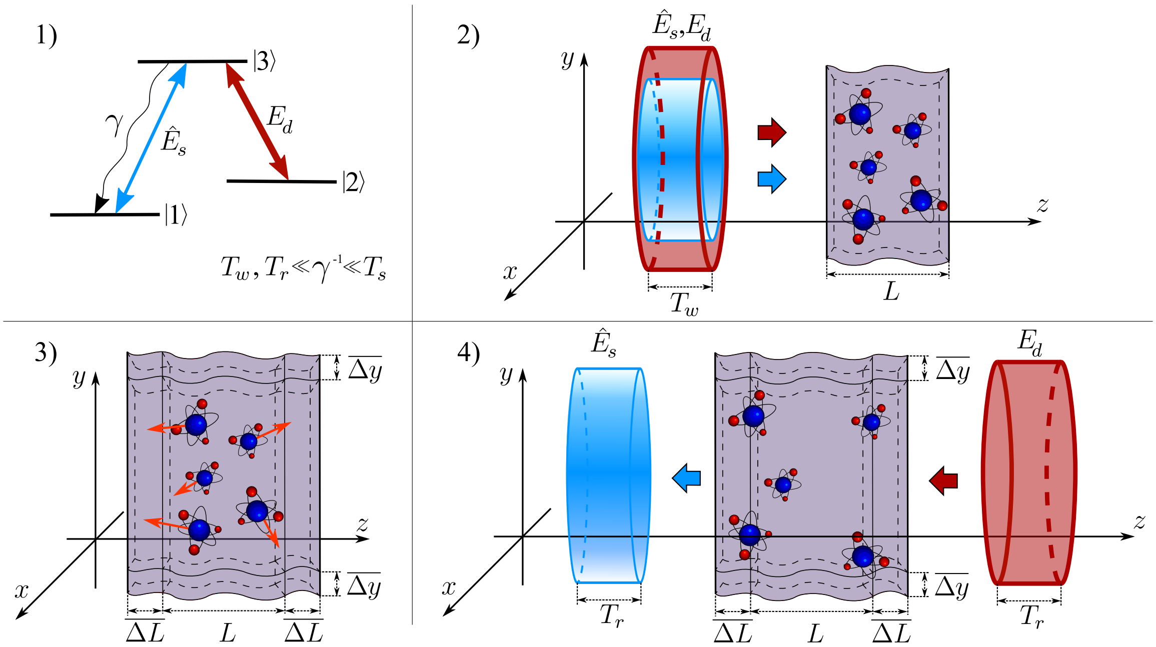

Figure 1: Sketch of the full cycle of the fast resonant quantum memory: 1) tomic energy levels with signal $\hat{E}_s$ and driving E_d light fields, 2) writing, 3) storage with thermal motion of atoms, 4) read out.

In our work, we considered the multimode fast resonant quantum memory protocol (fig. 1). This protocol is based on the resonant interaction of a homogeneous ensemble of three-level atoms in the Λ-configuration with signal $\hat{E}_s$ and driving E_d light pulses [2]. We studied the ability of the protocol to store broadband light pulses at different temperatures of the atomic ensemble. As a signal field, we chose quadrature-squeezed pulses emitted by a phase-locked single-mode sub-Poissonian laser. We estimated the influence of atomic motion on the correlation properties of quadrature-squeezed light stored inside the memory cell. Accordingly, we compare the signal-to-noise ratio for the squeezed light at the input and the output of the memory cell for different average atomic displacements during the storage stage. Fig. 2 shows the change of squeezing in the case of longitudinal motion of atoms.

In addition, we study the inluence diffraction of light that occurs in the case of backward retrieval of the squeezed light pulse from the memory cell. In this case, a relative phase shift appears between the different modes of the recorded light. It leads to mixing of the squeezed and unsqueezed quadratures, and

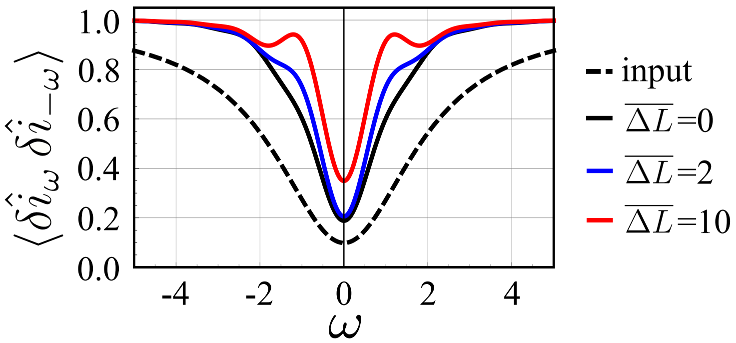

Figure 2: Spectra of squeezing of photocurrent fluctuations for different average longitudinal displacements of atoms during the storage stage.

as a result the quantum-statistical properties of the light at the output of the memory cell turn out to be significantly corrupted. In this work, we evaluate this effect depending on the geometric parameters of the system.

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References

[1] *V.M. Porozova, L.V. Gerasimov, I.B. Bobrov, S.S. Straupe, S.P. Kulik, D.V. Kupriyanov.* Raman sideband cooling of a single atom in an optical dipole trap: Towards theoretical optimum in a three-dimensional regime. Phys. Rev. A **99**, 043406 (2019).

[2] *T. Golubeva, Yu. Golubev, O. Mishina, A. Bramati, J. Laurat, and E. Giacobino.* High-speed spatially multimode atomic memory. Phys. Rev. A. **83**, 053810 (2011).