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Multi-mode optical quantum memory for quantum processing and communication

The promising approaches for multi-mode optical quantum memory and its use in quantum processing and communication are discussed. Herein, we are interested in specific properties of the recently developed photon echo schemes in solid state and gaseous media. The photon echo approach opened a number of convenient protocols for storage of multi-mode light fields such as well-known CRIB-, GEM- and AFC-protocols and approaches using atomic systems with natural inhomogeneous broadening of resonant transitions such as ROSE-type –protocols. We discuss basic properties, advantages and difficulties of these protocols, new experimental achievements in these schemes and possible progress in its future development. Here we consider new realizations using particular properties of resonant systems used for quantum storage and different types of the light-atom interactions. At first, we propose convenient experiment realizations of efficient broadband ACF-protocol. A special attention, we paid to off-resonant Raman interaction of light fields with atomic systems for considerable improvement of the photon echo QM schemes. Here, we discuss new properties of the Raman echo QM in free space and in the optical cavity schemes. In particular, we are interested in the properties of multi-color, associate multi-mode QM, and efficient wavelength conversion. Also, we elaborate new approach for realization of broadband photon echo quantum storage in optical cavity. In our analysis, we discuss importance and role of time-reversal dynamics in the light-atom interactions for high quantum efficiency and fidelity in light field storage. Finally, we discuss a potential realization of the studied photon echo schemes in the planed experiments on the inorganic crystals doped by rare-earth ions and potential application of these schemes for quantum repeaters and quantum processing.

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