양자결맞음 통제에 기초한 양자정보처리

Dynamic quantum information processing based on quantum coherent control

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Abstract: A light stop and retrieval phenomenon, which is a simple extension of coherence transfer from two-photon to one-photon via resonant Raman interactions and nondegenerate four-wave mixing processes, is analyzed for dynamic quantum information processing.

Summary

It is well known that light interactions with an optical system can change the refractive index profile due to coherence excitations based on either population transfer or phase redistribution. For last decades there has been much interest in coherent control of light for the change of absorption and dispersion profile at or near resonance frequencies. In general absorption profile has a close relation with dispersion. In a two-level system, due to strong absorption at resonance frequency, coherent control for nonlinear optics has been limited for practical applications.

When two-color lights interact with a three level optical system, however, the dispersion or nonlinearity can be changed without the absorption suffering in the two-level system. In the name of electromagnetically induced transparency, one laser can control the optical properties of the interacting medium, so that another laser can experience a sudden dispersion change across two-photon resonance without any absorption. This abrupt dispersion change without absorption makes the light travel through the optical medium in a slow speed even comparable to the speed of a bicycle.[1] Moreover, the probe beam can be manipulated stopped and retrieved in an optically dense medium by an action of its counterpart.[2] This light stop and retrieval can also be applied for a new area of quantum information processing based on collective atom related quantum computing.

In this paper, we analyze the physics of the light stop and retrieval numerically by solving simple time-dependent density matrix equations. In the analysis, we show that the light stop and retrieval based on the group velocity slowdown is a special case of general two-photon coherence created by resonant Raman interactions in a lamda-type three-level system and the coherence recovery by a third light via nondegenerate four-wave mixing processes. In other words, the light stop and retrieval based on slow light is just a coherence transfer from two-photon coherence to one-photon coherence by an action of the third light satisfying time dependent nondegenerate four-wave mixing. We also demonstrate that the magnitude of the retrieved is directly proportional to the magnitude of the two-photon coherence used for the coherence transfer process. Here, it should be noted that the two-photon coherence can be efficiently generated by resonant Raman interactions even in a much shorter time scale compared with its optical decay time, so that the coherence recovery via the third laser pulse satisfying phase matching condition is possible without the requirement of electromagnetically induced transparency. In a population-shelved optical medium with a long lifetime, it is also demonstrated that the coherence transfer as an optical emission has nothing to do with the population transfer, where the population transfer is essential in stock or anti-stock Raman processes.

For implementations of the presented coherence transfer to quantum memory, we expand the homogeneously broadened system to inhomogeneously broadened one in the spin transitions. Unlike in a spin homogeneously broadened system, a series of optical pulses utilize the spin inhomogeneity to be stored in a form of spin phase modulations as superposition of the two-photon coherence. Therefore, present coherence transfer based on two-photon coherence and nondegenerate four-wave mixing processes is a simple, easy, efficient, and robust method for dynamic quantum memory.

References

1. L. V. Hau *et al.*, Nature **397**, 594 (1999); M. Kash *et al.*, Phys. Rev. Lett. **82**, 5229 (1999).
2. C. Liu *et al.*, Nature **409**, 490 (2001); D. F. Philips *et al.*, Phys. Rev. Lett. **86**, 783 (2001); A. V. Turukhin *et al.*, Phys. Rev. Lett. **88**, 023602 (2002).