17.45 QTuI9

On Nonlinear Optics of Free Space

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Photon possesses the inertial and gravitational mass which is proportional to its energy and the light velocity depends on the local value of gravitational potential. These two statements of the theory of relativity premise the possibility of nonlinear behavior of EM-waves in vacuum similar to well known nonlinear optical effects in material media with permeabilities depending on the field strength

So the nonlinear wave propagation in a free space which possesses all the features of optical self-focusing arises due to the positive sign of the derivative of speed of light with respect to potential of gravity. Therefore the equivalent mass of an intense photon beam may "cave in" for itself some kind of 2D potential well or. in other words, may form the induced waveguide in vacuum.

The selfconsistent solution of this problem includes the relativistic calculation of photon trajectories in the field of gravity caused by the total mass of photon beam in paraxial approximation of a single-mode model in the case of weak gravitational potential. Conditions of arising a set of periodical transverse-restricted photon trajectories manifesting the waveguide-type propagation are as following: the total EM energy of a photon beam must exceed the critical value which is equal to the Planck's energy ($\sim 10^{10}$ J) and the coherence length must sufficiently exceed the beam diameter. Numerical estimates show that such a kind self-focused photon jets in vacuum may arise only if the beam length is comparable with interstellar distances.

Effect of harmonic generation in vacuum has many basic features of usual optical nonlinear process in crystals, but in some respect is more simple one because vacuum is dispersion free medium. Thus the vacuum harmonic generation is an isotropic effect with an infinite length of synchronism.

The nonlinear EM-pulse shaping process in vacuum leads to the shortening of pulse duration and intrapulse frequency modulation during the long distance propagation through free space.

Considered nonlinear vacuum effects presumably should be of interest for solving various cosmological problems of photon propagation in free space.

15.30-18.00 QTuJ - Quantum Information & Entanglement
Presider: W. Braginsky, *Moscow State University, Moscow, RUSSIA*

SEMINAR

15.30 QTuJ1 (Invited)

Experimental Quantum Teleportation and Entanglement Swapping

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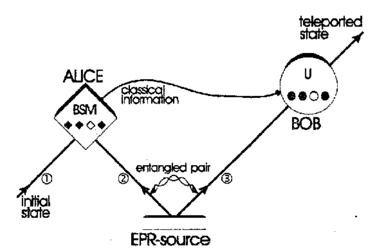
SUMMARY

We implemented the quantum teleportation scheme, proposed by Bennett et al. [1]. using single photons and entangled photons as produced by parametric down-conversion. The teleportation scheme is illustrated in the figure below. The idea is that Alice has particle 1 in a certain quantum state. in our experiment a single photon with a certain polarization. and she wishes to transfer this quantum state to Bob, but she cannot deliver the particle directly to him. Any quantum measurement will destroy the quantum state at hand without revealing the necessary information. So how can she provided Bob with the information of the quantum state? The way out is to use an ancillary pair of entangled particles 2 and 3 (EPR pair). where particle 2 is given to Alice and particle 3 is given to Bob. If Alice now performs a Bell state measurement (BSM) on particles 1 and 2. that is, she projects the two particles onto an entangled state, then Bob's particle will simultaneously be projected onto a state which is directly related to the initial state. All that Alice has to tell to Bob is in which entangled state her two particles have been projected by the Bell state measurement. This is enough information for Bob to transform the state of his particle by a unitary transformation (U) into the initial state. In our experiments we created the EPR pair of photons by pulsed type-II parametric down-conversion. Creating the initial photon by the same pulse and using additional optical elements enabled us to overlap the initial photon with one of the photons from the EPR pair onto a beamsplitter. Detecting one photon in each output port of the beamsplitter yields a projection onto the Ψ^- state. which is one of the four Bell-states. The corresponding unitary transformation that Bob has to perform in order to obtain a replica of the initial photon is simply the unitary transformation. Analysing the polarization properties of the photons received by Bob under the condition that Alice measures a projection onto the Ψ^- provides the experimental proof of quantum teleportation [2].

Entanglement swapping can be seen as an extention of the teleportation scheme. If the initial particle is one of an entangled pair, the final result of the telportation is that two particles that have never interacted become entangled.



[1] C.H. Bennett. G. Brassard. C. Crépeau. R. Jozsa. A. Peres. and W.K. Wootters. Phys. Rev. Lett. **70**, 1895-1899 (1993).
[2] D. Bouwmeester. J-W Pan. K. Mattle. M. Eibl. H. Weinfurter. A. Zeilinger. Nature **390**. 575 (1997).