Effective photon-photon interaction under light localization in a system of nanoparticles

V.V. Maksimenko [1,2] , V.A. Zagaynov [1,2] and I.E. Agranovski [3]

[1] National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), 31, Kashirskoe shosse, 115409, Moscow, Russia

[2] Karpov Institute of Physical Chemistry, Vorontsovo Pole, 10, 105064, Moscow, Russia

[3] School of Engineering, Griffith University, Brisbane, 4111 QLD, Australia

Keywords: light, localization, nanoparticle, scattering.

Presenting author email: I.Agranovski@griffith.edu.au

Recent interest towards effective photon-photon interaction was ignited by a paper (Firstenberg, 2013), where attraction of a pair of polarization-entangled photons was observed. It is well known that photon-photon interaction in the linear media is impossible in principle. On the other hand, it is not prohibited in nonlinear media if the field intensity is of sufficient magnitude. Some attraction of entangled photons was demonstrated (Firstenberg, 2013), under condition of excitation of Rydberg's states of atoms when the medium becomes nonlinear in weak fields.

As was shown later (Maksimenko, 2015), some alternative process of effective photon interaction could exist. This interaction does not require any nonlinearity of a medium and is not related to quantum entanglement. In addition, a coincidence of photons' frequencies is not indispensable condition.

It was shown (Maksimenko, 2013) that even in situation of photon scattering on a pair of resonance particles, a trajectory of virtual photon becomes isomorphic to Antoine's chain set (Antoine's necklace) possessing zero topological dimension. For this reason, the trajectory acquires specific mechanical rigidity due to singularity of the energy density along it. Analysis of Feynman's diagrams shows that the photon mass operator interlaces rigid sections of the Antoine necklace. As a result of such interlacing, the photon is able to localize even in this simplest system. The localization could also be considered as creation of a bound state of a pair of virtual photons passing a closed loop on trajectory along two alternative ways; clockwise and counterclockwise.

Propagation of a photon in a densely packed system of small conducting particles at frequencies being in the vicinity of frequency of a dipole surface plasmon resonance was considered in (Maksimenko, 2013). The similar photon localization was predicted. It was shown that under light localization condition in a system of small non-absorbing closely packed resonance particles, the effective photon-photon interaction appears due to peculiarities of the photon trajectories. Taking into account this interaction, the scattering cross section of photon's pairs is calculated. Elastic scattering cross section taking into account this interaction contains an extra degree of small Rayleigh's factor $\left(\omega R / c\right)^4$ in comparison with classic expression (ω is the frequency, R is the particle radius, c is the light velocity in vacuum). This interaction manifests itself for the frequency range where imaginary part of the effective dielectric permeability of the system appears (see Fig.1). This phenomenon appears as an emission of localized photons by means of other photons with different frequency due to interlacing of the rigid Antoine's trajectories.

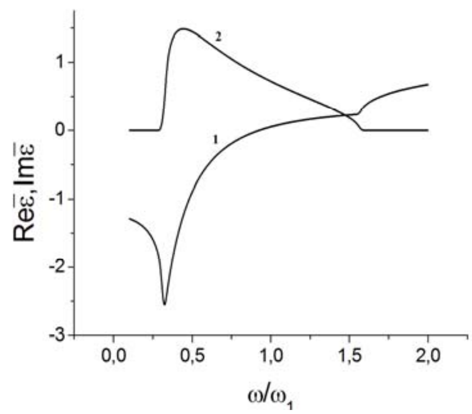

Figure 1. Frequency dependence of real (1) and imaginary (2) parts of effective dielectric permeability, ω_1 is the frequency of the dipole surface plasmon in separated particle.

A possibility of effective photon-photon interaction at small intensity electromagnetic fields opens a principal possibility to control light with alternative light fluxes eliminating need for utilization of complex and slow optoelectronic converters.

This work was supported by RSCF (No 14-03-00507).

Firstenberg, O., Peyronel, T., Liang, Qi-Yu, Gorshkov, A.V., Lukin, M. D., Vuletic, V. (2013) *Nature* ***502***, 71.

Maksimenko, V. V., Zagaynov, V. A., Agranovski, I. E. (2013) *Phys. Rev. A* **88,** 053823.

Maksimenko, V. V., Zagaynov, V. A., Agranovski, I. E. (2013) *Prog. Theor. Exp. Phys.* (2015), 093D02.

Maksimenko, V. V., Zagaynov, V. A., Krylov, S. Yu., Agranovski, I. E. (2013) *Prog. Theor. Exp. Phys.* 013101.