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Single photon transport by a moving atom through sub-wavelength hole

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Abstract. The results of investigation of photon transport through the subwavelength hole in the opaque screen by using single neutral atom are represented. The basis of the proposed and implemented method is the absorption of a photon by a neutral atom immediately before the subwavelength aperture, traveling of the atoms through the hole and emission of a photon on the other side of the screen. Realized method is the alternative approach to existing for photon transport through a subwavelength aperture: 1) self-sustained transmittance of a photon through the aperture according to the Bethe's model; 2) extra ordinary transmission because of surface-plasmon excitation.

The simplest way to transport of photon energy from the one side of opaque screen to another is using of photon transmission through the hole in the screen. Unfortunately as was shown by Bethe [1] and Bouwkamp [2] the efficiency of such transport is low in the case of subwavelength holes. A remarkable discovery about the transmission of light through a subwavelength hole in a metal screen of a finite thickness and a finite conductivity that has been made by Ebbesen et al. [3] has shown that the standard theory of diffraction by small holes is invalid, and, in this case, the transmission of light through the subwavelength hole can be strongly enhanced. The majority of researchers agree that the central role in this phenomenon is played by surface waves, such as surface plasmons.

We have proposed and investigated [4] a fundamentally different mechanism by which a photon can be transferred through a subwavelength hole. It is based on the photon transport that involves the participation of a particle other than a plasmon, namely, a neutral atom. In this scheme, a single atom transfers a single photon through a nanohole. Besides the using of a new particle for photon transport it opens up a new possibilities for surface science. It is possible to use such scheme for investigation of van der Waals interaction of atom inside the hollow cylinder [5]. Another application of the described scheme it could be useful for atom – plasmon interaction investigation. Indeed the subwavelength hole is a highly nonlinear plasmonic element. So the interaction of excited atom with such structure opens new way for tailoring the spectral properties of materials [6].

The basic idea of the single photon transport by a moving atom is presented in Fig. 1. An atom moving toward a metal screen with a hole absorbs a photon of laser radiation immediately in front of the hole. If the lifetime of the atom is substantially larger than the

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time of flight of the atom through the subwavelength hole, the transition of the atom from the excited state to the ground state with emission of a photon can occur under certain conditions on the other side of the screen, which means the transfer of the energy of the photon through the subwavelength hole.

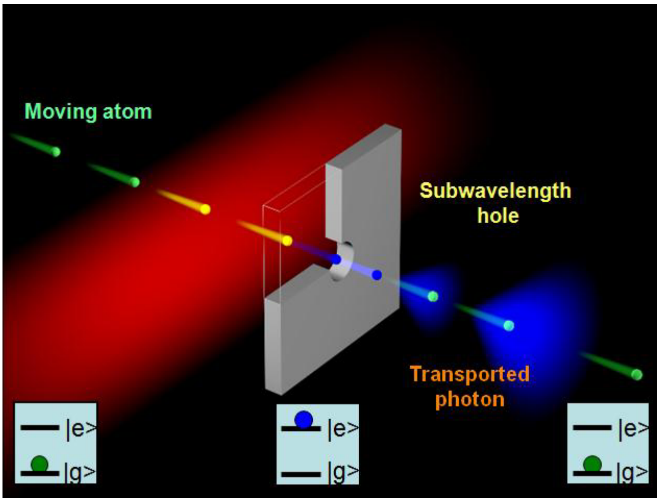

Fig. 1. Basic idea of single photon transport by a moving atom. An atom that moves toward a screen with a nanohole is excited in front of the screen. The long lifetime of the excited atom enables this atom to transfer the excitation energy through the nanohole and reemit it as a photon on the other side of the screen.

The photon transfer efficiency depends on the geometrical dimensions of the hole, the material of the screen with holes, and the velocity and the scheme of energy levels of the atom. At small sizes of the hole, the photon transfer efficiency decreases substantially because of the interaction of the excited atom with the surface, as a result of which the surface of the nanohole in the screen causes deexcitation of the atomic state.

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