Spontaneous emission, elastic scattering and Anderson localization of exciton-polaritons in multilayer quantum-well structures

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Resonant effects due to multiple scattering of quantum-well exciton-polaritons were studied theoretically for semiconductor multilayer structures with both intra-well and inter-well disorder. Along with the preliminary considerations [1-3], single quantum wells with laterally fluctuating width and random arrays of quantum wells were used as the basic objects to investigate.

A theory is developed for spontaneous emission and elastic (Rayleigh) scattering of light via quasi-2D excitons of a quantum well either on homogeneous dielectric background or in semiconductor microcavity (Fabry-Perot microresonator). When all interfaces are plane (the zeroth-order approximation), the radiative decay rates of quasi-2D excitons in a multilayer arrangement, particularly in a microcavity, are derived in terms of the internal reflection coefficients taking account of the interior boundary conditions. For quasi-2D excitons of a quantum well bounded by randomly rough interfaces, an optical model is developed whose statistical parameters enter the observable optical magnitudes. On this background, the steady-state scattering cross-sections are evaluated in the lowest (Born) approximation in the quantum-well width fluctuations. The cross-sections are presented for all the scattering channels specified by linear polarizations of incident and scattered radiation. The spectral-resonant and angle dependences of scattering intensity are analyzed for various (Gaussian and exponential) correlation functions of the interface shapes. The typical resonant scattering efficiency due to exciton-polaritons of a quantum well is found to exceed by two orders of magnitude the non-resonant contribution due to scattering from an interface (surface) of a microcavity.

The effects of inter-well disorder on the electromagnetic transfer through multiple quantum wells are studied, as well. Treated are two models of resonant quantum wells distributed randomly, one corresponding to low spatial density of quantum wells and another relating to short-period superlattices with non-resonant quantum wells settled in random. Based on these models, a self-consistent theory of resonant scattering and one-dimensional Anderson localization is presented for exciton-polaritons, which originate in non-overlapping quasi-2D exciton states of different quantum wells. The averaged one- and two-photon characteristics are calculated giving the analytical expressions for electromagnetic energy flux and the Anderson-localization length. In disordered multiple-quantum-well structures, the mean electromagnetic field is concluded to manifest polaritonic features caused by coherent re-emission of quasi-2D excitons between resonant quantum wells. The localization length is shown to be resonantly reduced in the polaritonic spectral range where the scattering from a single quantum well strongly increases.

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[1]. V.A. Kosobukin. Spontaneous Emission and Elastic Scattering of Light from Quantum-Well Excitons in a Fabry-Perot Microcavity. Phys. Solid State, 2003, **45** (4), pp. 736-751.

[2]. V.A. Kosobukin. Excitonic Polaritons and Their One-Dimensional Localization in One-Dimensional Localization in Disordered Quantum-Well Structures. Phys. Solid State, 2003, **45** (6), pp. 1145-1153.

[3]. V.A. Kosobukin, A.V. Sel'kin. Resonant elastic scattering of light from single quantum wells in semiconductor multilayers. Physica E, 2003, **18** (4), pp.452-468.