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Strong optical absorption of nanostructures containing quantum dots: Theory

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At present, the optical and electro-optical properties of quasi-zero-dimensional structures are extensively studied. Such structures commonly consist of spherical semiconductor, metal and insulator nanocrystals (the so-called quantum dots (QDs)) with a radius ≈1-10 nm grown in dielectric (or semiconductor) matrices. The studies in this field are motivated by the fact that such nanoheterosystems represent new promising materials for the development of new elements of nanooptoelectronics to be used, specifically, for controlling optical signals in optical computers or for manufacturing active layers of optical lasers as well as new strongly absorbing nanomaterials. Special attention is paid to analysis of optical properties of such nanosystems in view of its unique photoluminescence properties and the ability to effectively emit light in the visible or near infrared ranges at room temperatures. The features of the interaction of light with QDs of metals, semiconductors and dielectrics are studied under conditions in which absorption at resonance frequencies of local surface vibrational modes predominates both in the phonon and electronic subsystems of a solid. The effect of increasing the electromagnetic field of a light wave was caused by excitation of resonant surface modes. Such effects cause the intensification of various photo-physical phenomena. Investigations in the theory of absorption and scattering of light at outer surface Coulomb states in nanosystems have not been performed as of yet; to fill this gap, a theory of interaction of the electromagnetic field with the Coulomb states of charge carriers emerging in nanosystems on the outer surface QDs is developed in this study. In present work in framework of dipole approximation it is shown, that the oscillator strengths of transitions as well as the dipole moments for transitions for one-particle electron Coulomb states emerging above the spherical surface QDs of semiconductor, metal and insulator assume giant values considerably exceeding the typical values of the corresponding quantities for dielectrics. It has been established that the giant values of the light absorption cross section in the nanosystems under investigation make it possible to use such nanosystems as strongly absorbing nanomaterials in a wide range of infrared waves with a wavelength that can be varied in a wide range depending in the type of contacting materials.

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