Abstract

Various experimental realizations of few-particle nanosystems, such as quantum wells, nanowires or semiconductor quantum dots, offer a unique opportunity to get an insight into the quantum structure of the world. An important advantage of artificially produced nanosystems is that a single particle system can be addressed. Not only the number of particles, but also the strength of interaction between them and the shape of an external potential may be experimentally controlled. The current experimental possibilities provide a wide perspective for quantum systems research, which requires us to develop theoretical methods for describing them. The thesis involves theoretical investigations on the properties of the bound and resonance states of few-body quantum systems.

The first part of the thesis, where only single-particle systems are considered, provides a prelude to the analysis of complex systems. For a system of two-dimensional anharmonic oscillators, the effectiveness of the optimized variational method with various base functions is investigated. We propose a new method, for determination of resonance energy end lifetime. The method is more effective than the commonly used complex scaling one.

The second part of the thesis focuses on two-particle systems, where properties of an anisotropic two-electron quantum dot and double excited state of helium are studied. In the case of strong lateral confinement the excitations of a quantum dot occur only in the longitudinal direction and the system can be approximately described as a quasi-one-dimensional one with the effective electron-electron interaction. The impact of the form of quasi-dimensional Coulomb interaction on the energy spectrum of the system is investigated. We determine the ionization thresholds, that is, the critical energies below which the two-electron system is bound. We perform a detailed analysis of the effect of the lateral and longitudinal confinement parameters on the energy and lifetime of resonances. Especially, we pay attention to the quantum correlation of resonance states. The entropic measures of them are shown, which are based on the diagonal representation of the non-Hermitian reduced density matrix and its renormalised form as well. The entropic measures of the correlation are obtained for doubly excited metastable states of the helium atom and for autoionising resonance states of the quantum dot.

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