TOWARDS SPECTROSCOPIC QUALITY ENERGY DENSITY FUNCTIONALS

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Density functional theories [DFT] (both in relativistic [covariant] and non-relativistic incarnations) are well established theoretical tools for the description of nuclear systems. However, there are still a number of important topics which have not been either addressed or satisfactorily resolved within their frameworks. One of them is the description of the single-particle degrees of freedom.

In our study of these degrees of freedom we use covariant density functional theory [CDFT] [1]. The polarization effects in time-even (deformation changes) and time-odd (single-particle alignments) mean fields induced by a particle(s) are well described in DFT. This shows that some aspects of the single-particle motion are described on average better and in a more consistent way in self-consistent DFT than in phenomenological microscopic+macroscopic (MM) method. On the other hand, systematic investigation of the energies of deformed one-quasiparticle states in actinide and rare-earth mass regions [2] shows that nuclear spectra are not that well described. It is obvious that the DFT theories do not possess spectroscopic quality description of the single-particle spectra which is achievable in the MM method as a consequence of the fit of the potential parameters to experimental single-particle energies. The sources of the discrepancies between CDFT and experiment are analyzed.

Although some improvements in the description of nuclear spectra can be achieved by better parametrization of the energy density functional, the analysis of Ref. [2] suggests that spectroscopic quality of their description can be achieved only in theoretical framework which takes into account particle-vibration coupling. This has been illustrated on the example of spherical nuclei in Ref. [3]. In this work, particle-vibration coupling is treated fully self-consistently within the framework of the relativistic particle-vibration coupling model and polarization effects due to deformation and time-odd mean field induced by odd particle are computed within CDFT. The impact of particle vibration coupling on different physical observables such as the energies of predominantly single-particle states, the spin-orbit splittings, the shell gaps, the energy splittings in pseudospin doublets will be illustrated in spherical nuclei ranging from light up to superheavy ones.

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