On the importance of using exact pairing in the study of pygmy dipole resonance†

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One of the major issues in the theoretical study of the pygmy dipole resonance (PDR) in medium and heavy nuclei is the discrepancy in the predictions of different approaches regarding the strength and collectivity of the PDR. While the relativistic random-phase approximation seems to predict a prominent peak identified as the collective PDR below 10 MeV in heavy nuclei[1,2], the results of calculations including monopole pairing within the quasiparticle RPA (QRPA) do not expose any collective states in the low-energy region of the $E1$ strength distribution[3]. One of the possible sources of such discrepancy may well lie in superfluid pairing, which plays a crucial role in open shell nuclei in the vicinity of the neutron drip line. However all the theoretical calculations of the PDR so far either neglected pairing, such as the relativistic RPA, or adopted the mean-field pairing. The latter is taken into account within the Hartree-Fock-Bogolyubov, Hartree-Fock + BCS formalisms, or coupling of QRPA particle-hole (ph) states to more complicate configurations like the 2p2h ones. Given the progress in the exact solutions of the pairing problem in recent years, it is highly desirable to see how exact pairing affects the PDR as compared to the predictions given by the approaches employing the conventional mean-field pairing gap.

The present paper studied the effect of superfluid pairing on the PDR in light, medium and heavy neutron-rich oxygen, calcium and tin isotopes. Beside the conventional BCS gap, the exact pairing gap obtained by diagonalizing the pairing Hamiltonian with constant parameters G_N and G_Z for neutron and proton pairing interactions, respectively, is also employed to calculate the strength function of the giant dipole resonance (GDR) in these nuclei within the framework of the phonon-damping model (PDM)[4]. The analysis of the numerical calculations allows us to make the following conclusions: 1) Exact pairing decreases the two-neutron separation energy in light nuclei, but increases it in heavy nuclei as compare to that obtained within the BCS theory; 2) Exact pairing significantly enhances the PDR in medium (calcium) and heavy (tin) nuclei, whereas the BCS pairing causes a much weaker effect as compared to the case when pairing is neglected. This observation indicates that BCS pairing might not be sufficient to describe the PDR in medium and heavy neutron-rich nuclei; 3) The significant change in the line shape of the GDR with increasing the mass number A indicates that the values for the model's parameters cannot be kept fixed when the calculations are extended to the nuclei in the vicinity of the neutron drip line. This includes the parameters of the nuclear mean field such as the parameters of the Woods-Saxon potential or the parameters of effective interactions such as various Skyrme types, which are used in microscopic calculations of the GDR and PDR.

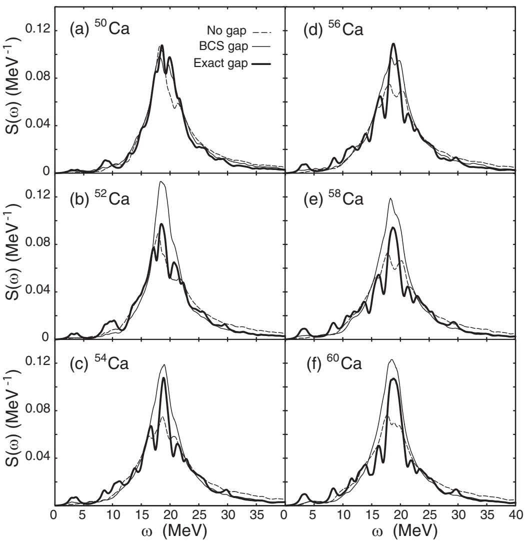

Fig. 1. GDR strength functions for calcium isotopes obtained within the PDM. The predictions without pairing, including BCS pairing and exact pairing are denoted by the dashed, thin solid, and thick solid lines, respectively.

The obtained results may serve as a hint to clarify while several microscopic approaches, mentioned in the Introduction, are in disagreement regarding the strength and fine structure of the PDR. The present paper also emphasizes the necessity of using exact pairing, whenever possible, instead of the BCS one or the HFB average pairing gap in the future study of the PDR.

References

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