Shape evolution of giant resonances in Nd and Sm isotopes †

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A giant resonance (GR) is a typical high-frequency collective mode of excitation in nuclei. Effects of nuclear deformation on GRs have been investigated both experimentally and theoretically. Among them, the deformation splitting of the isovector giant dipole resonance (GDR), due to different frequencies of oscillations along the major and minor axes, is well established. Emergence of a double-peak structure of the photoabsorption cross section of ^{150}Nd and ^{152}Sm clearly indicates the onset of the deformation in the ground state. For the GRs with higher multipolarity, although deformation splitting is less pronounced, peak broadening has been observed. The detailed and systematic investigations of GRs would give us unique information on the shape transition in nuclei.

In contrast to low-energy modes of excitation, GRs substantially reflect bulk nuclear properties. Thus, their studies may provide information on nuclear matter. Although various macroscopic models have been applied to GRs, a quantitative description of GRs requires a microscopic treatment of nuclear response. For heavy deformed open-shell nuclei, the leading theory currently for this purpose is the quasiparticle-random-phase approximation (QRPA) based on the nuclear energy-density-functional (EDF) method. The QRPA based on the deformed ground-state configuration with superfluidity can treat a variety of excitations in the linear regime.

We develop a new calculation code of the deformed HFB and QRPA for use in the massively parallel computers to examine the applicability of the Skyrme-EDF-based QRPA to the excitation modes in heavy deformed systems. Using this new parallelized code, the deformation effects on the GRs in Nd and Sm isotopes are investigated. We perform numerical analysis for GRs with a multipolarity $L = 0 - 3$ with both isoscalar (IS) and isovector (IV) characters, and examine the incompressibility and the effective mass both in spherical and deformed nuclei.

Figure 1 shows the strength distributions of IS monopole and quadrupole excitations in the Sm isotopes. We discuss first the giant quadrupole resonance (GQR). With an increase in the mass number, the peak energy of the ISGQR becomes smaller. This is consistent with the experiment on the systematic observation[1),2)]. The K splitting, $E_{K=2} - E_{K=0}$, for the ISGQR is 2.8 MeV in ^{154}Sm. This is consistent with the experimental observation. Since the energy splitting associated with deformation is comparable to the smearing parameter of 2 MeV, the deformation splitting, which is clearly visible in the photoabsorption cross sections does not appear in the ISGQR.

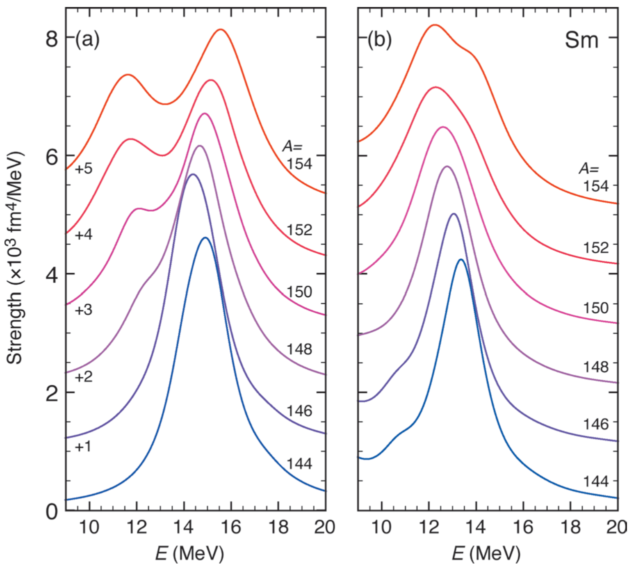

Fig. 1. Strength distributions (shifted) of (a) ISGMR and (b) ISGQR in Sm isotopes.

Next, let us discuss the giant monopole resonance (GMR). In the spherical nuclei, we can see a sharp peak at around 15 MeV which is identified as the ISGMR. The ISGMR in deformed nuclei has a double-peak structure. The higher-energy peak of the IS monopole strength is identified as a primal ISGMR and the lower-energy peak is associated with the coupling to the $K^\pi = 0^+$ component of the ISGQR. The lower peak of the ISGMR around 11 MeV is located at the peak position of the $K^\pi = 0^+$ component of the ISGQR.

For the ISGMR in ^{154}Sm, the SkM* functional gives the excitation energy, which is very close to the observed value[1)]. However, in ^{144}Sm, the SkM* underestimates the observation, and the SLy4 gives the reasonable energy. The present calculation suggests that the nuclear-matter incompressibility corresponds to about 230 MeV, as deduced from the comparison of the GMR excitation energy for ^{144}Sm, and 210 MeV for ^{154}Sm.

References

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