Quadrupole Oscillation in the Bose-Fermi Mixtures in the Time-Dependent Approach

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Over the last several years, there have been significant progresses in the production of ultracold gases, degenerate atomic Fermi gases. In particular the Bose-Fermi (BF) mixing gases attract physical interest as a typical example in which particles obeying different statistics are intermingled. The spectrum of the collective excitations is an important diagnostic signal for these systems. Such oscillations are common to a variety of many-particle systems and are often sensitive to the interaction and the structure of the ground state and the excited states.

We study the collective monopole motion¹ and dipole motion² of the BF mixture by solving the time-dependent Gross-Pitaevskii (TDGP) equation and the Vlasov equation. When the boson-fermion interaction is weak, RPA can also describe the above behaviors in early time stage². When the interaction becomes stronger, however, our approach shows quite different behaviors from RPA: fast damping of the fermion oscillation in the strongly repulsive interaction [1,2], and large expansion in the strongly attractive interaction.

In this work we calculate the quadrupole oscillations in the system $^{170}$Yb-$^{173}$Yb, which are realized by Kyoto group. The number of the bosons and the fermions are taken to be $N_b = 10000$ and $N_f = 1000$. In Fig. 1 we show results of the root-mean-square radius in the axial direction ($R_L$) and that in the transverse direction for boson (upper panel) and fermion (lower panel) which are normalized by each root-mean-square radius. In this system the boson-fermion interaction is strongly attractive, and we see that the fermi gas is expanded. We will find that the intrinsic frequency of the fermion quadrupole oscillation is very close to the intrinsic frequency of boson monopole oscillation. When the amplitude is large, the total angular momentum is much larger than $2\hbar$ and the quadrupole motion is mixed with the monopole motion and make resonance.