A numerical method of solving time-dependent Hartree-Fock-Bogoliubov equation with Gogny interaction

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The structure and dynamics of exotic nuclei have been the main subject of investigation both in the theoretical and the experimental nuclear physics. The peculiar feature of the exotic nuclei is that the Fermi level is located near the continuum levels. In this situation, the nucleons near the Fermi level are easily brought to the continuum states by pairing correlations. The low energy excitation modes are oten in the continuum energy region. The general mean-field method to treat the pairing correlations as well as the mean-field is the Hartree-Fock-Bogoliubov (HFB) method, which has played a central role in the investigation of the static ground state properties of the nuclei in a wide area of the nuclear chart [1]. The typical method to study the excited collective states of nuclei on top of the mean-field ground state with the pairing correlations is the quasiparticle random phase approximation (QRPA), which is known to be a small amplitude limit of the more general time-dependent Hartree-Fock-Bogoliubov (TDHFB) method. [2]

In the case of the HFB calculations with the Skyrme interactions (Skyrme HFB), the Skyrme interaction is used for the particle-hole channel, while the pairing interaction is introduced only for the particle-particle channel. Since the zero-range interaction is assumed in the Skyrme HFB, it is necessary to set the appropriate cut-off energy and choose the optimum parameter set in the pairing part.

In contrast with the Skyrme HFB, in the HFB calculations with the Gogny interaction (Gogny HFB), the particle-hole channel and the particle-particle channel are treated on an equal footing. Therefore, the Gogny force is suitable for the formulation of the self-consistent TDHFB.

Here in this short note, we report the formulation of the self-consistent TDHFB with the Gogny interaction and the results of solving the TDHFB equations in the case of oxygen isotope ^{20}O.

The equations of motion of the TDHFB matrices U and V are given as

$$i\hbar\frac{\partial}{\partial t}\begin{pmatrix} U(t) \\ V(t) \end{pmatrix} = \mathcal{H}\begin{pmatrix} U(t) \\ V(t) \end{pmatrix}, \quad \mathcal{H} = \begin{pmatrix} h & \Delta \\ -\Delta^* & -h^* \end{pmatrix}. \tag{1}$$

The mean-field Hamiltonian h and the pairing potential Δ are calculated by using the Gogny interaction. As an example of the numerical integration of Eq. (1), we show the case of oxygen 20 with a quadrupole type impulse initial condition. [3]

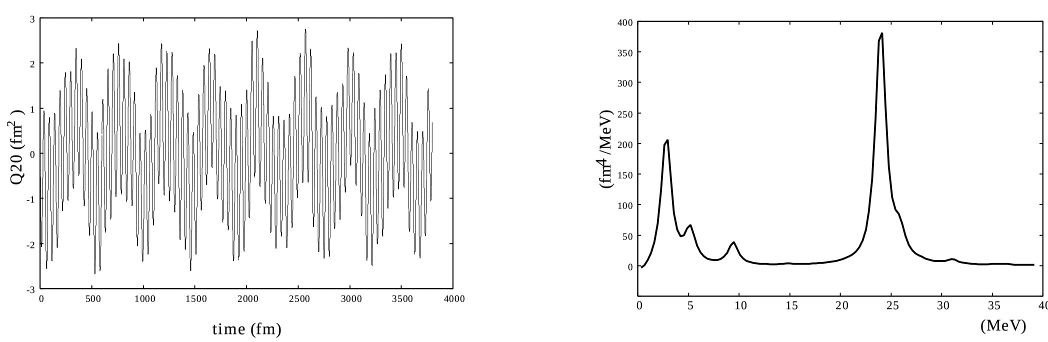

Figure 1: Time dependence of quadrupole moment in oxygen 20 (left) and strength function (right).

The left panel in Fig. 1 displays the time dependence of the quadrupole moment in oxygen 20. The right panel is for the strength function. Since, in oxygen 20, the neutrons (protons) are in the superconducting (normal) phase, the lower energy peaks in the strength function are related to the neutron excitations.

The numerical method of integrating the TDHFB equation (1) is not restricted to the case with spherical nuclear shape, but is applied to the deformed nuclei with pairing correlation. This is just the realization of the deformed quasi-particle random phase approximation (deformed QRPA). The results of the application of our method to the deformed nuclei will be reported elsewhere.

References

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