Numerical Calculation of Monomer Density Matrix of Nuclear Shell Model

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Abstract: The monomer density matrix was proposed independently by foreign scholars in 1927. The method of monomer density matrix has important applications in quantum mechanics. Therefore, the numerical calculation of the monomer density matrix of the nuclear shell model is studied. A method for calculating the density matrix of nucleus monomer in the mean field shell model is proposed, and the reliability of the method is verified. Studies have shown that the monomer density matrix is an important task in nuclear theory. In addition, the author believes that when further consider the nucleus as a system and link the multi-body association with the hierarchical structure of the system, the development trend of the multi-body association theory of nucleus can be shown. This is one aspect of the systematic tendency in the development of physics.

1. Introduction

The wave function of the nucleus contains all the information of the nucleus, but the calculation and representation of the multi-body wave function are more complicated [1]. The development of microscopic or semi-microscopic optical potential has a long history. It is based on the theory of nuclear multibody, using the nuclear-nuclear interaction potential and nuclear structure information to describe the interaction between the incident particle and the target nucleus. To some extent, it overcomes the difficulty in the application of phenomenological optical potential [2]. The two-level atom is an ideal model of the actual atom and can serve as a carrier of quantum information—a qubit for building memory cells or quantum logic gates in quantum computers. As important as the wave function in quantum mechanics, the density matrix has a wide range of applications in various physical branches [3]. The motion of independent particles, collective motion, group motion and random fluctuation in non-equilibrium process can be described in a unified way. Several commonly used nuclear multibody theories are unified and their results under different approximations [4]. One-body density matrix is the basic physical quantity of nuclei. It can easily calculate many physical quantities, such as the expected value of single-particle operators of ground state properties of nuclei, commonly used nucleon density, momentum distribution and so on. In recent years, great progress has been made in the development of micro-optical potential, which can describe and predict experimental data more accurately and extensively [5]. In addition to the theoretical study of nuclear structure, monomer density matrix has been widely used in many nuclear reaction model calculations, such as the calculation of semi-classical distorted wave (SCDW) model of multi-step direct reaction and the calculation of folding model of optical potential.

When the wave function of a single particle is approximated by plane wave, the density matrix of a single particle usually has an analytical form, such as that of an analytical density matrix based on the Fermi gas model [6]. The JLM model uses the Br-bit ekner-Hartre-eoFck (BHF) theory to calculate the mass operator in nuclear matter. The optical potential in nuclear matter is obtained from the mass operator, and then the optical potential of finite nucleus is obtained by local density approximation (LD) A [7]. If the weakly time-dependent external potential has been recognized, then Dyson's desired resonance function can obtain an accurate calculation of the magnetization of the interacting electronic system. In addition, the magnetic susceptibility appears polarity at the correct transition frequency [8]. However, quantum computers cannot be completely isolated from the external environment, and interaction with the environment will cause the encoded information to be lost into an environment beyond our control, thus destroying quantum computing [9]. In

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recent years, with the development of quantum computer and quantum information research, the density matrix form has been widely used [10]. However, there are always some differences and arguments about the definition and understanding of density matrices. Currently, in the calculation of nuclear reaction models, it is relatively simple. Based on the shell model, this paper proposes a simple calculation method for the single density matrix under the Woods-Saxon potential, which can be conveniently applied to the nuclear reaction model to describe the state of the nucleus. In principle, the method is also applicable to any form. Interaction potential.

2. Calculation Method of Shell Model Monomer Density Matrix

2.1. Density matrix calculation method

The computable form of the single density matrix under the average field-shell model is derived. The purpose is to conveniently apply to the calculation of the nuclear reaction model, rather than to study the nature of the nucleus. Therefore, the influence of the residual interaction is not considered in the interaction. The two key points are the description of the interaction of two nucleons in the nuclear medium and the description of the state of the target nucleus. Therefore, the improvement and development of the folding model are mostly concentrated on these two aspects. For the study of the exact state including the symmetric low energy density function constructed by the hypothesis, the direct method is to use the Hohenberg-Kohn theorem. The feature quantity of this case is determined by the symmetric operation of the Hamiltonian. Firstly, we define that the neutron and proton orbits of the nucleus are closed shells, and derive the monomer density matrix of the neutron or proton. At the end of this section, we will give an approximate treatment of the monomer density matrix of the neutron and proton orbits in the case of non-closed shells. Generally speaking, the environment is very complex, with a certain temperature of gas or liquid, thermal radiation, light, etc., the most typical is the electromagnetic field. We note that the problem begins with whether there is quantum entanglement in NMR quantum computation. The folding model uses BHF theory to construct the effective NN interaction potential in finite nuclei, and folds the effective NN interaction between the nuclear density and the effective NN interaction to obtain the optical potential.

In general form, the monomer density matrix of nuclei is defined as:

$$-\ln\left(\frac{C}{C_0}\right)=kt \tag{1}$$

In the mean field shell model, the monomer density matrix can be written as follows:

$$WS=\sum_{j=1}^{m} w_j FS_j \tag{2}$$

The monomer density matrix of nuclei can be expressed as the sum of the neutron monomer density matrix and the proton monomer density matrix.

$$I=I_L-I_D-I_{sh} \tag{3}$$

For neutron or proton monomer density matrix, where I is the number of neutrons or protons, and T is the single particle wave function of the S th neutron or proton. The diagonal element of the monomer density matrix is the density distribution of the nucleus.

$$I_L=\left(\frac{S_T}{S_{T,\tau}}\right)\left[I_{L,\tau}+\mu_{I_{SC}}\left(T_c-T_{c,\tau}\right)\right] \tag{4}$$

2.2. The application of algorithms

The above deduction is applicable to all nuclei with closed proton and neutron levels (orbits). In order to better describe the experimental data, a density-dependent factor, called DDM3Y, was

introduced into the M3Y effective interaction. Later, the density-dependent effective interaction, which can give both the optical potential and the properties of nuclear matter, was further developed. The density function of the symmetric label in the symmetric wave function of the restricted minimum estimate can be accurately expressed by the constraint method. Whether spin particles or two-level atoms will interact with the electromagnetic field, and this background electromagnetic field is ubiquitous, it may come from the external, or from the electromagnetic radiation generated by adjacent particles in the system. We further found that the key to the problem is whether the ensembles with the same density matrix are physically equivalent, which are generally considered equivalent, but there are also some well-known physicists who think they are not equivalent. The multi-body association caused by the remaining interacting clusters of fish is responsible for group movement. Fluctuations in the flat field and multi-body associated structures caused by residual effects other than the mean field and the agglomerating force result in random motion. Our research suggests that the incompatibility of superluminal speed is not related to the indistinguishability of ensembles. Therefore, self-consistent mean field, multi-body association (especially two-body, four-body association) and fluctuations are some basic elements for understanding the structure and motion of the atomic nucleus.

3. Calculation Results and Analysis

In folding model, the energy dependence of folding potential comes not only from the energy dependence of the effective interaction potential, but also from the self-exact calculation of the exchange term. How to calculate the exchange term well is very important in folding model. Here, molecules are generalized. Any quantum system can become a molecule, such as a nucleus, an atom and an electron. It can be called a molecule in a broad sense. It is worth pointing out that there is no interaction between molecules in the ensemble, and there is no phase consistency between wave functions of different molecules. Therefore, the multi-body association caused by interaction is a more basic concept. Correctly describing and dealing with multi-body association is one of the keys to understanding the structure of the atomic nucleus. However, the shell model also does not describe well the larger momentum components of the nucleus. This is because the shell model does not consider the nuclear residual interaction. Considering the nuclear model of the residual interaction, such as the coherent density fluctuation model (CDFM), the larger momentum component is described compared to the shell model. In the classical electric field, if the non-decaying two-level atomic system starts in a pure state, then it will also be in a pure state and maintain good coherence. From the meaning of the density matrix, we believe that the quantum properties of nuclear magnetic resonance are reflected in each molecule rather than in the ensemble, even if all the states of the ensemble are pure, there is no entanglement between different molecules.

The calculated monomer density matrix cannot be directly verified by experimental data. Therefore, the folding model can only give the real part of the optical potential, and the imaginary part must be added to calculate the scattering cross section in the optical model. The characteristic equations for finite families and different lattice structures and periodic boundary conditions can be explained numerically. Even if two molecules are in the same microscopic quantum state, the phase factor between the two molecules is arbitrary. Nuclear physics is developing with the deepening of the understanding of nuclear multi-body associations; the multi-body theory of nucleus is also developing along the direction of correctly dealing with multi-body associations. The key to the controversy is whether the ensemble with the same compressive density matrix is physically equivalent. We consider that ensembles with the same compressive density matrix are physically inequivalent. Inspired by various dispersed and specific multibody correlation theories (model theory), the multibody correlation dynamics of nuclei has been developed on the basis of the general Multibody Theory of nuclei. However, recently it has been considered that there is no quantum entanglement in NMR quantum computation, so it is not considered that NMR quantum computation is a real quantum computation.

4. Conclusions

We know that the method of solving density matrix can describe the information of a system more generally than the method of solving state function. Moreover, using density matrix to represent state can describe pure state system and mixed state system in a unified way. We suggest three different names: complete density matrix, compact density matrix and reduced density matrix. In the review, we found and emphasized the development trend of nuclear multibody theory, that is, from perturbation theory to multibody correlation theory. The calculated density distribution and the number of nucleons calculated from the density distribution are in good agreement with the experimental or theoretical values. When the nucleus has obvious deformation, the nuclear deformation factor should be further considered and the single particle wave function should be solved in the deformation field. It should be noted that this paper only considers the average field effect, and further work should consider the effects of residual interactions. The monomer density matrix of the nucleus is not only used for the study of the properties of the nucleus, but also for the description of the state of the nucleus in the nuclear reaction model. We are planning to use it in the calculation of the optical model of the nuclear reaction. One point is to consider the dispersion relationship to study the matching of the real part and the imaginary part of the optical potential, and to uniformly consider the optical potential of the scattering nucleus and the single-particle potential of the bound nucleus, in order to deepen the understanding of the nuclear potential and achieve better results.

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