SD-Pair Shell Model and Proton-Neutron Interacting Boson Model*

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Abstract The typical spectra corresponding to the $U(5)$, $SO(6)$ and $SU(3)$-limiting cases in the interacting boson model are studied within the framework of nucleon-pair shell model truncated to SD-subspace. It is found that they can all be reproduced approximately in the SD-pair shell model.

Key words nucleon-pair shell model, interacting boson model

1 Introduction

The discovery of collective motions, such as collective vibration, collective rotation, giant resonances, etc. in the medium and heavy nuclei is one of the great wonders in nuclear physics. How to describe these collective motions in terms of fermion degree of freedom is an interesting and challenging problem in theory of nuclear structure.

Since the modern computing tool is still out of reach for a direct large––space shell model calculation, one has to use some kinds of truncation schemes. By using the generalized Wick theorem for fermion clusters\cite{1}, the nucleon-pair shell model (NPSM) has been proposed for nuclear collective motion\cite{2}. Because the computing time increases drastically with the size of the subspace, for applying this model to medium and heavy nuclei, we have to truncate the shell model space to the collective SD subspace, which is called the SD-pair shell model(SDPSM).

It is the aim of this paper to see if the SDPSM can reproduce the vibrational, rotational and $\gamma$-soft spectra corresponding to those of $U(5)$, $SU(3)$ and $SO(6)$-limit spectra shown in the IBM\cite{3}.

2 A Brief review of the model

The Hamiltonian is chosen to be

\[ H = H_\sigma + H_\nu - \kappa Q_\pi^2 Q_\nu^2, \]
\[ H_\sigma = \sum_{\sigma a} \varepsilon_{\sigma a} n_{\sigma a} - GS^+ (\sigma) S (\sigma), \]
\[ Q_\mu^2 = \sqrt{16\pi/5} \sum_{i=1}^n r_i^2 Y_{2\mu} (\vartheta_i \varphi_i), \]

where the $\varepsilon_{\sigma a}$, $G_\sigma$ and $\kappa$ is the single particle energy for orbit $a$, pairing interaction strength and quadrupole-quadrupole interaction strength, respectively.

The E2 transition operator is

\[ T(\text{E2}) = e_\pi Q_\pi^2 + e_\nu Q_\nu^2 \]

where $e_\nu$ and $e_\pi$ are effective charges of neutron and proton, respectively. The collective pairs $A_{\mu}^+$ of angular momentum $r = 0, 2$ with projection $\mu$ are

\[ A_{\mu}^+ = \sum_{ab} y(abr) (C_{\mu}^+ \times C_{\mu}^+) , \]

where $y(abr)$ is the structure coefficients. We shall restrict ourselves in this paper to the case of degenerate $j$-orbits to simplify the treatment. Thus the $S$-pair structure coef-