Triaxial projected shell model study of γ-vibrational bands in ^{80}Sr

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Introduction

The nuclei in the mass region A = 60 - 90 have been the subject of extensive experimental and theoretical treatment in the last many years. These nuclei exhibit a variety of nuclear phenomena like co-existence of shapes, large ground state deformation, band crossing, rapid variation of structure with changing nuclear number, etc. From the study of literature, it has been found that ^{80}Sr is a classic example of soft deformed rotor in the A~80 region. It was one of the first nuclei to be identified as having a large quadrupole deformation in a pioneering heavy-ion study by Morinaga's Munich group [1]. Moreover, the study of low-and high-spin phenomena in the neutron-deficient mass-80 nuclei has also attracted considerable interest in recent years. T.A. Sienko et al [2] have investigated shape softness and quasiparticle excitations in ^{80}Sr. They have found several new rotational bands. They have clearly delineated the γ-vibrational band and identified more than ten quasiparticle band heads.

The purpose of the present work is to investigate the high-spin properties of ^{80}Sr using the recently-developed multi-quasiparticle (qp) Triaxial Projected Shell Model (TPSM) approach [3].

Outline of the Framework

In TPSM, apart from 0-qp, the higher quasiparticles like 2- and 4-qp configurations are explicitly included in the basis space. Therefore, it is possible for the model to study high-spin band structures, which emphasizes the interplay between collective and single-particle excitations, and thus, to probe single-particle structures in the neutron-rich mass region A~ 80.

In TPSM, triaxially-deformed Nilsson states are employed as a starting basis to describe a nucleus exhibiting axial and triaxial deformations. An explicit three-dimensional angular-momentum projection is then performed for configurations built from the deformed Nilsson states. A triaxial qp configuration is an admixture of different K (projection along the symmetry axis) states, and the vacuum configuration is composed of K=0,2,4,...states for an even-even system. It has been shown that the angular-momentum projection from the K = 0, 2, and 4 states correspond to the ground, γ- and γγ-bands, respectively.

The model has recently been extended [4,5] to include multi-qp configurations in the model space, which allows one to describe states of collective γ-vibrations and qp excitations on an equal footing. For instance, the multi-qp TPSM approach has been used to investigate the interplay between the vibrational and the quasi-particle excitation modes in $^{166-172}$Er [4]. It was demonstrated that a low-lying K=3 bands observed in these nuclei, the nature of which had remained unresolved, are built on triaxially-deformed 2-qp states. This band is observed to interact with the γ-vibrational band and becomes favored at high angular-momentum.

Results and Discussion

TPSM calculations proceed in several stages. In the first stage, the deformed basis space is constructed by solving the triaxially-deformed Nilsson potential. In the present work, we have employed $\varepsilon = 0.308$ and $\varepsilon' = 0.175$ in the Nilsson potential to generate the deformed basis for ^{80}Sr. The value of ε has been adopted from "Moller and Nicks" and the value of ε' is chosen in such a way that the band head of the γ-band is reproduced and is also consistent with the value obtained from the minimum of the potential energy surface. Pairing is described by performing a BCS calculation for the single-particle states generated by the triaxially-deformed Nilsson potential. In the second step, the good angular-momentum states are obtained from the deformed basis by employing the three-dimensional angular-momentum projection technique. The projected bands obtained from 0-, 2-, and 4-qp states close to the Fermi surface are displayed in Fig. 1, the so-called band diagram. A band diagram is a set of projected energies for various intrinsic configurations, i.e., the diagonal matrix elements before configuration mixing. The projection formalism not only projects out the angular momentum, but also the "K" value which is specified in the projection matrix and, therefore, projected bands are also specified by this quantum number. The projection from the 0-qp configuration gives rise to band structures with K=0, 2, 4, corresponding to the ground-, γ- and γγ-band. In the third and the final stage, the projected bases are used to diagonalize the shell model Hamiltonian. The band energies, obtained after diagonalization are shown in Fig.2, along with the available experimental data. It is evident from this figure that TPSM results are in excellent agreement with the known experimental energies for both ground- and γ-bands. In Fig.2, the excitation spectrum is predicted for the γγ-band, and we hope that this well-developed band will be populated in future experimental studies. However, we would like to mention here that one of the major discrepancy that has surfaced in the application of the TPSM approach is the band head energy of the γγ-band. It has been observed that for most of known cases, TPSM calculations underpredicts band head energy of this band by more than 1 MeV. It is expected for the γγ-band to have siginificant vibrational component because of mixing with the quasiparticle states which are close in energy. We hope that by performing GCM (Generator coordinate method) with both β and γ as generator coordinates, the γγ-band and other properties shall be described more accurately.

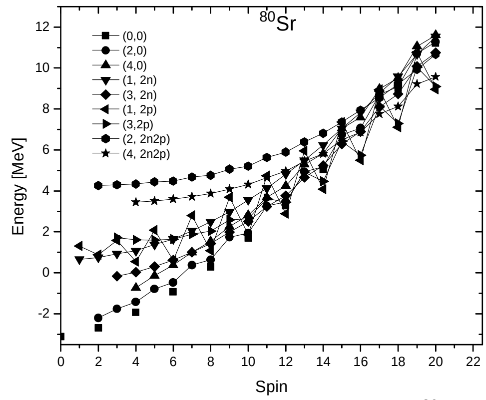

Fig. 1. Theoretical band diagram for ^{80}Sr.The labels (0,0), (2,0),and (4,0) correspond to the K=0 ground-, K=2 γ-, and K=4 γγ-band, respectively.

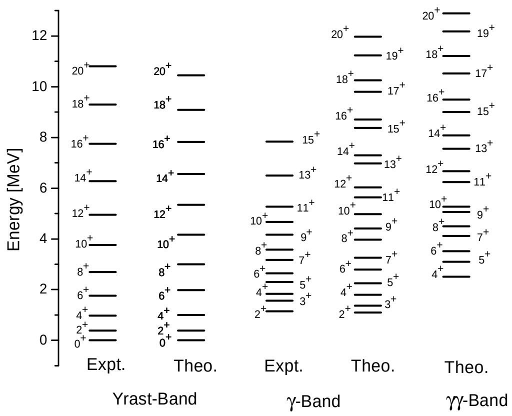

Fig. 2. Comparison of experimental and the calculated band energies for ^{80}Sr.

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