A New Microscopic Multiphonon Approach to Nuclear Spectroscopy : Application to ^{16}O

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We have derived a more consistent version of an equation of motion method developed few years ago [1, 2] to generate a basis of multiphonon states. We obtain eigenvalue equations within subspaces spanned by states built of products of n Tamm-Dancoff phonons. All quantities are expressed in terms of those obtained in the $(n-1)$-phonon subspace. This makes feasible a recursive procedure for generating a basis of $\{|n=0>, |n=1>, \ldots, |N>\}$ phonon states. In such a basis, the Hamiltonian matrix has a very simple structure and can be brought easily to diagonal form.

The eigenvalue problem so formulated is, in principle, exact and, as such, is equivalent to shell model. Unlike random-phase-approximation (RPA) or higher RPA, it does not rely on the quasi-boson approximation and yields an explicitly correlated ground state.

We applied the method to ^{16}O, which represents a challenge to all many-body approaches. The calculations were performed in a space spanned by up to $N = 3$ phonon states using either the Nilsson or the Hartree-Fock single particle basis and a realistic two-body potential. To our knowledge, this is the first microscopic multiphonon calculation which diagonalizes a realistic Hamiltonian in a space covering up to three-phonon states and includes explicitly correlations in the ground state.

We found that both energy levels and transition strengths are quite sensitive to the single-particle basis and to the phonon coupling. The choice of the basis affects the position of the levels as well as the shape of the giant resonances. Concerning the phonons, we found that the coupling between states differing by two phonons is the strongest one. More specifically, the two-phonon states affect greatly the properties of the ground state, while the three phonons couple strongly to the one-phonon states. Such a phonon coupling induces a large shift of the levels as well a quenching and a redistribution of all the $E\lambda$ giant resonance peaks. It follows that the three-phonon states are an essential ingredient of any microscopic multiphonon study of collective nuclear spectra and giant resonances.

1. F. Andreozzi F. Knapp, N. Lo Iudice, A. Porrino, and J. Kvasil, Phys. Rev. C **75**, 044312 (2007).
2. F. Andreozzi, F. Knapp, N. Lo Iudice, A. Porrino, and J. Kvasil, Phys. Rev. C **78**, 054308 (2008)