Nuclear Structure at High Temperature

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Abstract: Fully self-consistent microscopic approaches to the nuclear structure in the off-yrast region are reviewed with special emphasis layed on the basic importance of the thermal Hrtree-Fock-Bogoliubov (THFB) approximation.[1-4] for the description of average properties of highly excited nucleus, and the thermal RPA (TRPA) on top of the THFB quasiparticle picture in taking account of the thermal effect on the mean field for the description of giant dipole resonances (GDR) built on the hot rotating nucleus.[5-8]

It has been shown that the particle number- and angular momentum-constrained Hartree -Fock-Bogoliubov (CHFB) approximation[9] can provide correct microscopic interpretation of the backbending behaviour of rotational level sequence along yrast in terms of the gapless superconductivity,[10] detailed informations about behaviour of single-particle orbitals in coexisting different shapes,[11] accurate simultaneous reproduction of both backbends and g-factors[12] and reproduction of superdeformed bands for the nuclides in the $A = 130$ region.[13] Preserving these outstanding merits of the CHFB scheme as a fully self-consistent mean field approximation, one can extend the formalism with statistical recipe to the thermal HFB (THFB) approximation which is useful in the description of the off-yrast states of nucleus. Some details of the variational derivation of the THFB equation and related formalism have been presented in Ref. 2). The THFB solution can produce a detailed phase diagram of deformed nucleus showing the super-normal phase transition caused by the combined effect of rotation and temperature[1,3] and the possibility of bidirectional alignment of spins in the small angular momentum region for the case of ^{164}Er.[4]

A remaining fundamental problem for the THFB formalism was how to prove the Bloch-Messiah theorem[14] for the finite temperature formalism and how to define the level-dependent order parameters in the THFB frmalism. This problem can be solved[15] by applying the thermo field dynamics (TFD).[16,17] This must be the final completion of the THFB formalism.

The TRPA formalism[5,6] has been developed to describe the GDR at high tempera -

tures.[18] The basic quasiparticle picture is provided by the THFB solution, on top of which the linear response function for the dipole operator corresponding to the displacement vector from the center of mass for protons to the one for neutrons. Overall trends of the GDR observed in some deformed nuclei are well reproduced from the TRPA calculations.[7,8] To take account of more thermal correlations, further possibility of extending the TRPA formalism is discussed in Ref. 19). By applying the TFD to the variational derivation of the extended TRPA equation, a minimum point of the grand potential is searched for in the RPA parameter manifold of larger dimensionality corresponding to doubled single-particle operator space.

References

1) K. Tanabe and K. Sugawara-Tanabe, Phys. Lett. **97B** (1980) 337.
2) K. Tanabe, K. Sugawara-Tanabe and H. J. Mang, Nucl. Phys. **A357** (1981) 20.
3) K. Sugawara-Tanabe, K. Tanabe and H. J. Mang, Nucl. Phys. **A357** (1981) 45.
4) K. Tanabe and K. Sugawara-Tanabe, Nucl. Phys. **A390** (1982) 385.
5) K. Tanabe and K. Sugawara-Tanabe, Phys. Lett. **172B** (1986) 129.
6) K. Tanabe and K. Sugawara-Tanabe, Prog. Theor. Phys. **76** (1986) 356.
7) K. Sugawara-Tanabe and K. Tanabe, Prog. Theor. Phys. **76** (1986) 1272.
8) K. Sugawara-Tanabe and K. Tanabe, Phys. Lett. **192B** (1987) 268.
9) H. J. Mang, Phys. Rep. **18** (1975) 325.
10) B. Banerjee, H. Mang and P. Ring, Nucl. Phys. **A215** (1973) 366.
11) K. Tanabe and K. Sugawara-Tanabe, Phys. Lett. **135B** (1984) 353.
12) K. Sugawara-Tanabe and K. Tanabe, Phys. Lett. **207B** (1988) 243.
13) K. Tanabe and K. Sugawara-Tanabe, Prog. Theor. Phys. **83** (1990) 1149.
14) C. Bloch and A. Messiah, Nucl. Phys. **39** (1962) 95.
15) K. Tanabe and K. Sugawara-Tanabe, Phys. Lett. **347B** (1990) 202.
16) Y. Takahashi and H. Umezawa, Coolect. Phenom. **2** (1975) 55.
17) H. Umezawa, H. Matsumoto and M. Tachiki, *Thermo field dynamics and condensed states* (North-Holland, Amsterdam, 1982).
18) J. O. Newton et al., Phys. Rev. Lett. **46** (1981) 1383.
19) K. Tanabe, Phys. Rev. C **37** (1988) 2802.