CONF-8705188--1

CONF-8705188--1

DE87 012925

OCTUPOLE INSTABILITY IN THE HEAVY BARIUM REGION

W. Nazarewicz[a,b], G.A. Leander[c] and S. Tabor[d]

[a]Florida State University, Supercomputer Computations Research Institute, Tallahassee, Florida, U.S.A.
[b]Institute of Physics, Warsaw Institute of Technology, Warsaw, POLAND
[c]UNISOR, Oak Ridge Associated Universities, Oak Ridge, Tennessee, U.S.A.
[d]Dept. of Physics, Florida State University, Tallahassee, Florida, U.S.A.

Quasi-molecular rotational bands characterized by spin states of alternating parity connected by enhanced E1 transitions have recently been observed in several transitional nuclei around ^{224}Th. The appearance of such bands can easily be understood by assuming the absence of intrinsic parity symmetry in these nuclei. Strong correlations resulting from an octupole interaction between intruder states and normal parity states may lead to pear-like shapes which violate the mirror symmetry.

Another likely region on the chart of nuclides to find octupole-unstable nuclei is the region of nuclei around ^{146}Ba. In fact, in several Xe, Ba and Ce isotopes with N≈88 calculations yield octupole-unstable ground states [1]. The calculations of ref. [1] have been supported [2] by various experimental evidences but, until very recently, no quasimolecular rotational bands in nuclei near Z=56 and N=88 have been found. These nuclei are fission products and are not accessible with heavy ion induced reactions.

In the present study we extended the I=0 calculations of ref. [1] to higher spins. The main goal was to calculate equilibrium deformations of doubly-even Xe, Ba, Ce, Nd, Sm and Gd nuclei with neutron numbers between 84 and 94. The method used was the Woods-Saxon-Bogolyubov cranking model combined with the shell correction approach. Recently this model was employed [3] to discuss selected high spin properties of light Ra and Th nuclei around ^{224}Th. There are, however, two main points which differ the model of ref. [3] from the present approach. First, the total routhian is now minimized with respect to the hexadecapole deformation β_4. Secondly, the pairing gap is assumed to be a smoothly decreasing function of the rotational frequency. The actual form of this function was determined on the basis of the particle-number conserving HFBC calculations.

Selected results of the deformation self-consistent calculations are summarized in figs. 1 and 2, which display deformation trajectories for the yrast (and sometimes: yrare) configurations of the relevant Ba and Sm nuclei. According to previous calculations [1] ^{144}Ba nad ^{146}Ba are the most octupole-deformed nuclei at I=0 of all the nuclei discussed.

MASTER

DISCLAIMER

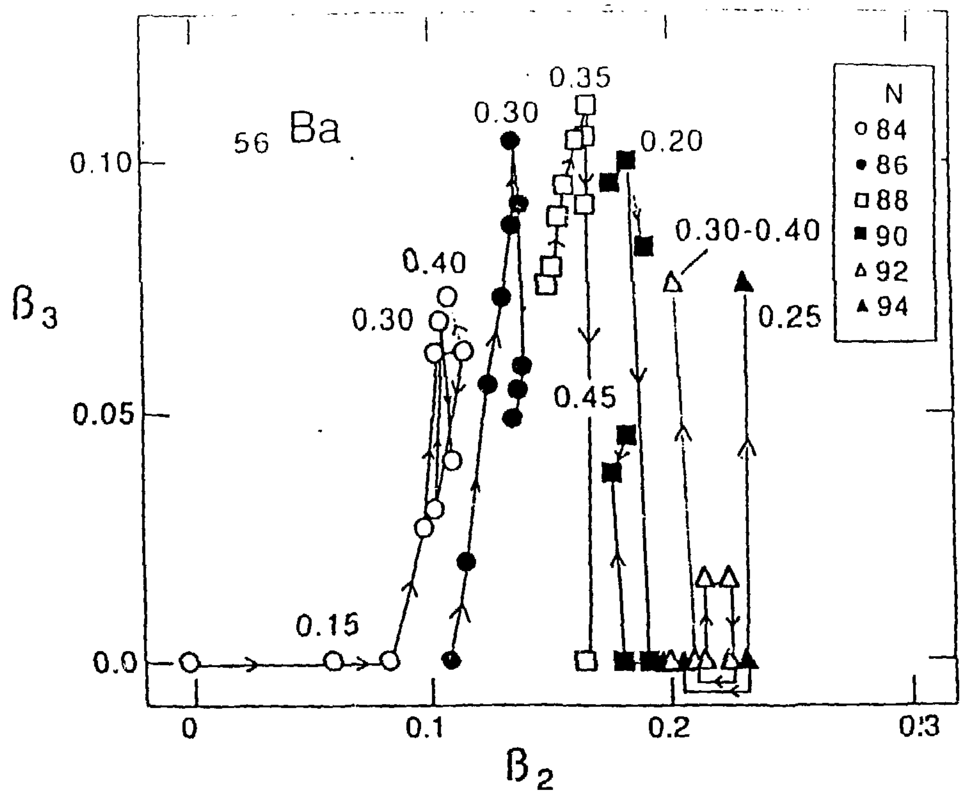

Fig. 1 Calculated equilibrium deformations for doubly-even $^{140-150}$Ba nuclei at rotational frequencies going from 0 to 0.5 MeV/ħ.

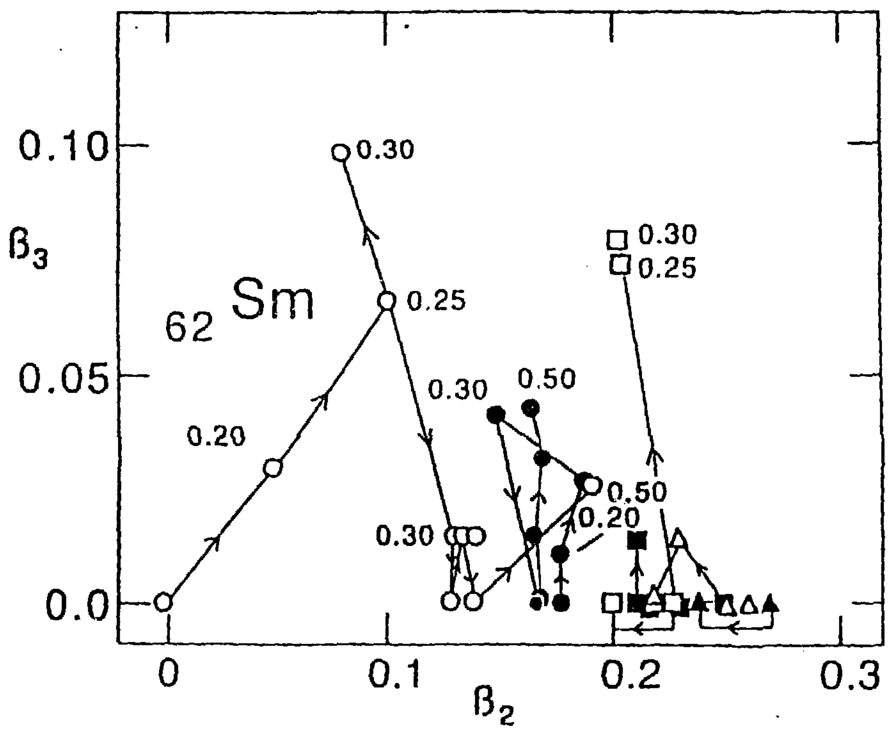

Fig. 2 Similar to fig. 2 but for $^{144-154}$Sm nuclei.

The calculations indicate that they become even more pear-shaped at higher rotational frequencies. For example, at $\hbar\omega$=0.35 MeV the octupole deformation in ^{144}Ba becomes as large as β_3=0.11. Recently, experimental data for ^{144}Ba and ^{146}Ba have been reported [4]. The observed rotational patterns and the presence of enhanced E1 transitions strongly support the picture of octupole deformation in these nuclei setting in at medium spins, see fig. 3.

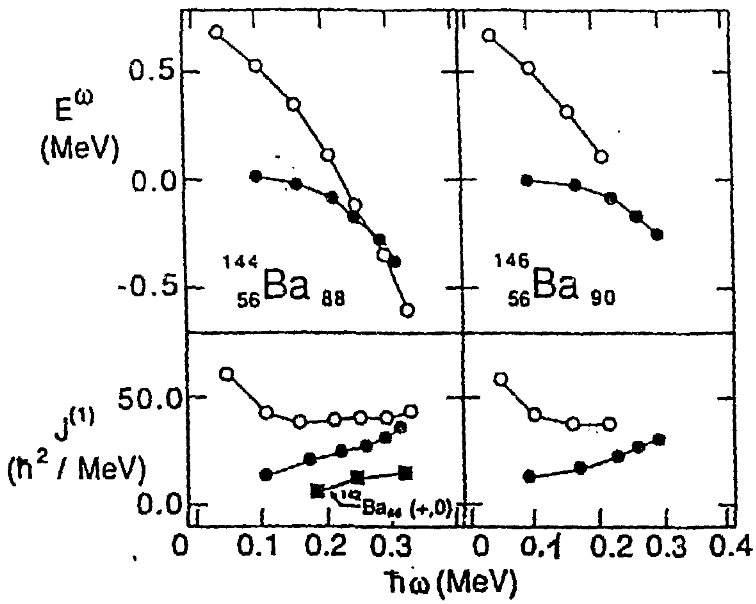

Fig.3 Experimental routhians and kinematical moments of inertia for the π=+ (●) and π=− (O) yrast bands in ^{144}Ba and ^{146}Ba. Experimental data were taken from ref. [4].

At frequencies above 0.3 MeV a shape transition towards β_3=0 is expected due to the band crossing with the $\nu(i_{13/2})^2$ and $\pi(h_{11/2})^2$ bands. Similar shape changes (caused by the alignment of $\nu j_{15/2}$ and $\pi i_{13/2}$ pairs) have recently been predicted [3] for neutron deficient actinide nuclei to occur slightly above I=24. In nuclei around ^{222}Th such effects may be very difficult to observe experimentally because of fission competition. However, in the considered Xe−Sm isotopes the transition to reflection symmetric shapes is expected to occur around I=12 which is more easy to reach experimentally. Indeed, recent data on ^{148}Sm [5] and ^{150}Sm [6] suggest that a band crossing associated with a shape change does occur in these nuclei. The results shown in fig. 2 fully support such interpretation. For ^{148}Sm as well as for ^{150}Sm the octupole-deformed configurations are predicted to become yrast or close to yrast at $\hbar\omega$=0.25−0.30 MeV. While ^{150}Sm stays at the β_3=0 limit after the neutron and proton crossings, in ^{148}Sm the second transition into the octupole plane is predicted at higher spins.

^{140}Ba has a spherical ground state minimum but due to the centrifugal stretching it quickly becomes deformed. In fact, at $\hbar\omega \gtrsim$0.25 MeV the shape of ^{140}Ba becomes octupole unstable. Another possible candidate for an octupole rotor is ^{142}Ba. The octupole instability stays in this nucleus up to the highest rotational frequencies considered in our calculations.

A pronounced octupole instability at high spins has also been predicted in $^{138-144}$Xe, $^{142-146}$Ce, $^{144-148}$Nd, i.e. in all the nuclei with neutron numbers N=84, 86, 88.

Another piece of evidence supporting the octupole picture comes from the B(E1) transitions between the lowest positive and negative parity bands. The E1 moments in the octupole - unstable actinides have been already interpreted in ref. [7] by means of the shell correction method. A similar approach has been employed in the present study. The theory nicely accounts for the observed values in ^{144}Ba, ^{146}Ba and ^{150}Sm. The very large B(E1)/B(E2) branching ratios of the order of 10^{-6} fm^{-2} seen in ^{150}Sm can be explained in terms of constructive proton and neutron contributions to the total E1 moment. Also reduced B(E1)/B(E2) values in ^{146}Ba compared to ^{144}Ba are explained within the same shell model picture.

In summary, the Woods-Saxon-Bogolyubov cranking calculations [8] confirm previous expectations of octupole deformed mean fields at low and medium spins in Xe-Sm nuclei with neutron numbers around N=86. Recent experimental data support theoretical results.

Supported in part by the Florida State University Supercomputer Computations Research Institute which is partially funded by the U.S. Department of Energy through contract no. DE-FC05-85ER250000 and by the Polish Ministry of Science and Higher Education through contract CPBP 01.09. UNISOR is a consortium of twelve institutions, supported by them and by the Office of Energy Research of the US Department of Energy under contract no. DE-AC05-76OR0003 with Oak Ridge Associated Universities.

1. W. Nazarewicz, P. Olanders, I. Ragnarsson, J. Dudek, G.A. Leander, P. Möller and E. Ruchowska, Nucl. Phys. A429 (1984) 269.
2. G.A. Leander, W. Nazarewicz, P. Olanders, I. Ragnarsson and J. Dudek, Phys. Lett. 152B (1985) 284.
3. W. Nazarewicz, G.A. Leander and J. Dudek, Nucl. Phys. A, in press.
4. W.R. Phillips, I. Ahmad, H. Emling, R. Holtzmann, R.V.F. Janssens nad T.-L. Khoo, Phys. Rev. Lett. 57 (1986) 3257.
5. W. Urban, R.M. Lieder, W. Gast, G. Hebbinghaus, A. Krämer-Flecken, K.P. Blume and H. Hübel, Phys. Lett. 185B (1987) 331.
6. W. Urban et al., to be published
7. G.A. Leander, W. Nazarewicz, G.F. Bertsch and J. Dudek, Nucl. Phys. A453 (1986) 58.
8. W. Nazarewicz, G.A. Leander, S. Tabor and J. Dudek, to be published.