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Акулиничев С.В., Малов Л.А.

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Описание гигантских квадрупольных резонансов в нечетных деформированных ядрах

В рамках полумикроскопической модели предложен способ описания электромагнитных переходов в широком диапазоне энергий для нечетных деформированных ядер.

Приведены результаты расчетов для ^{165}Ho, ^{155}Gd.

Работа выполнена в Лаборатории теоретической физики ОИЯИ.

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Akulinichev S.V., Malov L.A.

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On Giant Quadrupole Resonances in Odd-A Deformed Nuclei

In the framework of the semimicroscopic model a method is proposed for description of the electromagnetic transitions in a large energy range for odd-A deformed nuclei. Calculation results are given for ^{165}Ho, ^{155}Gd.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

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The structure of odd-A nuclei at present is successfully described within the semimicroscopic model taking account of pairing and residual multipole-multipole, spin-multipole, spin-spin and other interactions (see, e.g., /1/ and references therein). Such an approach allows one to describe the energy and structure of low-lying states of odd-A deformed nuclei /2/. However, at energies of several *MeV* a detailed study of each level makes no sense due to strong increase in the density of states and its complicated structure. Under these conditions, nuclei should be described by means of strength functions and other averaged characteristics /3,4/.

To determine $E2$ -transitions from the state i to states in the energy range near $\mathcal{E}$ one may introduce the strength function

$$b(E2,\mathcal{E}) = (I_i K_i \lambda\mu | I_f K_f)^2 \sum_f \langle i | \mathfrak{M}(E2) | f \rangle^2 \rho(\eta_f - \mathcal{E}), \quad (1)$$

where $\mathcal{E}$ is a searched energy, η_f - the energies of excited states, $\rho(\eta_f - \mathcal{E}) = \frac{1}{2\pi}\frac{\Delta}{(\eta_f - \mathcal{E})^2 - (\Delta/2)^2}$, $\mathfrak{M}(E2)$ is the operator of the electric quadrupole transition.

We make use of the intrinsic wave functions which are the eigenfunctions of the Hamiltonian including the interaction of quasiparticles with isoscalar multipole-multipole phonons /1/. The phonons are calculated within the RPA (random phase approximation) and are taken in an odd-A nucleus the same as in a neighbouring even-even nucleus. Therefore in the odd-A nucleus there are no free parameters. Due to normalization of the weighted function the integral of (1) over some energy range equals approximately the reduced transition probability to states in that range. The result thus is almost independent of Δ that influences only the smoothness of the function $b(E2, \mathcal{E})$.

The use of the properties of analytic functions allows one to dispense with solving the eigenvalue problem of the excited states of a nucleus: one uses just the property that the sum of residues at poles of a function, analytic throughout but a finite number of points, equals zero. Expression (1) can be represented as a sum of residues of some complex function at single poles which are situated on the real axis and are the roots of the energy secular equation for η_f. Hence $b(E2, \mathcal{E})$ can be found by determining the sum of residues of the function at all remaining poles of the complex plane [5].

In the numerical calculations we utilize parameters of the Saxon-Woods potential and interaction constants following ref. [2]. The effective charge is taken zero, the averaging parameter $\Delta = 0.15$ *MeV*. Results shown in *fig. 1* correspond to the transitions to levels with all

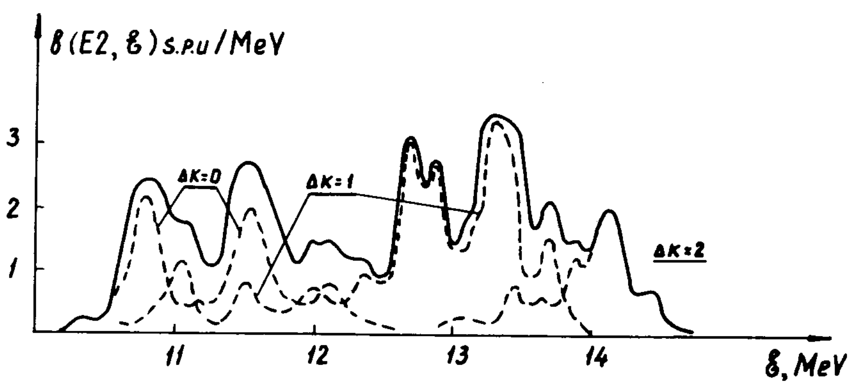

Fig. 1. The strength function of the E2-excitation for ^{165}Ho *(dashed curves are individual strength functions for* $\Delta K = 0,1,2$*).*

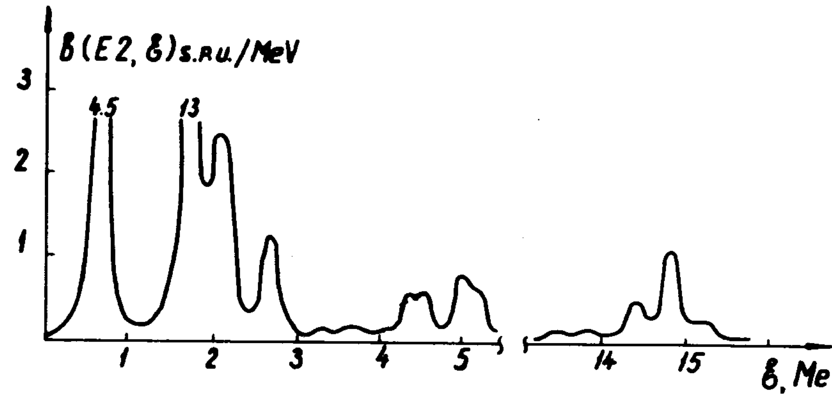

Fig. 2. The strength functions of E2-transitions to the ground state $K^{\pi} = 3/2^-$ *in* ^{155}Gd *from levels* $I^{\pi}K = 1/2^- 1/2$.

admissible values of the total moment I_f for definite K_f. For ^{165}Ho we calculate the quadrupole resonance characteristics: the position of the center $E_{res} = 12.5$ *MeV* (it decreases with including the isovector part of interaction [6]), the width $\Gamma_{res} = 3.5$ *MeV*, the reduced probability of excitation $B(E2)\uparrow = 0.14 e^2 barn^2$, the contribution to the energy weighted sum rule EWSR= 25%. Experimental results [7]: $E_{res} = (11.6 \pm 0.2)$ *MeV*, $\Gamma_{res} = 3.6$ *MeV*, $B(E2)\uparrow = (0.15 \pm 0.03) e^2 barn^2$, EWSR = (21 ± 4)%. Three peaks observed experimentally at different scattering angles (see [7]) correspond evidently to transitions with $\Delta K = 0,1,2$.

It should be noted that the resonance in the odd-A nucleus differs slightly from that in the neighbouring even-even nucleus. The difference consists in an additional splitting of each peak.

The proposed calculation procedure of the strength function is convenient for studying both the giant resonance and the electromagnetic transitions around the

Table

The reduced probability of E2 -transitions to the ground state $I^{\pi} K = 3/2^- 3/2$ from individual states and from groups of states $I^{\pi} K = 1/2^- 1/2, 3/2^- 1/2$ in the nucleus ^{155}Gd

$I_i^{\pi_i} K_i$	Calculations		Experiment /8/	
	$\mathcal{E}_\gamma$, keV	B(E2), e^2barn^2	$\mathcal{E}_\gamma$, keV	B(E2), e^2barn^2
$1/2^- 1/2$	600	0.022	558	0.014 ± 0.006
$3/2^- 1/2$	-	0.012	614	0.011 ± 0.005
$1/2^- 1/2$	$(4.2-5.2)10^3$	0.015	-	-
$1/2^- 1/2$	$(13.5-15.5)10^3$	0.020	-	-

neutron binding energy. The experimental research of transitions in this energy range can be realized, e.g., through (n,γ) reactions.

From *fig. 2* and the *table* it is clear that the same calculation produces the transition probabilities for individual states at low energies, and the transition probabilities for groups of states with definite K^{π} at intermediate and high energies.

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