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Inelastic proton scattering exciting the gamma-vibrational band in deformed nuclei and the hexadecapole degree of freedom in the gamma-motion

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The collective vibrational states in deformed nuclei are of considerable interest in investigating the nuclear structure. In particular, the interpretation of the gamma-band is a long-standing open problem. It can be understood as the quadrupole shape oscillation around an axially symmetric equilibrium by the Mottelson model. [1] Another understanding of the gamma-band is based on Davydov-Filippov model; the nuclei is assumed to be triaxial rigid rotor and the gamma-band is generated from the rotation. [2]

So far, the experimental data on the gamma-band have been limited to the B(E2) values measured from the gamma ray. The excitation of the gamma-vibrational bard by the inelastic scattering of the polarized protons is very interesting. Because the higher order degree of the freedom in the gamma motion, which cannot be observed from the gamma ray, can be directly observed by the hadronic inelastic scattering. In addition, measurements of the analyzing power data using the polarized beam reduce the ambiguities in fitting the parameters in the optical potential.

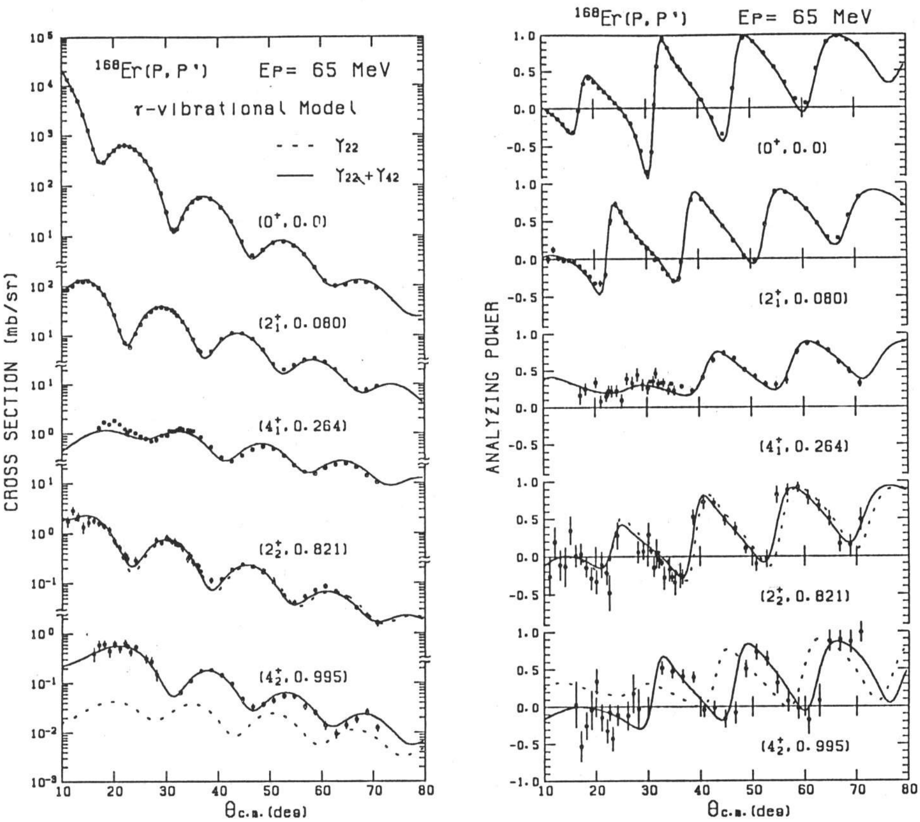

Fig. 1. Measured cross sections and analyzing powers for the ^{168}Er(p, p') scattering at 65 MeV. The dashed (solid) curves show the best-fit result of the coupled-channel calculation assuming the Y_{22} mode ($Y_{22} + Y_{42}$ mode) γ-vibration. The optical potential parameters used are $V_R = 37.87$ MeV, $r_R = 1.224$ fm, $a_R = 0.724$ fm, $W_v = 9.992$ MeV, $r_{wv} = 1.018$ fm, $a_{wv} = 0.723$ fm, $W_s = 6.808$ MeV, $r_{ws} = 1.232$ fm, $a_{ws} = 0.619$ fm, $V_{\ell s} = 5.544$ MeV, $r_{\ell s} = 1.164$ fm, $a_{\ell s} = 0.615$ fm, $r_C = 1.110$ fm, $\beta_{20} = +0.2832$, $\beta_{40} = -0.0096$ and $\beta_{60} = -0.0197$.

The inelastic scattering of the 65-MeV polarized protons exciting the gamma-vibrational band in ^{168}Er has been measured at the Research Center for Nuclear Physics (RCNP), Osaka University. [3] The scattered protons were analyzed using the high-resolution spectrograph RAIDEN. [4] The overall energy resolution was 20-26 keV (FWHM).

A coupled-channel analysis has been performed assuming the gamma-vibrational mode and the asymmetric rotor model. [5] The prime difference in these two models lies in whether the gamma-motion is assumed to be a dynamic oscillation or a static deformation.

The result of the coupled-channel analysis [6] for ^{168}Er assuming the quadrupole gamma-vibrational model is shown in Fig. 1 as dashed curves. Good fits have been obtained for 2_2^+ state, while for the 4_2^+ state the calculated cross section is about a factor 10 too small, whereas the analyzing powers are out of phase. The broad peak in the forward-angle region for the 4_2^+ state suggests a direct coupling to the ground state. [7-9]

Solid curves in Fig. 1 show the best-fit result assuming both the quadrupole and the hexadecapole degree of freedom in the gamma-vibration. The calculated curves for the $4^+{}_2$ state change drastically; the cross section has the correct magnitude ant the phase of both analyzing power and the cross section is also correct. Excellent fits have been obtained for all states.

A coupled-channel analysis assuming the asymmetric rotor model has been also performed. [2,10] The overall trend is quite similar to the case of the gamma-vibrational model. [6] Excellent fits have been obtained for all the states by introducing the static Y_{42} deformation.

In both model, the fits have been drastically improved by introducing the hexadecapole degree of freedom in the gamma-motion.

In order to investigate the systematic trend in the hexadecapole component in the gamma-band, the systematic measurement and analysis for the gamma-vibrational band for ^{152}Sm, ^{154}Sm, ^{160}Gd, ^{164}Dy, ^{166}Er, ^{168}Er and ^{176}Yb have been performed. It has been revealed that the hexadecapole component in the gamma-band depends strongly on the neutron number. [11] Therefore it would be concluded that the hexadecapole component in the gamma-band is tightly related to the (N,n3)=(5,2) neutron sub-major shell. [1]

From another point of view, recent IBM theory has asserted the necessity of the L=4 g-boson. There might be some relations between the hexadecapole component in the gamma-vibration and the g-boson in the IBM theory.

For further investigation, measurement for the gamma-band in Os and Pt region is in progress.

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