Enhancement of B(E1) rates in ^{100}Ru

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Introduction

The breakdown of reflection symmetry and the presence of an intrinsic dipole moment result in a distinctive rotational band structure for octupole-deformed even-even nuclei. This structure features two alternating parity bands connected by relatively fast electric dipole (E1) transitions. Such properties are observed in even-even isotopes of Ra–Th (Z $\approx$ 88, N $\approx$ 134) and Sm–Ba (Z $\approx$ 56, N $\approx$ 88) nuclei, which exhibit permanent octupole deformation [1, 2]. In a recent study [3], seven interleaved E1 transitions were identified in ^{100}Ru between the alternating parity bands. To confirm octupole collectivity in ^{100}Ru, a direct level lifetime measurement is crucial to estimate the B(E1) rates. In this communication, we report the lifetime measurements of the high spin levels of all four bands reported in our previous work [3] using the Doppler Shift Attenuation Method (DSAM).

Experiment

The excited states of ^{100}Ru were populated via the ^{100}Mo(^{4}He, 4n)^{100}Ru reaction using a 45 MeV beam from the K-130 cyclotron at the Variable Energy Cyclotron Centre, Kolkata. Gamma rays were detected with the Indian National Gamma Array (INGA) [4], consisting of 11 Compton-suppressed clover detectors positioned at 40°, 90°, and 125° relative to the beam direction. A 10 mg/cm^2 thick ^{100}Mo target was used. Data acquisition employed a 250 MHz, 12-bit PIXIE-16 digitizer (XIA LLC), recording 4×10^9 γ-γ coincidence events, of which 58% were attributed to ^{100}Ru.

Analysis and Results

Angle-dependent asymmetric matrices were generated using BiNDAS [5]. Gated spectra for fitting lineshapes were extracted from the bottom gates of each of these 4 bands. The lineshape analysis was carried out using the LINESHAPE package along with the development reported in Ref. [6]. The velocity profiles for the ^{100}Ru residues at the three angles of 40°, 90° and 125° were simulated using the stopping powers calculated by SRIM.

The B(E1) rate of 1.8(4) $\times$ 10^{-6} e^{2}fm^2 has been estimated for 10^+ [$h^2_{11/2}$] $\rightarrow$ 9^- [$h_{11/2}$ $\bigotimes$ ($g_{7/2}$/$d_{5/2}$)] transition in the neighbouring ^{110}Cd. It may be observed from Table. I that the measured B(E1) rates in ^{100}Ru are two orders of magnitude enhanced compared to that observed for ^{110}Cd. This is a clear indication of the presence of octupole collectivity in

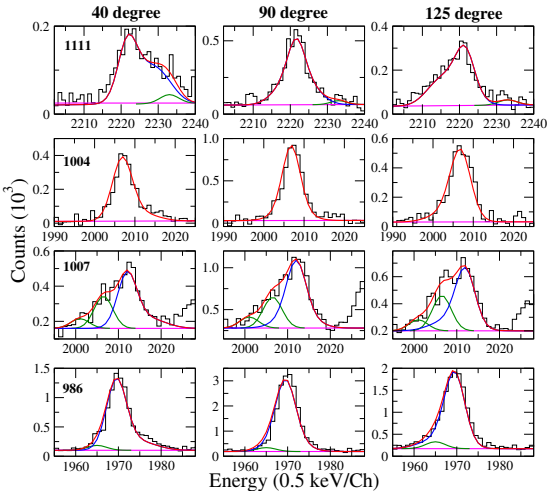

FIG. 1: The line shape fits for 1111 keV (Band 2), 1004 keV (Band 3), 1007 keV (Band 4) and 986 keV (Band 5) at 40°, 90° and 157° to the beam direction. The fitted Doppler broadened line shapes are drawn in blue lines while the contaminant peaks are shown in green lines. The result of the fit to the experimental data is shown in red lines.

^{100}Ru. It can also be noted from Table. I that the B(E2) values are nearly the same for the alternate parity bands (Band 2 and Band 3) while the values for the other two bands (Band 4 and Band 5) are significantly smaller.

Conclusion

The alternate parity bands show higher B(E2) values than the other two high-spin negative parity bands of ^{100}Ru, indicating a higher collectivity. The B(E1) rates of the interleaved E1 transitions among these bands show a two-order of magnitude larger transition rates compared to the single particle rates of other nuclei in this mass region.

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TABLE I: The measured lifetimes of electric quadrupole transitions of the ^{100}Ru levels for Band 2, 3, 4 and 5. The uncertainties in the lifetime measurements were derived from the behaviour of the χ^2 in the vicinity of the minimum for the simultaneous fit at the three angles. The E1 and E2 branching ratios for each level are adapted from Ref. [3].

Fitting E_γ (keV)	J^i_π	τ (ps)	B(E2) (e^2fm^4)	B(E1) ($\times 10^{-4}$ e^2fm^2)
		Band 2		
795.3(3)	14^+	1.02(9)	2418(218)	1.42(39)
1000.5(3)	16^+	0.32(3)	2465(192)	2.40(62)
1111.4(4)	18^+	0.17(1)	2672(241)	7.46(228)
1229.5(5)	20^+	0.14^u	2073^l	-
		Band 3		
931.9(2)	13^-	0.40(3)	1966(152)	1.93(34)
1035.7(3)	15^-	0.31(2)	2139(147)	2.69(63)
1003.5(4)	17^-	0.29(2)	2672(191)	4.56(147)
1253.7(5)	19^-	0.12^u	2194^l	-
		Band4		
959.9(4)	13^-	0.70(5)	1291(89)	-
1006.7(5)	15^-	0.56(4)	1302(93)	-
1109.1(5)	17^-	0.41^u	1172^l	-
		Band5		
806.0(3)	12^-	1.30(6)	1469(68)	-
985.8(3)	14^-	0.50(3)	1670(120)	-
1099.2(4)	16^-	0.40^u	1273^l	-

References

[1] P. A. Butler *et al.*, Phys. Rev. Lett. **124**, 042503 (2020).
[2] W. Andrejtscheff *et al.*, Phys. Lett. B **437**, 249, 1998..
[3] A. Karmakar *et al.* Phys. Rev. C **109**, 054312 (2024).
[4] S. Muralithar *et al.*, Nucl. Instrum. Methods A **622**, 281 (2010).
[5] S. S. Nayak and G. Mukherjee, IEEE Transactions on Nuclear Science, **70**, 12, 2561-2571 (2023).
[6] S. Das *et al.*, NIM A, **841**, 17–23, 2017.