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ON A SELFCONSISTENT MEASUREMENT OF THE ANGULAR CORRELATION OF THE 879-87 keV CASCADE AND THE MAGNETIC MOMENT OF THE 87 keV 2^+ LEVEL OF ^{160}Dy

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A self-consistent time-differential measurement of the angular correlation of the 879-87 keV cascade of ^{160}Dy and the magnetic moment of the 87 keV 2^+ level has been performed. The values of $A_2 = -0.019 \pm 0.019$ and $A_4 = +0.332 \pm 0.070$ suggest a value of $\delta(879) = -12.5^{+2.5}_{-7.5}$. This is consistent with the theoretical predictions of Tamura and Yoshida as also the value recommended by Krame from his analysis of all available experimental data. The halflife of the 87 keV level is found from a fit of the $A_0(t)$ vs time curve. The value is $T_{1/2} = 1.96 \pm 0.03$ ns. The magnetic moment of the 87 keV level is found out using a new technique based on the third relation of A. Z. Hrynkiewicz. The value is $\mu = +(0.696 \pm 0.32)\mu_N$. The result is compared with theoretical predictions.

О САМОСОГЛАСОВАННОМ ИЗМЕРЕНИИ УГЛОВОЙ КОРРЕЛЯЦИИ КАСКАДНОГО ПЕРЕХОДА 879-87 КЭВ И МАГНИТНЫЙ МОМЕНТ 2^+ УРОВНЯ ЯДРА ^{160}DY С ЭНЕРГИЕЙ 87 КЭВ

В работе приводятся результаты самосогласованного временно́го дифференциального измерения угловой корреляции каскадного перехода 879-87 кэв в ядре ^{160}DY и магнитного момента 2^+ уровня с энергией 87 кэв. Значения величин $A_2 = -0,019 \pm 0,019$ и $A_4 = +0,332 \pm 0,070$ приводят к значению величины $\delta(879) = -12,5^{+2,5}_{-7,5}$, что согласуется с теоретическими предсказаниями Тамуры и Иошиды, а также со значением,рекомендованным Крейном на основе его анализа всех доступных экспериментальных данных. Период полураспада уровня с энергией 87 кэв определен на основе постоения величины $A_0(t)$ как кривой, зависящей от времени, и равен $T_{1/2} = 1,96 \pm 0,03$ нс. Магнитный момент уровня с энергией 87 кэв определен при помощи нового метода, основанного на третьем соотношении Гринкевича, причем его величина равна $\mu = +(0,696 \pm 0,032)\mu_N$. Проведено сравнение этого результата с теоретическими предсказаниями.

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INTRODUCTION

The angular correlation of the 879-87 keV cascade in the decay of ^{160}Tb to ^{160}Dy (Fig. 1) has been studied by many a group both with NaI(Tl) detectors [1, 2] as well as with

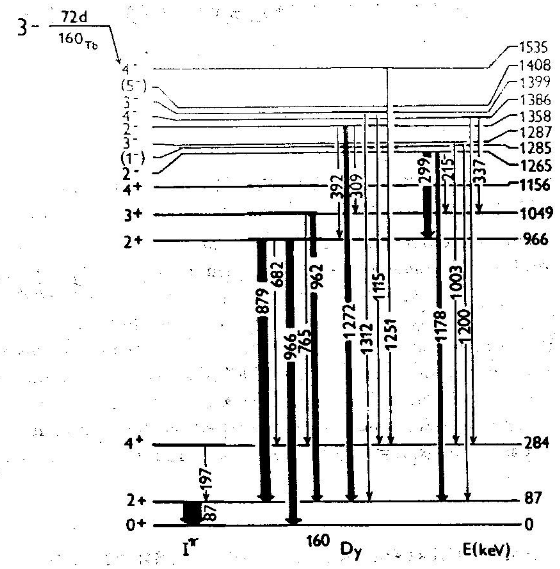

Figure 1. Level scheme of ^{160}Dy.

NaI(Tl) detector combinations. A summary of the results is presented in Table 1. One finds that the experiments with Ge(Li) as one of the detectors mostly use this cascade to find out the integral attenuation factor G_4 of the A_4 coefficient, and use this value of G_4 to correct results for other cascades. The mixing ratio $\delta(879)$ used to find the theoretical unattenuated A_2, A_4 values for this cascade is generally found from another cascade. From a table of A_2 and A_4 vs δ for a 2(1,2)2(2)0 cascade it is found that while the A_4 value does not change much over a wide range of δ-values the value of A_2 does, and thus a proper test for the consistency of the integral angular correlation results with Ge(Li) detectors would be the comparison of the G_2A_2 and the G_4A_4 values. Here, however, one notices large disagreement between these values found by different authors. For example, the G_2A_2 value as found by Krane et al. [6] is one order of magnitude less than that found by Jaklevic et al. [3]. The value found by Krane et al. [6] is positive although others report a negative value. There are also disagreements between the G_4A_4 values. Since Forker et al. [2] have found that the differential attenuation coefficients and hence the integral attenuation coefficients remain constant over a large range of

Table 1

Results of the Angular Correlation of the (879-87) keV Cascade of ^{160}Dy.

Authors	A_2^{exp}	A_4^{exp}	$\delta^{exp}_{(879)}$	G_2^{exp} and λ_2^{exp} (ns^{-1})	G_4^{exp} and λ_4^{exp} (ns^{-1})	G_2A_2	G_4A_4	Coincidence resolving time used (ns)	Detectors
Gunther et al. [1]	-0.043 ± 0.006	$+0.327\pm0.006$	$+17.7^{+5.2}_{-2.8}$	$G_2=(0.740\pm0.020)$ $\lambda_2=(0.122\pm0.013)$	$G_4=(0.597\pm0.025)$ $\lambda_4=(0.235\pm0.024)$	—	—	3.0	NaI—NaI(Tl)
Forker et al. [2]	—	—	—	$\lambda_2=(0.080\pm0.003)$	$\lambda_4=(0.245\pm0.008)$	—	—	—	NaI(Tl)—NaI(Tl)
Jaklevic et al. [3]	-0.014 ± 0.034	$+0.325\pm0.003$	-11^{+3}_{-13}	$G_2=0.9\pm2.3$	$G_4=0.503\pm0.049$	-0.015 ± 0.009	$+0.163\pm0.016$	90	Ge(Li)—NaI(Tl)
Bhati et al. [4]	-0.026 ± 0.006	$+0.325\pm0.039$	$-16\leq\delta\leq13$	Gunther's value used	Gunther's value used	-0.019 ± 0.004	$+0.195\pm0.023$	50	Ge(Li)—NaI(Tl)
Singh et al. [5]	—	—	-5.6 ± 0.5	—	—	—	—	6.0	Ge(Li)—NaI(Tl)
Krane et al. [6]	$+0.002\pm0.017$	$+0.324\pm0.025$	$-11.0^{+1.9}_{-1.5}$	$G_2=0.72\pm0.07$ $\lambda_2=0.15\pm0.07$	$G_4=0.64\pm0.06$ $\lambda_4=0.19\pm0.05$	$+0.0014\pm0.0122$	$+0.207\pm0.025$	50	Ge(Li)—NaI(Tl)
Gardulski et al. [7]	-0.030 ± 0.004	$+0.322\pm0.017$	-16.3 ± 1.3	$G_2=0.92\pm0.04$	$G_4=0.49\pm0.02$	-0.028 ± 0.004	$+0.158\pm0.011$	—	Ge(Li)—Ge(Li)
Present work	-0.019 ± 0.019	$+0.332\pm0.070$	$-12.5^{+2.5}_{-7.5}$	$G_2=0.737\pm0.019$	$\lambda_4=0.20\pm0.04$	—	—	2.1	NaI(Tl)—NaI(Tl)
Theoretical value		+(0.320—0.327)	±7.00 to ±100.00						

acid concentration of HCl the discrepancies in the G_2A_2 and G_4A_4 values cannot be explained in this way. We also find from Table 1 that the G_4 value found by Krane et al. [6] is about 30 % larger than that of Jaklevic et al. [3] and Gardulski et al. [7]. Thus the integral angular correlation study of this cascade by using Ge(Li) detectors is not at all advantageous. The good energy resolution of the Ge(Li) detector is no substitute for its poor time resolution at least in this case.

Two groups viz. Gunther et al. [1] and Forker et al. [2] report a differential angular correlation study of this cascade. However, the study for Forker et al. [2] is solely devoted to finding the nature of the perturbation in liquid source of ^{160}Dy. Thus Gunther et al. [1] is the only group that reports an A_2 and an A_4 value directly from a differential angular correlation study. However, one finds from Table 1 that the value of A_2 and A_4 as reported By Gunther et al. [1] viz. $A_2 = -0.043 \pm 0.006$ and $A_4 = 0.327 \pm 0.006$ is not consistent with their experimental value of $\delta(879) = +17.7^{+5.2}_{-2.8}$. This value of δ is consistent only with a value of A_2 in the range of $+(0.11-0.13)$. On the other hand, the value of A_2 and A_4 as found by Gunther et al. [1] is consistent only with a value of $\delta(879) = -22^{+3}_{-5}$ as recalculated and tabulated by Krane [8] from Gunther's data. This seems surprising and has led us to remeasure the value of A_2 and A_4 for this cascade by differential angular correlation.

From Table 2 it is found that there are six reported measurements on the magnetic moment of the 87 keV 2^+ state of ^{160}Dy but only one by differential perturbed angular correlation method [9—14]. The two measurements by Mössbauer spectroscopy [11, 12] report a somewhat higher value of the magnetic moment. However, the Mössbauer method only determines the ratio of the ground state moment and the excited state moment. A rather large value of the magnetic moment differing by almost 20 % from the value reported by others has been reported by Begzhanov et al. [14] from a perturbed angular correlation study. Thus a measurement of this magnetic moment by a direct method such as by a differential angular correlation method seems to be desirable.

Table 2

Magnetic moment of the 87 keV 2^+_1 state of ^{160}Dy

Author	μ_{exp} [μ_N]	Method
Ofer et al. [11]	0.76 ± 0.05	Mössbauer effect
Cohen et al. [12]	0.74 ± 0.08	-do-
Gunther et al. [1]	0.704 ± 0.038	IPAC
Gunther et al. [1]	0.728 ± 0.022	DPAC
BenZvi et al. [13]	0.712 ± 0.034	CEAD
Begzhanov et al.	0.844 ± 0.005	IPAC
Present work	0.696 ± 0.032	DPAC

We feel that the large A_4 coefficient of this cascade offers a possibility of finding the magnetic moment of the 87 keV level with a better precision than by the ordinary differential delay reversed field (DDRF) method. This can be done by using the variant of the above method first suggested by A. Z. Hrynkiewicz [15] in which the larmor frequency is found from a function of the: $C(t) = A \sin 4\omega_L t$, where A is a constant simply related to the A_4 coefficient and ω_L is the larmor frequency. Sinha and Bhattacharyya [16] have shown that this has two important consequences: a) even with a smaller available magnetic field the measurement of ω_L is possible with a better precision and b) since one cycle of the larmor frequency curve is completed in a shorter time, i. e., in the earlier part of the lifetime curve which it modulates, the data points taking part in the evaluation of the larmor frequency have generally a chance of better statistical accuracy even for a short lifetime of the intermediate level of the cascade than in the case of an ordinary DDRF experiment, which also leads to a better precision in the final result. We may mention in passing that to our knowledge this is the first instance of the application of this method to measure the magnetic moment of a level. Even a cursory glance through the Table of Isotopes (7th edition, 1978, eds. C. M. Lederer and V. S. Shirley) reveals more than twenty possible casses where this method may be applied with profit. The above considerations have led us to study the differential angular correlation of the 879-87 keV cascade of ^{160}Dy and measure the magnetic moment of the 87 keV level by the method suggested above.

EXPERIMENTAL ARRANGEMENT

The source was obtained from the Bhabha Atomic Research Centre, Trombay, India as $TbCl_3$ in HCl. The source was encapsulated in a small perspex holder 3 mm dia. × 1.5 mm height and placed between the pole tips of an electromagnet. The detectors were 38 mm dia. × 25 mm height Bicron NaI(Tl) phosphors of guaranteed resolution of 7 % at 662 keV coupled to Philips XP1021 photomultiplier tubes. The photomultipliers were shielded by lead cylinders with lead cones of proper design. Lead stops were used between the pole pieces to avoid crystal to crystal backscattering of gamma rays. To reduce the intensity of the strong X-ray (46 keV) thin tinfoils were used in front of the detectors detecting the 87 keV gamma ray. A typical singles spectrum in each of the two detectors, the coincidence spectrum with a proper gate in the two detectors as also the window selection in the side channel are shown in Fig. 2.

DIFFERENTIAL ANGULAR CORRELATION EXPERIMENT

The differential angular correlation experiment was done with the source rigorously centred to a better than 1 % precision between the pole tips of the

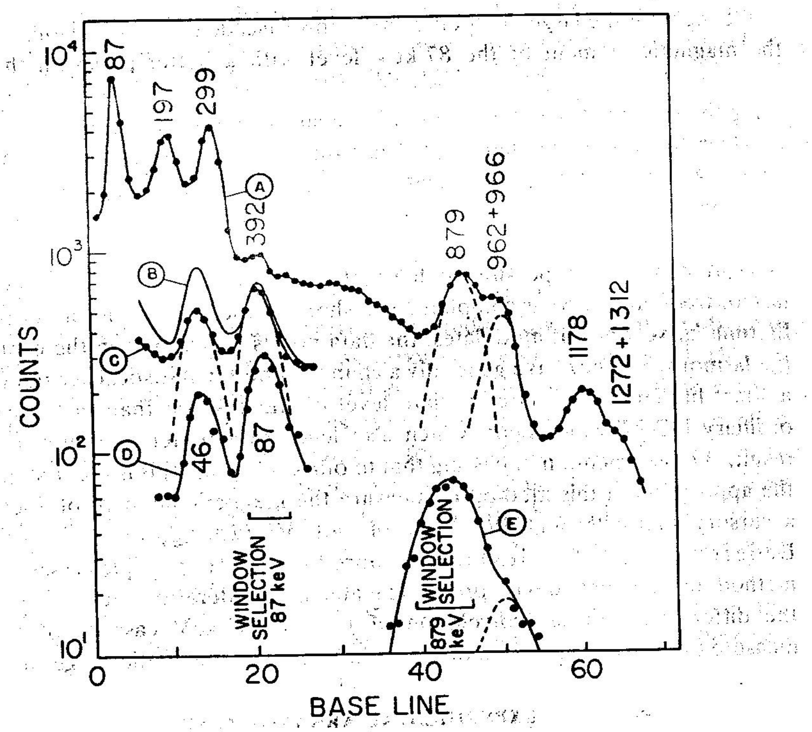

Figure 2. Various gamma spectra of ^{160}Dy: (A) Singles gamma spectrum in the moving channel, (B) Singles gamma spectrum in the fixed channel in the region of interest, (C) same as (B) but with a 0.006 cm thick Tin absorber, (D) same as (C) but gated by the 879 keV peak selected in the moving channel, (E) same as (A) but gated by 87 keV selected in the fixed channel. The window selection for the experiment are also shown.

electromagnet. The data were taken at four angles 90°, 112.5°, 135° and 157.5° and stored in the four memory subgroups of a ND120 multichannel analyser in the form of a delayed coincidence curve. The angular excursion of the moving detector was limited to 157.5° in order to avoid any crystal to crystal backscattering present around 180°. The prompt coincidence time resolution with our energy selection was obtained using a ^{60}Co source ($2\tau_0 = 2.1$ ns) (Fig. 3).

MEASUREMENT OF THE MAGNETIC MOMENT

The differential measurement of the magnetic moment was done with the same source by putting on the magnetic field and taking coincidence counts $W_1^{\pm}$ and $W_2^{\pm}$ at $\theta_1 = 112.5°$ and $\theta_2 = 157.5°$ for two directions up and down of the transverse magnetic field. The data were stored in the four memory subgroups of the

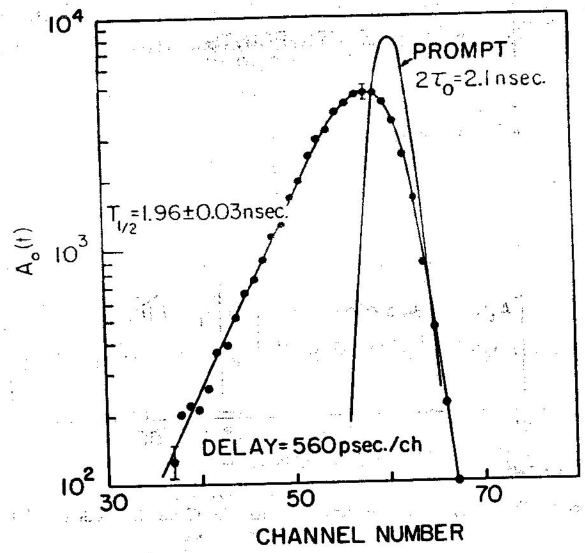

Figure 3. $A_0(t)$ vs time curve of the 879-87 keV cascade showing the half-life of the 87 keV level. The prompt coincidence curve is also shown. Error bars are shown only for a few points.

multichannel analyser. The magnetic field $H_{ext} = 21.4$ kilogauss was measured with a Hall probe calibrated in a Varian NMR setup.

ANALYSIS OF DATA AND EXPERIMENTAL RESULTS

Each point of the delayed coincidence spectrum corrected for chance coincidences was least square fitted to find out A_0, A_2, and A_4. The curve of A_0 vs time is shown in Fig. 3. This curve was the least square fitted to find out the half-life of the 87 keV level giving $T_{1/2} = 1.96 \pm 0.03$ ns, taking into account the half-width of the prompt time resolution curve and its slope. Finding the half-life from such a fit of A_0t vs time eliminates any effect that the strong anisotropy of the angular correlation and the sizeable attenuation of it present in the source may have on the measured value. This value of the half-life agrees well with the value as found by Forker et al. [2] using similar methods.

The curve of A_4 vs time is shown in Fig. 4. It will be found that the first few channels give more or less a constant value which shows the effect of the prompt cascade still remaining under our selection. To ensure their exclusion in the final result only those points in the $A_4(t)$ vs time curve were considered which are away from the time zero channel by a time gap of 3 ns — somewhat more than one prompt resolution time. A least square fit of the remaining points gives a value of

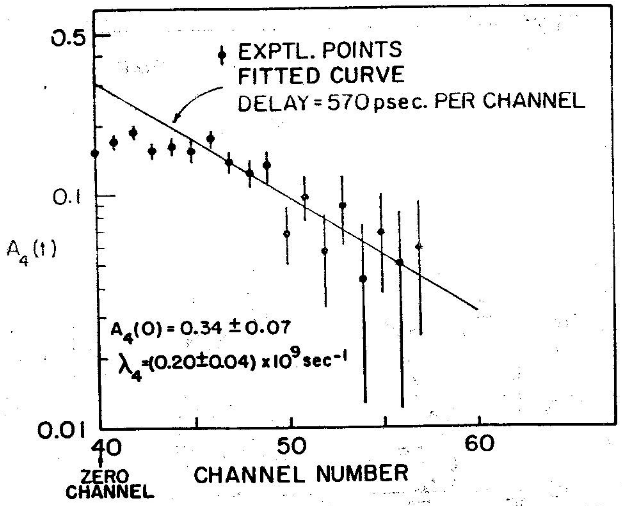

Figure 4. TOP: $A_4(t)$ vs time curve for the 879-87 keV cascade of ^{160}Dy.

$A_4(0) = +(0.284 \pm 0.060)$ and $\lambda_4 = (0.20 \pm 0.04) \times 10^9 \text{ sec}^{-1}$. This value of $A_4(0)$ after geometry corrections gives $A_4(0) = +(0.332 \pm 0.070)$. Because of the large statistical error no attempt was made to correct for the finite time resolution of the coincidence system used. The value of A_4 in our case is within error the same as the saturation value of $A_4 \cong 0.327$ as seen from Table 1. The value of $\lambda_4 = (0.20 \pm 0.04) \times 10^9 \text{ sec}^{-1}$ is in good agreement with the value of Gunther et al. [1], viz., $\lambda_4 = (0.235 \pm 0.024) \times 10^9 \text{ sec}^{-1}$ and that of Forker et al. [2] viz., $\lambda_4 = (0.245 \pm 0.008) \times 10^9 \text{ sec}^{-1}$.

Because of the very small A_2 value of this cascade and because of the fact that the first few point near the time zero channel contain contributions from interfering cascades no fit of $A_2(t)$ vs time was possible in this experiment. However, from the intergrated area of the delayed spectrum at the four angles corrected for chance coincidences as well as for the interferences from other cascades under the window selection used in the present experiment, an integral angular correlation was done. A value of $A_2 = -(0.014 \pm 0.014)$ was obtained after geometry corrections, which, when corrected for by the integral attenuation factor G_2 (as found by taking the weighted average of the values obtained Gunther et al. [1] and Krane et al. [6] i.e., $G_2 = 0.737 \pm 0.019$), is $A_2 = -(0.019 \pm 0.019)$. The use of the G_2 value from other experiments with $TbCl_3$ in HCl in our case is not unreasonable since Forker et al. [2] have shown that over a wide range of concentration of HCl the λ_2 value and hence the G_2 value remains the same within error. This value of A_2 gives a value of the mixing ratio of the 879 keV gamma transition taking the 87 keV gamma transition as a pure E2 transition, $\delta = -12{,}5^{+2.5}_{-7.5}$, a value consistent with the observation by other workers as well as with the value recommended by Krane [8]. It is, howerver, somewhat smaller than that obtained by Gardulski et al. [7], who found $\delta = -16.3 \pm 1.3$.

For the magnetic moment determination the four quantities $W_1^\pm$ and $W_2^\pm$ were combined channel by channel to form a quantity $C(t)$ as suggested by Hrynkiewicz [15] in the third of his six relations for the measurement of magnetic moments.

This is

$$C(t) = \frac{(W_2^+ - W_2^-) + (W_1^- - W_1^+)}{0.5[W_1^+ + W_1^- + W_2^+ + W_2^-]} = 2b_4 \sin 4\omega_L t.$$

In least square fitting of the $C(t)$ vs time curve (Fig. 5) only the points beyond the fiftythird channel were considered. This was necessary because the data in the first few points contained admixtures from the strong prompt cascade as described in connection with the $A_4(t)$ measurement. The dashed portion was drown only for showing a complete cycle. However, the amplitude of the $C(t)$ vs time curve in the first half cycle is smaller than that expected for $A_4(0) \cong 0.33$ because of the prompt contributions. However, such contributions could not disturb the time period of the curve which was solely dependent on the magnetic moment being measured as well as the magnetic field applied.

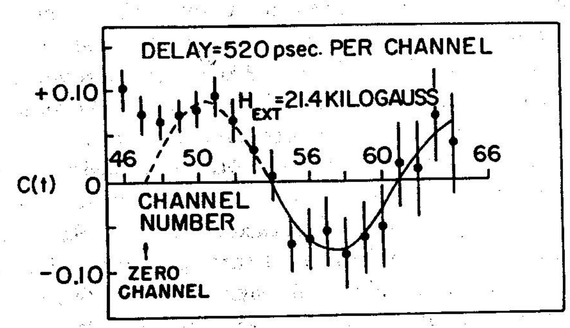

Figure 5. (BOTTOM): $C(t)$ vs time curve for the 879-87 keV cascade of ^{160}Dy.

The value of ω_L obtained from such a fit was $\omega_L = (0.218 \pm 0.010) \times 10^9 \text{ radsec}^{-1}$, which gives a value of g from the relation $g = \omega_L h / \mu_N H_{eff}$ as $g = 0.348 \pm 0.016$. In this calculation $H_{eff} = \beta H_{ext}$ where H_{eff} was the effective magnetic field at the site of the nucleus, β was the paramagnetic susceptibility for Dy at the temperature of the source which was 32 °C and H_{ext} was the external applied magnetic field. From a graph of β vs temperature, we estimated $\beta = 5.85$ at 32 °C. The above value of g gave a value of $\mu = (0.696 \pm 0.032)\mu_N$. From Table 2 we find that this value agrees within error with the value of $\mu = (0.728 \pm 0.022)\mu_N$ as obtained by Gunther et al. [1] but does not support the value of the magnetic moment as obtained by Begzhanov et al. [14].

DISCUSSION

We have performed the differential angular correlation measurement on the 879-87 keV cascade of ^{160}Dy and have measured the magnetic moment of the 87 keV 2^+ level. Our value of A_4 although agreeing with the theoretical limiting value of A_4 within error is somewhat large and has a larger relative error than the other measured values. This is because we had to discard points lying within 3 ns from the time zero channel in the $A_4(t)$ vs time curve because of contributions from other prompt cascades when we made a least square fit of the data. A better counting statistics could have helped in this regard but the main aim of the present study was to find the mixing ratio of the 879 keV transition and the A_2 and A_4 values of the 879-87 keV cascade. Although the value of A_2 could not be found from this time differential study and an integral angular correlation study had to be resorted to, we find that our measured value of $\delta(879)$ is consistent with that found by most of the other workers and also with the value recommended by Krane [8] from a study of all the available data on this cascade, viz. $\delta(879) = -15 \pm 1$. It is to be noted that Tamura and Yoshida [17] from a theoretical study estimated a value of $\delta \sim 10$ for the magnitude of the mixing ratio of this transition.

The magnetic moment of the 87 keV 2^+ level as found from this study is in agreement with the value found by other workers but is a little too low. A part of this difference may be due to the error in the assumed value of the paramagnetic correction factor, which was found from a curve of β vs temperature. It is to be noted that although the applied magnetic field was lower than that used by Gunther et al. [1] a comparable accuracy could be achieved without much trouble. The value found by us seems to rule out the value obtained by Begzhanov et al. [14] from their perturbed angular correlation study.

The value of the g-factor as found by us for this level agrees with the general trend of g_R values for the first excited states in the even-even rare earth isotopes all of which lie between $g_R = 0.3 - 0.4$. Prior et al. [18] have calculated the gyromagnetic ratios of the ground state rotational band in deformed nuclei. Their value of g_R for ^{160}Dy is $g_R = 0.38$, which is somewhat higher than the value obtained by us. According to him the collective gyromagnetic ratio measures the magnetic properties of the collective flow while the moment of inertia measures the total mass of the collective flow. The collective gyromagnetic ratio is approximately given by the relative fraction contributed by the protons to the moment of inertia. If all the particles contribute equally to the collective rotation, the collective gyromagnetic ratio is given by Z/A, which is equal to 0.41 for ^{160}Dy. However, it is generally found that g_R is smaller than Z/A. This is because of the fact that the energy gap Δ_p for protons is larger than the energy gap Δ_n for neutrons.

The determination of the collective gyromagnetic ratio in the different members of the ground state rotational band in even-even nuclei is important because as Sano et al. [19] show in ^{158}Dy, the collective g_R value decreases with an increase in the angular momentum and reaches a minimum value at the critical angular momentum for neutrons. For the angular momentum exceeding the critical point, g_R increases with the rotation and reaches a value of the collective g_R associated with the rotation of a rigid body at the critical angular momentum for protons. The nucleus ^{160}Dy is expected to behave in the same way.

Kumar [20] has shown from theoretical considerations that for ^{160}Dy the g_R value should decrease from 0.31 ($I = 0$) to 0.20 ($I = 16$) and become negative (-0.006) at $I > 16$. This observation is not fully supported by Sano et al. [19]. Kalish and Kosler [21] have measured the precession of short-lived excited states of even-even Dy-nuclei recoiling into ferromagnetic backing and have found that the g_R value of the ground state rotational band is constant up to at least $I = 8^+$ and $g_R = 0.36 \pm 0.07$. The measurements of Dhar et al. [22] ($g_R = 0.34 \pm 0.05$) and Khan et al. [23] ($g_R = 0.37 \pm 0.15$) on the 4^+ second excited state of ^{160}Dy seem to lend support to this view. Since states having a spin up to al least 6^+ of ^{160}Dy are excited in radioactive decay, precise measurements of the magnetic moments of the different members of the ground state rotational band may help in deciding between the different models of ^{160}Dy.

REFERENCS

[1] Gunther, G. et al.: Z. Physik *183* (1965), 472.
[2] Forker, M. et al.: Nucl. Phys. *A 138* (1969), 97.
[3] Jaklevic, J. M. et al.: Nucl. Phys. *A 99* (1967), 83.
[4] Bhati, S. S. et al.: Aust. J. Phys. *29* (1976), 405.
[5] Jasbir Singh et al.: Proc. Intl. Conf. on Nucl. Phys. Florence (Italy) 1983, vol. 1, p. 280.
[6] Krane, K. S., Steffen, R. M.: Nucl. Phys. *A 164* (1971), 439.
[7] Gardulski, P. L., Wiedenbeck, M. L.: Phys. Rev. *C 7* (1973), 208.
[8] Krane, K. S.: Atomic Data and Nuclear Data Tables *16* (1975), 383.
[9] Shirley, V. S.: in *Hyperfine Interactions in Excited Nuclei*, Vol. 4, ed. G. Goldring and R. Kalish (Gordon and Breach Science Publishing, New York, 1971), p. 1255.
[10] Nuclear Data Sheets *12* (1974), 477.
[11] Ofer, S. et al.: Nucl. Phys. *69* (1965), 173.
[12] Cohen, R. L.: Phys. Rev. *137* (1965), A 1809.
[13] Ben-Zvi, I. et al.: Nucl. Phys. *A 151* (1970), 401.
[14] Bengzhanov, R. B. et al.: *Proc. 22nd Ann. Conf. Nucl. Spectrosc. Structure At. Nuclei*, Kiev 1972, p. 227.
[15] Hrynkiewicz, A. Z.: Nucl. Instr. and Meth. *16* (1962), 317.
[16] Sinha, B. K., Bhattacharyya, R.: Nucl. Inst. and Meth. *219* (1984), 443.

[17] Tamura, T., Yoshida, H.: Nucl. Phys. *30* (1962), 579.
[18] Prior, O. et al.: Nucl. Phys. *A 110* (1968), 257.
[19] Sano, M. et al.: *Proc. Int. Conf. on Nucl. moments and Nucl. Structure*, Osaka 1972 ed. H. Horie and K. Sigimoto, Phys. Soc. of Japan, Tokyo, 1973.
[20] Kumar, K.: Phys. Rev. Lett. *30* (1973), 1227.
[21] Kalish, R., Kossler, W. J.: in *Hyperfine Interactions in Excited Nuclei.* Vol. 1. Ed. G. Goldring and R. Kalish (Gordon and Breach Science Publishing, New York, 1971).
[22] Dhar, A. K. et al.: Proc. Nucl. Phys. and Sol. St. Phys. (India) *15 B* (1972), 343.
[23] Khan, S. N. et al.: J. Phys. *G 1* (1975), 727.

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