Collective bands in ^{125}I

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An in-beam γ-ray spectroscopic study of the nuclear structure of ^{125}I has led to extensions and alterations of the level scheme of this nucleus. Several new intraband and interband transitions are observed in the positive parity bands based on $\pi d_{5/2}$ and $\pi g_{7/2}$ configurations, indicating mixing of the two configurations in these bands. The strongly coupled $\pi g_{9/2}$ band has also been extended and characteristic quadrupole crossover transitions, hitherto unreported, have been observed, providing estimates of the $B(M1;I\rightarrow I-1)/B(E2;I\rightarrow I-2)$ ratios for transitions in this band. New experimental results are presented concerning the three-quasiparticle structure and likely members of the unfavored signature of the prolate $\pi h_{11/2}$ band, showing excellent agreement with the theoretical results. Experimental results are discussed in relation to the systematics of the neighboring odd-A nuclei. [S0556-2813(99)07605-0]

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I. INTRODUCTION

The nuclei in the mass region $A\sim120$–130 with $50<Z<57$ have been of considerable interest as they lie in the transitional region between primarily spherical and well-deformed nuclei. The iodine nuclei with $Z=53$ display the characteristic features of the structure of nuclei in this region and form an important link in the systematics of these nuclei. The neutron-deficient odd-mass iodine isotopes have recently been found to display a rich variety of nuclear structure. They exhibit softness with respect to the triaxiality parameter γ, sensitivity to the shape polarizing effects of the valence quasiparticles, and, as a consequence, coexistence of different shapes and collective bands based on intrinsic states with different shapes and deformations [1,2]. The collective features systematically observed in the odd-mass iodine isotopes are the occurrence of $\Delta I=2$ bands with stretched $E2$ intraband transitions, based on $\frac{5}{2}^+$, $\frac{7}{2}^+$, and $\frac{11}{2}^-$ states and a $\Delta I=1$ band characterized by $M1$ cascade and $E2$ crossover transitions, based on a $\frac{9}{2}^+$ state. The $\Delta I=1$ band has been explained as a rotational band based on a deformed $g_{9/2}$ proton-hole state. The $\Delta I=2$ bands, on the other hand, have been described as decoupled bands based on bandheads arising from $\pi d_{5/2}$, $\pi g_{7/2}$, and $\pi h_{11/2}$ configurations of protons. The *decoupled* nature of these bands is inferred from the similarity of the energy level spacings in these bands with those of the corresponding even-even cores. The systematics of the odd-mass iodine isotopes [3] show that the $h_{11/2}$ band in the heavier isotopes of iodine, including ^{125}I, shows good correspondence with the energy level spacings of the core, whereas the positive parity $\Delta I=2$ bands tend to deviate significantly. In recent reports [1,2] on the structure of the neighboring odd-mass iodine nuclei ^{121,123}I it is noticed that the mixing of the $\pi d_{5/2}$ and $\pi g_{7/2}$ configurations of protons can significantly affect the structure of the positive parity bands based on the $\frac{5}{2}^+$ and $\frac{7}{2}^+$ states, and that interconnecting dipole transitions occur between the members of these bands. Previous reports on ^{125}I [4–6] show the $\Delta I=2$ sequences of levels based on $\frac{5}{2}^+{}_1$ (g.s), $\frac{7}{2}^+{}_1$, $\frac{7}{2}^+{}_2$, and $(\frac{11}{2})^-$ states up to spin parity $I^\pi=(\frac{21}{2}^+)$, $(\frac{15}{2}^+)$, $(\frac{15}{2}^+)$, and $(\frac{27}{2}^-)$, respectively. The $\Delta I=1$ band members of the $\frac{9}{2}^+$ band are known up to the $(\frac{15}{2}^+)$ state. A cascade of dipole transitions ending on the $\frac{9}{2}^+$ bandhead is reported to occur in this band, but the quadrupole crossover transitions expected to occur in such a strongly coupled band based on the deformed $\frac{9}{2}^+$ state have not been reported. Several levels in ^{125}I have been reported as uncertain in a previous work [4]. In many odd - A isotopes of I and Cs in this mass region, rotational bands based on three-quasiparticle (3qp) configurations have also been observed [1,7–9]. In ^{125}I, however, a few states at excitation energy $E_x>2$ MeV have been described as resulting from 3qp configurations but no rotational structures have been identified [10]. With these points in view, to identify new levels and transitions, and for understanding the nature of various bands, the structure of ^{125}I has been investigated by in-beam γ-ray spectroscopic measurements in this work.

II. EXPERIMENTAL PROCEDURE

Identification of γ-ray transitions and their assignment and placement in the level scheme of ^{125}I have been done by γ-ray-singles and $\gamma\gamma$-coincidence measurements. The levels of ^{125}I were populated in the fusion-evaporation reaction ^{123}Sb$(\alpha,2n\gamma)^{125}$I using 99% enriched elemental ^{123}Sb targets of 10 mg/cm^2 thickness, at projectile energy of 30 MeV at the Variable Energy Cyclotron Centre, Calcutta. The γ-ray measurements were done with two HPGe detectors of 25% efficiency relative to a 7.6 cm$\times$7.6 cm NaI(Tl) detector at 25 cm distance and 2.6 keV energy resolution [full width at half maximum (FWHM)] at 1.33 MeV, surrounded by axial BGO Compton suppression sheilds. The detectors were placed at a distance of 8 cm from the target at about 90° to the beam for $\gamma\gamma$-coincidence measurements, whereas for the singles measurements the target-detector distance was 25 cm. The γ-ray energies and relative intensities were determined with detectors placed at 90° and 55°, respectively,

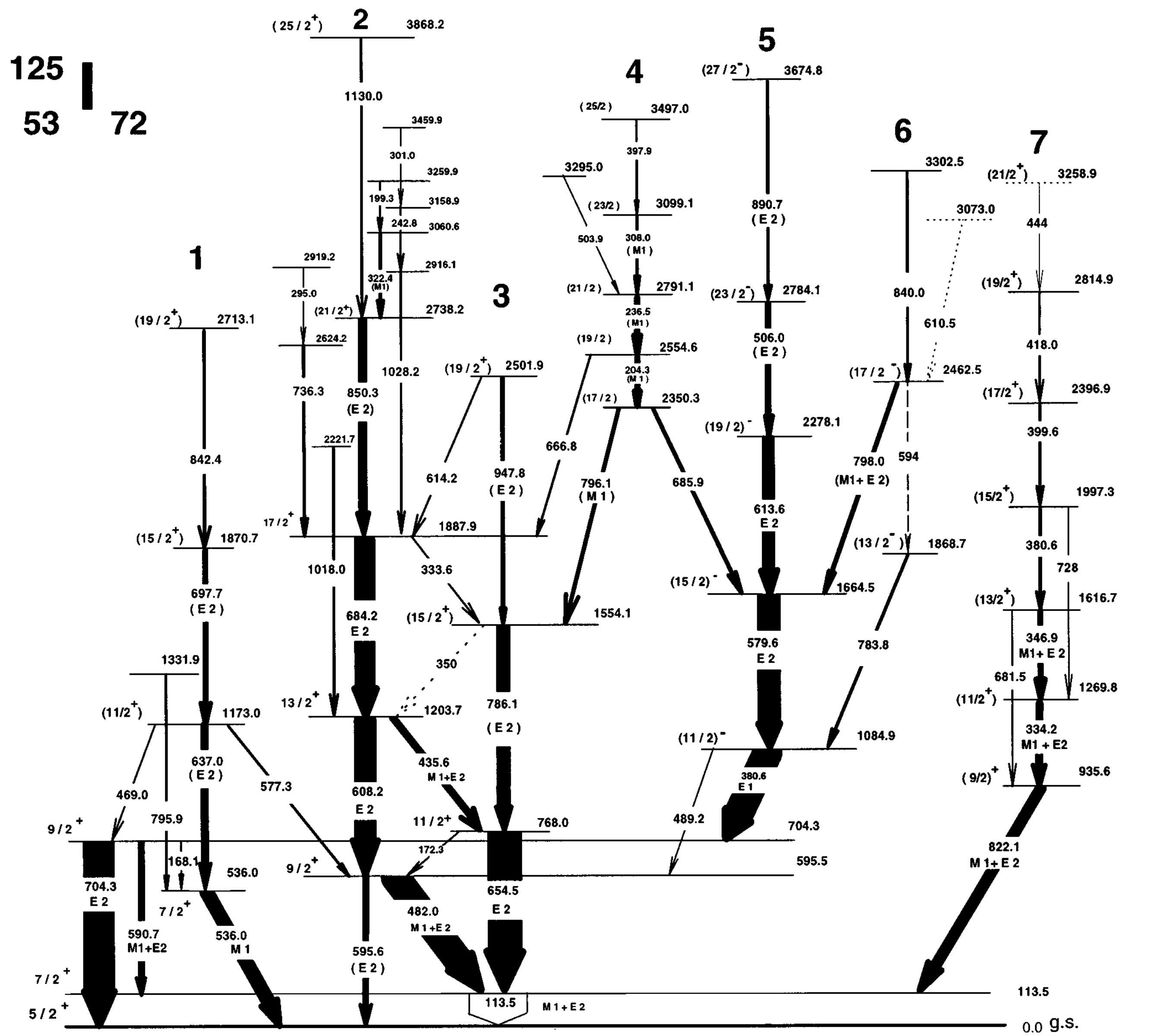

FIG. 1. Level scheme of ^{125}I deduced from this work. The transition energies are given in keV and the width of the arrows indicates their relative intensities. The J^{π} assignments of the previously known states and the multipolarities of tranisitions are from Ref. [6]. The J^{π} values for the states at 2713.1, 3868.2, 2501.9, 2554.6, 3497.0, 1868.7, 2396.9, 2814.9, and 3258.9 keV observed in this work are based on considerations described in the text and are tentative.

with respect to the beam direction. The $\gamma\gamma$-coincidence data were recorded event by event in list mode on a PC-based data-acquisition system with Ortec AD413A CAMAC ADC and Ortec NIM modules for processing of electronic signals. The energy-gated spectra were generated by off-line sorting of the list data, and the contributions of the Compton and random events were subtracted from the projected spectra. The assignment of the γ rays to ^{125}I and their placement in the level scheme was done on the basis of their coincidence relations with the other γ-ray transitions in the same nucleus, and considerations based on their energies and relative intensities.

III. EXPERIMENTAL RESULTS

Several new levels and transitions are observed in ^{125}I, resulting in extensions and alterations in the previously reported [4–6] level scheme. The level scheme of ^{125}I deduced from the measurements in this work is presented in Fig. 1. The energies and the relative intensities of the γ rays measured in the reaction ^{123}Sb$(\alpha,2n\gamma)^{125}$I at $E_{\alpha}=30$ MeV are given in Table I. The relative γ-ray intensities presented in Table I have been normalized with respect to that of the 654.5 keV γ ray which is taken to be 100 units, and not with respect to the 380.6 keV γ ray as in the previous reports [4,5], because the 380.6 keV γ ray is an unresolved doublet. The relative intensities reported in Ref. [4] in the same reaction at $E_{\alpha}=27$ MeV have been normalized also with respect to the 654.5 keV transition and presented in Table I for comparison.

A new γ-ray transition of 842.4 keV is observed to populate the $(\frac{15}{2}^{+})$ state at 1870.7 keV in band 1, extending the sequence of transitions in this band to the 2713.1 keV state.

TABLE I. Energies (E_γ) and relative intensities (I_γ) of the γ rays assigned to ^{125}I in the reaction ^{123}Sb(α,$2n\gamma$)^{125}I at $E_\alpha = 30$ MeV in present work. The relative intensities reported by Hagemann *et al.* [4] at $E_\alpha = 27$ MeV are given for comparison.

E_γ [a] (keV)	Initial state (keV)	I_γ Present [b]	I_γ Ref. [4]	E_γ [a] (keV)	Initial state (keV)	I_γ Present [b]	I_γ Ref. [4]
113.5	113.5	209	129	594 [f]	2462.5		...
168.1	704.3	3	3	595.6	595.5	20	17
172.3	768.0	4	4	608.2	1203.7	68	65
199.3	3259.9	6	9	610.5 [f]	3073.0	...	
204.3 [c]	2554.6	14	14	613.6	2278.1	37	36
236.5 [c]	2791.1	18	16	614.2	2501.9	4	...
242.8 [c]	3158.9	6	6	637.0	1173.0	29	22
295.0 [d]	2919.2	6	6	654.4	768.0	100	100
301.0 [c,e]	3459.9	4	4	666.8	2554.6	6	...
308.0	3099.1	10	9	681.5	1616.7	6	...
322.4	3060.6	12	12	684.2	1887.9	64	60
333.6	1887.9	5	...	685.9	2350.3	13	12
334.2	1269.8	23	22	697.7	1870.7	19	16
346.9	1616.7	16	16	704.3	704.3	91	90
350 [f]	1554.1		...	728	1997.3	3	...
380.6	1084.9	97	86	736.3	2642.2	11	...
380.6	1997.3	9	9	778.0 [g]		4	...
397.9 [e]	3497.0	4	4	783.8	1868.7	9	...
399.6 [e]	2396.9	5	5	786.1	1554.1	50	41
418.0	2814.9	3	...	795.9	1331.9	8	...
435.6	1203.7	22	31	796.1	2350.3	13	16
444	3258.9	2	...	798.0	2462.5	15	16
469.0	1173.0	3	3	822.1	935.6	32	33
482.0	595.5	86	84	840.0	3302.5	8	...
489.2	1084.9	3	4	842.4	2713.1	7	...
503.9	3295.0	4	...	850.3	2738.2	31	25
506.0	2784.1	20	17	890.7	3674.8	9	9
536.0	536.0	43	41	947.8 [e]	2501.9	16	12
577.3	1173.0	6	...	1018.0 [d]	2221.7	8	9
579.6	1664.5	69	67	1028.2	2916.1	7	...
590.7	704.3	18	19	1130.0	3868.2	8	...

[a]Typical energy errors are 0.2–0.5 keV depending on the energy, intensity, and the complexity of the spectrum, except in a few cases where the errors are 1 keV and the energy values are quoted without a decimal place.
[b]Typical errors in the relative intensities I_γ are 5–20 % for $I_\gamma > 10$ and 20–40 % for the weaker lines.
[c]Shown from different level in Ref. [4].
[d]Not placed in level scheme of Ref. [4].
[e]Uncertain placement in Ref. [4].
[f]Weak transition observed in coincidence only.
[g]Not placed in the level scheme in this work.

Another new transition of 795.9 keV is observed to populate the $\frac{7}{2}^+$ state of this band. These transitions are seen in coincidence with gate on the 536.0 keV γ ray (Table II). The in-band transitions of this band are relatively more pronounced in the added spectrum with gates on the 536.0, 637.0, and 697.7 keV γ rays, shown in Fig. 2(a). In band 2, a new transition of 1130.0 keV populates the previously reported highest spin state ($\frac{21}{2}^+$) of this band. Other new transitions of 736.3 and 1028.2 keV populate the $\frac{17}{2}^+$ state of band 2. A previously reported [4] cascade of 301.0 and 242.8 keV γ rays is confirmed in this work but contrary to the earlier report it is seen to proceed via the 1028.2 keV transition to populate the $\frac{17}{2}^+$ state of band 2. A γ ray of 295.0 keV which agrees in energy with an unplaced γ ray in Ref. [4] is now placed in the level scheme to form a cascade with the 736.3 keV transition as shown in Fig. 1. Another γ ray of 1018.0 keV observed in this work also agrees closely in energy with an unplaced line reported in Ref. [4], and is now placed in the level scheme of ^{125}I (Fig. 1) on the basis of the coincidence data. The coincidence data also show the presence of an interband transition of 577.3 keV ($\frac{11}{2}^+ \rightarrow \frac{9}{2}^+$) between band 1 and band 2. Most of the transitions associ-

TABLE II. $\gamma\gamma$ coincidences in ^{125}I with a few selected energy gates relevant to the new results presented in this work. Numbers in parentheses indicate weak coincidences.

Gate (keV)	Transitions observed in coincidence (keV)
204.3	113.5, 236.5, 308.0, 380.6, 397.9, 503.9, 579.6, 654.5, 685.9, 704.3, 786.1, 796.1
236.5	113.5, 204.3, 308.0, 380.6, 397.9, 435.6, 482.0, 503.9, 579.6, 608.2, 654.5, 666.8, 685.9, 704.3, 786.1, 796.1
295.0	113.5, 435.6, 482.0, (608.2), 684.2, 736.3
301.0	113.5, 242.8, 435.6, 482.0, 608.2, 684.2, 1028.2
308.0	113.5, 204.3, 236.5, 380.6, 397.9, (482.0), 579.6, 654.5, 666.8, 685.9, 704.3, 786.1, 796.1
322.4	113.5, 199.3, 333.6, 435.6, 482.0, 608.2, 654.5, 684.2, 850.3
346.9	113.5, 334.2, 380.6, 399.6, 418.0, 822.1
418.0	113.5, 334.2, 346.9, 380.6, 399.6, 822.1
482.0	113.5, 172.3, 199.3, 236.5, 242.8, 295.0, 301.0, 308.0, 322.4, (350), 489.2, 577.3, 608.2, (614.2), 666.8, 684.2, 736.3, 850.3, 1018.0, 1028.2, 1130.0
536.0	168.1, 637.0, 697.7, 795.9, 842.4
637.0	536.0, 697.7, 842.4
666.8	113.5, 236.5, 308.0, (435.6), 482.0, 608.2, 684.2
704.3	204.3, 236.5, 380.6, 469.0, 506.0, 579.6, (594), 613.6, 685.9, (778.0[a]), 783.8, 798.0, 840.0, 890.7
736.3	113.5, 295.0, 435.6, 482.0, 608.2, 654.5, 684.2
850.3	113.5, 199.3, 322.4, 333.6, 435.6, 482.0, 595.6, 608.2, 654.5, 684.2, 1130.0
1018.0	113.5, 435.6, 482.0, 608.2, 654.5
1028.2	113.5, 242.8, 435.6, 482.0, 608.2, 654.5, 684.2

[a] γ ray not placed in the level scheme.

ated with band 2, including the new ones mentioned above, can be seen in the coincidence γ-ray spectrum with sum of the gates on the 482.0, 608.2, 684.2, and 850.3 keV γ rays, shown in Fig. 2(b). The 577.3 keV interband transition can also be seen in Fig. 2(a).

An uncertain level at 2502.5 keV has been reported [4] in band 3. Results of coincidence measurements in this work, with energy gates on 113.5, 654.5, and 786.1 keV γ rays, show the presence of a 947.8 keV transition populating the 1554.1 keV ($\frac{15}{2}^+$) state of this band. The placement of this transition in the level scheme (Fig. 1) is supported by the energy gate on the 947.8 keV γ ray, which shows the daughter transitions of band 3 [Fig. 2(c)]. A weak 614.2 keV linking transition is observed to connect the $\frac{17}{2}^+$ state of band 2. A relatively stronger interband transition of 333.6 keV from the $\frac{17}{2}^+$ state of band 2 to the $\frac{15}{2}^+$ state of band 3 is observed and a weak indication is obtained for the presence of a 350 keV transition between the $\frac{15}{2}^+$ and $\frac{13}{2}^+$ states. It is worth mentioning that the new interband transition of 333.6 keV ($\frac{17}{2}^+ \rightarrow \frac{15}{2}^+$) shown in the level scheme (Fig. 1) is very close in energy to the previously known 334.2 keV transition placed elsewhere in the level scheme ($\frac{11}{2}^+ \rightarrow \frac{9}{2}^+$; band 7). For this reason the energy gate selecting both 333.6 and 334.2 keV transitions together, presented in Fig. 4(b), shows prominently the transitions belonging to band 7 but at the same time it does show the presence of the related transitions of bands 2 and 3, supporting the placement of the 333.6 keV $\frac{17}{2}^+ \rightarrow \frac{15}{2}^+$ transition. This transition also appears in the sum gate shown in Fig. 2(b), which includes the gate on the 850.3 keV transition.

The 2350.3 keV state of band 4 is the lowest observed state of this band. The excitation energy of this state is deduced from the energies of the two depopulating γ rays from this state, viz., the 796.1 and 685.9 keV transitions to the well-known [6] $\frac{15}{2}^+$ and $\frac{15}{2}^-$ states of band 3 and band 5, respectively. A new level is observed at 2554.6 keV which is found to decay to the 2350.3 keV state by the 204.3 keV transition. The identification of this level is supported by the observation of a new γ ray of 666.8 keV from this state to the $\frac{17}{2}^+$ state of band 2. Various levels assigned to band 4 are connected by a cascade of mutually coincident γ rays with energies 204.3, 236.5, 308.0, and 397.9 keV. The results of the present work contradict the previous placement [4] of the 204.3 and 236.5 keV transitions, with reversed ordering of these two transitions. The level at 3497.0 keV reported as uncertain in Ref. [4] is confirmed in the present work. A level at 3295.0 keV is deduced from the connecting transition to the 2791.1 keV state of band 4. The 666.8 keV transition connecting band 4 and band 2 is observed consistently in the energy gates on prominent transitions from above and below, and its observed energy (666.8 keV) shows excellent agreement with the level energy difference deduced from other transitions. This transition can be seen in the sum-of-gates spectrum of band 2 transitions displayed in Fig. 2(b). The intraband transitions of band 4 in the added coincidence spectrum with energy gates on the 685.9 and 796.1 keV transitions are shown in Fig. 3(a). The 380.6 keV line appearing in the spectrum results from the feeding to band 5. The transitions of band 4 observed with the energy gates on the 204.3 and 236.5 keV transitions are displayed in Figs. 3(b) and 3(c), respectively. The energy gate on the 666.8 keV γ ray [Fig. 3(d)] shows, despite its relatively poor statistics, the related transitions of band 4 supporting its placement in the level scheme of ^{125}I (Fig. 1).

The levels of the negative parity band (band 5) reported

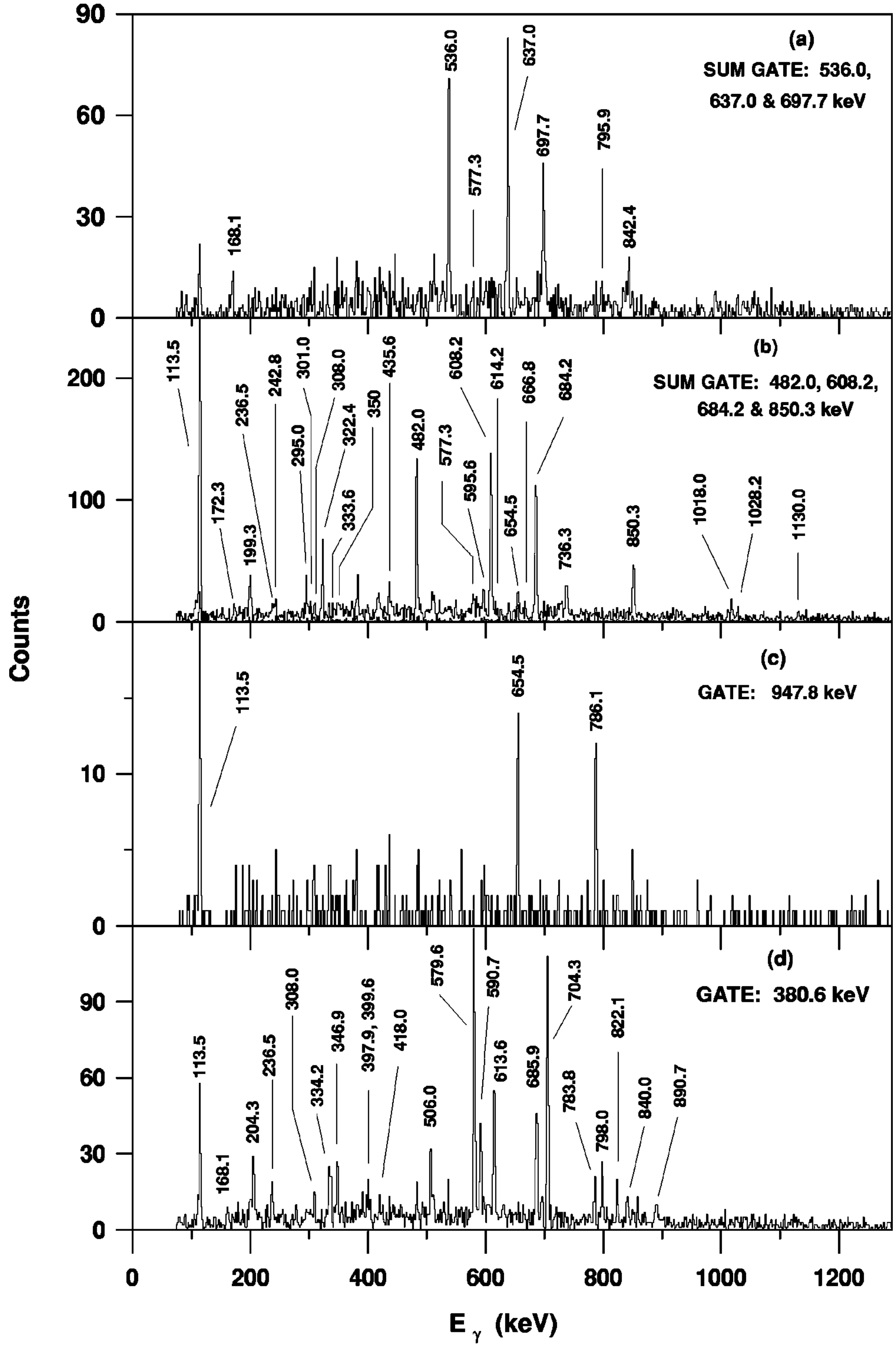

FIG. 2. Representative $\gamma\gamma$-coincidence spectra showing transitions associated with various bands in ^{125}I, with (a) the sum of gates on the 536.0, 637.0, and 697.7 keV transitions, (b) sum of the gates on the 482.0, 608.2, 684.2, and 850.3 keV transitions, (c) gate on the 947.8 keV transition, and (d) gate on the 380.6 keV γ ray.

earlier [4–6] up to the ($\frac{27}{2}^-$) state and its intraband transitions are well reproduced in the present work. A side feeding transition of 798.0 keV energy ($\frac{17}{2}^- \rightarrow \frac{15}{2}^-$) is also confirmed in this work. Besides this, new transitions of energies 783.8 and 840.0 keV are observed as shown in the level scheme of Fig. 1 and weak indication is obtained for the presence of 594 and 610.5 keV transitions. A representative coincidence spectrum with energy gate on the 380.6 keV γ ray showing the transitions associated with the sequences of levels labeled 5 and 6 in Fig. 1 is presented in Fig. 2(d). It may be mentioned that the 380.6 keV γ ray depopulating the $\frac{11}{2}^-$ state is not distinguishable from another γ ray of the same energy placed in band 7. Consequently, the transitions belonging to band 7 also appear in the spectrum of Fig. 2(d).

In the positive parity band based on the 935.6 keV $\frac{9}{2}^+$ state (band 7) a 399.6 keV transition shown with uncertain

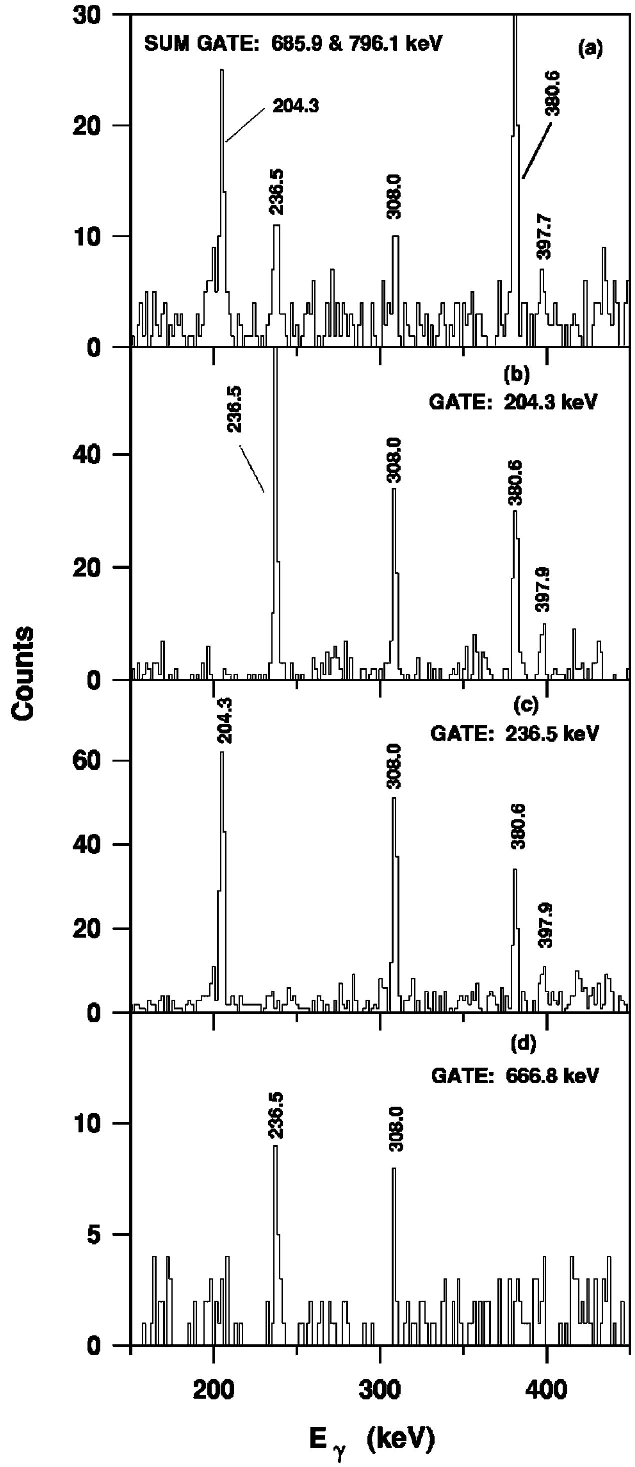

FIG. 3. Transitions of band 4 in the coincidence spectra with (a) sum of energy gates on 685.9 and 796.1 keV and energy gates on (b) 204.3 keV, (c) 236.5 keV, and (d) 666.8 keV transitions.

placement in Ref. [4] is now definitely placed as belonging to this band and forming a cascade with the previously reported transitions depopulating the $\frac{15}{2}^+$ state. Another new transition of 418.0 keV energy extends this cascade further to the 2814.9 keV state. A weak 444 keV transition is also observed in coincidence with the lower members of this cascade but not definitely placed owing to poor statistics in the reverse gate on this transition. Apart from the cascade transitions mentioned above, two new crossover transitions, viz., 681.5 keV $(\frac{13}{2}^+ \rightarrow \frac{9}{2}^+)$ and 728 keV $(\frac{15}{2}^+ \rightarrow \frac{11}{2}^+)$, are also observed. The cascade and crossover transitions of band 7 can be seen in the $\gamma\gamma$-coincidence spectrum projected with the energy gate on the 822.1 keV transition depopulating the $\frac{9}{2}^+$ bandhead of this band [Fig. 4(a)]. The gated spectra with energy gates on the 334.2 keV and sum of energy gates on the 334.2, 346.9, and 822.1 keV γ rays are displayed in Figs. 4(b) and 4(c), respectively, showing various transitions of band 7.

IV. DISCUSSION

A. Bands based on the $\pi d_{5/2}$ and $\pi g_{7/2}$ configurations of protons

New transitions of 842.4 and 1130.0 keV and confirmation of the placement of the 947.8 keV transition extend the level sequences of bands 1, 2, and 3 (Fig. 1) to higher energies. Based on the considerations of the transition energies, relative intensities, and results of the coincidence measurements in this work, these transitions could be likely candidates for the higher spin members of these bands. A noticeable feature of these bands is the occurrence of the interband $\Delta I = 1$ transitions connecting levels of bands 2 and 3. Besides the previously reported [4,5] interconnecting transitions below the $\frac{13}{2}^+$ state, new transitions have been observed also between the higher spin states of these bands, as shown in Fig. 1. Apart from this, several side feeding transitions are observed to populate the levels of band 2, which is the yrast band (Fig. 1).

Bands 2 and 3 in ^{125}I have been described as $2d_{5/2}$ and $1g_{7/2}$ decoupled bands based on the $\frac{5}{2}^+_1$ (g.s) and $\frac{7}{2}^+_1$ states, respectively [6]. On the other hand, the results of theoretical calculations using core-quasiparticle coupling model reported in Ref. [10] show both of these bands to arise mainly from the $\pi g_{7/2}$ configuration, with admixtures of $\pi d_{5/2}$ in the higher lying states. The observed features of bands 2 and 3, and the occurrence of interband $\Delta I = 1$ transitions between the levels of these bands, indicate a common configuration for these bands and hence favor the interpretation suggested in Ref. [10].

The $\pi d_{5/2}$ configuration, according to the calculations of Ref. [10], gives rise to the g.s. $(\frac{5}{2}^+_1)$ and another set of positive parity states, viz., $\frac{7}{2}^+_2$, $\frac{9}{2}^+_2$, $\frac{11}{2}^+_2$, $\frac{13}{2}^+_2 \ldots$, with admixtures of $\pi g_{7/2}$ in the higher-lying states. The experimental results show only the sequence of states $\frac{7}{2}^+_2$, $\frac{11}{2}^+_2$, $\frac{15}{2}^+_2, \ldots$, connected by a cascade of transitions, labeled as band 1 in Fig. 1. An interband transition $(\frac{11}{2}^+_2 \rightarrow \frac{9}{2}^+_1)$, hitherto unreported, is observed between bands 1 and 2. A search was made in this work for the theoretically predicted [10] $\frac{13}{2}^+_2$, $\frac{17}{2}^+_2 \ldots$ states, but none of these states were found. The new level at 1331.9 keV observed in this work (Fig. 1), although close in energy to the theoretically predicted [10] $\frac{13}{2}^+_2$ state, is ruled out as a member of this sequence because of its dominant decay to the $\frac{7}{2}^+_2$ state of band 1.

With the observation of new interband transitions in this work, the nature of bands 1, 2, and 3 in ^{125}I, and the decay modes of the levels in these bands, shows striking similarity to the observed characteristics of similar bands seen in the neighboring ^{119,121,123}I isotopes [1,2,11]. Calculations of

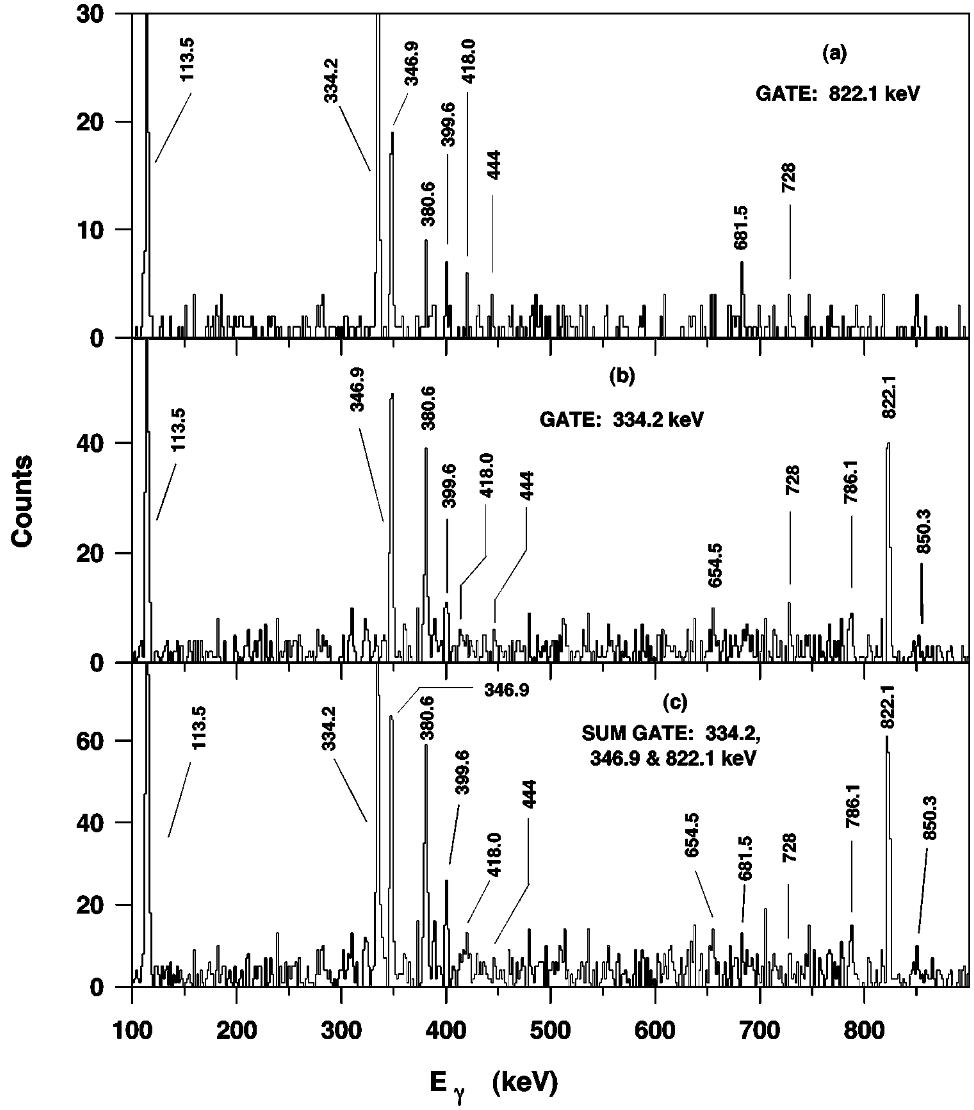

FIG. 4. Coincidence spectra showing the transitions of the positive parity band based on $\frac{9}{2}^+$ state (band 7) with energy gates on (a) 822.1 keV, (b) 334.2 keV, and (c) sum of gates on 334.2, 346.9, and 822.1 keV transitions.

low-lying single-quasiparitcle excitations for oblate as well as prolate shapes have been reported by Liang *et al.* [1] for a range of iodine isotopes. These calculations predict competing oblate and prolate shapes for the $d_{5/2}$ and $g_{7/2}$ configurations of protons. The bandheads built on these configurations with oblate deformation decrease in energy as the neutron number N increases. For the iodine isotopes with $N>66$ the energies of the oblate states become lower than those of the related prolate states. Thus, in ^{125}I with $N=72$, and in the neighboring iodine isotopes, the ground state is predicted to have an oblate deformation. Theoretical calculations [12] of band structures in ^{121,123}I with neutron numbers $N=68$ and 70, respectively, in the framework of the particle-rotor model show that the positive parity bands based on the $\pi d_{5/2}$ and $\pi g_{7/2}$ orbitals in these nuclei are well reproduced with oblate deformation $\beta=-0.15$. In view of these results for the neighboring nuclei and the close similarity in the systematics mentioned above, the experimentally observed features of bands 1, 2, and 3 in ^{125}I can be understood to have similar interpretation.

B. Bands based on the $\pi h_{11/2}$ configuration

The negative parity band with $\Delta I=2$ sequence of levels based on the $\frac{11}{2}^-$ state (band 5) in ^{125}I is analogous to similar bands known in the other odd-mass iodine isotopes, based on $\frac{11}{2}^-$ bandheads arising from the $\pi h_{11/2}[550]\frac{1}{2}^-$ Nilsson orbital at prolate deformation. The energy separations in this sequence in ^{125}I agree closely with those of the ground state band in ^{124}Te core, indicating the excellent decoupled nature of this band. A previously reported ($\frac{17}{2}^-$) state, which is also observed in this work, and a new state at 1868.7 keV show excellent agreement with the theoretically calculated $\frac{17}{2}^-$ and $\frac{13}{2}^-$ states in the framework of the core-quasiparticle coupling model [10]. A comparison of the experimental energies with those calculated theoretically in Ref. [10] is shown in Fig. 5. In odd-mass iodine isotopes the first experimental evidence of the occurrence of the unfavored signature of prolate $h_{11/2}$ band has been recently reported in ^{119}I [11]. It is noticed that the $\frac{17}{2}^-$ and $\frac{13}{2}^-$ states of the unfavored band decay to the $\frac{15}{2}^-$ and $\frac{11}{2}^-$ states of the favored band in ^{119}I. Considering this analogy with ^{119}I and the excellent agree-

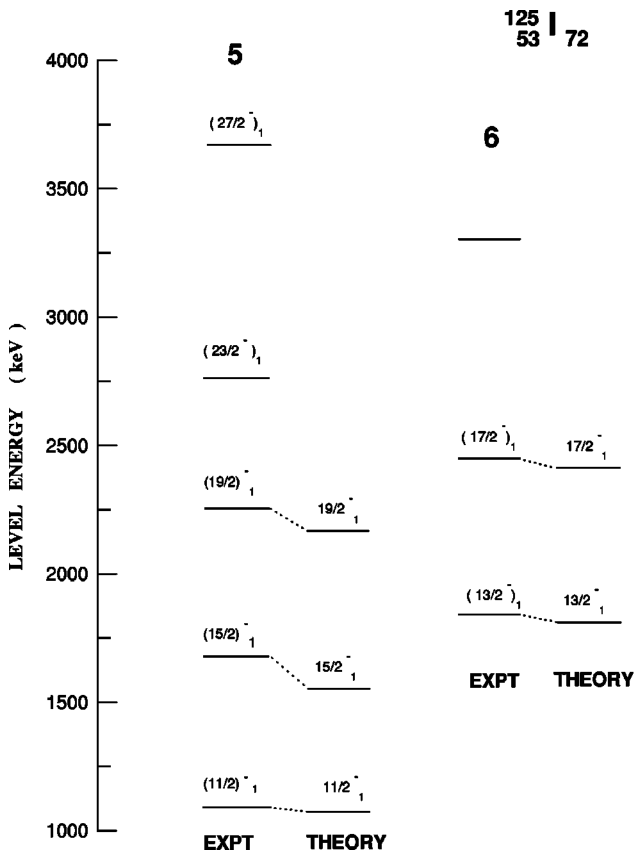

FIG. 5. Comparison of the experimental level energies in the negative parity bands of ^{125}I, with those theoretically calculated [10] in the framework of the core-quasiparticle coupling model.

ment with the energy of the theoretically predicted $\frac{17}{2}^-$ and $\frac{13}{2}^-$ states, the 2462.5 and 1868.7 keV states of ^{125}I may be members of the $\pi h_{11/2}$ unfavored signature band.

C. Band based on the $g_{9/2}$ proton hole state

Low-lying deformed $\frac{9}{2}^+$ proton hole states occur consistently in the odd-mass iodine nuclei [5]. Excitation of one proton from the pairwise filled $g_{9/2}$ proton orbital across the $Z=50$ gap gives rise to a strong tendency towards deformation, and leads to deformed minima in the potential energy of the nucleus [4]. From the Nilsson scheme a $\frac{9}{2}^+$ bandhead associated with the $\pi g_{9/2}[404]\frac{9}{2}^+$ proton-hole orbital with a prolate deformation of $\beta\sim0.2$ may be expected at low excitation energy [1,4]. In the odd-mass iodine nuclei such $\frac{9}{2}^+$ states are identified as bandheads of strongly coupled bands with a $\Delta I=1$ sequence of levels connected by an intraband cascade of predominantly dipole $\Delta I=1$ transitions and stretched quadrupole $\Delta I=2$ crossover transitions. In ^{125}I the 935.6 keV ($\frac{9}{2}^+$) state has been proposed to be the bandhead of a collective band (band 7) with band members reported up to the 1997.3 keV ($\frac{15}{2}^+$) state [4–6]. Characteristic crossover transitions of this band, viz., the 681.5 keV ($\frac{13}{2}^+\rightarrow\frac{9}{2}^+$) and 728 keV ($\frac{15}{2}^+\rightarrow\frac{11}{2}^+$), observed in the present work support this description of band 7.

Two more transitions of 399.6 and 418.0 keV now placed in the level scheme of ^{125}I form a cascade with the previously known lower-lying $\Delta I=1$ transitions in band 7. The increasing order of the energies of these transitions is suggestive of rotational character. The corresponding levels at 2396.9 and 2814.9 keV are fairly close to the expected energies of the $\frac{17}{2}^+$ and $\frac{19}{2}^+$ states from the $I(I+1)$ dependence of the energies of the lower-lying states, indicating these states to be likely members of the $\pi g_{9/2}$ band. The $E2/M1$ multipole mixing ratios of the $\Delta I=1$ transitions in the $\pi g_{9/2}$ bands in the odd-mass iodine nuclei are reported to be small [2,3,5,13]. Assuming these $\Delta I=1$ transitions in ^{125}I to be pure magnetic dipoles, the ratios of the reduced transition probabilities $B(M1;I\rightarrow I-1)/B(E2;I\rightarrow I-2)$ can be calculated from the relative intensities of the new crossover transitions $\frac{15}{2}^+\rightarrow\frac{11}{2}^+$ and $\frac{13}{2}^+\rightarrow\frac{9}{2}^+$ observed in this work. The values of this ratio for the transitions from the $\frac{15}{2}^+$ and $\frac{13}{2}^+$ states are found to be $\sim7(\mu_N/e\,\mathrm{b})^2$. This value agrees closely with the values of this ratio for the lower-lying states of the $\pi g_{9/2}$ band reported in ^{125}Cs [8].

D. Multiquasiparticle configurations

Multiquasiparticle states have been identified in many nuclei in the mass region $A\sim125$. In the odd-mass nuclei $^{117-121}$I [1,7] and ^{125,127}Cs [8,9] three-quasiparticle states with rotational bands built on them have been reported. The configurations of these states involve the odd-proton coupled to the two-quasiparticle states of the respective even-even Te or Xe core nuclei. In the simplest configuration of the valence particles in the even-even Te ($Z=52$) and Xe ($Z=54$) nuclei, the protons occupy the $\pi d_{5/2}$ and $\pi g_{7/2}$ orbitals while the neutrons are distributed in the $\nu d_{5/2}$, $\nu g_{7/2}$, and $\nu h_{11/2}$ orbitals. Two-quasineutron states involving the $\nu h_{11/2}$ orbital have been identified systematically in the even-even Te and Xe nuclei [7]. In the odd-mass I and Cs nuclei, the configurations suggested for the three-quasiparticle states involve a proton in $\pi d_{5/2}$, $\pi g_{7/2}$, or $\pi h_{11/2}$ orbital and two neutrons, with at least one in the $\nu h_{11/2}$ orbital [1,7–9].

The 2350.3 keV state in ^{125}I decays by 796.1 and 685.9 keV transitions to the $\frac{15}{2}^+$ and $\frac{15}{2}^-$ states of bands 3 and 5, respectively. A probable spin assignment $I=(\frac{17}{2})$ for the 2350.3 keV state has been given by Hagemann *et al.* [4]. The parity of this state, however, is unknown. A cascade of low-energy transitions populates this state. The lifetimes of the 2350.3 keV state and of the next two higher excited states have been reported to be 1.6 ± 0.3, $\leqslant0.2$, and 0.3 ± 0.1 ns, respectively, from beam-γ-delay measurements by Kostova *et al.* [10], based on the previously reported [4] level scheme. A significant change in the level scheme observed in the present work is that the ordering of the 204.3 and 236.5 keV transitions is reversed as compared to that reported previously [4]. Consequently, the energy of the next higher state above the 2350.3 keV state in band 4 is different, and the lifetime results need to be revised. The 397.9 keV transition reported with uncertain placement in Ref. [4] has now been definitely placed in band 4 as shown in Fig. 1. The multipolarities of the 204.3, 236.5, and 308.0 keV γ rays have been reported as likely magnetic dipoles, from γ-ray angular distributions and conversion electron measurements [4].

The characteristic features of the 2350.3 keV state of band 4 in ^{125}I (Fig. 1), viz., its excitation energy, spin, and fragmented decay to different bands, and the systematics of the odd-mass nuclei in this region are suggestive of a three-quasiparticle structure of this state. A noticeable feature of the higher excited states of band 4 is the increasing order of the energies of the intraband transitions observed in this work, following approximately the $I(I+1)$ rule for rotational bands.

The structure of states in band 4 has been discussed previously by Kostova *et al.* [10], suggesting three different quasiparticle configurations for the three lowest states of this band with arguments based on irregular level spacings according to the level scheme of Ref. [4] and transition probabilities deduced from the lifetime data. The configurations suggested [10] for the three states involve the $\pi d_{5/2}$ or $\pi g_{7/2}$ protons coupled to the neutron configurations of the type $\nu(h_{11/2}\ d_{3/2})$ or $\nu(h_{11/2}\ s_{1/2})$.

It is noticed, however, that the levels of band 4 in ^{125}I show close resemblance to a strongly coupled $\Delta I=1$ band reported in ^{125}Cs [8] based on a prolate-deformed three-quasiparticle state with $I^{\pi}=\frac{17}{2}^{-}$, decaying to the $\frac{15}{2}^{-}$ state of the negative parity $\pi h_{11/2}$ band. The configuration assigned to this three-quasiparticle state in ^{125}Cs [8] comprises the proton $\pi g_{7/2}$ coupled to the neutron configuration $\nu(h_{11/2}\ g_{7/2})$. In the odd-mass iodine isotope ^{121}I, the same neutron configuration coupled to the $\pi h_{11/2}$ proton gives rise to a prolate deformed three-quasiparticle state of positive parity with $I^{\pi}=\frac{23}{2}^{+}$ as the bandhead of a $\Delta I=1$ band with strong intraband $M1$ transitions [1]. These $\Delta I=1$ bands are characterized by large $B(M1;I\rightarrow I-1)/B(E2;I\rightarrow I-2)$ ratios. In ^{125}Cs the $B(M1)/B(E2)$ ratios of the above-mentioned three-quasiparticle band are reported to be greater than those for the strongly coupled $\Delta I=1$ band based on the $g_{9/2}$ proton-hole state in the same nucleus [8], whereas in ^{121}I the crossover $E2$ transitions have not been observed in the three-quasiparticle band [1]. These points of analogy favor an alternative interpretation of band 4 in ^{125}I as a three-quasiparticle band similar to those in ^{125}Cs and ^{121}I. More detailed work on the characteristics of this band in ^{125}I would be necessary to arrive at a proper interpretation [14].

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