A New Level Scheme of ^{127}I*

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Abstract Study of in-beam γ-ray spectroscopy of ^{127}I has been performed using ^{124}Sn(^{7}Li, 4n)^{127}I reaction at 32 MeV beam energy. A new level scheme of ^{127}I has been established including 25 new levels and 52 new γ transitions. Negative-parity levels based on $11/2^-$ $\pi h_{11/2}$ particle state have been observed up to $(35/2^-)$ extending our knowledge of decoupled structures to the heavier iodine isotope. Two $\Delta I = 2$ yrast positive-parity levels have been proposed to be associated mainly with the $\pi g_{7/2}$ configuration due to observations of several strong inter-band transitions. Two weakly populated $\Delta I = 2$ positive-parity levels and a high-lying $\Delta I = 1$ cascade have been newly identified and tentatively assigned as $\pi d_{5/2}$ one-quasiparticle and three-quasiparticle bands, respectively.

Key words in-beam γ-ray spectroscopy, level scheme of ^{127}I, quasiparticle configuration

Excited states of transitional nuclei $^{117-127}$I have been investigated in Refs. [1—4]. The collective features systematically observed in these unclei are the occurrence of $\Delta I = 2$ bands with stretched E2 transitions based on $5/2^+$, $7/2^+$, and $11/2^-$ states, and a $\Delta I = 1$ band characterized by M1 cascade and E2 crossover transitions based on a $9/2^+$ 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 the bandheads arising from $d_{5/2}$, $g_{7/2}$, and $h_{11/2}$ proton configurations[1—4]. However, the inter-band M1 + E2 transitions between the members of $d_{5/2}$ and $g_{7/2}$ bands have been found in the recent investigations on ^{121,123}I[5-7] and ^{125}I[7,8]. These authors attributed such coupled bands to the $\pi g_{7/2}$ configuration with admixture of $d_{5/2}$ quasiproton. An oblate shape associated with this band was also proposed[5,6] according to the calculations within the Strutinsky formulism using a Woods-Saxon potential. On the other hand, calculations within the core-quasiparticle coupling model[9,10] predict the existence of two coupled bands in ^{123,125}I based $\pi g_{7/2}$ and $\pi d_{5/2}$ configurations at low excitation energies. A search for the $\pi d_{5/2}$ coupled band in ^{125}I has been made but no positive evidence has been observed[8]. A previous investigation on ^{127}I[3,4] shows the $\Delta I = 2$ sequences of levels based on $5/2_1^+$ (g.s), $7/2_1^+$, and $11/2^-$ states up to $21/2^+$, $19/2^+$, and $23/2^-$ respectively. In order to identify new levels and transitions, and for understanding the nature of various bands, the structure of ^{127}I has been reinvestigated by in-beam γ-ray spectroscopic measurements in this work.

The experiment was performed at the tandem accelerator laboratory in the University of Tsukuba, Japan. We used the ^{124}Sn(^{7}Li, 4n)^{127}I reaction to populate the yrast and near-yrast levels

Received 22 October 2001
* Supported by NSFC(10025525), JSPS Invitation Fellowship(L00515), Major State Basic Research Development Program (G2000077400), and The Chinese Academy of Sciences

in ^{127}I The target was an enriched self-supporting ^{124}Sn metallic foil of 4 mg/cm^2 thickness. A γ-ray detector array composed of one planar detector and 9 BGO-Compton-suppressed Ge detectors was used for the in-beam γ-ray measurements. Five Ge detectors were positioned at 37° and the others near 90° with respect to the beam direction so that the DCO ratios (Directional Correlations of γ-ray de-exciting the Oriented states) could be deduced from the coincidence data. All the detectors were calibrated using standard ^{152}Eu and ^{133}Ba sources; typical energy resolution was 2.0—2.5 keV for the 1332 keV line from ^{60}Co source. The beam energy of 32 MeV was used during X-γ and γ-γ-t coincidence measurements. A total of 40 millions γ-γ-t and 3 millions X-γ coincidence events was accumulated. These coincidence events were sorted into a symmetric and a non-symmetric (DCO sorting) matrix for off-line analysis.

From detailed analysis on the γ-γ coincidence relationships, γ-ray relative intensities, and DCO ratios, a new level scheme of ^{127}I has been established as shown in Fig. 1 in which 25 new levels and 52 new γ-transitions have been assigned to ^{127}I. In this work, some high-energy and close-lying double peaks have been identified; the observed crossover transitions and γ-γ coincidence relationships support the placements of these γ-transitions in the present level scheme which is largely extended comparing with the previous one[3]. Brief comments and discussions are given in the following.

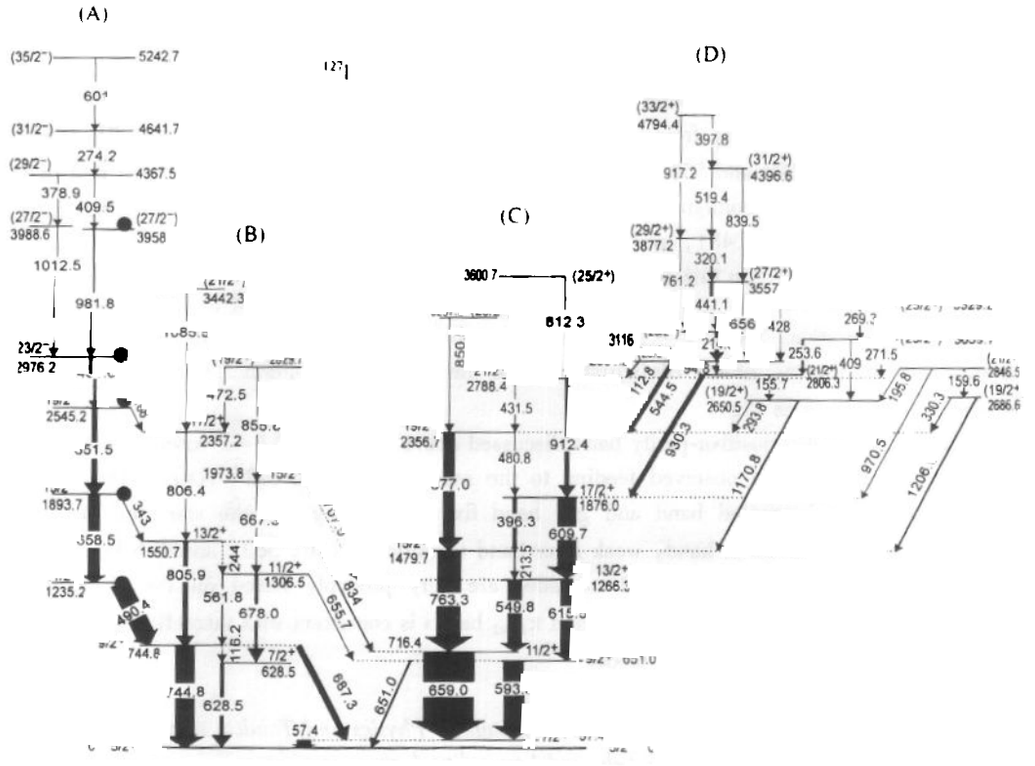

Fig. 1. Partial level scheme of ^{127}I deduced from the present work. Excitation energies of 0^+, 2^+, $\cdots 8^+$ states in ^{126}Te[11] relative to $11/2^-$ level in ^{127}I are indicated as black dots.

The negative-parity states labeled as (A) in Fig. 1 are extended from the $23/2^-$ level previously observed[3] up to ($35/2^-$) state at 5243 keV excitation energy. The deduced DCO ratios

show stretched quadrupole characters for 982, 1013, and 601 keV γ-rays and dipole characters for 410 and 274 keV lines. These results support the spin and parity assignments for the levels above $23/2^-$ state. A sequence of levels based on $11/2^-$ state has been observed in $^{119-127}$I and explained as decoupled bands based on the $h_{11/2}$ proton configurations[1-4]. The decoupled nature of these bands is inferred from the similar energy level spacings with those of the corresponding even-even cores. This is really the case comparing ^{127}I with ^{126}Te[11] as shown in Fig. 1 where the level spacings in ^{126}Te are indicated by black dots. The striking similarity suggests that the negative-parity levels from $11/2^-$ through$(27/2^-)$ are formed by coupling the aligned $h_{11/2}$ proton to the core states from 0^+ through 8^+.

The two $\Delta I = 2$ sequences of band (C) have been established previously[3] up to $19/2^+$ and $21/2^+$, respectively, by adding 880 and 934 keV transitions to the yrast $15/2^+$ and $17/2^+$ states. These two γ rays may be the 877 and 930 keV lines observed in this work; several parallel crossover transitions from the de-excitation of the new level at 2901 keV support the placements of the associated γ transitions and γ-ray energies determined in this work. Three new γ rays (912, 812, and 851 keV) are observed and placed in the level scheme extending the $\Delta I = 2$ sequences up to $(25/2^+)$ and $(23/2^+)$, respectively. The deduced DCO ratios show stretched quadrupole characters for 912, 812, 850, 545, 930, and 1171 keV γ rays, and dipole characters for 113, 95, 156, and 294 keV lines supporting the spin and parity assignments shown in the figure. Above $(23/2^+)$ state at 2901 keV, a $\Delta I = 1$ cascade with weak crossover transitions has also been observed; this is probably a 3-qp band.

The two $\Delta I = 2$ cascades of band (C) have been described in Refs. [1,4] as decoupled bands based on the bandheads arising from $d_{5/2}$ and $g_{7/2}$ proton configurations, respectively. The strong inter-band transitions (593 and 550 keV γ rays) between these $\Delta I = 2$ sequences suggest that these $\Delta I = 2$ bands have similar configuration with a large overlap in their wave functions. Other inter-band transitions (214, 396, 481, and 432 keV γ rays) are also observed connecting states up to $21/2^+$ at 2788 keV. Based on this and the systematics of the similar bands and decay patterns in the neighboring iodine nuclei[5-8], the two yrast $\Delta I = 2$ bands may be interpreted as signature partners of the same configuration. The $\alpha = -1/2$ signature branch is favored in energy, therefore, the main component may be the $g_{7/2}$ proton configuration, and the 651 keV transition is assigned as out-of-band decay as arranged in Fig. 1

Apart from the yrast positive-parity band discussed above, two new $\Delta I = 2$ cascades labeled as band (B) have been newly observed feeding to the second $7/2^+$ and $9/2^+$ states. The linking transitions with $h_{11/2}$ decoupled band and $g_{7/2}$ band fix the ordering and the spin and parity of associated levels. On the other hand, weak inter-band transitions (116, 562, and 475 keV lines) are also observed. These two $\Delta I = 2$ cascades are very probably based on the $d_{5/2}$ proton configuration. The observation of both $\pi d_{5/2}$ and $\pi g_{7/2}$ bands is consistent with theoretical predictions within the core-quasiparticle coupling model[9,10].

The authors wish to thank the staffs in the Institute of Physics and Tandem Accelerator Center, University of Tsukuba, Japan for their help and hospitality during experiment.

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^{127}I 核的新能级纲图*

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摘要　利用^{124}Sn(^{7}Li,4n)^{127}I 反应研究了^{127}I 核的在束 γ 谱，建立了包括 25 个新能级和 52 条新 γ 射线构成的新能级纲图. 将基于 $\pi h_{11/2}$ 粒子态($11/2^-$)的负宇称能级推高到($35/2^-$)，在较重的^{127}I 核中得到了退耦合能级结构. 由于在两个正宇称带 $\Delta I = 2$ 能级系列中观测到了强的带间跃迁，建议此带的主要成分为 $g_{7/2}$ 质子的组态. 另外还观测到了两个正宇称 $\Delta I = 2$ 和 $\Delta I = 1$ 能级系列，它们可能基于 $\pi d_{5/2}$ 的单准粒子带和一个 3 准粒子带.

关键词　在束 γ 谱^{127}I 核的能级纲图　准粒子组态

2001 - 10 - 22 收稿

* 国家杰出青年科学基金(10025525)，日本学术振兴会 JSPS(L00515)，国家重点基础研究发展规划(G2000077400)和中国科学院资助