Isomer spectroscopy of neutron-rich Nd isotopes

M. Tanaka,†1 E. Ideguchi,†1 G. Simpson,‡2 R. Yokoyama,†3 S. Nishimura,‡4 P. Doornenbal,‡4 G. Lorusso,‡4 P.-A. Söderström,‡4 Z. Xu,‡4 J. Wu,‡4,12 N. Aoi,†1 H. Baba,†4 F. Bello,‡4 F. Browne,‡4,16 R. Daido,‡7 Y. Fang,‡7 N. Fukuda,‡4 G. Gey,‡2,4,48 S. Go,‡3,4 N. Inabe,‡4 T. Isobe,‡4 D. Kameda,‡4 K. Kobayashi,§9 M. Kobayashi,§9 T. Komatsubara,‡10 T. Kubo,‡4 I. Kuti,‡11 Z. Li,‡12 M. Matsushita,‡1 S. Michimasu,‡3 C.-B. Moon,‡13 H. Nishibata,‡7 I. Nishizuka,‡14 A. Odahara,‡7 Z. Patel,‡4,15 S. Rice,‡15 E. Sahin,‡4,16 T. Sumikama,‡14 H. Suzuki,‡4 H. Takeda,‡4 J. Taprogge,‡17,†18 Z. Vajta,†20 H. Watanabe,†19 and A. Yagi†7

Prolate-deformed nuclei are found to appear in the neutron-rich part of the nuclear landscape around \( Z = 60 \) and beyond \( N = 90 \), after the systematic studies of excited states. In strongly deformed nuclei, quantum number \( K \) is known to be a good quantum number. Since transitions with large changes in \( K \) are suppressed, many nuclei in this region have isomeric states. In addition to the quadrupole deformation, appearances of higher-order deformations such as octupole and hexadecupole deformations have been predicted; however, they are not yet understood well. Isomer spectroscopy is a useful method to gain information on such structures of these nuclei.

Neutron-rich \( 60 \)Nd isotopes have been investigated by means of isomeric \( \gamma \)-ray spectroscopy. Such isotopes were produced by the in-flight fission of \( 238 \)U at RI Beam Factory in RIKEN Nishina Center, and were selected and identified by using the BigRIPS separator. The identification of the nuclei was performed on the basis of the \( \Delta E \)-TOF-\( B\rho \) method, which allows an event-by-event determination of their atomic number and the mass-to-charge ratio, where \( \Delta E \), TOF, and \( B\rho \) denote energy loss, time of flight, and magnetic rigidity, respectively. The identified particles were implanted into passive and active stoppers. A passive stopper made of Cu was used for the measurement at a high count rate, while the WAS3ABi2 active stopper consisting of five double-sided silicon strip detectors was used for the \( \beta \)-\( \gamma \) spectroscopy. Delayed \( \gamma \) rays were detected by the germanium cluster detector array EURICA.3 Gamma rays previously known from the \( 5^- \) \( K \)-isomeric state of \( ^{156} \)Nd4) were observed, and new \( K \)-isomeric states of heavier isotopes were discovered.

Figure 1 shows the \( \gamma \)-ray energy spectra of \( ^{158} \)Nd and \( ^{160} \)Nd using both the passive and active stopper data. We have observed three strong peaks at 151.6, 233.4, and 1198.2 keV for \( ^{158} \)Nd, and two strong peaks at 150.2 and 893.0 keV for \( ^{160} \)Nd. In both \( ^{158} \)Nd and \( ^{160} \)Nd, the half-lives of \( \gamma \) rays were preliminarily obtained as 0.339(20) \( \mu \)s and 1.63(21) \( \mu \)s, respectively. From the systematics of Nd isotopes, the energy of the first \( 2^+ \) states will be around 70 keV. However, such low-energy \( \gamma \) transition is highly converted, and accordingly, the 70-keV peaks could not be observed. Further analysis to make spin-parity assignments based on the decay pattern and coincidence relations is now in progress.

References

*1 Research Center for Nuclear Physics, Osaka University
*2 LPSC, Université Grenoble-Alpes, CNRS/IN2P3
*3 Center for Nuclear Study, The University of Tokyo
*4 RIKEN Nishina Center
*5 University of Oslo
*6 The University of Brighton
*7 Department of Physics, Osaka University
*8 ILL, 38042 Grenoble Cedex
*9 Department of Physics, Rikkyo University
*10 University of Tsukuba
*11 MTA Atomk
*12 Peking University
*13 Hoseo University
*14 Department of Physics, Tohoku University
*15 The University of Surrey
*16 University of York
*17 Instituto de Estructura de la Materia, CSIC
*18 Universidad Autónoma de Madrid
*19 Beihang University
*20 Department of Physics, The University of Tokyo