Nuclear Spectroscopy Laboratory
Chief Scientist: Hideki Ueno (D.Sci.)

(0) Research field

CPR Subcommittee**:** Physics

Keywords:

experimental nuclear physics, accelerator-use experiment, radioactive-isotope beams, radiation measurement, nuclear spin orientation

(1) Long-term goal of laboratory and research background

Atomic nuclei are substances governed by the nuclear forces, and are thus separated from atoms or other macroscopic external substances governed by electromagnetic interactions. However, nuclei interact with the external substances through hyperfine interactions owing to the nuclear spin accompanied with electromagnetic properties. Utilizing the characteristic of the hyperfine interaction, the research group investigates the properties of nuclei, and develops methods to manipulate nuclear spin, through the response of the external substances, or conversely investigates the properties of the external substances using nuclei as microscopic probes. For this purpose, the group has been developing new experimental techniques based on various nuclear spectroscopic methods, aiming at extending nuclear-physics technologies to cross-disciplinary research subjects in, e.g., fundamental physics and materials science.

(2) Current research activities (FY2020) and plan (until Mar. 2025)

The group has been developing a technique to enable nuclear-structure study through ground-state nuclear moments for rare RIs, which have not yet been realized for the high-energy RI beam produced, e.g., from the RIBF-BigRIPS RI separator. In the previous year, we demonstrated a new β-ray-detected NMR (β-NMR) spectroscopy based on fragmentation-induced spin-aligned RI beams, without utilizing spin polarization, which is usually required for this measurement. In 2020, we conducted an experiment using the QST HIMAC accelerator facility and succeeded in obtaining a β-NMR spectrum that clearly shows that this method is effective (activities mainly at the RNC).

The nuclear-reaction-based method has produced many results owing to its advantageous feature of element-independent spin polarization. However, it is difficult to extend the observation to further rare RIs and to other research fields, due to the limited magnitude of spin polarization. In order to break out of this situation, we are developing new methods/apparatus for nuclear laser spectroscopy and RI atomic beam resonance spectroscopy that can produce highly spin-polarized RI beams. We aim to complete the system development within the period of the mid-term plan (activities mainly at the CPR). As the former subject, we are developing an apparatus for collinear laser spectroscopy. In FY2020, we proceeded with offline R&D, and published the development of an ion source system with an RF ion guide. When the system development is completed, it will be installed downstream the universal slow RI beam system SLOWRI at RIBF, which is currently being developed jointly with the RNC Instrumentation Development Group. In FY2020, as a joint research project led by KEK including us, systematic mass measurement of RIs by a method combining SLOWRI and MRTOF (multi-reflection time-of-flight mass spectrometer) was conducted, and great results were obtained. As another R&D of laser spectroscopy, we are conducting R&D of unique laser spectroscopy utilizing superfluid He (He II), taking advantage of the Stokes shift in atoms introduced into He II. The direct observation of the time evolution of the Stokes shift has been conducted in collaboration with the CPR Molecular Spectroscopy Laboratory, as an important subject. Regarding RI atomic beam resonance spectroscopy, the development of the RI-ion trap and neutralization system, which forms a key component of the system, is ongoing. In FY2020, offline development was carried out, where ion trapping of Rb stable isotopes was confirmed. As the next step, we are working on the neutralization by gas introduction.

We are also working on the application of heavy-ion/RI beams to materials-science research (at CPR/RNC). Utilizing the above-noted ^{21}O as a nuclear spin probe, the first β-NMR experiment with a CuO single crystal was performed at RIBF. In addition, in collaboration with the CPR Condensed Molecular Materials Laboratory and the RNC Accelerator Group, experimental studies to control of the electrical conductivity of diamond have been conducted. We also performed materials-science studies based on Mössbauer spectroscopy at HIMAC and RIBF.

(3) Members as of March, 2021

(Chief Scientist)
UENO, Hideki

(Senior Research Scientist)
YAMAZAKI, Hiroki

(Research Scientist)
TAKAMINE, Aiko

(Postdoctoral Researcher)
IMAMURA, Kei
TAJIMA, Minori

(4) Representative research achievements

1. "Offline ion source for laser spectroscopy of RI at the SLOWRI," M. Tajima, A. Takamine, M. Wada, H. Ueno, Nucl. Instrum. Methods Phys. Res. B **486**, 48–54 (2021).
2. "The impact of nuclear shape on the emergence of the neutron dripline," N. Tsunoda, T. Otsuka, K. Takayanagi, N. Shimizu, T. Suzuki, Y. Utsuno, S. Yoshida, H. Ueno, Nature **587**, 66–71 (2020).
3. "Magnetic moment of the isomeric state of ^{75}Cu measured with a highly spin-aligned beam," Y. Ichikawa, H. Nishibata, Y. Tsunoda, A. Takamine, K. Imamura, T. Fujita, T. Sato, S. Momiyama, Y. Shimizu, D. S. Ahn, K. Asahi, H. Baba, D. L. Balabanski, F. Boulay, J. M. Daugas, T. Egami, N. Fukuda, C. Funayama, T. Furukawa, G. Georgiev, A. Gladkov, N. Inabe, Y. Ishibashi, Y. Kobayashi, S. Kojima, A. Kusoglu, T. Kawaguchi, T. Kawamura, I. Mukul, M. Niikura, T. Nishizaka, A. Odahara, Y. Ohtomo, T. Otsuka, D. Ralet, G. S. Simpson, T. Sumikama, H. Suzuki, H. Takeda, L. C. Tao, Y. Togano, D. Tomonaga, H. Ueno, H. Yamazaki and X. F. Yang, JPS Conf. Proc. **32**, 010047-1–4 (2020).
4. "Experimental studies of the two-step scheme with an intense radioactive ^{132}Sn beam for next-generation production of very neutron-rich nuclei," H. Suzuki, K. Yoshida, N. Fukuda, H. Takeda, Y. Shimizu, D. S. Ahn, T. Sumikama, N. Inabe, T. Komatsubara, H. Sato, Z. Korkulu, K. Kusaka, Y. Yanagisawa, M. Ohtake, H. Ueno, T. Kubo, S. Michimasa, N. Kitamura, K. Kawata, N. Imai, O. B. Tarasov, D. Bazin, J. Nolen, W. F. Henning, Phys. Rev. C **102**, 064615 (2020).
5. "In-gas-cell laser resonance ionization spectroscopy of ^{196,197,198}Ir," M. Mukai, Y. Hirayama, Y. X. Watanabe, S. Schiffmann, J. Ekman, M. Godefroid, P. Schury, Y. Kakiguchi, M. Oyaizu, M. Wada, S. C. Jeong, J. Y. Moon, J. H. Park, H. Ishiyama, S. Kimura, H. Ueno, M. Ahmed, A. Ozawa, H. Watanabe, S. Kanaya, and H. Miyatake, Phys. Rev. C **102**, 054307 (2020).

Supplementary

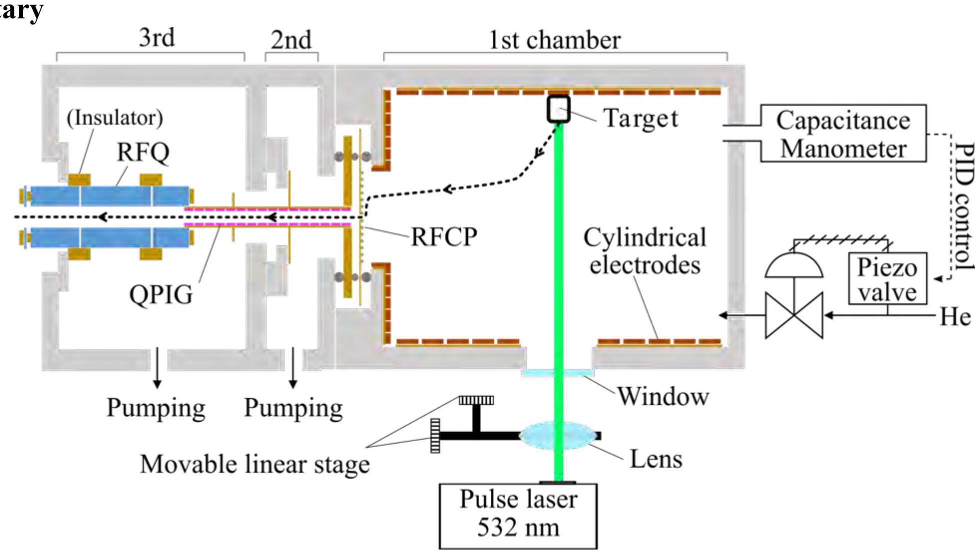

Fig. 1. An ion source system for offline collinear laser spectroscopy. Details are described in Ref. 1 of (4).

Laboratory Homepage
https://www.riken.jp/en/research/labs/chief/nucl_spectro/index.html