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Development of ion transportation, extraction and neutralization systems for atomic beam resonance method

Daisuke Nagae[a,*], Koichiro Asahi[a], Hisanori Miyoshi[a], Kenzi Shimada[a], Akihiro Yoshimi[b], Hideki Ueno[b], Jiro Murata[c], Makoto Uchida[a], Daisuke Kameda[a], Go Kato[a], Shoken Emori[a], Go Kijima[a], Sachiko Oshima[a], Makoto Takemura[a], Takemasa Arai[a], Yoshio Kobayashi[b], Tomohito Haseyama[b], W.D. Schmidt-Ott[d]

[a]*Department of Physics, Tokyo Institute of Technology, 2-12-1 O-okayama, Meguro-ku, Tokyo 152-8551, Japan*
[b]*RIKEN, 2-1 Hirosawa, Wako-shi, Saitama 351-0198, Japan*
[c]*Department of Physics, Rikkyo University, 3-34-1 Nishiikebukuro, Tokyo 171-8501, Japan*
[d]*II. Physikalisches Institut, Der Universität Göttingen, Bunsenstrasse 7-9, D-3400 Göttingen, Germany*

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Abstract

A device that produces a low-energy and largely spin polarized RI beam based on the atomic beam resonance method (RIABR) has been developed. We have performed measurements of stopping and drifting an incoming RI ion beam in a gas chamber, extraction of the ions into a vacuum region, and neutralization of the extracted low-energy ion beam. The drift efficiency of RI ions in a gas and the extraction efficiency at a Laval-type glass nozzle were found to be 0.72 ± 0.04 and 0.033, respectively. The result of the experiment for the neutralization is also discussed.

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Keywords: Atomic beam resonance method; RI beam; Spin polarize; Drift; Extraction; Neutralization

1. Introduction

Spin polarized low-energy radioactive isotope (RI) beams are useful not only in nuclear physics but also in material and surface physics. Nuclear structure is studied via electromagnetic moments, β decays and γ decays. Condensed matter studies with radioactive nuclei as spin probes can be made by: covering the whole region of elements in the periodic table, using intense beams of RI atoms with spins polarized/aligned, and controlling the

*Corresponding author. Fax: +81 35 734 2716.
E-mail address: nagae@yap.nucl.ap.titech.ac.jp (D. Nagae).

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position of implantation in nano-meter scale. Thus, by implanting the RI probes into matter (metals, semiconductors, surfaces, interfaces, and even in liquid phases), β-ray asymmetry, γ-ray anisotropy, and angular correlation between the two cascade γ-rays will be used to analyze the microscopic structures and dynamics of matters through the rotation, relaxation, and resonance of spins. We are developing a device that produces low-energy and largely spin polarized RI beam based on the atomic beam resonance method (RIABR).

RIs are polarized by atomic spin selection and hyperfine state transition. Spin is selected by the interaction of an atomic spin and an external magnetic field. In order to effectively select the spin, the RI ion should be a neutral particle. The kinetic energy of the RI should be as small as the thermal energy to effectively separate the orbits of the RIs with the different spin states. Primary tasks for realizing the RIABR are: (1) stopping the RI beam in a gas volume, (2) extraction of the stopped RI using ion drifting with static electric field, (3) neutralization of the RI ion and (4) transportation of the RI into the spin selection system.

2. Stopping and drifting ions in a gas chamber

On-line measurements of stopping and drifting ions [1] were performed at RIKEN using an RI beam delivered by the fragment separator RIPS. The setup used for the test experiments is schematically illustrated in Fig. 1. In these experiments, we employed neon gas as the stopping material. The RI-stopping/collecting gas chamber is made of glass. The total length of the chamber is 1150 mm, and the inner diameter is about 50 mm. Twenty electrodes installed outside the chamber were 1-mm-thick discs of 8.0 cm outer diameter and 5.0 cm inner diameter. They were connected by 300 kΩ resistors with intervals of 18 mm between each of them, to create a uniform electric field [2]. The high voltage applied between the first electrode and the 19th one was 3 kV. The high voltage of the last electrode was the same to that of the 18th one in order to trap the extracted RI. We calculated the electric field using Poisson code [3], and obtained that the uniform axial electric field was 87 V/cm. The pressure of the neon gas in the chamber was approximately 600 Torr. We chose a beam of ^{30}Al ions produced by the fragmentation of ^{40}Ar projectile at an energy of 95 MeV/u on a

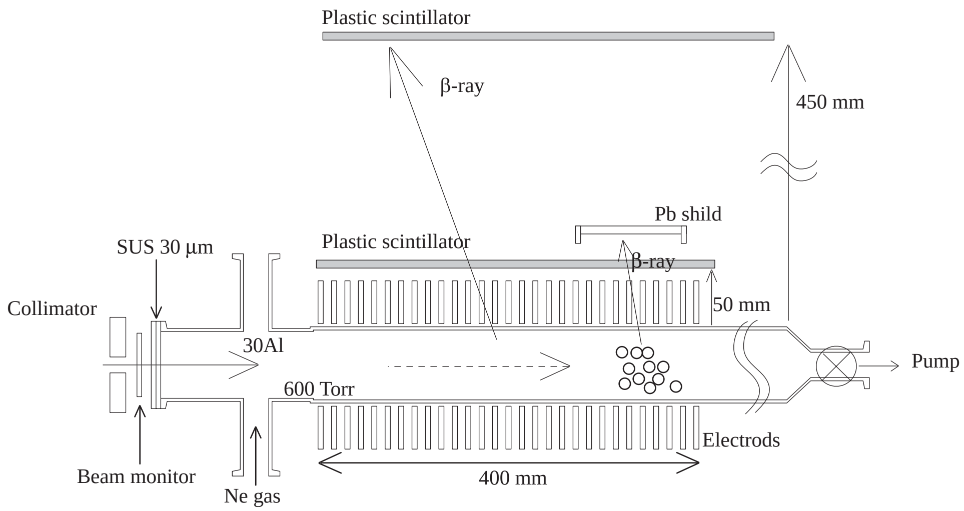

Fig. 1. Schematic view of the on-line setup. The cylindrical glass chamber was surrounded by an array of 20 pieces of ring electrode. The length of the drift field is about 400 mm.