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STATUS OF THE ION TRAP PROJECT AT IGISOL*

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The IGISOL facility at the Department of Physics of the University of Jyväskylä (JYFL) is delivering radioactive beams of short-lived exotic nuclei, in particular the neutron-rich isotopes from the fission reaction. These nuclei are studied with the nuclear spectroscopy methods. In order to substantially increase the quality and sensitivity of such studies the beam should undergo beam handling: cooling, bunching and isobaric purification. The first two processes are performed with the use of an RFQ cooler/buncher. The isobaric purification will be made by a Penning trap placed after the RF-cooler element. This contribution describes the current status of the ion trap project and its future prospects. The latter comprise the precise nuclear mass measurements, nuclear spectroscopy in the Penning trap interior as well as the laser spectroscopy on the extracted beams.

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1. Introduction

A project for improving the quality of radioactive ion beams produced at IGISOL [1] has been started in 1997 [2,3]. Basic parameters of a radioactive beam at IGISOL presently are: beam energy spread $\Delta E \approx 80$ eV, transverse emittance $\xi \geq 10\pi$ mm mrad and mass resolving power $R = M/\Delta M =$ 200–1000. In order to enhance the quality of experiments at IGISOL it was necessary to improve the radioactive beam quality. The goal was to obtain:

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$\Delta E \leq 1$ eV, $\xi \approx 1\pi$ mm mrad and $R = 10^5$. The latter means a possibility of rejecting even isobaric contaminants, obtaining a pure monoisotopic beam. This improvement will be achieved due to radioactive beam handling, which consists of three steps: beam cooling (which improves both ΔE and ξ), bunching and purification (due to high R). The first two steps are done with use of an RFQ cooler/buncher (see [4]). The beam purification is performed with the use of a cylindrical Penning trap similar to the one described in Ref. [5].

2. Project description

The RFQ cooler/buncher [4] exists at JYFL already. Its performance as follows: $\Delta E = 0.6$ eV, $\xi \approx 1$–2π mm mrad, transmission TR> 60% and cooling time around 1 ms. Bunching possibility was also demonstrated. In the Penning trap case, mass-selective buffer gas cooling technique [6] will be used for purification. In order that the purification could take place, the trap interior has to be filled with a buffer gas at low pressure (10^{-3}–10^{-4} mbar), usually helium. A low-energy (of the order of 100 eV) ion beam coming from the RFQ cooler/buncher is captured in the trap center and then the buffer gas cooling can start. For this purpose, the central ring electrode is segmented azimuthally into 4 segments. The segments are supplied with an oscillating RF-potential so that an oscillating quadrupole field in the azimuthal plane is created. The RF-frequency is chosen so that it is equal to the cyclotron frequency of the ions of interest, which are usually mixed with other, contaminating ions. The joint action of the RF-field and the buffer gas is cooling and centering the ions of interest on the trap axis, whereas contaminants are not centered. The ions of interest are then ejected through a small hole in the endcap of the trap. This process can have a high mass resolving power, of the order of 10^5, which permits to reject even isobaric contaminants [5]. This is particularly important for the experimental program at IGISOL, which in future will be centered on exotic neutron-rich nuclei, produced in fission. The isobaric purification will allow for rejecting of all unwanted members of the isobaric chain, leaving only a species of interest. This will significantly improve signal-to-background ratio, sensitivity and precision of the experiments, and will extend the range of the isotopes investigated.

The task of the purification Penning trap at IGISOL is to perform the isobaric purification and to deliver clean, monoisotopic beams for nuclear and laser spectroscopy as well as precise nuclear mass measurements. In order to achieve this goal, it is planned to place the Penning trap inside a $B = 7$ T superconducting magnet. This magnet was delivered already by Magnex Scientific Ltd. and installed at the IGISOL area in November

1999 (see Fig. 1). It is a solenoid with two homogeneous magnetic field regions (inhomogeneities within 1 cm^3 volume below 10^{-6} and 10^{-7}, respectively). The isobaric purification of radioactive beam will be performed in the cylindrical Penning trap positioned in the first region. As mentioned, it will substantially enhance the sensitivity and precision of collinear laser and nuclear spectroscopy experiments. The former will profit already of the presence of the RFQ cooler/buncher, delivering a bunched beam with very good emittance [4].

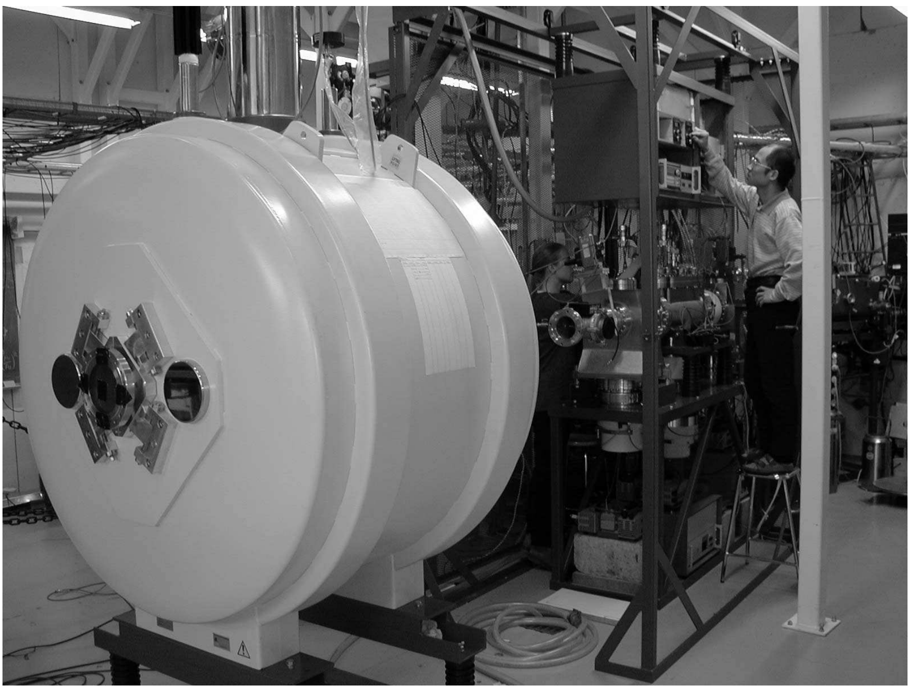

Fig. 1. The 7 T superconducting solenoid.

The second step of the ion trap development will consist of building a second Penning trap for the precise nuclear mass measurements of radioactive ions. It will be placed directly after the purification trap in the same superconducting magnet, in the second homogeneous magnetic field region. A trap of a cylindrical type will be used, which should assure the measurement accuracy of 10^{-6}–10^{-7}. It will enable mass measurements of many neutron-rich isotopes not reachable anywhere else (*e.g.* of refractory elements) and will significantly broaden experimental program at IGISOL.

In the third step of Penning trap development, nuclear spectroscopy in a Penning trap interior is foreseen. This means placing the detectors of a needed type directly inside the trap and positioning the radioactive sample in front of them. Such a scheme has certain advantages over conventional spectroscopy, like very good quality radioactive source (very thin, small size, no backing, free of intensity attenuation, energy degradation and backscattering problems), minimization (in a given detector) background contribution from other types of radiation, and an efficient passive shielding for background radiation with the magnet cryostat.

It is planned to install and test the purification trap in the year 2000. A part of the necessary vacuum components (*e.g.* turbo-pumps) has been delivered already. The electronics and control system (LabVIEW based) are under development. The Penning trap system is done in close collaboration with GSI Darmstadt, where a similar trap project SHIPTRAP aiming at experiments with transuranium isotopes [7] is in preparation.

The ion trap development at IGISOL is done in a collaboration with other nuclear physics laboratories grouped in a European network EXOTRAPS (JYFL is a coordinator of this network). Within this collaboration, IGISOL group has participated (November 1999) in precise nuclear mass measurements with the ISOLTRAP Penning trap set-up at ISOLDE, CERN [8]. Then, the mass of ^{33}Ar (accuracy of 10^{-7}) with $T_{1/2} = 174$ ms was measured (see [9]). Thus, the nuclei with half-lives of the order of 0.1 s should also be available in the future for precise nuclear mass measurements at IGISOL.

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