THE NEW 14 GHZ ION SOURCE FOR THE U-400 HEAVY ION CYCLOTRON

Leporis M.*, BIONT, Bratislava, Slovakia
Bekhterev V., Bogomolov S., Efremov A., Gulbekian G., Kostyukhov Yu., Lebedev A., Loginov V., Yazvitsky N., JINR, Dubna, Russia.

Abstract

The new 14 GHz ion source DECRIS-4, to be used as a second injector of heavy multiply charged ions for the U-400 cyclotron and, in the future, also as a "charge breeder" (the "1+ → n+" method) for the second phase of the DRIBs project, has been designed and constructed at the FLNR. The main feature of the ion source design is the creation of the extended resonance zone in a comparatively compact ECRIS. For this purpose the axial magnetic field is formed with a flat minimum by mounting only one additional solenoid coil to the classical "CAPRICE" magnetic structure. In this case the superposition of the axial magnetic field and the radial field of the permanent magnet hexapole, made from NdFeB, allows one to create a larger resonance volume. First results of the ion source tests show that in this resonance volume electrons are heated very efficiently which allows to produce intense beams of medium charge state ions with comparatively low level of input microwave power. The basic design features, construction issues and the first results of ion source tests are presented.

INTRODUCTION

The new ECR ion source DECRIS-4 for the cyclotron U–400 was started in the end of 2003 [1]. The design of the source was aimed of solving two problems:

a) The use of the ion source as the second injector of the U–400 cyclotron (operating time is about of 6000 hours per year) for more effective exploitation.

b) The ion source (after some modification) can be used as a "charge breeder" for the second phase of DRIBs project.

Since 1997 up to now the U–400 cyclotron successfully works with ion source ECR4M, supplied by GANIL. The most frequently accelerated ion beam (more than 70% of the operation time) [2] within the past few years is the beam of 48Ca. For this reason the improvement of the 48Ca beam production including the increasing of the ionization efficiency, the prolongation of the microoven "life time", the improvement of the beam transport efficiency and so on, are the main goals of this ion source design.

The DRIBs (Dubna Radioactive Ion Beams) project started in accordance with the plan of the FLNR development few years ago. The idea of using the secondary radioactive nuclei beams strongly extends the possibilities for the investigation of properties of atomic nuclei and nuclear reactions. The production of exotic nucleus beams is one of the main scientific lines in FLNR.

In the second stage of the DRIBs project [3, 4], it is planned to use a primary electron beam from the Microtron MT-25 for the production of radioactive neutron–rich nuclei (238U photo fission fragments). The beam of single–charged radioactive ions can be turned to the low-energy laboratory or post–accelerated in the cyclotron U–400. In this case the single–charged ions will be transported into the ECR ion source and then extracted with the n+ charged state required for the acceleration, because the cyclotron U–400 can accelerate ions with A/Z from 6 to 12. In this article, we present the design parameters, the results of the magnetic field measurements and some preliminary results of ion source tests.

DESIGN OF THE ION SOURCE

The design of the magnetic structure of the source was based on the idea of the so-called "magnetic plateau" in the center of the source suggested by Alton and Smithe [5] and successfully realized by the Munster University

Table I: The main parameters of DECRIS-4

Main Parameters	
B_{inj}	1.3 T
B_{ext}	1.3 T
L_{mirror}	29 cm
Max. coil current	1000 A
Water cooling ΔP	15 barr
Hexapol field on the wall of plasma chamber	> 1.05 T
Plasma chamber internal diameter	74 mm
Max. extraction voltage	30 kV
UHF freqency	14 GHz

* Also at: JINR FLNR, Dubna, Russia

Team[6]. The main parameters of the ion source DECRIS–4 are collected in Table I.

Magnetic structure

The axial magnetic field is formed by 3 independent solenoids enclosed in separated iron yokes. All three coils are connected to three independent power supplies. An enlarged resonance zone can be created with the help of the middle coil and two movable soft iron rings. The position of the rings depends on the coil current and it is assigned experimentally. Thus we can obtain symmetric as well as asymmetric distribution of magnetic field with remaining of the flat minimum. The maximal magnetic field at the axis is up to 1.3 T on both sides which provides a mirror ratio about of 2.5. The length of the flat minimum is about of 60mm and it depends on the coils current. Example of axial magnetic field distributions and comparison with the calculation are shown in Fig. 1. The line with square (number-1) corresponds the distribution, where the value of the magnetic field of flat minimum is approximately same to resonance field and in the second one (the line with cross) magnetic field slightly falling down in the region of resonance magnetic field.

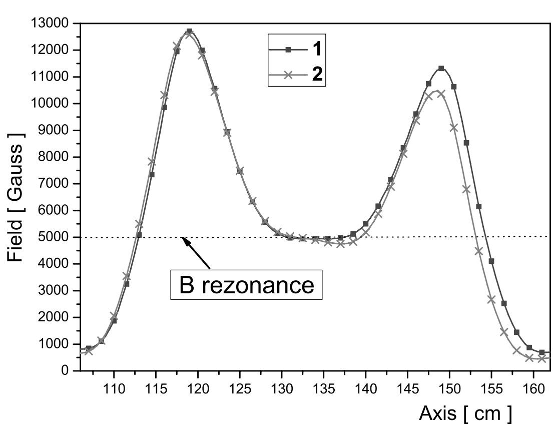

Fig. 1:Magnetic field distribution on the axis DECRIS-4.

The hexapole for the radial confinement has a Halbach structure. It consists of 24 permanent magnet identical sectors with the corresponding easy axis direction. The outer diameter is 160 mm, the inner one is 80 mm. The measured magnetic field on the plasma chamber wall is 1.05 T. The superposition of the coils and hexapole magnetic fields (three-dimensional view) is shown in Fig. 2. It is easy to see the enlarged resonance surface marked with dark colour.

The whole magnetic structure is moveable along the axis with respect to the plasma chamber to optimize the plasma electrode position during the source operation.

Plasma chamber and injection side

To improve the 48Ca beam production some innovations of the plasma chamber and injection side of

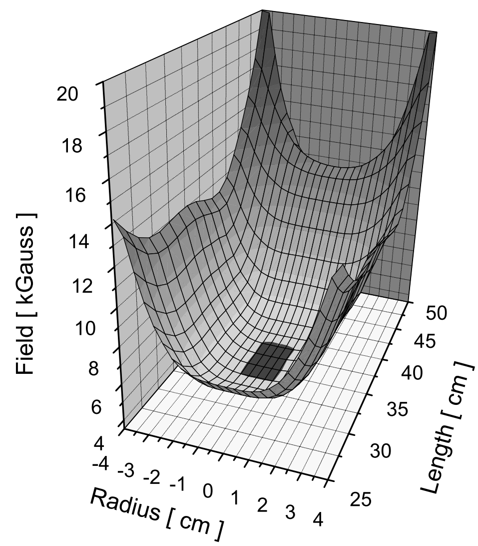

Fig. 2: Three-dimensional view of magnetic field distribution. The dark area in the centre corresponds to the enlarged resonance zone.

the source were applied. The plasma chamber is made as double-wall water-cooled stainless steel tube. As compared with the previous versions of DECRIS, it has constant inner diameter of 74 mm. UHF coupling fed by the standard waveguide instead of coaxial feeding and a movable bias electrode for precise cavity tuning are also used. The injection side of the source has more room for the installation of a new micro-oven with temperature control and a bigger size crucible. More room gives the possibility to install direct ohmic heater of the screen. This innovations allows us to increase the efficiency and time of nonstop operation during the ^{48}Ca or other solid elements ion beams production.

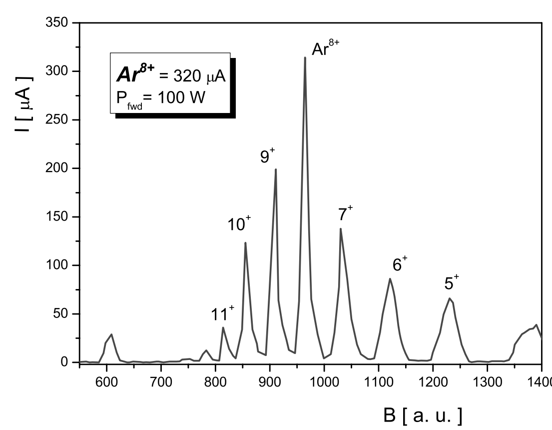

Fig. 3: Argon spectra optimized to Ar^{8+}.

FIRST EXPERIMENTAL RESULTS

The final assembly of the DECRIS–4 was finished on June of last year and after that it has carried out tests of the ion source at the FLNR test bench. Some preliminary results of the ECR ion source testing are collected in the Table II. All these results were obtained with a 18 kV extraction voltage and the extraction aperture 10 mm.

Table II: Ion yields from DECRIS-4 [eμA]

ion	***Charge state***								
	6+	7+	8+	9+	11+	12+	15+	18+	20+
Argon			400	220	125	65			
Oxygen	400	80							
Krypton				80	110	85	35		
Xenon							55	30	25

The first experiments showed very good performance of the ion source, which there is able to produce e.q. 280μA of Ar8+ with pure Ar and 320μA with mixture of Ar and He when only 100W of microwave power was used. The Ar spectrum, when source was tuned for Ar8+ production, is shown in Fig.3. The dependence of the Ar8+ ion yields versus the microwave power for DECRIS–4 and DECRIS–2m ion sources is shown in Fig.4. DECRIS–2m [7] has ordinary "caprise type" magnetic structure with approximately the same level of axial magnetic field. It is absolutely evident that the magnetic structure with "flat minimum" has better microwave energy absorption and for production the same beam intensity we have to fed up 2-3 times lower level of mikrowave power. The similar dependencies have seen on the other gases.

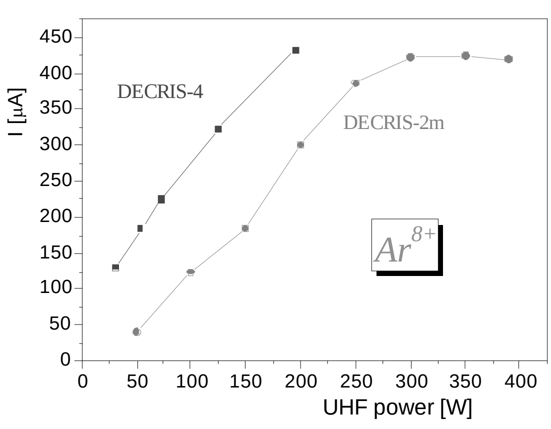

Fig. 4: Comparison of Ar^{8+} ion yields from the DECRIS–4 and DECRIS–2m ion sources.

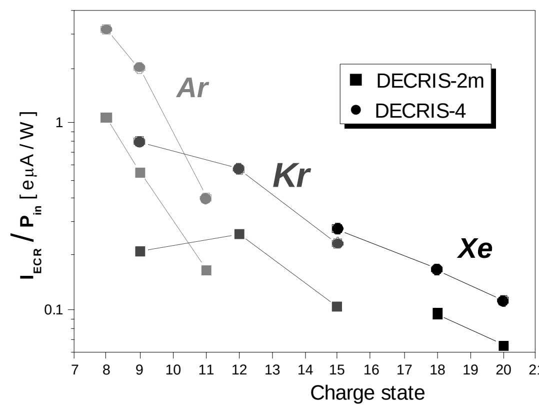

Fig. 5: Comparison of efficiency of ion sources.

CONCLUSION

The ion source DECRIS–4 was designed as an injector of medium charge state ion beams for the U–400 cyclotron. The first tests showed the ability of the source to produce intense ion beams with comparatively low microwave power.

In the nearest future we are going to test the source with the higher levels of microwave power, more precise tuning of the magnetic field distribution and position of plasma electrode to obtain the maximum beam current.

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