DECRIS-5 ION SOURCE FOR DC-110 CYCLOTRON COMPLEX RESULTS OF THE FIRST TESTS

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Abstract

The project of the DC-110 cyclotron facility to provide applied research in the nanotechnologies (track pore membranes, surface modification of materials, etc.) has been designed by the Flerov Laboratory of Nuclear Reactions of the Joint Institute for Nuclear Research (Dubna). The facility includes the isochronous cyclotron DC-110 for accelerating the intensive Ar, Kr, Xe ion beams with 2.5 MeV/nucleon fixed energy. The cyclotron is equipped with system of axial injection and ECR ion source DECRIS-5, operating at the frequency of 18 GHz. The main parameters of DECRIS-5 ion source and results of the first tests are presented in this report.

INTRODUCTION

The project of the DC-110 [1] cyclotron facility to provide applied research in the nanotechnologies (track pore membranes, surface modification of materials, etc.) has been designed by the Flerov Laboratory of Nuclear Reactions of the Joint Institute for Nuclear Research (Dubna). The cyclotron has 2m pole diameter, and to provide the energy of 2.5 Mev/nucleon the accelerated ions should have the mass to charge ratio about of A/Z = 6.6, that is 40Ar6+, 86Kr13+ and 132Xe20+. The parameters of the source are determined mainly by required intensity of the 86Kr13+ and the 132Xe20+ ion beams at the level of 200 eμA and 150 eμA correspondingly. The prolonged beam stability (few hours) is also important during the track pore membrane irradiation.

In recent years ECRIS has made considerable progress with the continuing increase of extracted ion beam intensity in which the fully superconducting ECRIS and hybrid ECRIS take the leading role. At the same time a room temperature ECRIS has the advantages of easy operation and lower cost in comparison to a SC ECRIS but with lower performance. Taking into account the operating conditions and that the production of very high charge states is not required the use of RT ECRIS in our case is more preferable.

A room temperature (RT) ECRIS consists of a set of water cooled resistive solenoids and a permanent sextupole magnet. To meet the requirement of an optimum 3D confinement magnetic field configuration the GTS-type [2] magnetic structure was chosen. This kind of magnetic structure provides a high enough level of an injection magnetic field keeping the reasonable ac power consumption.

DESCRIPTION OF THE SOURCE

The new 18 GHz RT ECRIS DECRIS-5 was constructed and built at FLNR JINR, Dubna, Russia. The magnetic structure of the source is composed by three independent copper coils. The injection and extraction coils are enclosed in soft iron yokes. By adding an iron plug at the injection side, which is situated directly inside the discharged chamber, the injection magnetic field can be effectively increased. At full excitation of the injection solenoidal coil, the injection magnetic field can be as high as 2.25 T. The calculated axial magnetic field distribution and the scheme of the magnetic structure are shown in the Fig.1 and Fig.2 correspondingly. The maximal current of the power supplies for the injection and extraction coils is 1200 A, for the middle coil – 800 A. The power consumption of the coils is about of 150 kW.

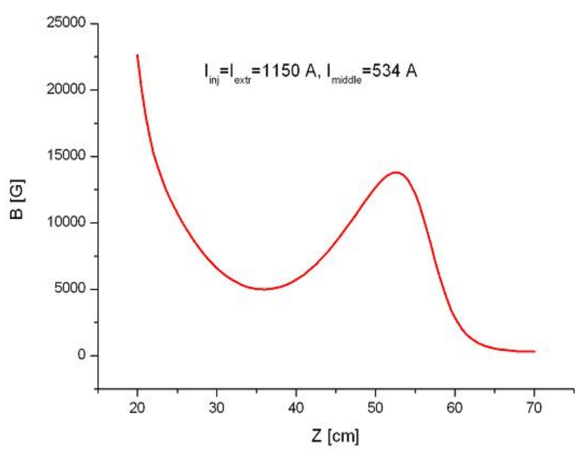

Figure 1: The axial magnetic field distribution.

The new hexapole for DECRIS-5 ion source (Fig.3) for radial confinement of plasma has a Halbach structure. It consists of 36 permanent-magnet identical trapezoidal sectors with the corresponding easy axis direction. In order to obtain a smooth magnetic field distribution along the pole an each sector was made from the whole piece of the magnetic material. This technology allows to eliminate some failings in magnetic field distribution near permanent magnet junctions. The inner diameter, the outer diameter, and the length of the hexapole are 86 mm, 230 mm, and 300 mm, respectively. Fig.4 shows the measured radial magnetic field strength on the plasma chamber wall in front of each pole. The comparison between radial field distributions of sectional hexapole for

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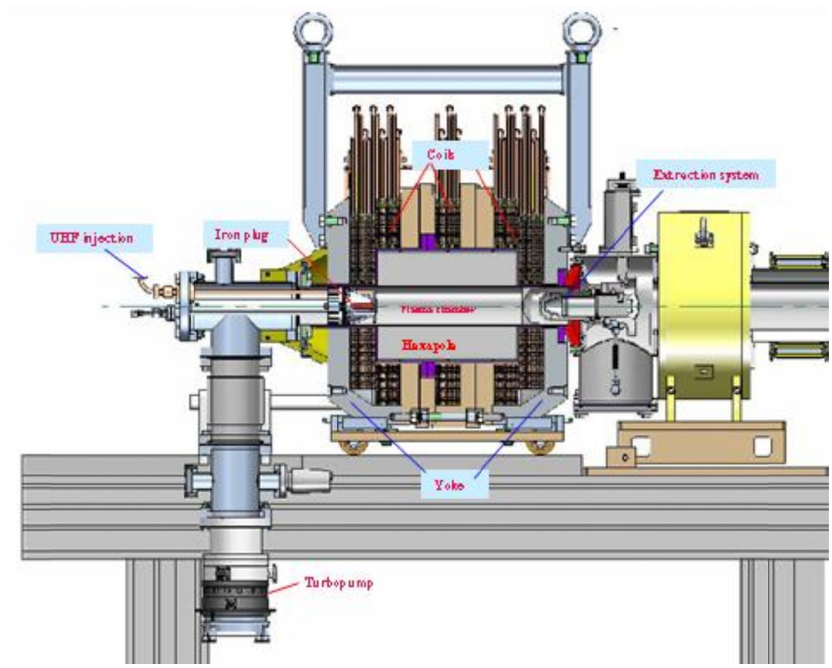

Figure 2: The cross-sectional view of the DECRIS-5 ion source.

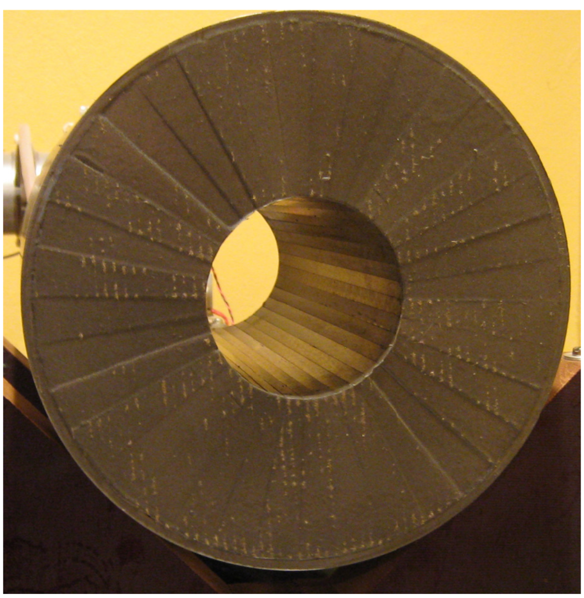

Figure 3: The new hexapole.

DECRIS-SC ion source (consists of 7 sections) and new hexapole is shown in Fig.5.

The stainless-steel plasma chamber is made as a water-cooled double wall tube. To enhance the ion source performance the internal diameter of the plasma chamber was increased up to 80 mm. On the injection flange there are mounted soft iron plug, water cooled standard waveguide, gas feeding tubes. Biased electrode is made from Ta and mounted on the soft iron plug. The shape and size of the bias electrode was designed to protect the iron plug from a direct interaction with plasmas.

The working gases (Ar, Kr, Xe) and support gas (O2) are fed into the source chamber by two double channel piezoelectric valves.

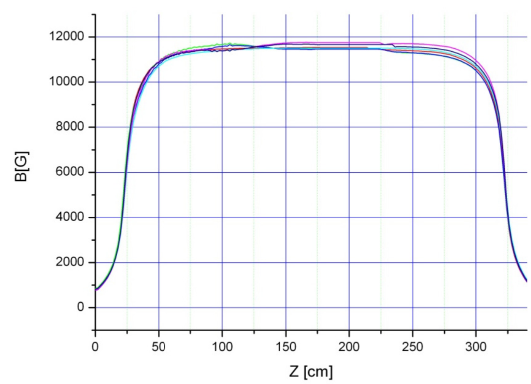

Figure 4: The measured radial magnetic field.

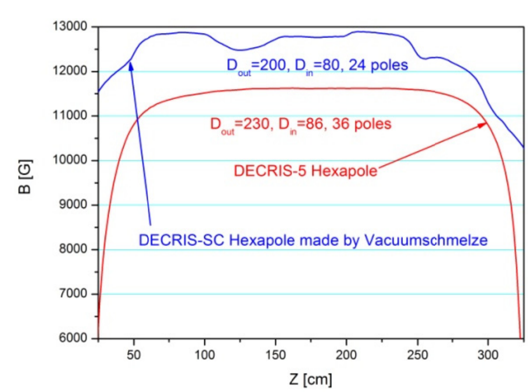

Figure 5: Comparison of sectional and new hexapoles.

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The source is pumped by 150 l/s turbopump from injection side, from the extraction side it is pumped by 150 l/s turbopump and 800 l/s cryopump.Subsection headings should not be numbered.

The source is equipped with three electrode extraction system, shown in Fig. 6. The plasma electrode aperture is 10 mm in diameter. The negatively biased extraction electrode is water cooled, and position of the whole assembly can be adjusted manually without breaking vacuum.

The main parameters of the DECRIS-5 ion source are collected in Table 1.

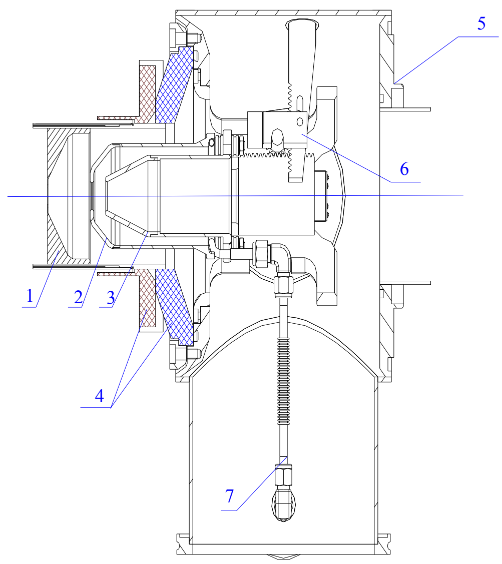

Fig.6 The extraction system of DECRIS-5 source.

Table 1: Main Parameters of DECRIS-5

UHF Frequency	18 GHz
Injection side magnetic field	2.25 T
Extraction side magnetic field	1.35 T
Radial magnetic field	1.15 T
Plasma chamber inner diameter	80 mm
Power consumption of the coils	150 kW

RESULTS OF THE TESTS

The test of the source was performed during December 2011 – February 2012. For the tests the source was assembled with the part of the axial injection beam line of DC-110 cyclotron. The main optical elements of the system are the analyzing magnet IM90, solenoid and two dipole correcting magnets. In the diagnostic box after analyzing magnet a Faraday cup and 30 mm diaphragm were installed. All elements are movable with pneumatic actuators. The vacuum system provides background vacuum about 2×10-8 torr in the extraction and diagnostics boxes.

The source was tested with the temporary mounted water cooling system. The cooling power of that system was lower than required. As a result the input water temperature was about of 30 ^{0}C when coils were exited with the maximum current. For this reason the time of continuous operation was limited (about of 30 min). With the nominal current) and the input UHF power was no more than 700 W.

The ion source was tested for production of Ar, Kr and Xe ion beams. The production of required intensity of the Ar^{6+} beam should present no problem. During the tests the operation of the DECRIS-5 ion source was very stable and reproducible. For the Ar^{8+} ion beam with the intensity of about 1 mA the measured beam stability reaches the value of 10^{-3} (20 min.). Fig. 7 shows the Ar charge state distribution when the source was tuned to maximize Ar^{8+}. The results, obtained during the tests are summarized in Table 2.

Table 2: Ion Yields from the DECRIS-5 Ion Source

Z	8	9	11	15	18	19	20
Ar	1200	750	300				
Kr				320	180	120	70
Xe							200

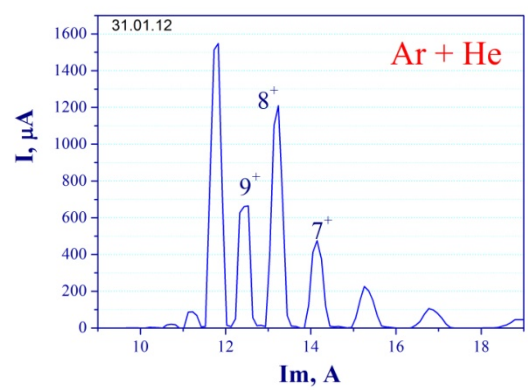

Figure 7: Charge state distribution for Ar. The source was tuned to maximize Ar^{8+}.

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