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MODERNIZATION OF THE ECR ION SOURCE DECRIS-2M. RESULTS OF THE FIRST TESTS

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Abstract

The article describes the design of the modernized ECR ion source DECRIS-2M. The upgrade consists in increasing the magnetic field to improve plasma confinement and enhance the source performance. The modernization also made it possible to increase the inner diameter of the plasma chamber and replace the coaxial microwave power input by a waveguide. Redesigned injection chamber significantly expands the possibilities of production ions of solids using different methods.

The article also presents the first results of experiments production of Ar, Xe and Bi ion beams from a modernized ion source. The results demonstrate substantial increase of the ion beams intensity, especially in the case of high charge states.

INTRODUCTION

The ECR ion source DECRIS-2m [1] was developed at FLNR JINR in 2001 and is a CAPRICE-type source with a coaxial microwave input of 14 GHz power. The magnetic structure of this source consists of two independent windings with an iron yoke to form an axial field; the radial magnetic field is created by a hexapole (permanent NdFeB magnet with "Halbach structure"). The main parameters of the ECR ion source DECRIS-2m are presented in Table 1.

Table 1: Main Parameters of the ECR Ion Source DECRIS-2m

Frequency (GHz)	14
Magnetic field in the inj. region B_{inj} (T)	1.25
Magnetic field in the extr. region B_{extr} (T)	1.05
Plasma chamber diameter (mm)	64
Number of coils	2
I_{max} (A)	1300
Hexapole parameters	
Material	NdFeB
Inner diameter (mm)	70
Rad. field on the plasma chamber wall (T)	>1.0

The source allows one to produce beams of ions of gaseous and solid substances with medium charges and moderate intensities up to Xe. The disadvantages of the source design include the following:

- in the microwave power input system, a transition from a rectangular waveguide to a coaxial line is used, which leads to losses of microwave power, causing uncontrolled gas desorption in the injection region. This method of microwave power input also requires the use of a special tuning mechanism;
- the size of the evaporator for producing solid ions is limited by the diameter of the inner conductor of the coaxial line;
- there is no room to install additional elements in the plasma chamber, because the injection part of the chamber is used as a coaxial waveguide.

UPGRADED ECR SOURCE DECRIS-2M

During the development of the project, the experience of the mVINIS ECR source modernization was used [2]. The main goal of the modernization was to replace the coaxial input of microwave power with a standard rectangular waveguide. For this, the outer diameter of the plasma chamber was increased from 64 to 74 mm. This entailed changes in the magnetic system of the source, in particular, a new hexapole with an inner diameter of 80 mm was made, and the configuration of the magnetic inserts in the injection region was changed. The new hexapole consists of 24 identical trapezoidal sectors with the corresponding direction of magnetization. Each sector is made from a single piece of magnetic material, thus avoiding magnetic field irregularity along the hexapole poles.

The design of the injection chamber was changed, which made it possible to significantly expand the possibilities for placing devices for supplying solids (evaporators, sputtering electrodes) in the ionization chamber.

In Fig. 1 a cross-section of the upgraded source is shown.

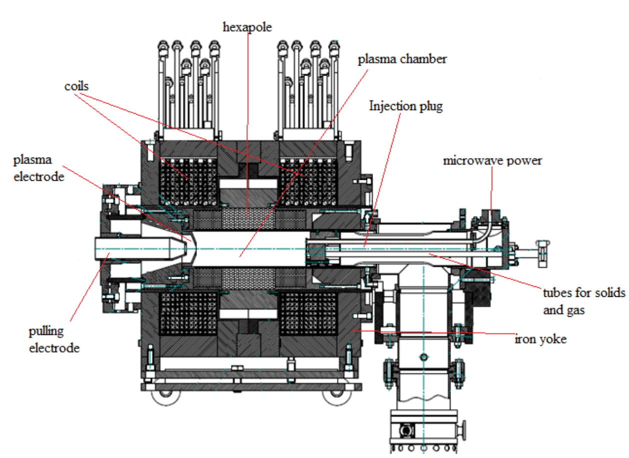

Figure 1: Upgraded DECRIS-2M.

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The main parameters of the upgraded ECR source DECRIS-2M are presented in Table 2.

Table 2: Main Parameters of the Modernized ECR Ion Source DECRIS-2M

Frequency (GHz)	14
Magnetic field in the inj. region B_{inj} (T)	1.25
Magnetic field in the extr. region B_{extr} (T)	1.05
Plasma chamber diameter (mm)	74
Number of coils	2
I_{max} (A)	1300
Hexapole parameters	
Material	NdFeB
Inner diameter (mm)	80
Rad. field on the plasma chamber wall (T)	1.05 - 1.15

The new design of the injection chamber allows the microwave power to be injected directly into the plasma chamber through a standard waveguide. Two identical stainless steel tubes are used for gas supply and micro-evaporator inlet for evaporation of solids. The bias-electrode is made of tantalum and is attached to a soft magnetic iron insert. The dimensions and shape of the electrode are selected so as to exclude the interaction of the magnetic insert with the plasma. The location of these elements is shown in Fig. 2.

Figure 2: Injection plug of the DECRIS-2M ion source with new inputs: microwave power, gas and solids.

PRODUCTION OF ION BEAMS FROM THE ECR SOURCE DECRIS-2M

The upgraded ECR source DECRIS-2M was tested at the ECR sources test bench for the production of argon, xenon, and bismuth ions. During the experiments, the operation of the source was stable and reproducible. The obtained results have shown a substantial increase of ion beam currents, especially in the case of high charge states.

Figure 3 to 8 shows the spectra of Ar, Xe and Bi ions. The spectra were produced at an extraction voltage of 20 kV on average. Oxygen was used as a mixing gas for production of Xe, Bi and Ar^{12+} ions, for production of Ar^{8+} ions helium was used as a mixing gas.

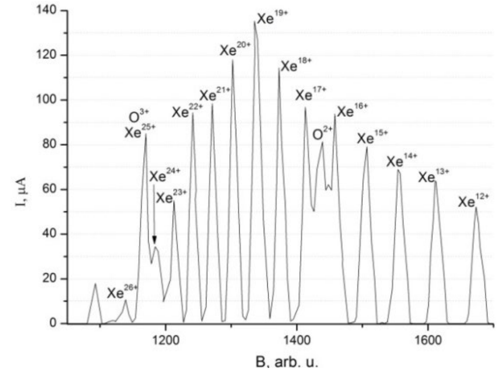

Figure 3: Xe ion spectrum. The operating mode is optimized to produce $^{132}Xe^{20+}$. Microwave power 308 W.

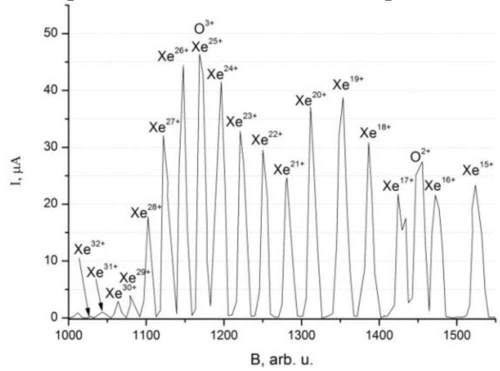

Figure 4: Xe ion spectrum. The operating mode is optimized to produce $^{132}Xe^{27+}$. Microwave power 290 W.

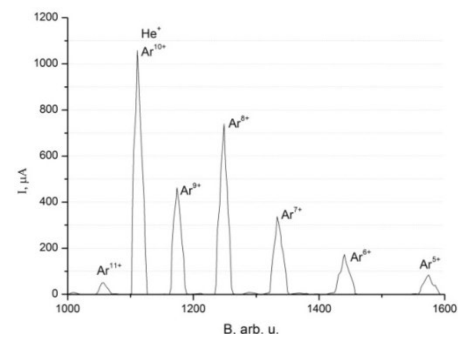

Figure 5: Ar ion spectrum. The operating mode is optimized to produce $^{40}Ar^{8+}$. Microwave power 274 W.

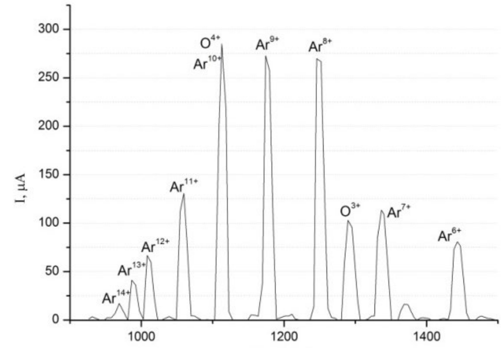

Figure 6: Ar ion spectrum. The operating mode is optimized to produce $^{40}Ar^{12+}$. Microwave power 309 W.

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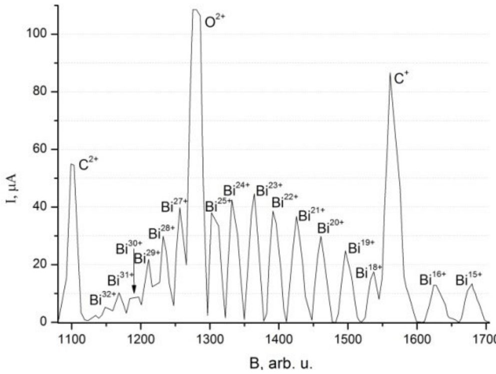

Figure 7: Bi ion spectrum. The operating mode is optimized to produce $^{209}Bi^{27+}$. Microwave power 220 W.

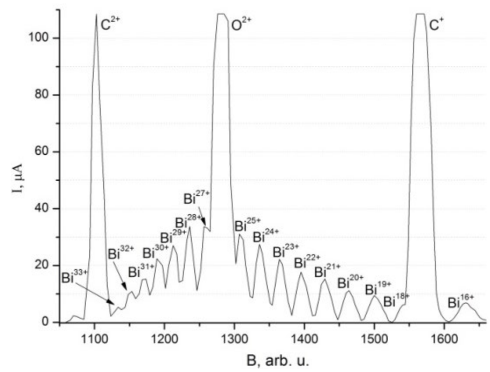

Figure 8: Bi ion spectrum. The operating mode is optimized to produce $^{209}Bi^{32+}$. Microwave power 221 W.

A comparison of the results produced from the ECR ion source before and after the upgrade are shown in Table 3. The results shown for the DECRIS-2m source before the upgrade were produced at an extraction voltage of 16 kV.

Table 3: Comparison of ion currents obtained from ECR sources DECRIS-2m and upgraded DECRIS-2M

Ion	Ion current, µA	
	DECRIS-2m	DECRIS-2M
$^{40}Ar^{8+}$	480	750
$^{132}Xe^{18+}$	30	114
$^{132}Xe^{20+}$	23	118
$^{132}Xe^{27+}$	-	32
$^{209}Bi^{27+}$	-	40
$^{209}Bi^{32+}$	-	11

CONCLUSION

The results obtained during the tests of the modernized source DECRIS-2M demonstrate substantial increase of the ion beams intensity, especially in the case of high charge states. The operating modes of the upgraded source are stable and reproducible.

Research and development of stable modes for obtaining high-intensity ion beams of solid substances will be continued at the ECR sources test bench.

ACKNOWLEDGMENTS

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[2] A. Efremov *et al*., “Upgrading of the CAPRICE type ECR ion source”, *AIP Conference Proceedings* 2011, 040017, 2018, doi:10.1063/1.5053291