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Upgrading of the CAPRICE Type ECR Ion Source

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Abstract. The CAPRICE-type ECR ion source mVINIS has been upgraded by increasing its magnetic field to improve a plasma confinement and thereby enhance the source performance. This modification made it also possible to increase the internal diameter of the plasma chamber and to replace the coaxial microwave input by a waveguide. Some major subsystems such as: the vacuum system, the microwave system, the gas inlet system, the solid substance inlet system, and the control system have been also refurbished. All these improvements have resulted in a substantial increase of ion beam currents, especially in the case of high charge states, with the operation of the ion source proven to be stable and reproducible. This modification can be applied to other CAPRICE-type ion sources.

INTRODUCTION

Research programs dealing with ion implantation and other methods of modification of materials with ion beams were initiated in the Laboratory of Physics of the Vinča Institute of Nuclear Sciences from Belgrade, Serbia in 1998. That was a result of successful completion of the designing, construction, assembling and commissioning of an electron cyclotron resonance (ECR) ion source – the mVINIS Ion Source [1]. The job was performed by a joint team of the Flerov Laboratory of Nuclear Reactions of the Joint Institute for Nuclear Research, Dubna, Russia (FLNR JINR), and the Laboratory of Physics of the Vinča Institute of Nuclear Sciences. That was a CAPRICE type ECR ion source operating at the microwave frequency of 14.5 GHz with the maximal extraction voltage of 25 kV. Different types of multiply charged ion beams produced with that ion source were being used extensively in an experimental channel for surface modification of materials [2,3].

During the 15 years of operation, we have noticed some disadvantages in the ECR ion source design, which are listed below:

- The use of the microwave coupling system having a standard waveguide connected to a coaxial line via a non-standard element (the injection cube) causes big losses of the microwave power. As a result, the injection side of the source body is strongly heated, causing an uncontrolled out gassing. A special mechanism to tune up the microwave coupling is also required.
- The manufacturing of the water cooled plasma chamber is complicated and expensive (the variable diameter double-wall chamber requires the welding of the parts made of copper and stainless steel).
- There is no room to install additional elements inside the plasma chamber because the injection part of the chamber is used as a coaxial waveguide.
- The only place to introduce a micro-oven to evaporate solid substances is the inner conductor of the coaxial line. It is also used as a bias electrode and has to be insulated from the plasma chamber. As a result, the oven

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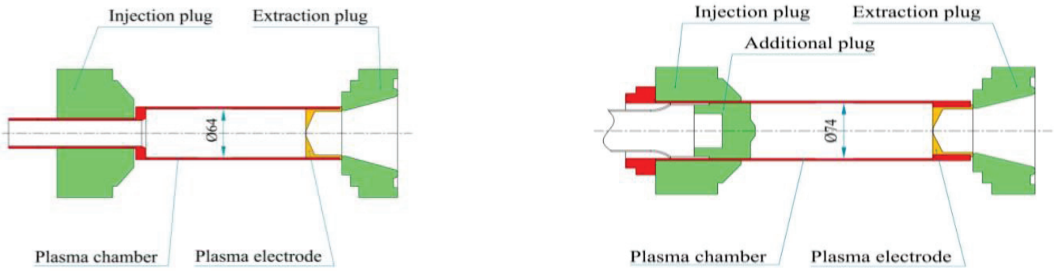
power supply should be also insulated. The size of the oven is strongly restricted by the diameter of the inner conductor of the coaxial line.

- The position of the micro-oven is exactly on the axis of the ion source. The interaction of the oven with plasma causes its additional heating. As a result, the oven temperature depends on the source regime. In order to minimize this effect, a fine tuning mechanism is required to define the optimal longitudinal position of the oven.

SOURCE UPGRADE

A key objective of the modernization of the ion source is the exclusion of the coaxial microwave input. Replacing a coaxial input to the standard waveguide virtually eliminates all the disadvantages listed above. First of all, we made a decision to increase the internal diameter of the plasma chamber from 64 mm to 74 mm to provide enough room for installation of all the required elements. As a consequence, this should also increase the plasma volume and ion lifetime, which will enable one to obtain higher charge state ion beams and higher beam intensities. Such a reconstruction required some changes in the magnetic structure and introduction of a completely new injection chamber. New water cooled double-wall plasma chamber has a constant diameter and has been completely made from stainless steel. We have increased the internal diameter of the injection soft iron plug to 80 mm to allow introduction of the new injection chamber into the source (see Fig. 1). In order to compensate the magnetic field losses at the injection side of the ion source, we inserted an additional soft iron plug directly into the plasma chamber. The shape of the additional plug has been optimized as to increase the level of the magnetic field at the injection region as well as for easy installation of additional elements such as biased electrode, gas feeding system and micro oven. In such a way, we significantly increased the axial magnetic induction at the injection side of the source, reaching 1.8 T for the maximal current of the injection stage coil, being 1300 A. Such a strong axial magnetic field significantly reduced the electron losses through the injection side of the source and should provide the increased currents of the extracted ion beams. In Fig. 2 is shown the comparison of the axial magnetic field distributions for the old and new versions of the axial magnetic system. The small magnetic field drop at the extraction side can be easily compensated by increasing the extraction coil current over 1000 A (the power supply can provide the current up to 1300 A).

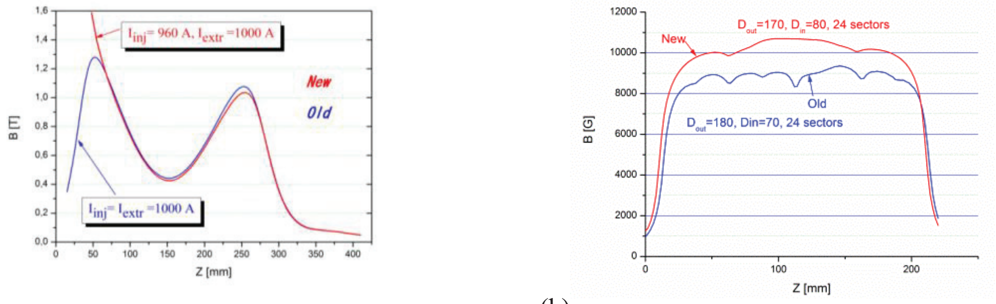


(a) (b)

Figure 1. Schematic presentation of (a) the old axial magnetic system and (b) the new axial magnetic system.

The old hexapole magnet, ensuring the radial confinement of plasma, was replaced by the new one, allowing installation of the new plasma chamber with a bigger external diameter. In order to obtain a smooth magnetic field distribution along the pole, each sector was made from a single piece of magnetic material. This technology eliminated some imperfections in the magnetic field near the permanent magnet junctions. The inner diameter, outer diameter, and length of the hexapole were 80 mm, 170 mm, and 200 mm, respectively. In Fig. 3 is shown the comparison of the radial magnetic field distributions for the old and new hexapoles. The measurements were performed in the region of the plasma chamber wall in front of the pole. It is obvious that the application of the modern magnetic material and new construction technology provided a higher level of magnetic field, despite the fact that the new hexapole inner diameter is bigger and the outer diameter is smaller than the corresponding dimensions of the old hexapole.

Reduced outer diameter of the hexapole magnet allowed introduction of additional soft iron ring around the magnet preserving the required minimal level of the axial magnetic field (above 0.4 T). At the same time, the level of the magnetic field at the injection region has been increased.



(a) (b)

Figure 2. (a) Axial magnetic field distribution and (b) radial magnetic field in front of one of the pole for old and new source configuration.

RESULTS OF COMMISSIONING OF THE ECR ION SOURCE

The upgraded ECR ion source was tested via the production of nitrogen, argon, xenon and lead ion beams, and the best obtained results were compared with the corresponding results obtained with the old ion source. During these tests, 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 (see Fig. 3). The old results were obtained with the extraction voltages between 15 and 20 kV and the new results with the extraction voltage of 20 kV. This comparison is presented in Table I.

(a) (b)

Figure 3. Beam intensity of (a) Xe and (b) Pb ions for old (red columns) and new (green columns) magnetic configurations.

TABLE 1. Comparison of ion yields (eμA) from the source with old and new magnetic configurations.

Ion	**N^{5+}**	**N^{6+}**	**Ar^{8+}**	**Ar^{11+}**	**Ar^{12+}**	**Xe^{20+}**	**Xe^{21+}**	**Xe^{23+}**	**Xe^{26+}**	**Pb^{18+}**	**Pb^{20+}**	**Pb^{21+}**	**Pb^{23+}**	**Pb^{26+}**
Old	470	87	660	130	36	41	37	25		15	10	7	2	
New	733	205	720	156	68	84	72	62	23	53	44	42	33	9

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