MODERNIZATION OF THE MVINIS ION SOURCE

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Abstract

The mVINIS Ion Source was designed and constructed jointly by the team of specialists from the Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research (JINR), Dubna, and the Laboratory of Physics, Vinča Institute of Nuclear Sciences, Belgrade. It was commissioned in 1998. From that time, it has been widely used in the field of modification of materials with different kinds of multiply charged ions. Recently, we decided to modernize this electron cyclotron resonance (ECR) ion source in order to improve its operation capability. Our main goal was to enhance the basic construction of the source in order to improve the production of multiply charged ion beams from gaseous and solid elements. We changed the shape of the plasma chamber and consequently reconstructed the magnetic structure. Also, we improved the construction of the injection chamber. Besides, we decided to refurbish its major components that have been in operation for quite a long time (the vacuum pumps, microwave generator, control system etc.). These improvements have resulted in a substantial increasing of the ion beam intensities, especially in the case of high charge state ions.

INTRODUCTION

The mVINIS Ion Source was designed and constructed jointly by the team of specialists from JINR, Dubna, and the Vinča Institute, Belgrade. This is a CAPRICE type ECR ion source [1], where the axial confinement of plasma is obtained by two solenoid coils with an iron yoke. The cone-shaped rings around the plasma chamber are used to increase the axial magnetic field peaks and fix their positions. The radial confinement of plasma is performed by a NdFeB permanent hexapole magnet with the Halbach type structure. The operating frequency of the source is 14.5 GHz. A detailed description of the components and performances of mVINIS have been published elsewhere [2, 3]. It was commissioned in 1998. From that time, it has been widely used in the field of modification of materials with different kinds of multiply charged ions4. During the 15 years of operation, we have noticed some disadvantages, which are listed below.

- The use of the microwave coupling system having the standard waveguide connected with a coaxial line through a non-regular element (the injection cube) causes big losses of the microwave power. As a result, we have a strong heating on the injection side of the source and an uncontrolled outgasing. A special tuning mechanism for the coupling system 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 parts made of copper and stainless steel).
- There is no room to install some additional elements inside the 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 substance is the internal 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 power supply should be also insulated. The size of the oven is strongly restricted by the diameter of the internal 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 an additional oven heating. As a result, the oven temperature depends on the source regime. In order to minimize this effect, the fine tuning mechanism is required to define the optimal position of the oven.

MODERNIZATION OF THE ECR ION SOURCE

We decided to enhance the basic construction of the ECR ion source in order to solve the above mentioned disadvantages and improve the production of multiply charged ion beams from gaseous and solid elements. We changed the shape of the plasma chamber and consequently reconstructed the magnetic structure. Also, we improved the construction of the injection chamber.

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 the 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.

ISBN 978-3-95450-158-8

The new water cooled double-wall plasma chamber has a constant diameter and has been completely made from stainless steel. We had to increase the internal diameter of the injection soft iron plug to 80 mm to allow the installation of the new chamber into the source (see Fig. 1). In order to compensate the magnetic field losses at the injection side, the additional soft iron plug was installed directly into the plasma chamber. The extraction soft iron plug was also adapted to the new chamber.

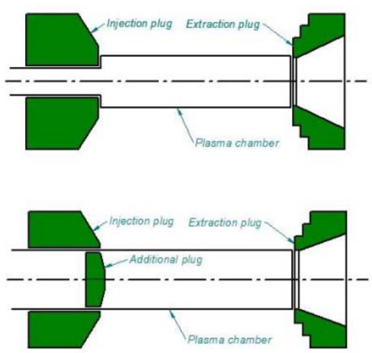

Figure 1: Schematic presentation of the old axial magnetic system (top) and the new axial magnetic system (bottom).

The comparison of the axial magnetic field distributions for the old and new versions of the axial magnetic system is shown in Fig. 2. The small magnetic field drop at the extraction side can be easily compensated by increasing the extraction coil current, Iextr, over 1000 A (the power supply can provide the current up to 1300 A).

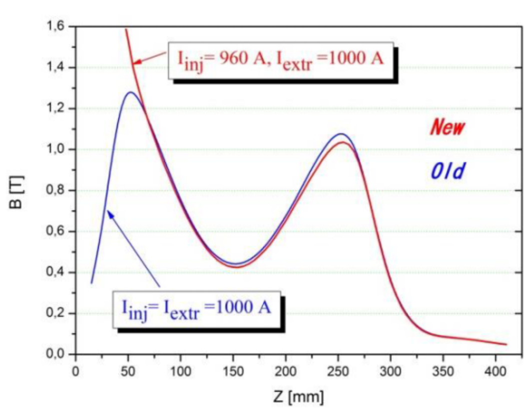

Figure 2: Axial magnetic field distributions for the old and new versions of the magnetic system.

The old hexapole magnet for radial confinement of plasma was replaced with a new one, allowing installation of the new plasma chamber with a bigger external diameter. The new hexapole with a Halbach type structure consisted of 24 identical trapezoidal sectors made of permanent magnet material (NdFeB) with the appropriate easy axis direction. 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. The comparison of the radial magnetic field distributions for the old and new hexapoles is shown in Fig. 3. The measurements were performed on 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 was bigger and the outer diameter was smaller than the corresponding dimensions of the old one.

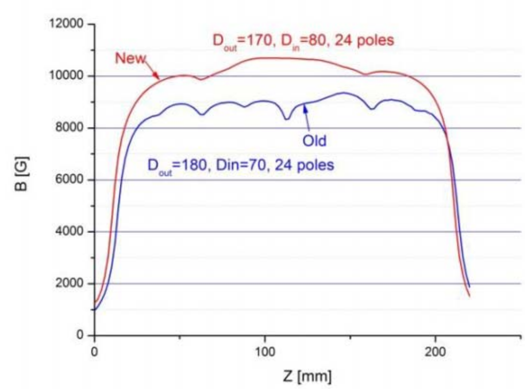

Figure 3: Radial magnetic field distributions for the old and new hexapoles.

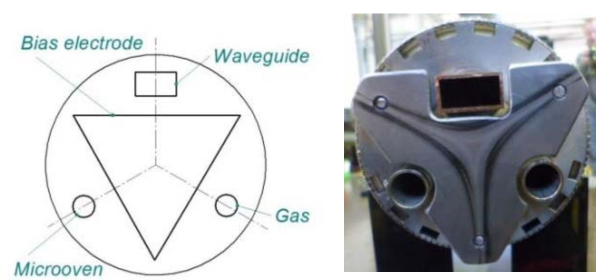

Figure 4: Injection side of the plasma chamber.

The microwave power is introduced directly into the plasma chamber through a standard waveguide. Two identical stainless steel tubes situated out of the axis are used for gas feeding and insertion of a miniature oven for evaporation of solid materials. A biased electrode made of tantalum is mounted on the soft iron plug. The shape and size of the bias electrode are chosen to protect the iron plug from direct interaction with plasma. The disposition of these elements is shown in Fig. 4.

The cross-sectional view of the new version of the mVINIS Ion Source is shown in Fig. 5. The maximal current of the injection and extraction coils is 1300 A. The additional iron plug installed directly inside the discharge chamber significantly increases the injection magnetic

ISBN 978-3-95450-158-8

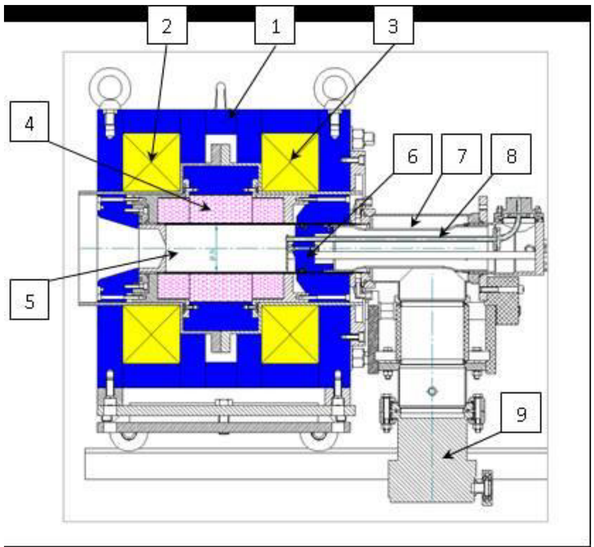

Figure 5: Cross sectional view of the mVinis Ion Source: 1 – the yoke, 2 – the extraction stage coil, 3 – the injection stage coil, 4 – the hexapole magnet, 5 – the plasma chamber, 6 – the additional iron plag, 7 – the injection chamber, 8 – the waveguide, and 9 – the turbomolecular pump.

field. At the full excitation of the injection solenoid, the magnetic field at the injection side can reach 1.8 T. This strong field significantly reduces the ion diffusion at the injection side and consequently increases the extracted beam intensity. The injection flange supports the soft iron plug, standard waveguide, gas feeding tubes and bias electrode. The working gases (e.g., Ar, Kr and Xe) and the supporting gas (He or O2) are introduced into the chamber with two fine gas dosing valves.

RESULTS AND CONCLUSION

The modernized ECR ion source was tested with a new 14.5 GHz UHF klystron power amplifier and the completely refurbished vacuum system (the new turbomolecular and cryogenic pumps), the gas inlet system, the solid substance inlet system, and the control system. The source was tested for production of Ar, Xe and Pb ion beams. During these tests, the operation of the source was very stable and reproducible. The obtained results have shown a substantial increase of the ion beam intensities, especially in the case of high charge state ions.

A comparison of the obtained results with the best results obtained with the old mVINIS Ion Source has shown that the increase of the intensities are mostly in the range from 50 to over 100 %. As an example, one of the obtained spectra of xenon ions is shown in Fig. 6. We used enriched isotope 129Xe with oxygen as a support gas and the source was tuned to maximize the Xe20+ production. The extraction voltage was 20 kV.

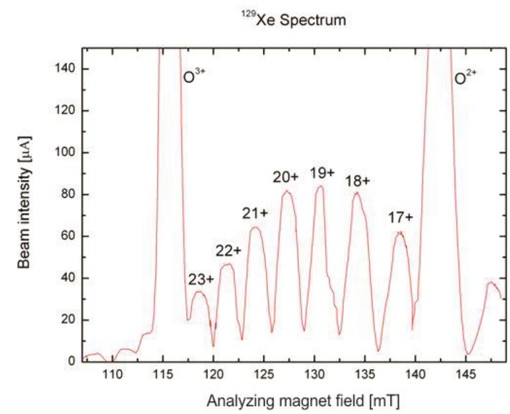

Figure 6: A spectrum of xenon ions optimized for maximal Xe20+ production.

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ISBN 978-3-95450-158-8