DEVELOPMENT WORK WITH THE JYFL ECR ION SOURCES

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Abstract

Two ECR ion sources are presently operational at the Accelerator Laboratory of the Department of Physics, University of Jyväskylä. The former JYFL 6.4 GHz ECRIS has worked reliably since its construction in 1989-90. It has been used approximately 4500 h/year for the production of heavy ion beams and more than 46 000 plasma-on hours have been achieved. Presently this source is also used for the experiments of material physics and it will be upgraded to better meet the ion beam requirements set by the new programs. The magnetic field calculations have shown that the known rules for the magnetic field configuration can be fulfilled by better iron and coil configuration. New power supplies for the coils are not needed. The new JYFL 14 GHz ECRIS was completed in spring 2000. Since that, several ion beams have been developed - for example 45 µA of Ti^{11+} ion beam using the MIVOC method. The internal oven for the production of calcium ion beams has been developed. In the first test, 75 µA of Ca^{11+} ion beam was obtained with a microwave power of 500 W.

1 INTRODUCTION

A new 14 GHz ECR [1] ion source was completed in spring 2000. The AECR-U [2] ion source at the LBNL in University of California was chosen as a basis of the design. The decision was also influenced by the parallel construction of the ARTEMIS [3] ECR ion source at the NSCL in Michigan State University. Operation during the first year has shown its good performance, like the measured maximum intensity of 174 µA of O^{7+} at the extraction voltage of 10 kV demonstrates.

Ion beams from the 14 GHz ECR ion source are further accelerated to the energy range of ≈4-10 MeV/u in the K130 MeV cyclotron for use in nuclear physics experiments or in applications. The ions from the JYFL 6.4 GHz ECR [4] source will also be used for studies in material physics. The ion energy covers then the range of ≈0.1-30 keV. That ion source will be used also as a backup for the K130 cyclotron [5].

2 DEVELOPMENT WORK WITH JYFL ECR ION SOURCES

The most important projects with the JYFL ECR ion sources during the past year have been the design work for the upgrade of the JYFL 6.4 GHz ECRIS and the construction of the oven for the JYFL 14 GHz ECRIS. In this section these projects will be described in more detail. Table showing the available ion beams from the new source will be also presented.

2.1 The upgrade of JYFL 6.4 GHz ECRIS

Versatility of the source is required for the program of material physics. The ion source has to be capable to produce intensive ion beams with a wide variety energies. This means that the acceleration voltage varies from about 0.1 kV to about 30 kV. The extraction system has to be optimized in order to deliver ion beams with the required energy and the intensity (range of µA). In addition to that the wide range of charge states is requested – for example from 1+ to 30+. Due to the above mentioned requirements the upgrade of the JYFL 6.4 GHz ECRIS was decided to be carried out. This will be done by optimizing the configuration of the magnetic field. The task will be carried out in two phases: first the improvement of the axial magnetic field and later the improvement of the radial magnetic field. The project is expected to be complete by the end of 2001.

The SC-ECRIS at NSCL/MSU is very powerful 6.4 GHz ECR ion source. Due to some similarities between these two sources (6.4 GHz, similar dimensions of the plasma chamber), the magnetic field configuration of the SC-ECRIS was decided to be used as a goal of the upgraded design. Figure 1 shows the strength of the magnetic field on the middle axis of the plasma chamber.

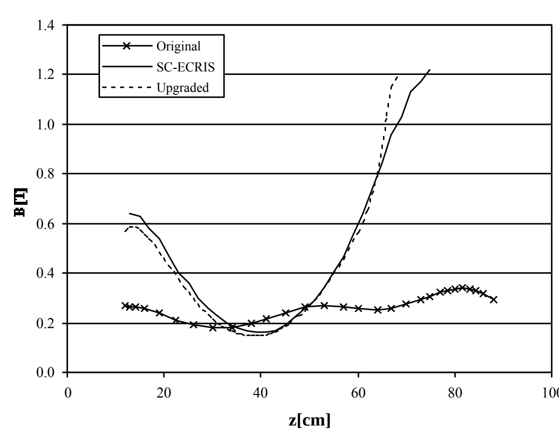

Figure 1: The magnetic field (on axis) of the SC-ECRIS (solid line), the original JYFL 6.4 GHz ECRIS (mixed line) and the upgraded JYFL 6.4 GHz ECRIS (dashed line).

As Figure 1 shows, the configuration of the magnetic field of the upgraded design is quite similar to the magnetic field configuration of the SC-ECRIS. The improvement can be achieved using the old power supplies – only the configuration of the coils and the iron

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yoke has been changed. The soft iron behind the permanent magnets will be tested later in order to improve the radial magnetic field. The calculations have shown that improvement of about 30 % can be achieved.

2.2 Internal oven for JYFL 14 GHz ECRIS

Most of the metal ion beams at our laboratory have been produced using the MIVOC method [6]. However, the method is not suitable for the production of all elements – like calcium. With the JYFL 6.4 GHz ECRIS calcium ion beam has been produced using a miniature oven. The oven is inserted close to the plasma through one radial port of the source. That source has produced very stable ion beam but the performance is not high enough to meet all future requirements. Consequently, the oven for the JYFL 14 GHz ECRIS was designed.

There are two limitations, which make the use of the original miniature oven with the new source complicated. The first one is that the source has a horizontal orientation. That causes limitation in the orientation of the oven inside the ion source. The radial ports are too narrow (about 6 mm) to insert the oven through. The open hexapole structure was chosen to make the efficient pumping of the plasma chamber possible. This also gives possibility to use a closed injection geometry to maximize the strength of the injection magnetic field. Due to these limitations the only possibility was to place the oven horizontally inside the injection iron plug (Fig. 2). The hole for the oven was kept as small as possible in order to minimize its effect on the magnetic field.

Very low power of the miniature oven is needed during operation (about 30 W). This indicates that the heat shielding of the oven is good and the most of the power is transferred to the heating of the material inside the oven. Due to the efficient heat shielding it was expected that the gap between the oven and the surrounding iron plug could be as small as 1 mm. The heat transfer between the oven and the iron was tested on the test bench before the oven was used with the JYFL 14 GHz ECRIS.

As figure 3 shows, the same temperature of the oven with and without the iron plug was reached. It also shows the effect of the heat shielding. The test indicates that no energy transfer between the oven and the iron plug occurs.

Figure 2: The miniature oven inside the iron plug of the JYFL 14 GHz ECRIS.

As a next step the oven was tested inside the JYFL 14 GHz ECRIS for the production of calcium ion beam. Calcium oxide with zirconium powder was used. Figure 4 shows the results obtained during the first test run. The ion source was tuned for the calcium charge state of 11+ and the intensity of 75 μA was measured. Helium was used as a mixing gas. Fairly low microwave power (530 W maximum) and temperature of the oven was used (about 800˚C). The extraction voltage was 10 kV. The consumption rate was measured to be about 0.3 mg/h

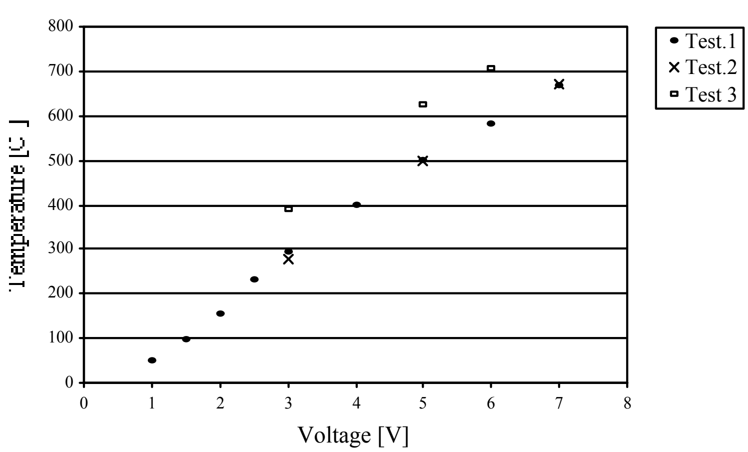

Figure 3: Temperature of the oven as a function of the voltage used for the heating. Three different cases have been measured: the oven was inside the iron plug (test1), without the iron plug (test2) and when the improved shielding with the oven was used (test3).

(for 30µA of 11+). The crucible can be loaded with the sample which is enough for a run of one week. The reloading of the oven can be done without the ventilation of the ion source.

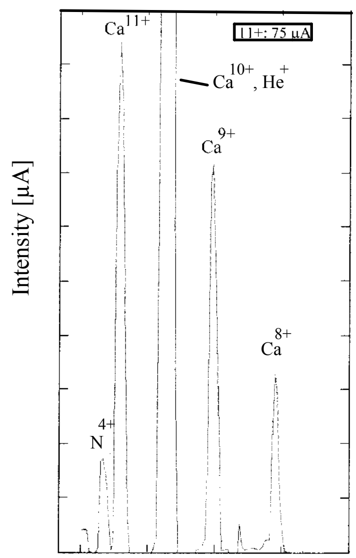

Figure 4: The calcium ion spectrum produced with the JYFL 14 GHz ECRIS.

2.3 *Ion beams from JYFL 14 GHz ECRIS*

Table 1 is a collection of the best ion beam intensities obtained with the JYFL 14 GHz ECRIS within the year after the first plasma was ignited in the source. All currents were measured using the extraction voltage of 10 kV. A biased Faraday cup was used. The diameter of the aperture in the plasma electrode was 8 mm. No gas mixing has been used (except oxygen with Kr). Microwave power between 500 W and 850 W has been used.

Table 1: Present records of the ion beam intensities [µA] of JYFL 14 GHz ECR ion source.

Q	B	O	Ar	Ca	Ti	Fe	Kr	Xe
3+	235							
4+	162							
5+	52	362						
6+		627						
7+		174						
8+			359					
9+			230					
10+								
11+			124	75	45	115		
12+			80		36			
13+			39			58		
14+			17					
15+						23		
16+								
17+							63	
25+								33

3 SUMMARY

The set of two ion sources at the laboratory makes it now possible for improved research and development work of the ECR ion sources, as well their ion beams. The magnetic field configuration of the old JYFL 6.4 GHz ECRIS will be upgraded in 2001. The maximum strength of the field will increase from 0.33 T to 1.2 T. The iron cylinder behind the hexapole magnets will be tested. The calculations have shown that an improvement of about 30 % to the hexapole field will be achieved. After these changes the magnetic field configuration will be very close to that of the SC-ECRIS at the NSCL/MSU. The upgrade will be completed by the end of 2001.

The new JYFL 14 GHz is dedicated for the K130 cyclotron. The first year of the operation has shown that it is performing well as can be seen from table 1. The internal oven for the new source has been designed. The oven is situated inside the iron plug due to the limited space available inside the source. No ventilation of the ion source is needed during the reloading of the oven.

Krypton has been so far the heaviest element that has been used for the studies of the nuclear physics. Due to the new source the ion beam variety can be extended towards heavier species. As a consequence, several new ion beams have to be developed with the new source. The use of old source for the studies of the materials physics will set new requirements for the ion beam development - for example cluster ion beams have been requested.

Acknowledgements

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