Development and upgrade of the ECRIS facility

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Upgrade of the ECR injector setup

A new version of the 1.2 T CAPRICE ECRIS (ECR Ion Source) was assembled and installed at the ECR injector setup (EIS). This version is equipped with a new hexapole construction with improved permanent magnet materials providing increased remanence. Table 1 shows a comparison of the specifications of the magnet materials.

The original 1.2 T hexapoles were assembled in 1999 from 6 cuboids for each pole, which were procured as magnetized single magnet pieces. At present improved technology facilitates the fabrication as one single piece with subsequent magnetization by the manufacturer [1]. As in the original version trapezoidal magnets are filling the space between the pole pieces to provide a closed magnetic flux. The new hexapoles were obtained from the manufacturer as complete items. The improved manufacturing technique should provide a good homogeneity of the magnetic flux density along the pole faces.

Table 1: Comparison of the magnet specifications.

	1,2 T new version		1,2 T original type	
	Pole	Trapezoid	Pole	Trapezoid
Material VACODYM®	745HR	655HR	362HR	383HR
Remanence typ. [T]	1,44	1,28	1,33	1,28
Coercivity [kA/m]	1115	990	1010	980
Temperature max. [°C]	70	150	120	150

In order to check the magnetic field distribution a field mapping was performed by the ENMA (NC Magnets & Alignment) department of GSI. For comparison one of the original hexapoles was included in this series of measurements. Due to the optimized design the magnetic flux density of the new hexapoles could be increased by about 3% with respect to the original design. As the new magnet materials for the poles tolerate lower limits of the operating temperature the cooling technique had to be improved by optimizing the conditions of the cooling water flow.

Ion beam development

Due to special operating conditions of the Alvarez LINAC a $^{12}C^{5+}$ ion beam was requested from the ECRIS. For the generation of hydrogen like C ions all L-shell electrons plus one further K-shell electron have to be ionized in the plasma by successive electron impact ionization. This requires high power operation modes of the ECRIS. In order to optimize for best C^{5+} performance various combinations have been explored. Besides the standard configuration for $^{12}C^{2+}$ ion beam with CO_2 as working gas and O_2 as auxiliary gas, respectively, CH_4 was investigated as alternative working gas, while H_2 or He were used as auxiliary gases. For both working gases the operation at the required high level of microwave power and high magnetic mirror field exhibited strong plasma instabilities inside the quartz gas injection tube at the location of the first electron cyclotron resonance. Therefore the normally used quartz tube was replaced by a pure copper tube of the same dimensions, which led to much better plasma stability. H_2 and He as auxiliary gas turned out to give better performance than O_2. With respect to the fixed frequency operation with the klystron amplifier slightly higher intensity could be obtained by careful frequency tuning of the travelling wave tube amplifier. Formerly CH_4 had been used without additional auxiliary gas for the production of a $^{12}C^{3+}$ beam; however, the absence of auxiliary gas did not facilitate a successful optimization of C^{5+} in the present experiments. Finally the combination of CO_2 with He as auxiliary gas turned out to be the best choice in order to provide stable long term conditions at an intensity level of 60 eμA analyzed C^{5+} beam.

Radiation protection survey

For an improved survey of the X-ray emission from the ECRIS as well as for related studies dedicated X-ray monitors (energy range: 6 keV to 15 MeV) were procured which can be operated continuously under long term conditions with remote data storing for offline analysis.

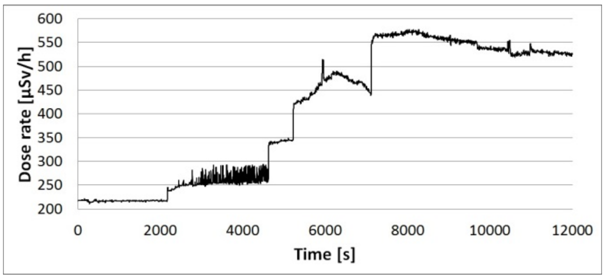

Figure 1: Recorded dose rate during optimization

For a first test one probe was placed next to the extraction of the ECRIS, where a high X-ray level is expected. Figure 1 shows the recorded dose rate during an optimization process of $^{48}Ca^{10+}$ operation in high power mode. The steps in the course of the dose rate are clearly correlated with a stepwise increase of the microwave power from 250 W to 450 W. Phases with plasma instabilities are also identified like around 4000 s in the diagram.

References

[1] VACUUMSCHMELZE GmbH & Co. KG, Grüner Weg 37, D-63450 Hanau, Germany; http://www.vacuumschmelze.de/

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