ARTEMIS, THE NEW ROOM TEMPERATURE ECR ION SOURCE AT MSU

H. Koivisto, D. Cole, A. Fredell, C. Lyneis[a], P. Miller, J. Moskalik, B. Nurnberger, J. Ottarson, A. Zeller, J. DeKamp, R. Vondrasek[b], P. Zavodszky and D. Xie[a]

The Coupled Cyclotron (CC)-operation of the MSU/NSCL existing cyclotrons has different requirements for production of ion beams: lower charge states and significantly higher intensity. Only the superconducting ECR ion source in operation for the last couple of years meets the requirements concerning the CC-operation. In order to have a second ECR ion source for reliable operation and fast change of ion beam type, we designed, constructed and commissioned a new room temperature ECR ion source: ARTEMIS (**A**dvanced **R**oom **TEM**perature **I**on **S**ource). This ion source was designed starting from the very successful AECR-U ion source at LBL [1]. In order to meet the NSCL's requirements, several modifications were made. The most visible one is the vertical orientation as seen in Figure 1. The other major modifications were to increase the magnetic field in the injection end of the plasma chamber and to allow the use of bias voltages up to 30 kV, necessary for CC-operation. The injection iron was redesigned, one double pancake was added and small modifications to the shape of the yoke were made. The radius of the coil was also increased slightly. Ventilation with air or dry nitrogen around the source is also possible in order to minimize the accumulation of O_3, reducing sparking.

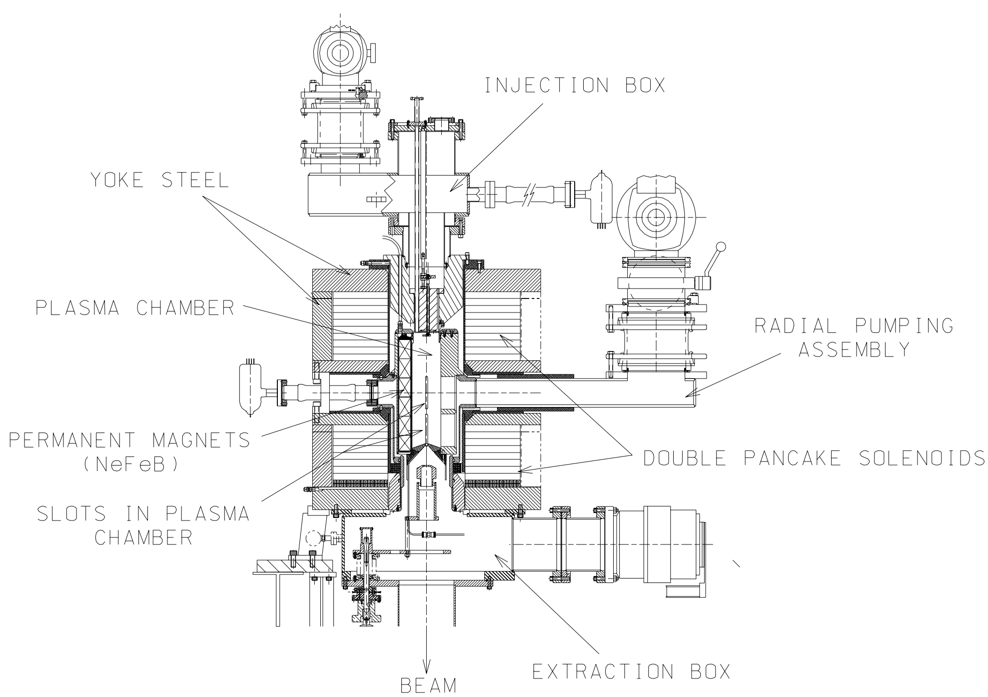

Figure 1. The assembly drawing of the new ECR ion source ARTEMIS.

Two solenoids made from normal conductors produce the axial magnetic field of ARTEMIS. Power supplies capable of 1000A/160V and 500A/120V excite the injection and the extraction coils, respectively. The coils are wound as double pancakes of sixteen turns per layer in order to get more efficient cooling. The conductor is 7.92 mm square with a 3.96 mm diameter cooling hole. The number of pancakes is 10 and 9 in the injection and the extraction solenoids, respectively. By running 1000 Amps in the injection solenoid and by lowering slightly the extraction current, the 2.6 T field will allow operation at both 14 and 18 GHz. Presently, only the 14 GHz microwave heating is implemented.

The radial magnetic field is produced by permanent magnets made from NdFeB with the minimum requirements of 1.30 T for the residual inductance (B_r) and of 45 MGOe for the maximum energy product. The magnets are arranged in an open hexapole structure. That makes possible radial access into the plasma chamber, for such purposes as radial pumping, gas feeding, a sputtering device, different kind of diagnostics, microwave feed etc. The material of the plasma chamber is aluminum, and it is cooled with low conductance water.

Before the first plasma was ignited the most important parameters were carefully tested. The capability of the source for holding high voltage was tested and 33 kV was successfully achieved. The water flow through the pancakes was measured to be slightly more than calculated value. This ensures that the cooling of the coils will be even better than was obtained by calculations. In order to ensure that the ECR resonance will be inside the plasma chamber and far enough from the walls, careful measurements of the magnetic field were carried out. Figure 2 shows the measured and calculated magnetic field of the new source on the axis. A current of 400 A was used in both coils. The extraction hole is situated at the maximum field in the extraction end, i.e. with the z value of 17.5 cm. In the injection end the wall of the plasma chamber is at the z value of 47.3 cm.

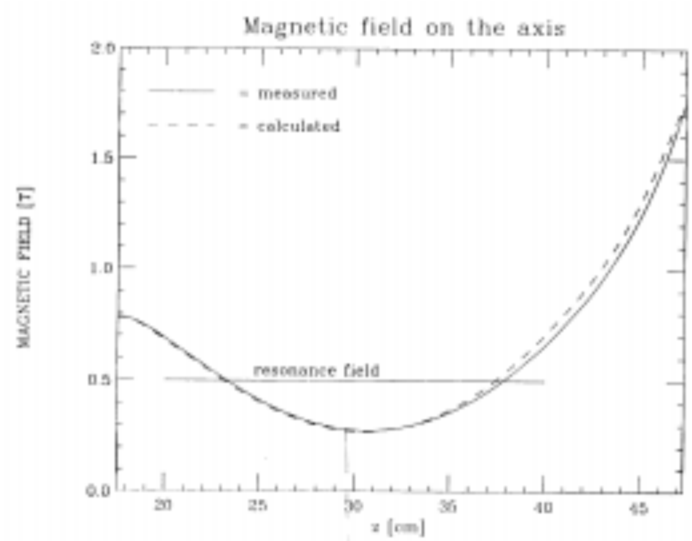

Figure 2. The magnetic field on the axis with a current of 400 A in both solenoids. The solid and dashed lines correspond to the measured and calculated magnetic field on the axis, respectively.

The agreement between the measured (solid line) and calculated (dashed line) magnetic field is good. The deviation concerning the injection and extraction maximum and the minimum magnetic field was less than 1 %. Between the z values from 37 to 45 cm the deviation was bigger, around 5%. Presently, the reason for this discrepancy is unknown.

Figure 3 shows the measured radial component of the magnetic field along one pole of the hexapole magnet. A value of 0 in z corresponds to the injection end of the permanent magnet and z-value of 29.5cm corresponds to the extraction end of the magnet. Data were measured at a radius of 2.5 cm and 3.1 cm. This figure also shows the end effect of the permanent magnet; that is, the effective edge is very close to the physical edge. The radial magnetic field component starts to decrease and to convert to other components of magnetic field about 2 cm before the end of the permanent magnet. Measurements also show that the hexapole field is quite homogeneous as a function of its length. All six magnets were measured. By comparing the measured and calculated values we determined that the measured value was almost 20% higher than expected. This corresponds to the difference of about 2 mm in the radius. Two possible causes were found: a) the probe sitting on the nose of long probe holder was closer to the wall than expected due to misalignment and b) the magnetic properties were better than specified.

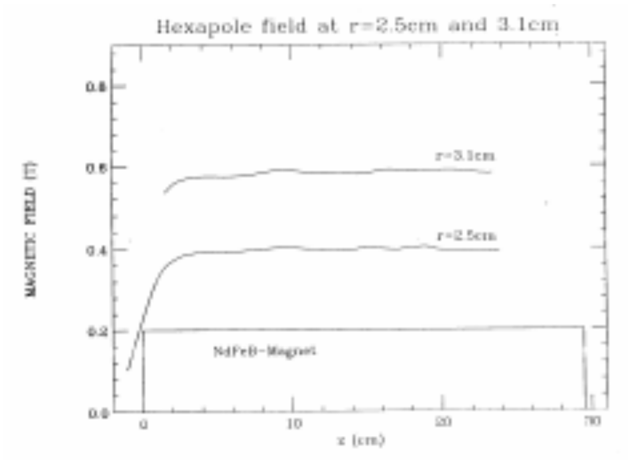

Figure 3. The measured radial component of the magnetic field of the permanent magnet as a function of its length. The radius of 2.5cm and 3.1cm from the middle axis were used.

These tests confirmed that the ECR resonance zone is closed and everything was ready for the first plasma. As a consequence no changes to the structure of the source were needed.

The first plasma of the RT-ECR3 was ignited in the middle of August 1999. At the beginning, when outgasing was strong, the intensities of low charge states of oxygen were dominant. When the pressure decreased over time the intensity of higher charge states started to increase.

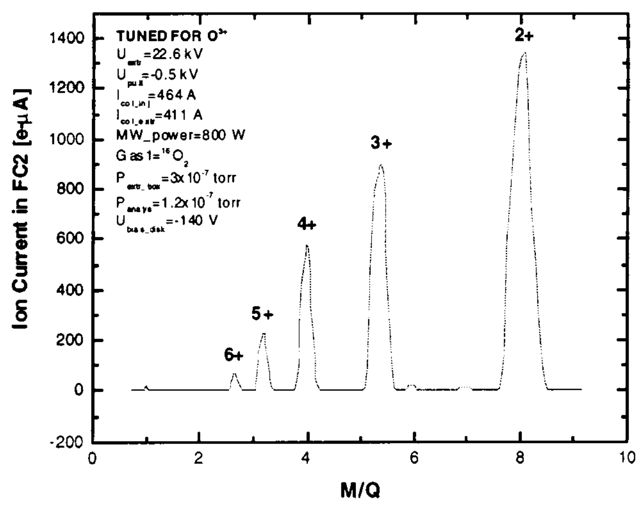

Figure 4. Mass over charge distribution of the measured ion current for ARTEMIS. The source was tuned for O^{3+} ions. The current was measured with a standard NSCL Faraday cup.

Figure 4 shows the best Oxygen spectrum when ARTEMIS was tuned for the CC-operation required O^{3+} ions. The microwave power was 800 W, the accelerating voltage 22.6 kV, the diameter of the plasma electrode hole was 8 mm.

As a next step, accurate emittance measurements are under way with this new source. Attention will also be paid to the extraction end of the source and to the optics in order to achieve the maximum brightness of the beam.

a. Lawrence Berkeley Laboratory, 1 Cyclotron Road, Berkeley, CA 94720, U.S.A
b. Argonne National Laboratory, Physics Division, 9700 S. Cass Ave, IL 60439, U.S.A.

Reference

1. Z.Q.Xie and C.M.Lyneis, Proceedings of the 13th International Workshop on ECR Ion Sources, February 26-28, College Station, Texas USA, (1997), p. 16.