# Transformation of the ATOMKI-ECRIS into a Plasma Device*

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**Abstract** In order to extend the capabilities of the ATOMKI-ECRIS it is being transformed into a modified plasma device by changing its three main components with new ones. The cylindrical plasma chamber is replaced by a larger one ($ID$=10cm, $L$=40cm). A new NdFeB multi-pole radial trap was designed and purchased. The basic configuration is 6-pole, but 8- or 12-pole arrangements can also be formed later. The present microwave source (2000W, 14.5GHz) and two additional low-power, wide frequency TWT amplifiers give many opportunities to form plasmas with different sizes and characters. Actually a new facility with two sharply different operation modes is being established. All the modifications are reversible so the transformation of the ECRIS into this new device or back can be easily done.

**Key words** plasma, ECR, ECRIS, ion source

## 1 Introduction

In the ATOMKI a 14.5GHz electron cyclotron resonance ion source (ECR, ECRIS) operates as a stand-alone device to produce variously stripped plasmas and low-energy ion beams[1, 2]. So far it delivered H, He, N, O, Ar, Kr, Xe (from gases) and C, $C_n$, $C_{60}$, F, Fe, Ni, Zn and Pb (from solids) plasmas and beams. It has been mainly used for atomic physics collision experiments and for plasma diagnostics and materials research. During the last few years some special research and applications sometimes demanded temporary, but major alterations in the assembly of our ECRIS. Here is a short list of the most important experiments of this type:

- plasma diagnostics with Langmuir-probes[3],
- X-ray pinhole camera imaging[4],
- fullerene plasmas and beams[5],
- experiments with two ovens[6],
- surface plasma treatments[2],
- very low RF-powers[5, 6].

The above mentioned and several other (planned) research and application fields require large-size, low-charged plasmas with convenient access to apply various diagnostic tools and sample holders with movement/cooling, etc. It became also clear that a wide range microwave frequency would also be an advantage.

By a EU-Hungary joint support the ATOMKI-ECRIS now is being transformed into a plasma facility by changing several main components of the ion source by new ones: the hexapole magnet, the plasma chamber and the microwave source. The two basic conditions of the transformation are: (1) most parts of the present ECRIS should be used in the new assembly in the same way and (2) the transformation time between the two operation modes should not be more than 2—3 days (in both directions). The following sub-systems will be used identically in both con-

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figurations: solenoid coils, vacuum system, gas dosing system, ovens, probes. The extraction optics and beam transport system can also be used in the new configuration to check the components and charge-state of the plasma.

The next sections describe the specifications of the elements to be changed and the overall status of the upgrading.

## 2 New multipoles

A new, very thin, 24-pieces (traditional structure with rotating easy axes) hexapole was designed with large internal and external diameters. Additionally, elementary trapezoidal magnetic blocks with different orientation of magnetism were also purchased to assemble later other types of multipoles (8-pole, 12-pole or shorter 6-pole). Every multipole produces a magnetic field larger than 0.6 Tesla in the plasma chamber so frequencies upto around 13 $\cdots$ 14GHz can be coupled (for 12-poles upto 12GHz). All magnets were made of NdFeB material (Neorem537i, $B_{\rm r}$=1.32 Tesla, $H_{\rm cj}$=1350kA/m) and were delivered at our institute this spring. In Fig. 1. The graphical output of the 2D Superfish[7] calculation for the case of the glued hexapole can be seen. Note the very small size of the hexapole wall (just 2cm). Table 1 summarizes the main geometrical and magnetic data of the multipoles. In Fig. 2. the radial magnetic field distributions in the middle plane are drawn for the 3 types of multipole (superposed with the magnetic field of the solenoid fields at maximum electrical power). In

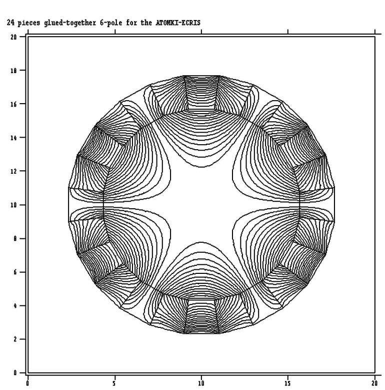

Fig. 1. The magnetic field line structure of the new NdFeB hexapole. Dimension units are in cm.

Fig. 3. a TrapCAD[8] simulation of the electron cloud in the 12-poles assembly is shown. The frequency of the microwave used in this simulation was 11GHz.

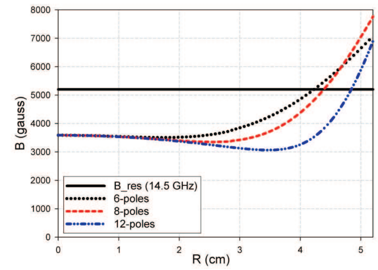


Fig. 2. Magnetic field distribution in radial direction for several designed multipoles. The magnetic field of the solenoids is superposed to the multipole fields.

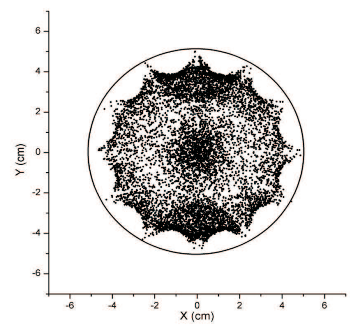


Fig. 3. TrapCAD[8] simulation of the electron cloud in the 12-pole trap.

## 3 Large plasma chamber

After the glued 6-pole was delivered we designed and manufactured a new, large-size plasma chamber with water cooling in all its walls around. The geometrical data of the chamber are shown in Table 1. We note that the diameter of the old chamber is 58mm, while the new one is almost twice as large (102mm). The large size at the injection side makes an easy access to the plasma (ovens, sample holders, electro-static probes, motion feedthroughs, water cooling, etc.). Another plasma chamber will be designed and fabricated for the other three multipoles (to be formed from individual pieces) in next years.

## 4 Microwave sources

We can probably keep and use the present high power klystron-based 14.5GHz microwave amplifier with the new hexapole, as well. Meanwhile two low-power, wide-frequency traveling wave tube amplifiers (TWTA) were also purchased (10W, 6.5—13.6GHz and 20W, 8—18GHz) and tested.

## 5 Assembly – present status

Very recently the new ECR plasma source was assembled and for a short time plasma was ignited at 9.2GHz frequency by one of the TWTAs. A more systematic installation and the first beam spectra are planned to be got in October 2006. Fig. 4. shows the modified ATOMKI-ECRIS with the new hexapole and chamber.

Actually a new facility with two sharply different operation modes was established: the “old” ECR ion source will be used to produce highly charged ion beams and the “new” ECR plasma device described in this paper will form large-size, low-charged plasmas.

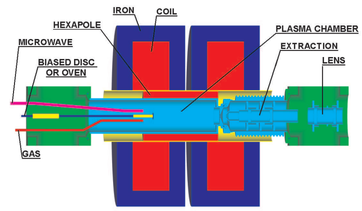


Fig. 4. The ATOMKI-ECRIS with the new hexapole and plasma chamber.

Table 1. Comparison of the multipoles and plasma chambers.

| | Old hexapole, glued | New hexapole, glued | Multipoles made from elementary blocks (not glued) | | |
|---|---|---|---|---|---|
| | | | 6-pole | 8-pole | 12-pole |
| Material (NEOREM) | 490i/400i | 537i | | 537i | |
| Sections*segments | 2*24 | 3*24 | | 3*24 | |
| Internal Diameter/mm | 65 | 115 | | 115 | |
| External Diameter/mm | 135 | 155 | | 155 | |
| Length/mm | 200 | 240 | | 242 | |
| Plasma chamber $ID$/mm | 58 | 102 | | 100 | |
| Plasma chamber length/mm | 180—250 | 200—400 | | 200—400 | |
| Magnetic induction at chamber wall/T | 0.95 | 0.65 | 0.64 | 0.62 | 0.54 |
| Plasma volume (liter) | 0.7 | >2 | | >2 | |
| Frequency/GHz | 14.5 (9.2 tested) | 6.5—13.6 variable | | 6.5—13.6 variable | |

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