AN ECR TABLE PLASMA GENERATOR

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Abstract

A compact ECR plasma device was built in our lab using the "spare parts" of the ATOMKI ECR ion source. We call it "ECR Table Plasma Generator". It consists of a relatively big plasma chamber (ID=10 cm, L=40 cm) in a thin NdFeB hexapole magnet with independent vacuum and gas dosing systems. For microwave coupling two low power TWTAs can be applied individually or simultaneously, operating in the 6-18 GHz range. There is no axial magnetic trap and there is no extraction. The technical details of the plasma generator and preliminary plasma photo study results are shown.

THE ATOMKI-ECRIS

In the ATOMKI a room-temperature, variable frequency ECR ion source operates as a stand-alone device to produce plasmas and ion beams from a variety of materials. So far H, He, N, O, Ar, Kr, Xe (from gases) and F, Ni, Fe, Zn, C, C_{60}, Zn, Pb (from solids) plasmas and beams were produced. The technical details and the recent applications of the ECRIS are shown elsewhere [1, 2]. The homepage of the ECR Laboratory [3] stores lots of information and photos.

The ATOMKI-ECRIS is a modular ion source which means that some of its main sub-systems are variable or changeable. It has two plasma chambers. The first one (internal diameter ID=5.8 cm, length L=20 cm) serves for highly charged ions (HCI) and a bigger one (ID=10 cm, L=20…40 cm, variable) was designed to host large-size, low charged plasmas (LCP). Both plasma chambers can be fit into their own NdFeB hexapole magnet which have logically appropriate IDs for the plasma chambers [4]. In Fig. 1 the plasma chambers and hexapoles are shown. Two room-temperature solenoid coils with optional iron plugs build the axial mirror trap of the ECRIS. The main microwave source is a klystron amplifier operating at 14.3 GHz frequency, with transmitted power between 5 and 1000 W. Occasionally we use a second microwave source which is one of our three travelling wave tube (TWT) amplifiers. The TWTAs can deliver microwave power up to 20 W in a wide frequency range (6-18 GHz).

The original goal was the usage of these two configurations (HCI and LCP) alternatively. But the frequent ECRIS disassembling and re-building sometimes caused inconvenience and the starting-up times (pumping down, plasma aging, etc.) was too long, occasionally 2-5 days. Furthermore, after more than 10 years of operation time our ECR laboratory owns many spare parts and devices (as pumping systems, vacuum measurement units, gas dosing tools, ovens, electrical and motion feedthroughs etc).

Therefore we decided to build a second ECR facility from the spare parts of the "big" ECRIS. It became a compact device which can be placed even on a table so we call it "ECR Table Plasma Generator". Its main elements are:

- plasma chamber (ID=10.2 cm, L=20-40 cm, variable), SS, double walled, water-cooled,
- NdFeB hexapole radial trap (L=24 cm, Br=0.65 T at chamber wall), Halbach-type,
- WR62 and WR90 connections
- microwave oscillator (HP 8350B + plug-ins)
- TWT amplifiers (max 20 W) with frequency 6-18 GHz (variable). One or two microwaves can be coupled.
- three vacuum ports for electrical or motion feedthroughs, for ovens, probes, etc.
- observing window or sample holder (alternative)
- gas dosing system, turbopump vacuum system.

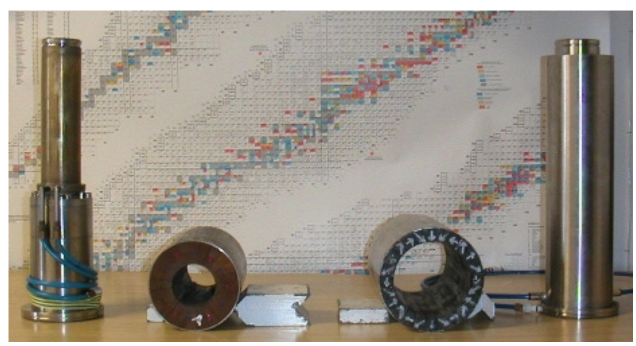

Figure 1. The HCI plasma chamber with its strong hexapole (left) and the LCP chamber with the large, weak hexapole (right).

The device is not equipped however, with axial magnetic trap (there are no coils or axial magnets) and there is no extraction system at all. In Fig. 2 the Table Generator is shown with explanation texts.

The first tests of the table device passed off without any major problems. A relatively high pressure (10^{-4} mbar) is necessary to ignite the plasma without a closed ECR-zone. In Fig. 3 residual gas plasma is shown. The strong asymmetry is caused by the side position of the gas tube.

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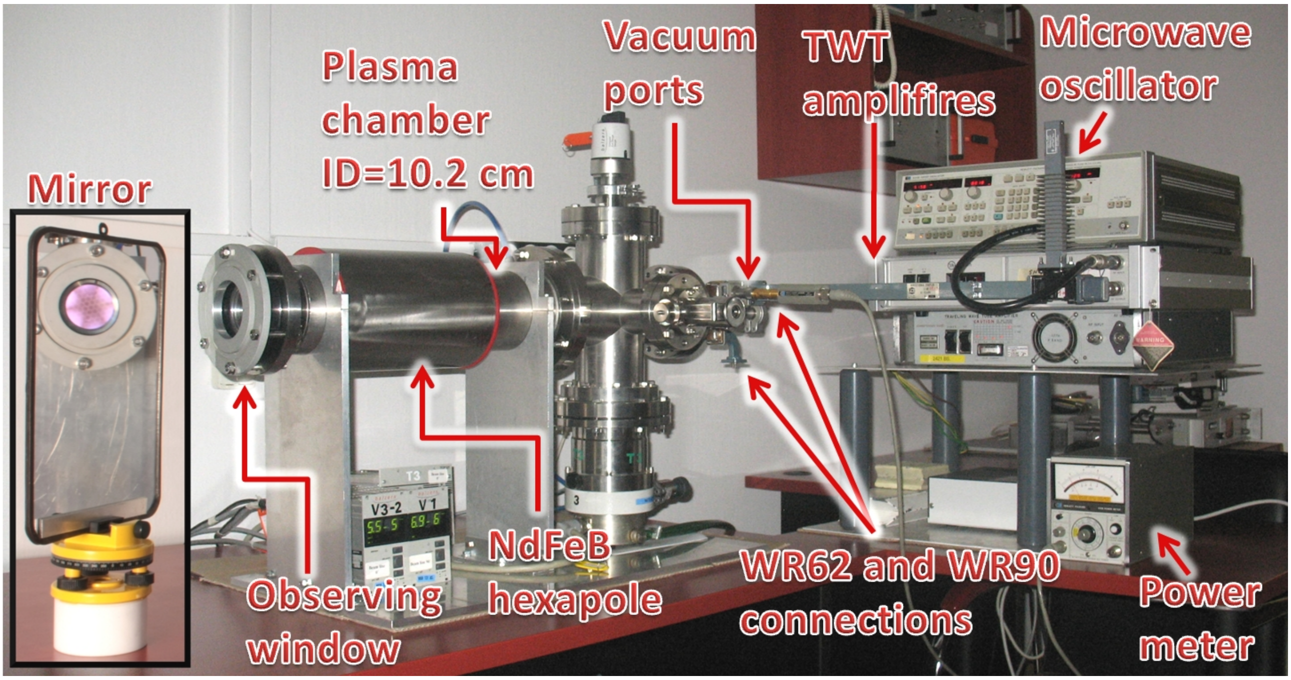

Figure 2. The ECR Table Plasma Generator of ATOMKI.

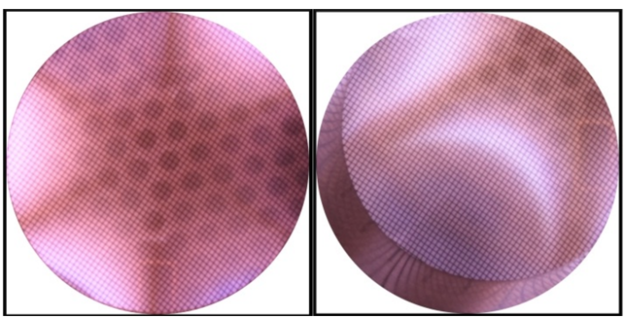

Figure 3. Typical plasmas produced by the ECR Table Plasma Generator. On-axis (left) and off- axis (right) views. Diameter of the resonant zone (7.14 cm) is larger than the diameter of the observing window (6.5 cm).

The intended fields of usage of the plasma generator are:

- A simple, cheap and safe educational working place for students.
- To prepare, to practice or to test measurements with electrostatic movable Langmuir probes.
- To prepare, to practice or to test plasma diagnostic measurements in the visible light and X-ray ranges using cameras and spectrometers.
- To cover and/or to modify solid surfaces with plasma particles, including with fullerene ions.
- To test and practice special microwave modes (pulsed power, frequency sweeper, double frequency etc.).

In the rest part of this paper the results of the first experiments carried out by the help of the ECR Table Plasma Generator, are shown.

VISIBLE LIGHT PLASMA STUDY

First we used the plasma generator to prepare and test a plasma diagnostic measurement in the visible light range.

The traditional visible light photos show the axial projection or integration of the ECR plasma spider in 2D but actually they contain enough information to build 3D pictures of the plasma. We are working out a method to get as much axial spatial information as possible. Fig. 4 shows the experimental setup.

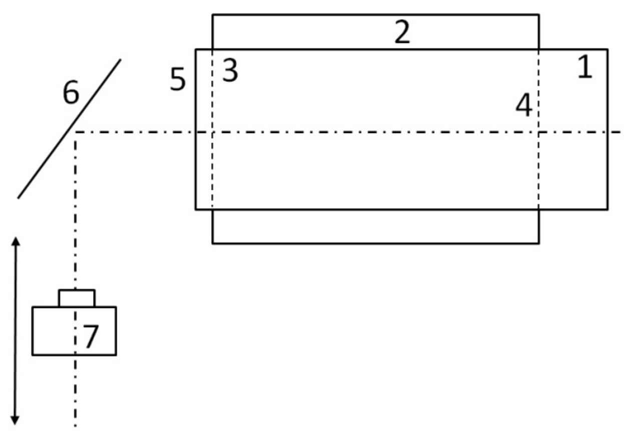

Figure 4. Experimental setup to take visible light photos at the Plasma Generator. Plasma chamber (1), hexapole magnet (2), meshes (3, 4), quartz window (5), mirror (6), camera (7).

Our 2D/3D method is based on elementary optical calculation. The lenses give exactly sharp images from the points of the objects plane. Points which are suited front of or back of the objects plane produce sharp images in front of or back of the film plane. These points form CoC (Circle of Confusion) on the film (Fig. 5.). There exists a limit of the CoC (1/20mm), which allow sensing sharp images. t_{back} and t_{front} mean the distances of the levels (back of and front of the object distance) from where the lens make 1/20mm CoC on the film plane.

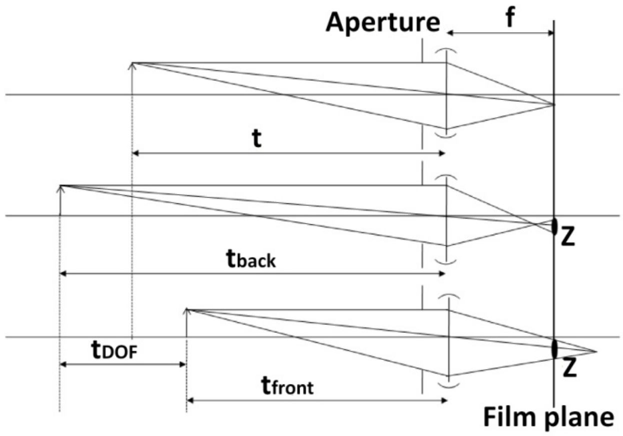

Figure 5. Imaging of the lens.

These distances define another distance: the Depth of Field (DOF).

$$(1) \quad t_{back} = \frac{t}{1+\frac{(t-f)zR}{f^2}}$$

$$(2) \quad t_{front} = \frac{t}{1-\frac{(t-f)zR}{f^2}}$$

$$(3) \quad t_{DOF} = t_{back} - t_{front}$$

Where *t* is the object distance, *f* is the focal length, *d* is the diameter of the aperture, *R=f/d* is the iris value *z* is the diameter of the tolerated COC [5].

According to these equations we can reach very low DOF value applying long focal distance (250 mm), low iris value (5.6) and very close object distance (1.1 m). With these settings the calculated DOF is 9.2 mm. Assuming a partly transparent plasma with homogeneous intensity distribution in visible light range we can get a 9.2 mm thick slice of the plasma in the given object distance using intensity filtering in the low intensity range (Fig. 6.).

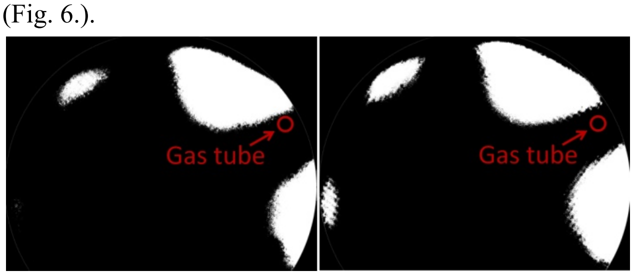

Figure 6.Ttypical slices of the plasma. The object distance was at 50mm (left) and 10mm (right) distance from mesh 4 (fig.4). The red circle shows the contour of the gas tube.

The intensity of the points which come from region out of DOF is significantly lower than those come from region inside of the DOF limit. In order to map axially through the plasma we took photo series by moving the camera on the axis in 10mm steps with unchanged camera settings.

These slices reconstruct the axial spatial distribution (3D image) of the plasma (Fig. 7).

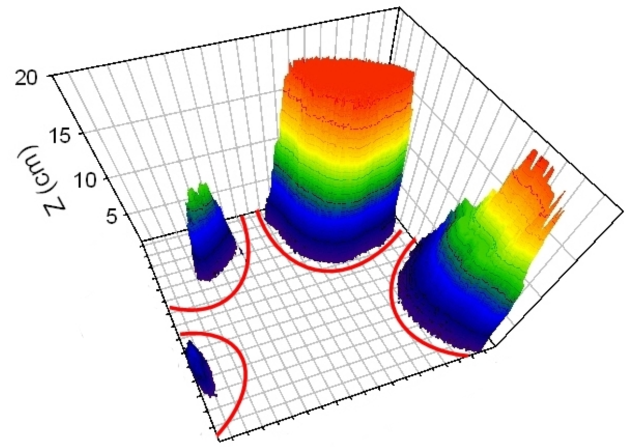

Figure 7. 3D picture of the plasma produced by the ECR Table Plasma Generator. Red lines show the theoretical contour of the hexapole-produced plasma.

We found that the position of the gas tube determine the structure of the plasma. Where the gas was injected the plasma appears close to the injection. However the other parts of the plasma appear at different axial distance from the injection plane (mesh 4 in Fig.4.)

We work out this method further and, in the near future, we want to answer the question: taking 2D axial photos only, is it possible to reconstruct the 3D map of a real ECR ion source plasma?

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