INSTITUTE OF APPLIED PHYSICS
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HOMOGENOUS DENSE PLASMA FLUXES FORMATION FROM HIGH FREQUENCY ECR DISCHARGE

Roman Shaposhnikov[1], Sergey Vladimirovich Golubev[1], Ivan Izotov[1], Roman L'vovich Lapin[1], Sergey Razin[1], Vadim Skalyga[2]

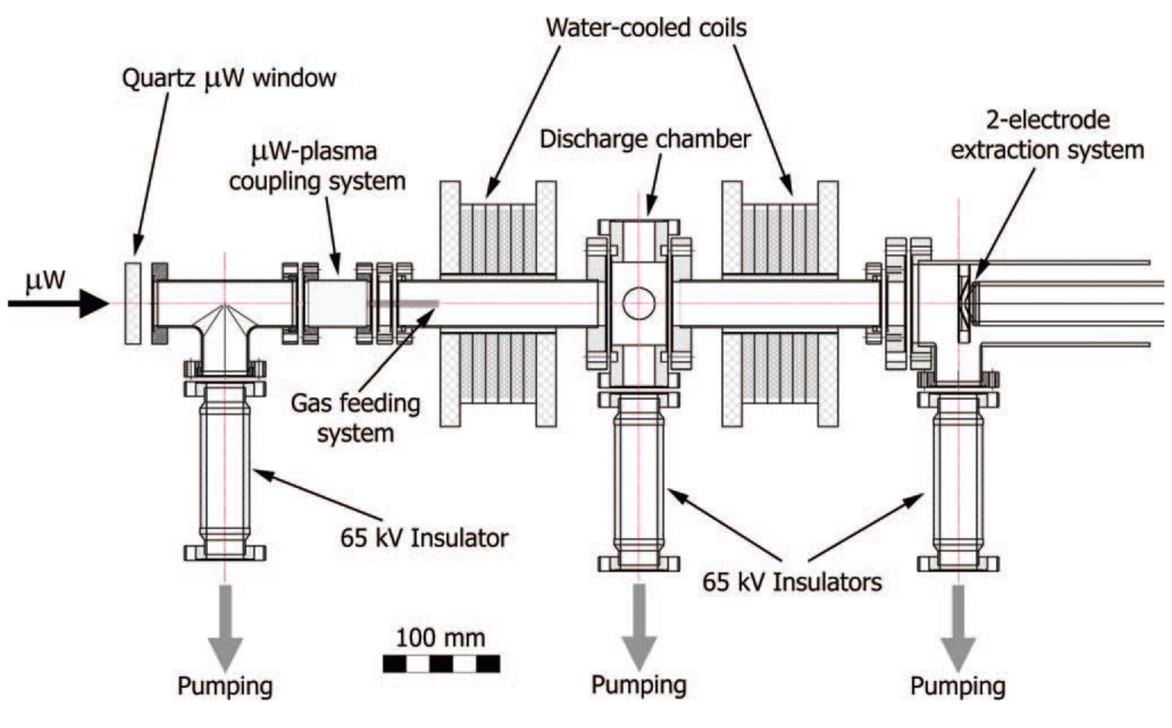
[1]IAP/RAS, Nizhny Novgorod

[2]IAP/RAS, Nizhny Novgorod; UNN, Nizhny Novgorod

shaposhnikov-roma@mail.ru

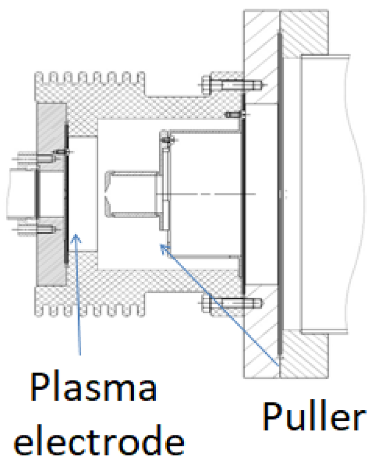
Abstract: Formation of ion beams with wide apertures and current at level of tens and hundreds Amperes is required in a wide range of studies. Usually plasmas of arc or high-frequency discharges are used for such applications. In this paper the possibility of using of an ECR discharge sustained by powerful millimetre wave gyrotron radiation for these purposes is considered. A high plasma density is required to solve the problem of obtaining high values of ion beam current density. The use of gyrotron as a source of millimetre wave radiation in the ECR discharge makes it possible to obtain plasma with high density and high ionization rate, close to 100%. Earlier at the IAP RAS the possibility of dense plasma fluxes production on the basis of ECR discharge in a magnetic field of one solenoid was demonstrated. In this paper, the characteristics of the outgoing plasma flux (density and homogeneity) were investigated. Estimations of the prospects for using such systems for high-current ion beams formation are presented.

High current proton beams production at Simple Mirror Ion Source 37



Gyrotron power Q = 100 kW
Radiation frequency 37.5 GHz
Pulse duration 1.5 ms

Extraction system

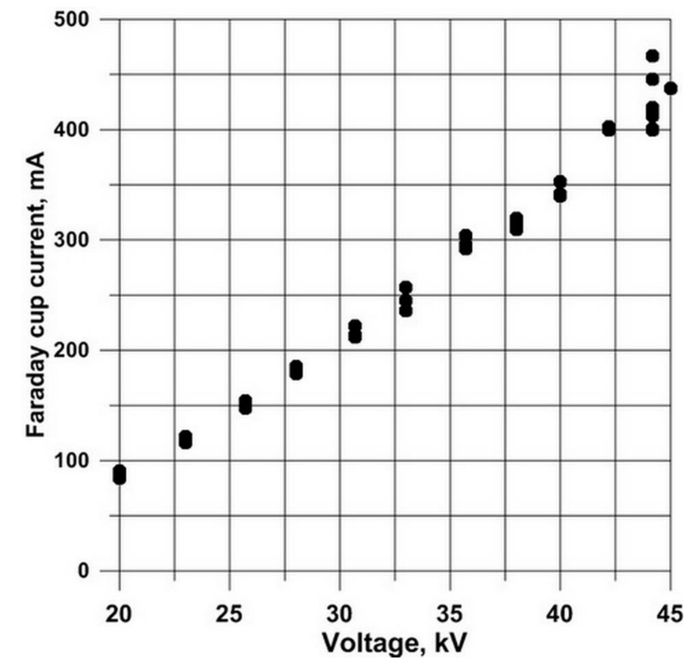


Plasma electrode diameter d = 10 mm

Puller electrode diameter d = 22 mm

Distance between electrodes r = 15 mm

Faraday cup current versus extraction voltage

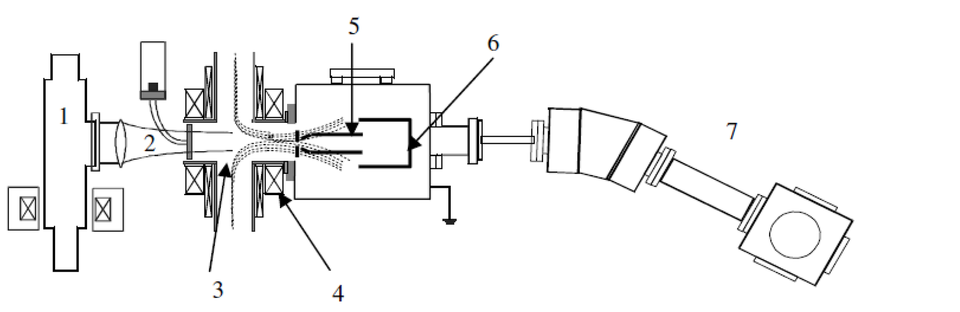


I_{max} = 450 mA through 10 mm hole
j_{max} ≈ 570 mA/cm^2

Hydrogen plasma

High current ECR source of multicharged ion beams

The cusp magnetic trap



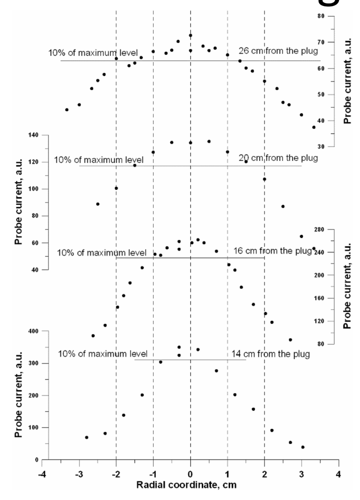
1 – gyrotron, 2 – microwave beam, 3 – vacuum chamber, 4 – coils of magnetic trap (some magnetic field lines are shown in the figure), 5 – extractor, 6 – Faraday cup (ion lens may also be used), 7 – ion analyzer

Plasma flux distribution in a cross section at different distances from the magnetic plug

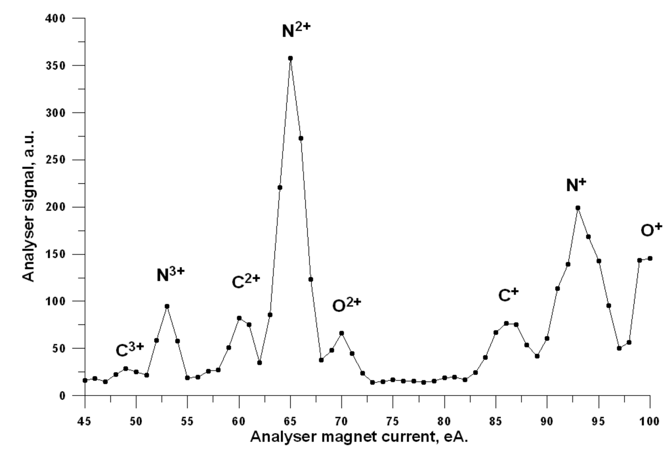
Plasma electrode diameter d = 1 mm

Puller electrode diameter d = 3 mm

Distance between electrodes r = 5 mm



Ion charge state distribution in the beam



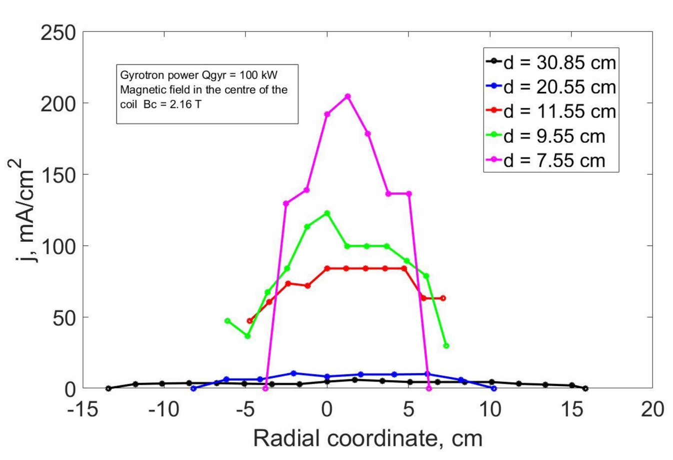
I_{max} = 10 mA through 1 mm hole
j_{max} ≈ 1.2 A/cm^2

Multi-aperture extraction system allows to obtain I_{max} ≈ 200 mA

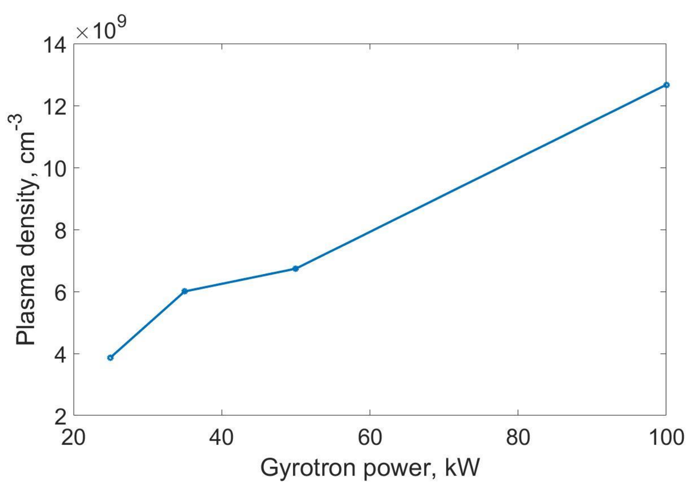
Nitrogen plasma

ECR discharge in a single coil magnetic field

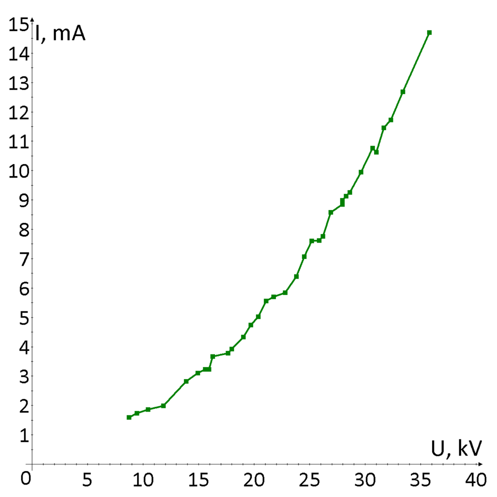
Plasma flux distribution in a cross section, d- distance between the probe and the centre of the coil



Dependence of plasma density on the gyrotron power, d = 30.85 cm



Ion beam current measurements (for different extraction voltage)

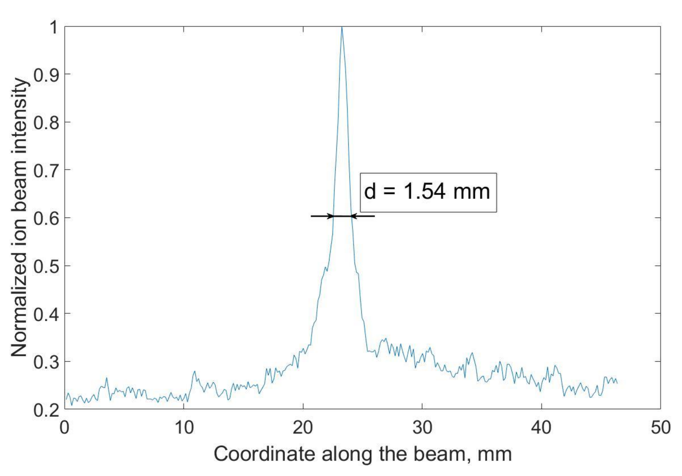


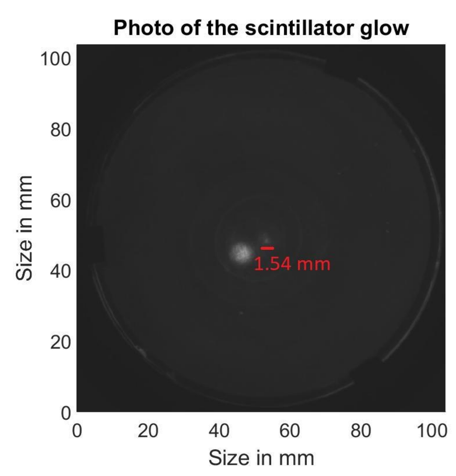
15 mA through 1 mm hole!
j_{max} > 1.5 A/cm²
Ne_{max} = $2.24 \cdot 10^{13} cm^{-3}$
Te ≈ 10-30 eV

Hydrogen plasma

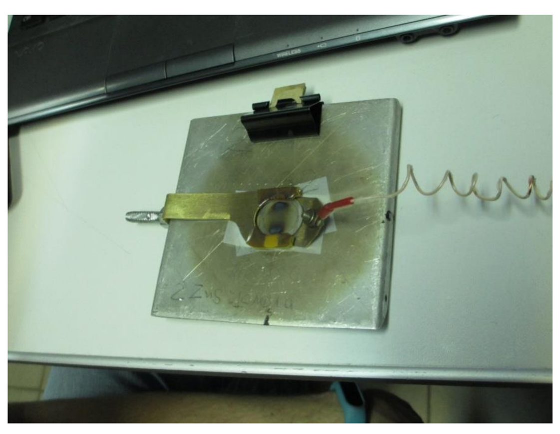
Ion beam focusing and point-like neutron source

The best focusing allows to obtain an ion beam with a width 1.54 mm at a half intensity

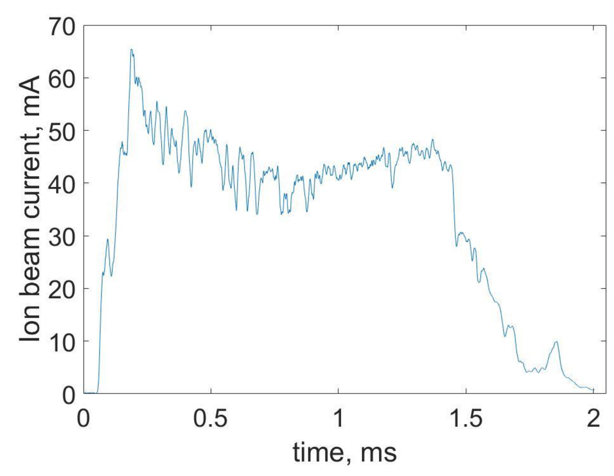




TiD_2 target



Ion beam current oscillogram



Total neutron flux from the target was up to $10^{10} s^{-1}$ which corresponds to the neutron flux density in the emitting region on the target up to $10^{12}\ s^{-1} cm^{-2}$

Conclusion:

- This system has clear prospects as a source of high-current ion beams with large apertures
- Electron temperature and density have values Te = 10-30 eV, Ne_{max} = $2.24 \cdot 10^{13} cm^{-3}$. Losses are enough for gas high ionization degree and obtaining atomic beams with low fraction of molecular ions
- Ion current density $j > 1.5\ A/cm^2$
- Transition to point-like neutron sources is a perspective step for the development of neutron tomography.

Further experimental steps:

- Measurement of extracted ion beam emittance
- Ion beam spectra measurements
- Increase of ion beam current
- Obtaining of ion beams with large apertures
- Increase of neutron flux from the target