He2+ source based on penning discharge with additional 75 GHz ECR heating

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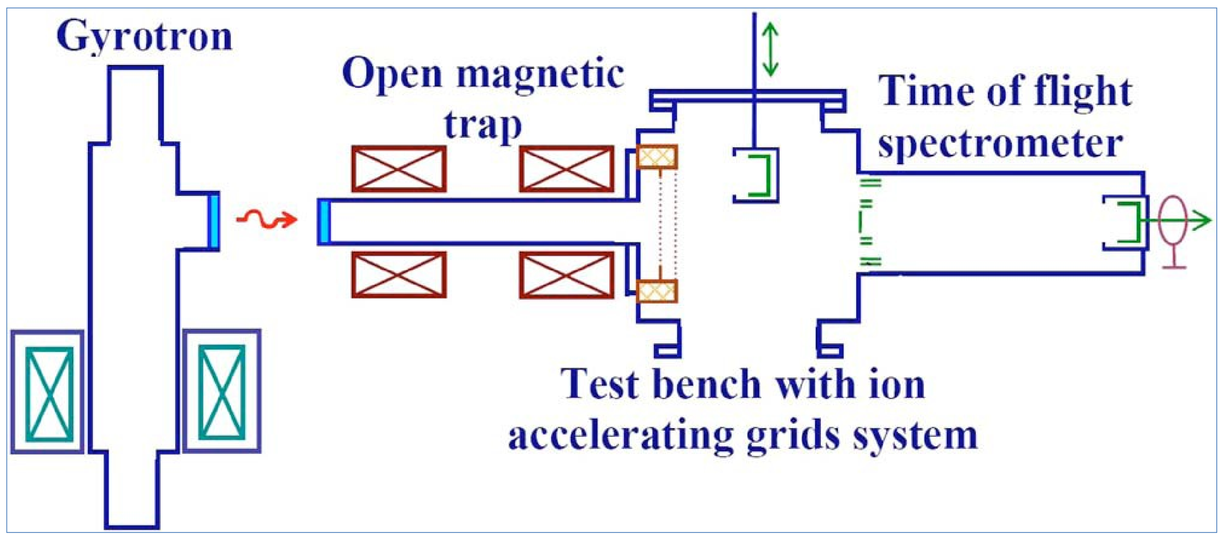
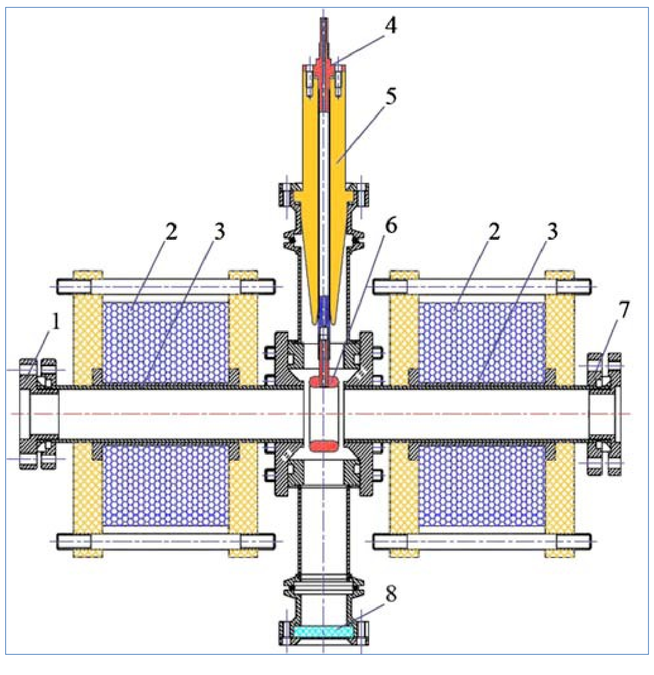
Abstract

It is well known that one can reach high average charge of ions in the ECR plasma by increasing plasma density and decreasing neutral gas pressure. ECR discharge could be realized at very low gas pressure, but discharge startup takes longer time when gas pressure is low. So, it is impossible to realize ECR discharge with limited microwave heating pulse duration at gas pressure lower certain threshold value. This problem could be solved with help of trigger plasma, which should be ignited at low gas pressure in the trap with high magnetic field. This fore plasma could help to decrease ECR plasma startup time significantly and make it possible to realize ECR plasma at very low pressure in pulse operation regime. We suggest penning type discharge as a trigger discharge for fast startup of pulsed ECR plasma. Penning type discharge glows at as low pressure as needed. Discharge was realized in the simple mirror magnetic trap at pressure about 1E-5 mbar. Helium was used as an operating gas. Significant plasma density (about 1e11 cm-3) was obtained at the moment just before microwave heating pulse started. Gyrotron radiation with frequency of 75 GHz, microwave power up to 200 kW and pulse duration up to 1 ms, was used for plasma heating. In the present work the fully striped helium ions were demonstrated, average charge of ions in the plasma was equal 2. Temporal evolution of charge state distribution was investigated. Charge state distribution over helium pressure was also studied.

Scheme of the experiment

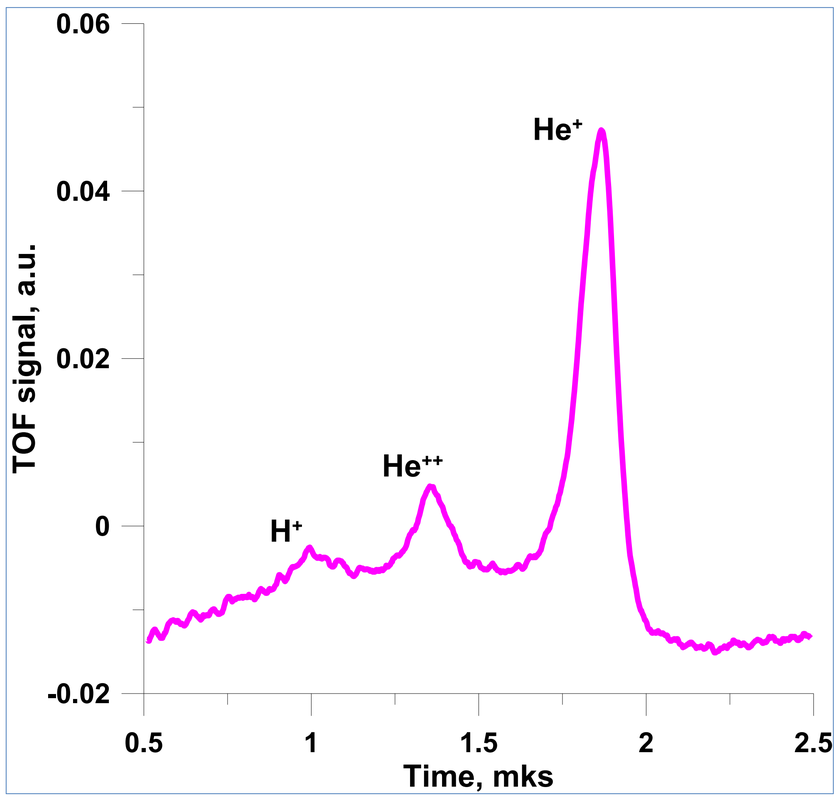




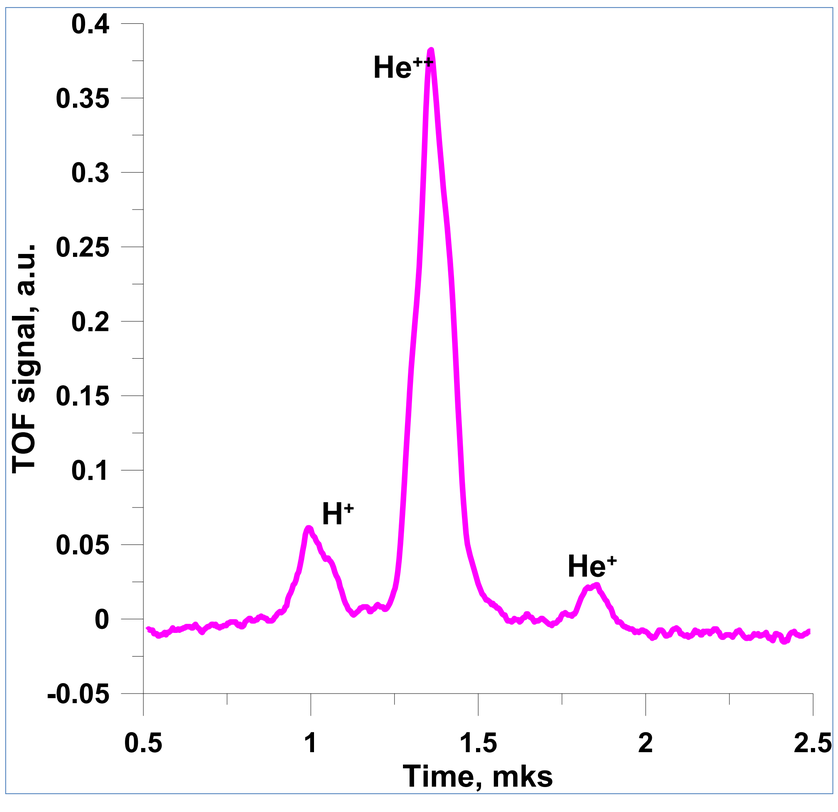
ECR magnetic trap with a GPT based on Penning discharge:
1 - to gyrotron
2 - magnetic coil
3 - trap cathode tube
4 - high-voltage/gas input
5 - highvoltage insulator
6 - anode
7 - to ion beam extractor
8 - MW window

Experimental results:

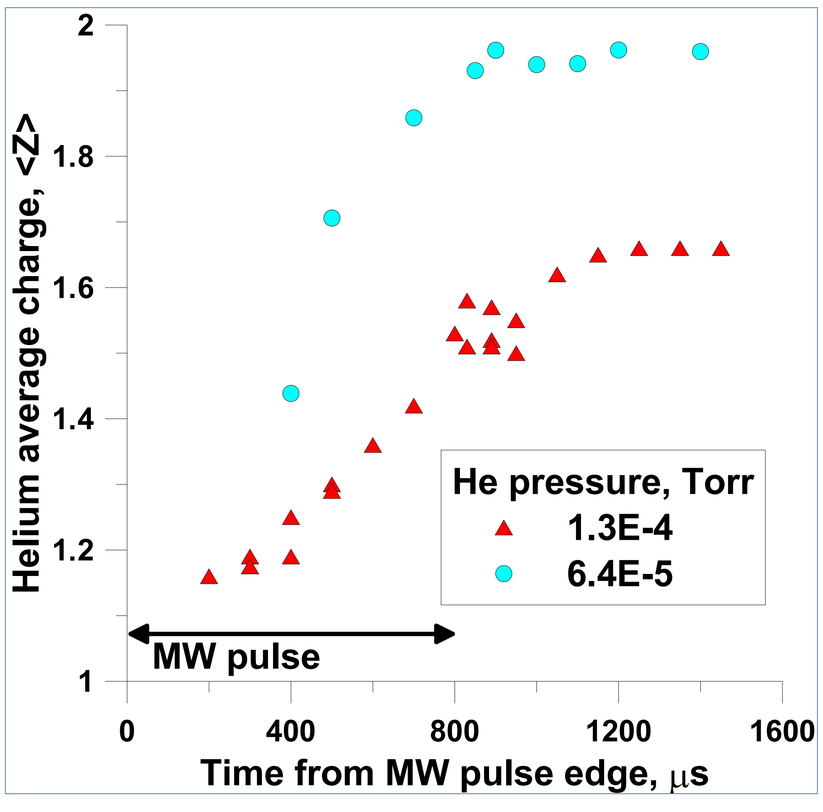
Charge state distribution (200 mks):



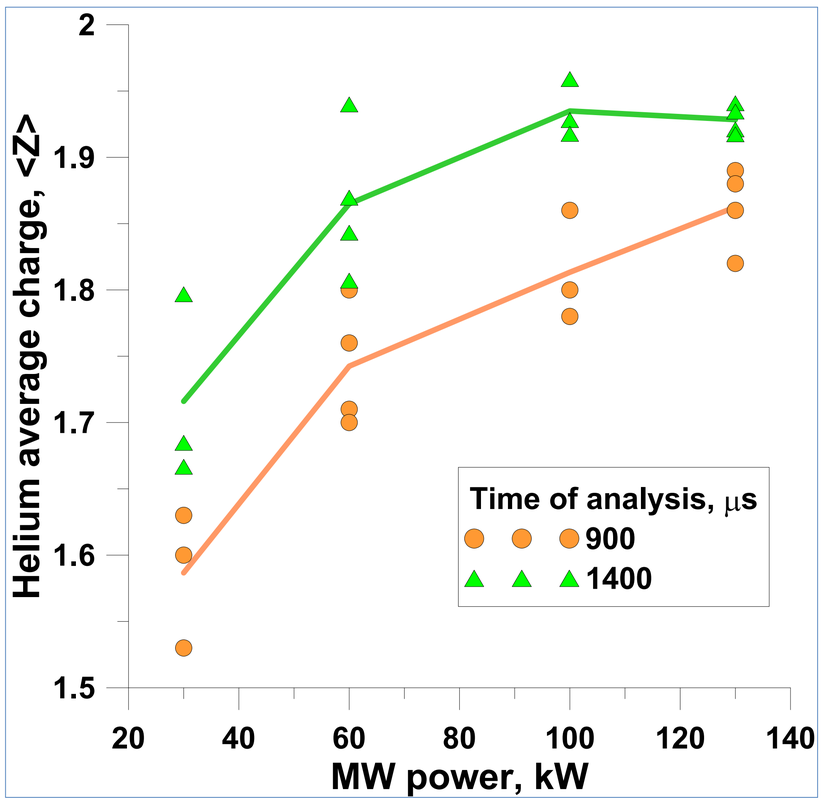
Charge state distribution (1400 mks):



Average charge evolution over time:



Average charge vs MW power:



Summary

Use of auxiliary plasma of Penning-type discharge in the magnetic trap and following ECR heating by millimeter wavelength microwaves make it possible to perform experiment at very low initial pressure. Previously such pressure was unattainable for the pulsed ECR discharges due to long development time of the discharge at low initial pressure. As a result, such hybrid source provides plasma consisted of fully stripped ions of helium and electrons with density about $2 \cdot 10^{12}$ cm^{-3}, Ion beam current extracted from the plasma was few mA. Source of twice ionized helium ions based on the described hybrid ECRIS can be used in the “beta-beam” project as ion beam injector.

Obtained experimental results let encourage concluding existence of MHD-stable plasma in the simple mirror trap, it was stable at least for 1.5 ms. But it is well known fact, simple mirror is MHD unstable magnetic trap. The most “dangerous” type of MHD instability in our case is flutter mode. Its increment approximately equals $1.5 \cdot 10^{5}$ s^{-1}. Thus stable glow of the discharge can not be longer than 10-20 μs. Probably, plasma was stabilized by its rotation in the crossed electric and magnetic fields. Crossed fields was formed by the magnetic trap field and electric field due to voltage applied to ring anode in the central part of the trap.