"PREGLOW" INVESTIGATION IN ECR DISCHARGE AT 37 GHZ, 100 KW

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Abstract

Multicharged ion beams generation in "Preglow" regime is now considered as the main way of short pulsed ion source creation for "Beta Beam" project [1]. The "Preglow" effect has been investigated at a several laboratories (LPSC, JYFL, IAP RAS). The effect was discovered at LPSC on PHOENIX ion source using 18 GHz radiation for plasma heating. Investigations at 14 GHz frequency were made at JYFL. Theoretical analysis demonstrated the advantage of MW frequency increase. Theoretical calculations predict possibility of "Preglow" peaks generation with duration about tens microseconds and rather high average ion charge. At present time at LPSC a joint construction of a new generation ECR ion source with 60 GHz gyrotron plasma heating is running.

As a continuation of previous research at 14, 18 and 28 GHz at present work results of experimental and theoretical "Preglow" effect investigations at SMIS 37 setup with 37,5 GHz MW plasma heating are reported. Received data are important as fundamental result in physics of ECRISs and at the same time it is the next step on the way of 60 GHz SEISM facility creation.

"Preglow" effect was observed and investigated in experiments with ECR discharge stimulated with gyrotron radiation @ 37.5 GHz, 100 kW. Received dependencies of the "Preglow" parameters are in good correspondence with results of numerical simulations. It was shown in experiments that generation of "Preglow" peak with duration about 30 μs is possible.

INTRODUCTION

Investigation of the preglow effect is one of the topical trends in the field of ECR sources of multicharged particles. This effect is, basically, generation of a sharp burst of multicharged ion (MCI) current at the beginning of a microwave pulse, which ensures gas breakdown and plasma confinement in an ion-source magnetic trap. The interest in the preglow effect is associated with prospects of creating an efficient short-pulse MCI source. Such sources are currently in great demand for research in nuclear physics and physics of elementary particles to be carried out on accelerators of new generation.

The preglow effect was first observed in experiments in LPSC and later modeled theoretically in the works [2, 3]. Present work is devoted to experimental demonstration of preglow effect in ECR ion source with gyrotron plasma heating @ 37 GHz, 100 kW.

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FORMULATION OF THE PROBLEM

In frame of short pulse creation problem first of all it is necessary to perform the analysis of gas breakdown dynamics dependences on different parameters.

A microwave breakdown of a rarefied gas in a magnetic trap under the ECR conditions may be separated conventionally into two stages [4], for which the rate of plasma density growth are determined by basically different processes. At the first stage the main process is ionization of the neutral gas by collisions with hot electrons; plasma density grows exponentially, the degree of gas ionization is less than unity, low-charge ions dominate in the distribution of ions over their charge states, and the power absorbed in the plasma is much less than the power of the microwave pumping. At the second stage the rate of density growth slows down significantly, the process of ion peeling goes further, their charge becomes higher, and the power absorbed by the plasma is equal to the power of the microwave pumping, approximately.

Electron energy distribution function (EEDF) which determines plasma life time and efficiency of gas ionization is rather different on those two stages. As it was shown in [2] that transition from breakdown to quasi-stationary stage could be attended with a unexpected transient peak of multicharged ions current. This effect was called preglow [2] and it looks very promising as a way of short pulses creation. Its amplitude and duration are depends on initial breakdown conditions which also determine discharge steady state parameters. It was shown that Preglow peak with duration about of a few tens of microseconds and high average ion charge could be created only with using of microwave with high frequency (more than 30 GHz) and power.

In present work experimental results obtained on SMIS 37 [5] stand demonstrating creation of short pulses under conditions of powerful plasma heating with gyrotron radiation @ 37 GHz are observed.

EXPERIMENTAL SETUP

The experimental research presented in this work was carried out on the SMIS 37 shown schematically in fig. 1.

A gyrotron generating linearly polarized radiation at the frequency of 37.5 GHz, with the power up to 100 kW, and pulse duration up to 1.5 ms was used as a source of pulsed microwave radiation.

In the greatest majority of the experiments the field in the magnetic plugs of the system was 2 Tesla.

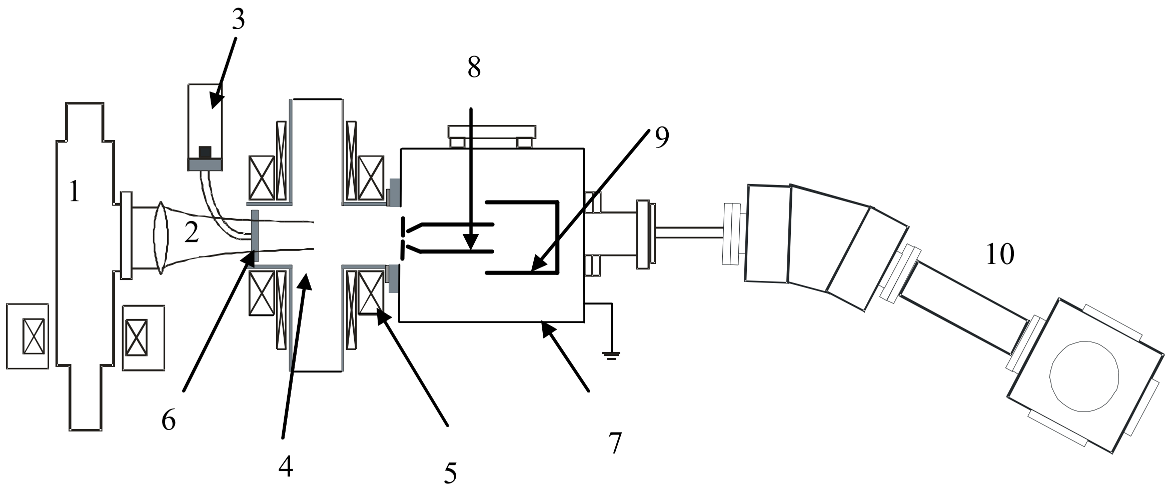

Figure 1: SMIS 37 experimental stand. 1 – gyrotron, 2 – MW beam, 3 – pulsed vacuum valve, 4 – discharge chamber, 5 – magnetic trap coils, 6 – quartz window, 7 – diagnostic chamber, 8 - extractor, 9 – Faraday cup, 10 – ion analyzer.

The operating gas was inlet into the trap along the axis of the magnetic system through a 20-cm long quartz tube with internal diameter of 5 mm; the tube was soldered at the centre of the input quartz window.

Ion extraction and ion beam formation were achieved by means of a traditional two-electrode extracting system. A plasma electrode was placed at an arbitrary distance from the trap plug. Maximum 55 kV voltage was supplied to the extractor. Total ion current was measured by a Faraday cup mounted on the magnetic trap axis. The cup had an input window 35 mm in diameter and intercepted the entire ion beam passed through the extractor puller.

Spectral analysis of the extracted beam of positive ions was performed by means of a magnetostatic analyzer.

EXPERIMENTAL RESULTS

As it was mentioned investigations of non-stationary generation of multicharged ions in Preglow regime in ECR sources are carried out in many laboratories. Typical oscillogram of Ar^{6+} ion current obtained on Phoenix experimental facility at LPSC [2] with plasma heating by 18 GHz radiation is presented in fig.2.

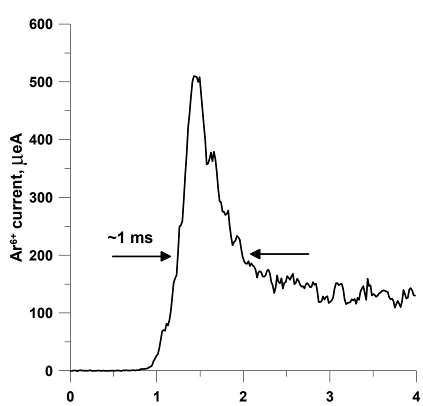

Figure 2: Typical Ar^{6+} current oscillogram on Phoenix 18 GHz facility.

It is evident that formation time of the peak in such conditions is too long for "Beta Beam project".

In experiments on SMIS 37 the Preglow effect was also successfully observed. The Preglow peak duration in this case was about 20 μs, and that is much sorter than shown in fig.3.

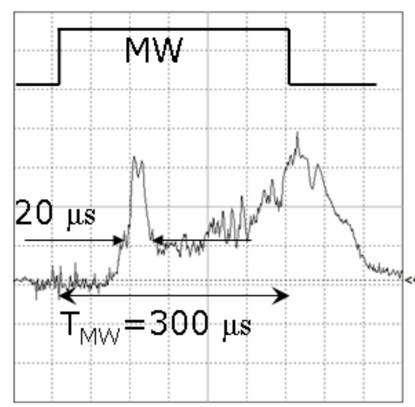

Figure 3: Total ion current.

Experimentally obtained dependences of peak parameters suit well to theoretical calculations. In present work the dependence of qualitative form of ion current pulse on initial neutral gas pressure is presented. In fig 4. a sequence of Faraday cup oscillograms obtained with increase of the pressure in discharge chamber is shown.

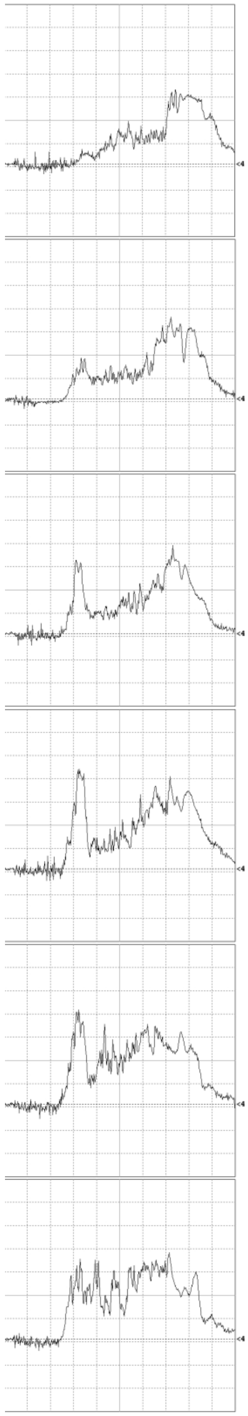

Figure 4: Oscillograms of total ion current in conditions of slight increase of gas pressure in discharge chamber.

Preglow peak could be observed in some narrow range of the pressure what was theoretically predicted in [3].

In such conditions the average ion charger in this peak could be high enough. In fig.5 corresponding ion spectrum in nitrogen is presented.

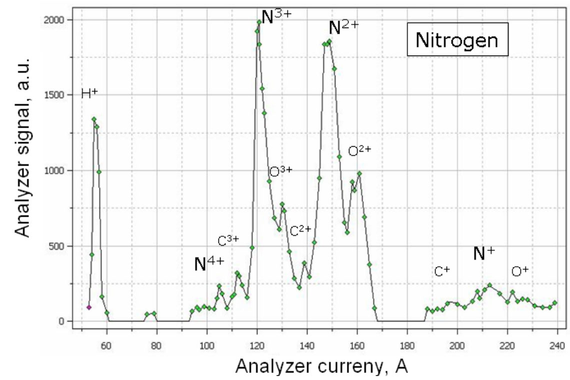

Figure 5: Ion charge state distribution. Nitrogen was used as operating gas.

CONCLUSIONS

Obtained results obviously demonstrate perspective of heating microwaves frequency increase for production of short pulsed multicharged ion beam.

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