STUDY OF THE DEPENDENCE OF ECR ION CURRENT ON PERIODIC PLASMA DISTURBANCE*

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Abstract

In a recent work we observed the existence of periodic current bursts from an ECR ion source when a biased disc is used for enhancing the extracted beam current. It was concluded that the current per burst in the source remains essentially constant. When the disc bias voltage is increased, the burst frequency increases, and so does the total current. The increase in ion current has been found to be proportional to the charge state. However, in the case of protons a different trend is observed. In this work we have studied the periodic bursts in the proton current in order to understand the difference in the behaviour of current jump in protons and heavy ions.

INTRODUCTION

ECR ion sources are used in accelerators and various other laboratories for producing ion beams. In many applications it is needed to produce highly charged heavy ion beams. However, in general, the higher the charge state, the lower is the ion current. A number of techniques are employed to enhance the ion current. Often a lighter gas is added to the sample gas which reduces the ion temperature thereby increasing the retaining time. Ion current increases in this process [1]. Supply of low temperature electrons to the main stage plasma is another method. In this process the plasma becomes more stable, as a result of which the ion confinement time increases. Wall coating [2], use of an electron gun [3], and the insertion of a biased disc [4-6] are the methods of the electron supplying technique.

When a negative potential is applied to the disc, the electron density increases and thus increases the ion current [7]. Another explanation by D. Meyer [8] suggests that with the application of a negative potential on the disc, the plasma potential decreases and the plasma becomes more stable. With a stable plasma, production of high charge state ions increases.

In order to understand the aspects of the ion current enhancement by using a biased disc, we have tried to explore the time characteristics of the ion beams of various charge states. In an earlier work we measured the time spectra of neon ions, and observed the presence of periodic ion bursts [9]. The burst frequency varied with the disc bias voltage, and the ion current showed a good positive correlation with the burst frequency.

For investigating this feature further, we have measured and analyzed the time spectra of various ion species of high and low charge states. Spectra have been measured at a number of disc bias voltages and microwave power levels. Above a threshold mircowave power, there is a consistent presence of ion bursts.

EXPERIMENT

Experiments were performed with VEC-ECR source [10] for oxygen ECR plasma with helium as mixing gas. The source pressure was kept at 1.8×10^{-7} Torr. An aluminium biased disc of 3cm diameter was placed on the axis at the injection mirror point. Bias voltage was varied in steps from 0 to –55 Volt.

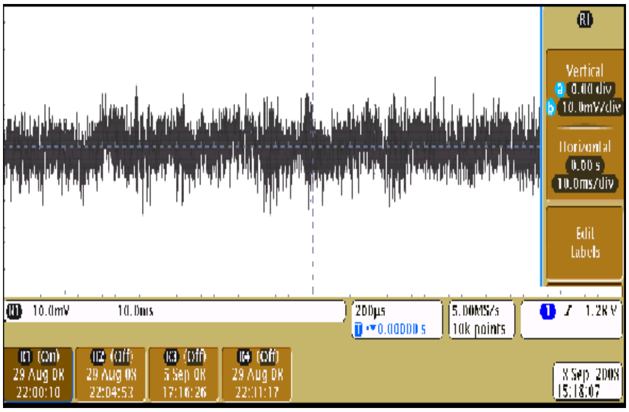

Figure 1: Time spectrum of O^{6+}

In the present experiment, a Faraday cup, located just beyond the image slit of the 90^0 analyzing magnet in the beam line, measured the ion current. Spectra for

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individual analyzed ion species could be recorded in this way. The output of the Faraday cup was fed to a storage type 500 MHz Tektronix digital phosphor oscilloscope (DPO-4054).

We stored data at intervals of 0.04 ms. Duration of each measurement was 400 ms allowing us to collect 10000 data points in each time spectra. Fig.1 shows a typical spectrum. The time spectra were Fourier analyzed on-line with the spectrum analyzer available with the oscilloscope.

RESULTS

Spectra were measured for typical high and low charge state ions, viz. O^{6+}, O^{3+} and H^{+} at various disc bias voltages and microwave power levels. The ion current for all the species shows a DC component and a periodic contribution. For low microwave power, bursts are not observed. Above a threshold of about 90 watt bursts appear suddenly as shown in Fig.2. The burst frequency steadily increases as the power level is increased (Fig.3). Another interesting feature is that for high charge state (O^{6+}) there is a correlated increase in the ion current with the burst frequency.

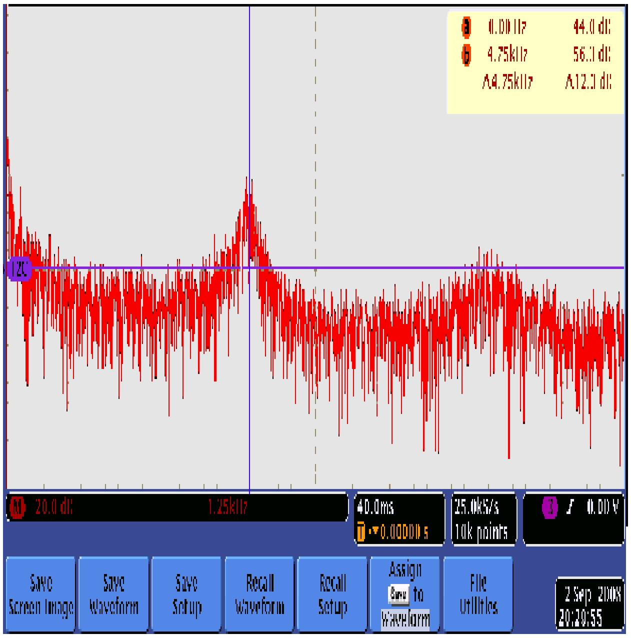

Figure 2: Typical Fourier spectrum

The correlation between the burst frequency and the increase in ion current suggests that the current per burst is a constant factor. The more the number of bursts, the higher is the contribution to the current.

For low charge states, e.g., protons, the trend is different. As the burst frequency increases the proton current decreases (Fig.4). One can understand this in the following manner. As the plasma absorbs more power, the higher charge states get populated at the sacrifice of lower charge states. This explains the increase in O^{6+} current and decrease of H^{+} current (Fig.5).

The burst frequency varies with the applied disc bias voltage also. As can be seen from Fig.5, for O^{6+} beyond a bias of –9 V the burst frequency increases with the bias voltage. The ion current also increases simultaneously.

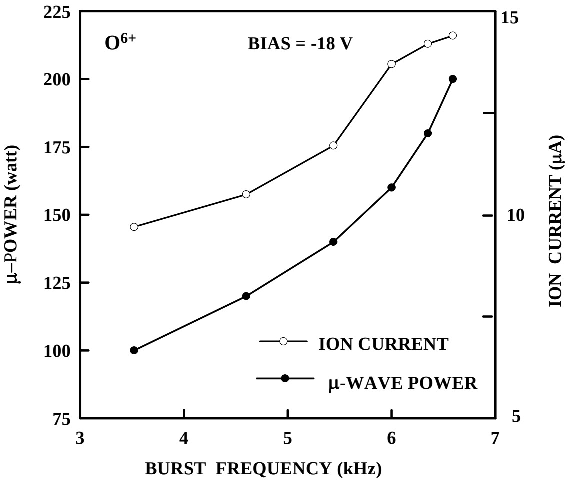

Figure 3: Ion current increases with burst frequency which, in turn, increases with absorbed μ-wave power.

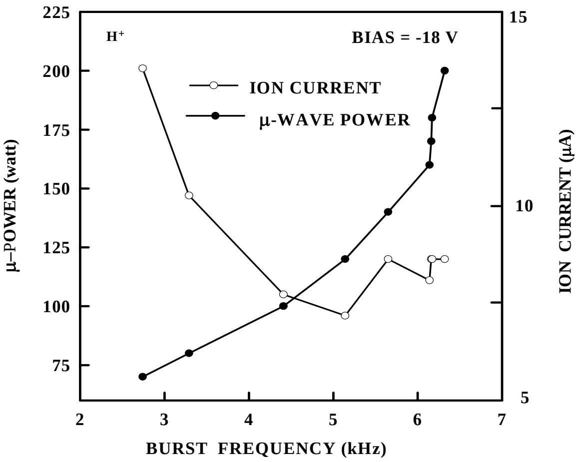

Figure 4: Ion current, in general, decreases with burst frequency in case of protons.

We have studied the effect of the disc bias potential on the observed appearance of burst frequency. Ion current and corresponding burst frequency for O6+, O3+ and proton were measured as a function of the disc voltage. It is clear from Fig.6 that as in the case of microwave power, the bust frequency and the ion current increase with the disc bias voltage in the case of O^{6+}.

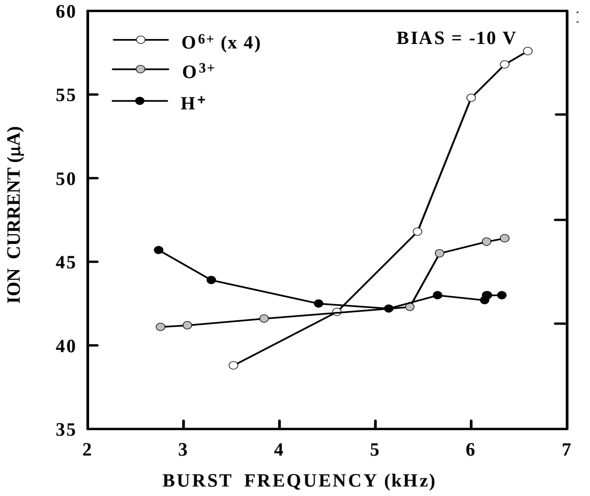

Figure 5: The nature of variation of ion current with burst frequency differs for high and low charge states.

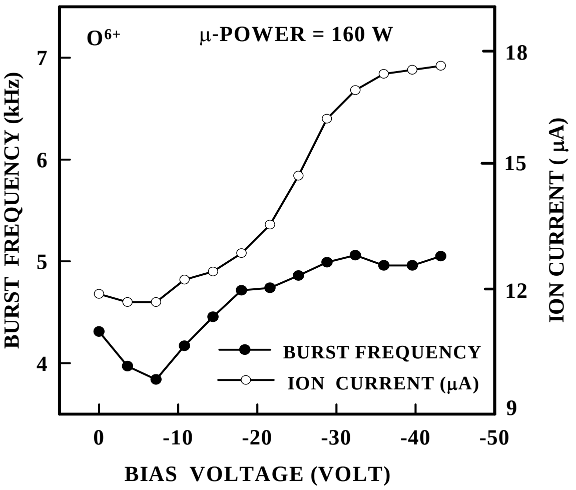

Figure 6: Burst frequency and ion current increases with bias voltage for O^{6+}

DISCUSSIONS

One is tempted to look at the phenomenon in terms of a periodic plasma disturbance and the electron and ion confinement time. Our recent work on ion and electron confinement showed [11] that ions inside an ECR chamber consists of two bunches (Fig.7). One bunch, which barely remains confined, are lost within an average confinement time of ~10^{-5} sec. These are the ions which escape quickly via straight radial or axial escape. Another bunch remains confined for a considerably longer time, and gain sufficient energy to take part in the ionization process. The average confinement time of such ions for a 6.4GHz source of our type is about 10^{-3} sec. The kilo-hertz oscillation observed by us is of similar time scale. The electrons inside the ECR chamber also show a similar behaviour (Fig.8). The average confinement time of the energetic electron component is 1.3×10^{-4} sec. If due to excess absorption of power by electrons, any plasma disturbance is created, the density of ionizing electrons are temporarily changed. Generation of another energetic electron bunch takes time to be confined. Thus ion production will show a temporal behaviour.

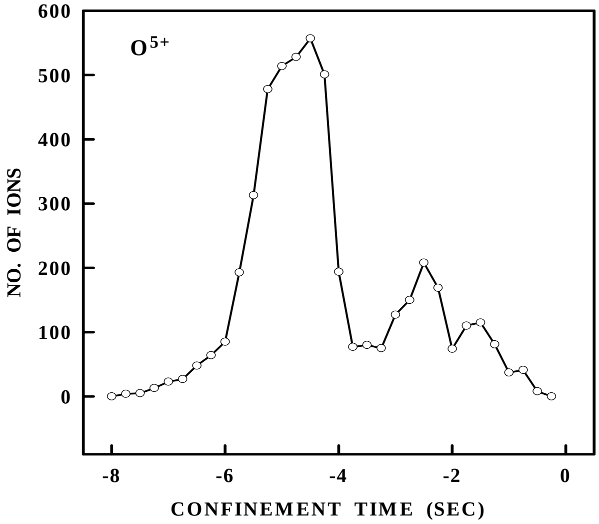

Figure 7: Two electron bunches of different confinement times.

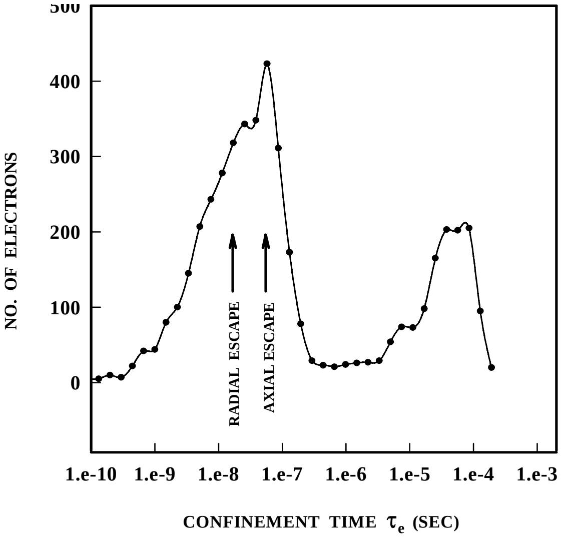

Figure 8: Electron confinement time

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