PERIODIC ION CURRENT BURST IN 6.4 GHZ ECR SOURCE

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Abstract

We studied the enhancement in extracted ion current in the 6.4 GHz ECR ion source at VECC, Kolkata by inserting a negatively biased disc. In addition to the expected increase in current, we observed a sudden jump in the current at some low bias voltage. We recently measured and analyzed the time spectra of high charge state ion current for neon to understand the origin of the jump. It revealed the presence of a burst frequency in kilohertz range. This frequency shows a synchronous jump with the ion current and also a good linear correlation with it. This may signify that current per burst is a constant factor ; higher current means that there are more number of bursts.

INTRODUCTION

Various techniques are employed for enhancing the extracted beam current from Electron Cyclotron Resonance (ECR) ion sources. The most common method is to add a lighter gas to the sample gas in order to reduce the ion temperature thereby increasing the retaining time and thus the ion current [1]. Another approach is to supply low temperature electrons to the main stage plasma. 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 emitter [3], and the insertion of a biased disc [4-6] are the cold electron supplying techniques.

The use of biased disc in ECR sources was first demonstrated by Melin et al. [4]. In recent years, this technique has become the most popular method of increasing the extracted ion current from an ECR ion source. Melin [4] and Gammino et al. [7] systematically studied the improvement in ion current by biased probes. The improvement was thought to be due to an increase in the electron density with the application of a negative potential. D. Meyer [8] suggested that when negative potential is applied on the disc, the plasma potential decreases making the ECR plasma more stable. As a result, high charge state production increases. Tarvainen et al. [9] and Mironov et al. [10] made measurements on the plasma potential and found that it decreased when the negative potential at the biased disk was increased.

In order to study the performance of the biased disc systematically we made measurements on the extracted ion current by varying the disc bias potential [11,12]. The modification undertaken on the vacuum system allowed the source to sustain a base pressure of 6×10-8 Torr on the injection side. The measurements showed that as the negative bias potential was increased, the extracted ion current for any species showed a small decrease and then at a small negative potential it jumped to a high value. As the potential was further increased, the ion current also increased and saturated at a large bias potential.

Fig.1. shows typical results of the measurement on ions of various charge states. It is to be noted that the potential at which the current abruptly jumps is the same for all species. Another interesting feature is that for H^+ the ion current jumps to a lower value.

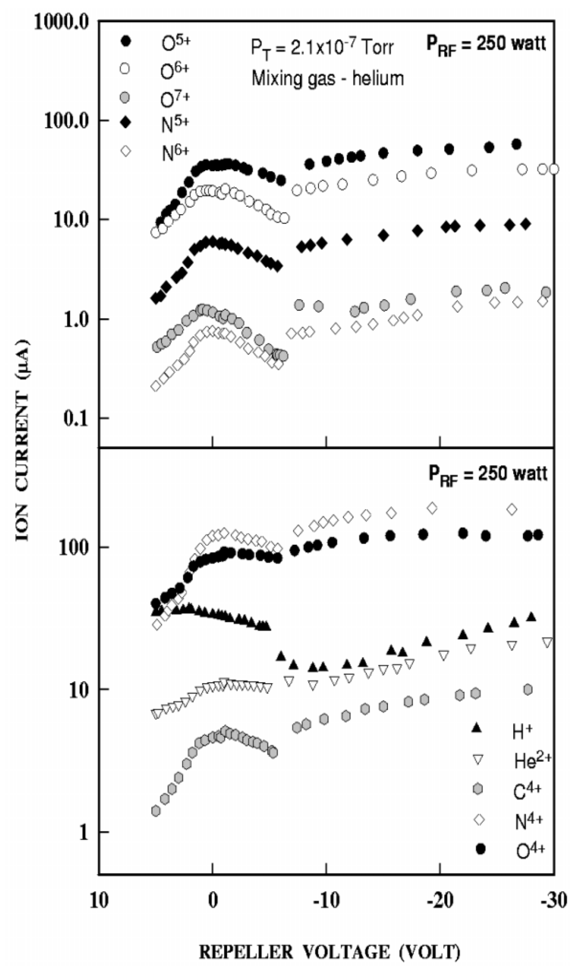

Figure 1: Variation of ion current with bias voltage.

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EXPERIMENT

In order to understand the origin of jump we investigated the time spectra of the extracted ion current. A Faraday cup, located beyond the 900 analyzing magnet, was used for measuring the ion current. In this arrangement we could measure the spectra for individual analyzed ion species. The output of the Faraday cup was fed to a 200 MHz Tektronix storage oscilloscope which stored data at intervals of 0.01 ms. Duration of each measurement was 100 ms allowing us to collect 10000 data points in each spectra.

Fast Fourier analysis was performed on the spectra using the MATLAB software. Fig.2 shows a typical time spectrum of Ne^{6+}. Figs.3 show the Fourier spectra before and after the jump in Ne^{7+} ion current.

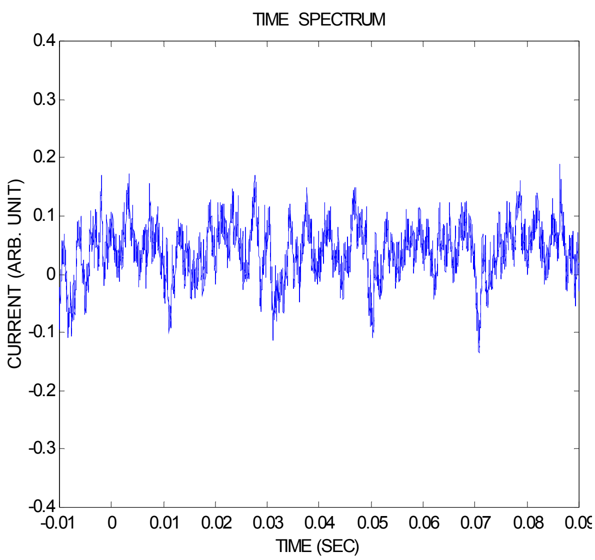

Figure 2: Typical time spectrum for Ne^{6+} with no bias. DISCussions

The time spectra were Fourier analyzed for a number of applied bias voltages. Presence of a frequency peak different from the usual 50 Hz noise were revealed in all the cases. With no disc bias the frequency was around 300 Hz. As the negative bias voltage was increased, the current showed a marginal decrease and showed an abrupt jump at a small negative voltage (-2.5V) (Fig.4). The frequency also showed a simultaneous abrupt change. It increased to a value of about 1170 Hz. Thereafter both the current and the frequency remained essentially constant.

Fig.5 plots the frequency as a function of the extracted ion current. The general trend is that the frequency increases as the current increases. In fact the plot shows a good linear correlation between the frequency and the current. The statistical correlation coefficient comes out to be 0.85. The presence of a frequency peak in the Fourier spectra means that a large portion of the ions come out of the source in periodical bursts. If we subtract the minimum ion current (just before the jump) then the frequency-current plot becomes a straight line passing through the origin. Thus one can see two parts of the current. The minimum part is constant part whereas the other part is frequency dependant.

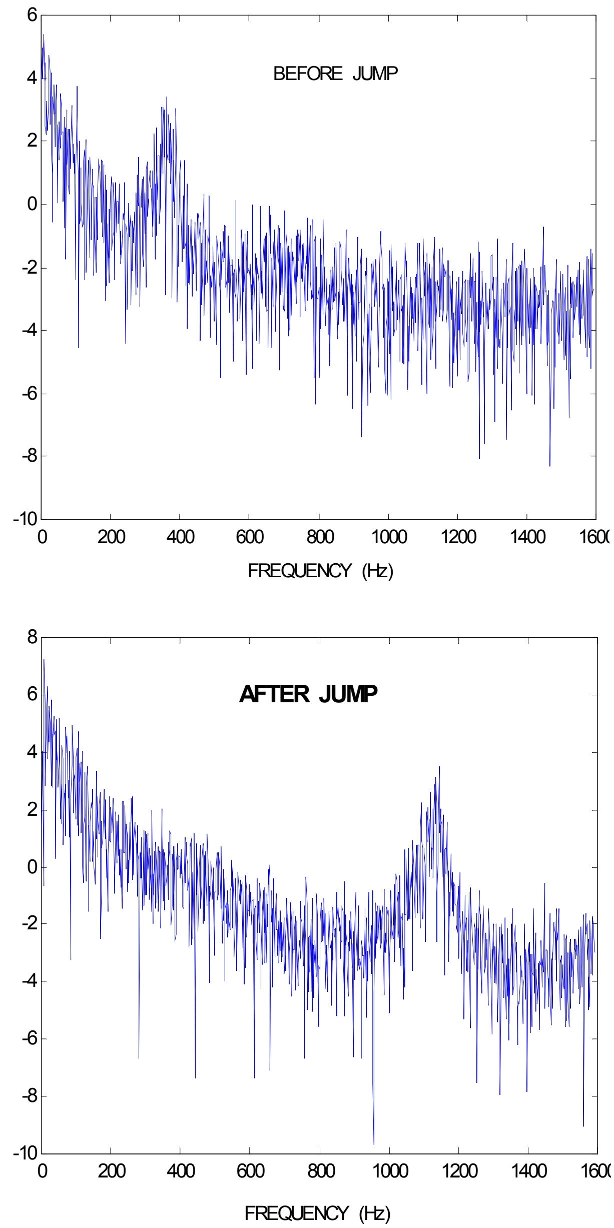

Figure 3: Fourier spectra of the ion current. The burst frequency changes with the applied bias voltage.

At saturation, the frequency dependant part gives the major contribution to the ion current. The fact that the ion current (I-Imin) is proportional to the burst frequency, then simply means that the more the number of bursts per unit time, the more is the current. It also says that the current per burst is a constant factor. Thus increasing the burst frequency by some means appears to be the key factor in increasing the extracted ion current. We have measured the time spectra and done the analysis for Ne^{7+} also. In this case also we have obtained similar results.

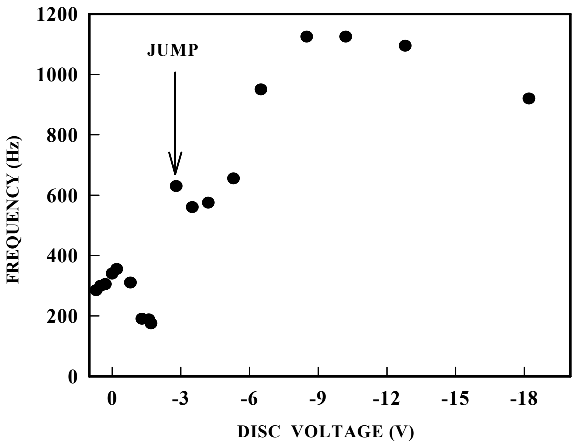

Figure 4: Jump in the burst frequency (Ne^{7+})

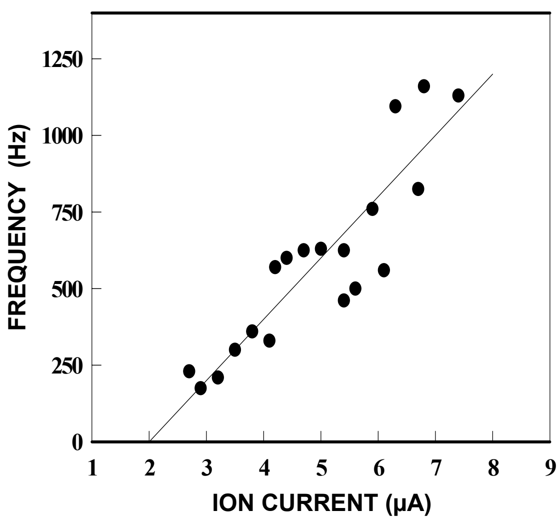

Figure 5: Correlation between the burst frequency and the ion current.

R.C. Garner et al. showed that the ions and electrons in a microwave generated plasma, show a burst in the kilo-Hertz frequency range. They observed [13-15] that a mirror confined plasma, which is inherently anisotropic when the electrons are heated to energies greater than the plasma potential, may be whistler unstable. The whistler instability means an electron micro-instability which is driven by the temperature anisotropy of the electron velocity space distribution. This whistler instability is driven by the warm electron component (~ 2 keV). Unstable rf emission in a regime near the electron cyclotron resonance frequency (0.7fce to fce) has been obtained in the mirror-confined ECR heated plasma. This rf emission associated with the micro-instability occurs in fairly regular burst with a fixed burst time. The energy per burst was found to maintain a constant value. It was also experimentally observed by them that the rf emission burst correlates with the electron end-loss burst as well as burst of ion end-loss.

The periodicity of the burst depends upon the mid-plane magnetic field and the operating pressure. Whistler B occurs at lower operating pressure (<5×10-7 Torr) and whistler B and C both exist at marginally high operating pressure (7×10-7 to 2×10-6 Torr). In case of whistler B the end losses are along the axis.

Garner quoted a value of 5×10-6 J per burst in their 10 GHz ECR device. In our 6.4 GHz source, the total ion current is about 400 μA. Taking a value of 30 eV for the energy per ion and a measured burst frequency of 1.2 kHz, the overall energy per burst comes out to be about 3×10-5 J. This is of the same order of magnitude as that obtained by Garner. So it may be surmised that the periodic current bursts observed in our experiment is of similar origin to that discussed by Garner. Further experiments with a bias voltage modulated by kilo-Hertz ac component may be of interest.

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