Contribution ID: **154**

Type: **Poster presentation**

Plasma Response to Amplitude and Frequency Modulation of the Microwave Power on a 14 GHz Electron Cyclotron Resonance Ion Source

Monday, October 16, 2017 6:45 PM (15 minutes)

This paper reports on experiments to study the effects of sinusoidal microwave power Amplitude Modulation (AM) on the performance of Electron Cyclotron Resonance (ECR) ion sources. The study was motivated by an inherent property of high frequency power sources such as gyrotrons, which exhibit amplitude modulation of the microwave power due to the use of high frequency switching power supplies to generate the required high voltage for these devices. Intentionally perturbing the plasma with AM helps us understand where the most stable operating parameters may be found. Additionally, the well-defined cutoffs observed in beam current and bremsstrahlung signal could possibly be used to better understand the microwave heating process and ion lifetimes in the plasma. The study was conducted on the 14 GHz ECR ion source ECR2 at the University of Jyväskylä. The klystron output was intentionally perturbed by a variable frequency sinusoidal amplitude modulation. The average microwave power was 350 W modulated between 530 W and 180 W from 0.011-25 kHz. In particular, the energy integrated x-ray signal responded linearly with microwave power and the modulation was no longer observable at approximately 1.7 kHz where the signal became solely dependent on the time averaged power. Similarly, the beam current from the ECR ion source responded more strongly to low frequency modulation, but the beam current did not preserve the sinusoidal waveform as well as the x-ray signal. The highest observable AM frequency was typically around 16 kHz but could decrease by 40%. The high charge states were observed to be more impacted by the amplitude modulation and were more linear with AM than lower charge states with respect to the charge state distribution peak. The solenoidal magnetic field was found to play an important role in defining the cutoff frequency about a minimum value. Qualitatively, we found this minimum to correspond to the field often used for beam injection into the K130 cyclotron. We will present how beam current and the x-ray signal depend on AM frequency for different magnetic fields. A qualitative interpretation of the results will be given.

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Session Classification: Poster Session 1

Track Classification: Production of highly charged ion beams