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

D. Neben*, O. Tarvainen, R. Kronholm, H. Koivisto, T. Kalvas, G. Machicoane, and D. Leitner

*nben@nscl.msu.edu

Abstract

This paper reports the effects of sinusoidal microwave power Amplitude Modulation (AM) on the performance of Electron Cyclotron Resonance (ECR) ion sources. The study was conducted on the 14 GHz ECR ion source ECR2 at the University of Jyväskylä. The klystron output was intentionally altered by a variable frequency sinusoidal amplitude modulation. The average microwave power 350 W was modulated between 530 W and 180 W from 0.011-25 kHz. The integrated x-ray energy, the mass analyzed beam current and the forward and reflected microwave power were measured. The energy integrated x-ray signal responded linearly with microwave power and the modulation was no longer observable at approximately 2.2 kHz where signal strength became solely dependent on the time averaged power. Similarly, the beam current from the ECR ion source responded strongly to low frequency modulation, but the modulation amplitude decreased with increasing frequency beyond 400 Hz. The solenoidal magnetic field was found to play an important role in defining the largest AM frequency observable in the beam current. In all cases, the beam current amplitude modulation disappeared or was strongly suppressed for frequencies above 10 kHz regardless of source tuning, magnetic field, or charge state. Qualitatively, we found source tuning parameters for which AM effects were reduced also produced the highest currents of Ne5+ in Continuous Wave (CW) mode. Furthermore, these parameters are typically used for optimized beam injection into the K130 cyclotron. The dependency of beam current and the x-ray signal modulation on AM frequency for different magnetic fields are reported. A qualitative interpretation of the results will be given.

Introduction

We pursue the development of a novel perturbative method for probing electron and ion lifetimes that is less destructive than afterglow [1] and does not introduce metallic contaminants to the plasma [2, 3].

Experimental Set-Up

- 14 GHz Electron Cyclotron Resonance (ECR) Ion Source [4].
- Microwave power modulated with sinusoidal waveform.
- Beam current and energy integrated x-rays measured.
- Modulation frequencies increased exponentially until beam modulation was no longer observable.

Results

- X-rays oscillated up to a maximum frequency between 1.6-3.3 kHz regardless of magnetic field.
- Ne5+ current frequency response changed dramatically with magnetic field.
- The field that produced the most Ne5+ current stopped modulating at the lowest frequency.

Discussion

We observed the x-rays to follow the microwave power time delayed by around 0.5 ms. Its interesting to note that 2.22 kHz (oscillation period of 0.45 ms) was often the point beyond which no modulation was observable. Some estimates for electron lifetimes [6] are close to this value. As the plasma is modulated beyond about 2 kHz instabilities that arise on the crest of the beam current waveform no longer significantly appear. The frequency response of Ne5+ current changed significantly with magnetic field and interestingly the field that minimized beam current modulation, B0/Bo=0.72 and generated the most CW current has an ecr zone that is 5.0 times the vacuum wavelength at the driving frequency of 14.056 GHz. It is possible to tune the magnetic field for efficient heating produces a denser population of hot ion confining electrons (lowering potential dip) and suppresses Ne5+ modulation at higher frequencies.

REFERENCES:


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