Effects of microwave frequency fine tuning on the performance of JYFL 14 GHz ECRIS

V. Toivanen[a], V. Aho[a], L. Celona[b], G. Ciavola[b], A. Galatà[c], S. Gammino[b], P. Jones[a], J. Kauppinen[a], H. Koivisto[a], D. Mascali[b,d], P. Peura[a], T. Ropponen[a,e], O. Tarvainen[a] and J. Ärje[a]

UNIVERSITY OF JYVÄSKYLÄ

[a]) *Department of Physics, University of Jyväskylä (JYFL), 40500 Jyväskylä, Finland*
[b]) *Instituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud (INFN-LNS), 95123 Catania, Italy*
[c]) *Instituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro (INFN-LNL), I-35020 Legnaro, Italy*
[d]) *Centro Siciliano di Fisica Nucleare e Struttura della Materia (CSFNSM), Viale A. Doria 6, 95125, Catania, Italy*
[e]) *National Superconducting Cyclotron Laboratory, Michigan State University (NSCL/MSU), East Lansing, Michigan 48824, USA*

JYFL ECR

Introduction

Improvement of ion source performance is crucial for the future of accelerator facilities. Currently many projects employing both measurements and simulations are under work around the world aiming to achieve this. One of the recent subjects has been the microwave frequency fine tuning of ECR ion sources, which has been shown to affect many of the beam characteristics. This presentation shows the latest results of this method obtained with the JYFL 14 GHz ECRIS when the microwave frequency was varied in an 85 MHz range around the normal operation frequency of 14.085 GHz.

Microwave frequency fine tuning

Feeding microwaves into a suitable vacuum chamber excites an electromagnetic field structure – a mode. With 14 GHz and ECRIS plasma chamber of usual dimensions, the mode separation is in the order of some MHz. The electric field inside the chamber can vary drastically between the modes, thus a slight change in the frequency can produce notable differencies in the electric field on the ECR surface. If the mode structure remains with plasma, it affects electron heating, ion dynamics and confinement, thus yielding changes in the characteristics of the produced ion beam.

EXPRIMENTAL RESULTS

Reflected power and mode structure

- Clear oscillatory behavior in the reflected power – indication of the mode structure inside the plasma chamber?
- Wave guide length varied ⇒ number of maxima change
- Plasma chamber replaced with a load element ⇒ oscillations remain
- Conclusion: oscillatory behavior in the studied frequency range of 85 MHz is mainly caused by the wave guide system, not the conditions inside the plasma chamber

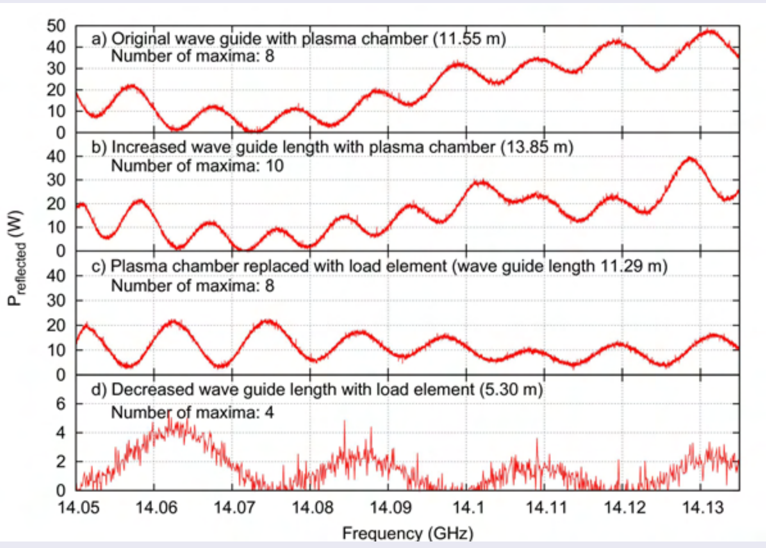

Figure 2: Reflected power behavior with plasma chamber and load element with varied wave guide length and 500 W of forward power.

Beam currents and bremsstrahlung emission

- Clear fluctuations seen in the beam currents and bremsstrahlung
- High charge states more sensitive than the low ones
- The fluctuations match well with the reflected power behavior
- Conclusion: power fluctuations obscure other possible narrow frequency range effects coming from the plasma chamber

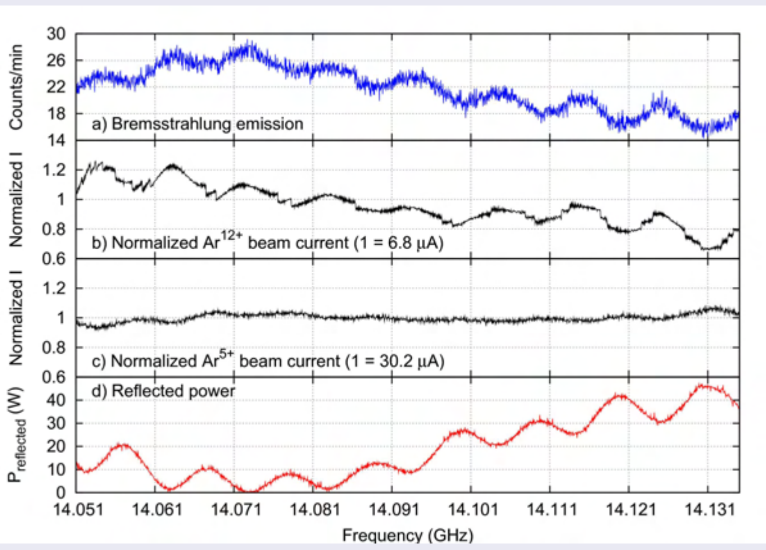

Figure 1: The bremsstrahlung count rate, normalized Ar^{12+} and Ar^{5+} beam currents and the reflected power with varied frequency and constant forward power of 460 W.

Contact: ville.toivanen@jyu.fi

Beam quality and transmission efficiency

- Varying frequency causes changes in the emittance and beam profile
- Changes do not correlate with the power fluctuations
- Enhancing the space charge compensation with neutral gas feeding into the beam line strenghtens the changes ⇒ a steplike emittance behavior accompanied by drastic beam shape changes
- Beam quality changes were reflected in the transmission efficiency behavior
- Measurements were done by sweeping the frequency range and by optimizing the transmission for a set of discrete frequencies

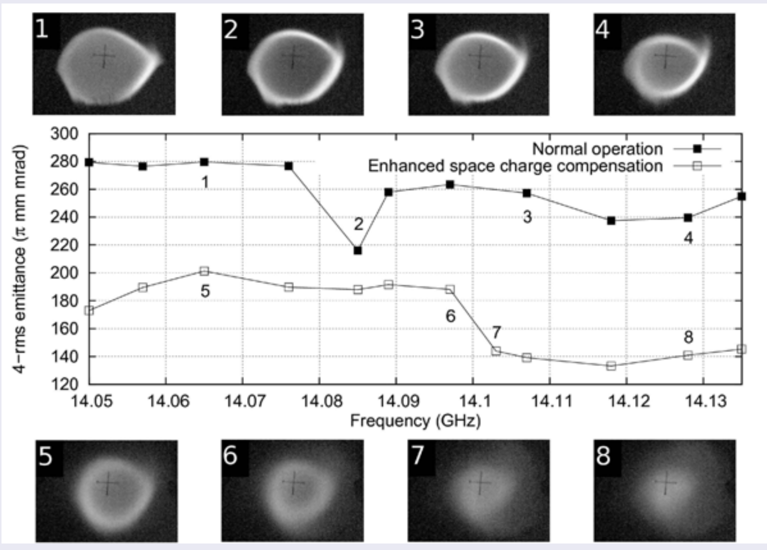

Figure 3: 4-rms emittance of Ar^{9+} with and without enhanced space charge compensation and beam profiles at selected frequencies.

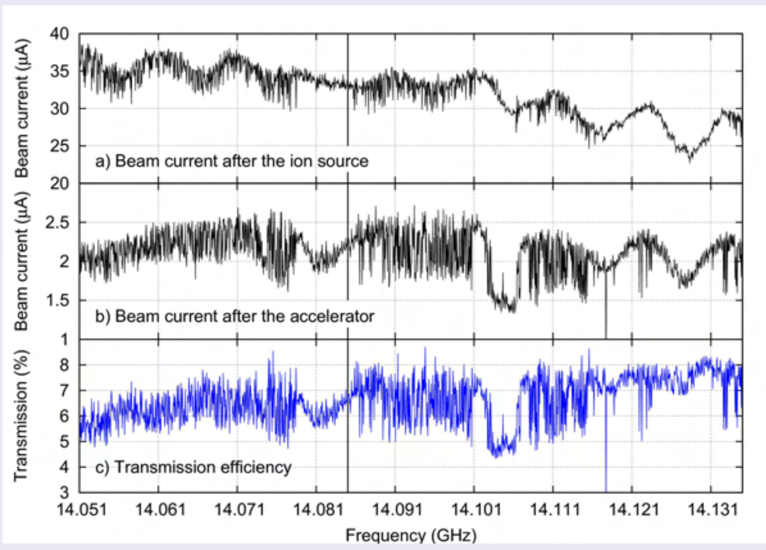

Figure 4: Ar^{12+} beam currents and transmission with varying frequency. Constant forward power of 667 W. ECRIS tuned with 14.085 GHz.

Table 1: Transmission efficiency T and maximum ion beam current I_{max} after the accelerator for frequency sweeps and separately tuned discrete frequencies.

	Frequency sweep		Discrete frequencies	
Beam	T (%)	I_{max} (µA)	T (%)	I_{max} (µA)
$^{16}O^{6+}$	1.0 - 1.4	2.9	1.2 - 1.4	2.7
$^{40}Ar^{12+}$	4.5 - 8.0	2.6	3.8 - 7.4	2.2
$^{82}Kr^{22+}$	2.5 - 9.0	1.3	6.1 - 7.5	1.1