

CHARACTERIZATION AND RECENT MODIFICATION OF A COMPACT 10 GHz ECRIS FOR ATOMIC PHYSICS EXPERIMENTS AND SPECTROSCOPIC INVESTIGATIONS

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Abstract

A compact 10 ECR ion source (200 mm long, 170 mm diameter) has been developed and tested. The complete magnetic structure made from permanent magnet material is comprised of four ring magnets producing an asymmetric axial magnetic field and a hexapole magnet with a maximum radial field of 0.94 T inside the plasma chamber. The coupling of the microwave to the plasma shows efficient ECR plasma heating at microwave power levels around 10 watts. Charge state distributions for various elements with intensities up to 320 eμA and their dependence on operation parameters will be presented as well as VUV spectra in the wavelength region down to 15 nm.

1 INTRODUCTION

There is a growing interest in the use of compact ECR ion sources with medium performances. In special environments, like small accelerators (Van-de-Graaff, Microtron), high voltage terminals or on line radioactive beam production systems with restricted space and low electrical power availability, this represents the only possibility to accelerate multiply charged ions. Recent advances in permanent magnet technology allow the design of compact all-permanent ECR ion sources operating at high frequencies. For use in an ion-ion experiment, employing the crossed beams technique [1] a first version of a compact 10 GHz ECRIS was built [2]. A detailed description of the ion source is given elsewhere [3,4]. Furthermore the ionization and recombination processes occurring in an ECR plasma produce photons which are the basis for well established spectroscopic diagnostics [5]. These photons can be used for atomic structure studies and spectroscopic application, e.g. spectrometer wavelength scale calibration. Of special interest is the spectral range of the extreme ultraviolet (EUV) below 20 nm, where existing PIG sources produce spectral lines with low intensities and short operations times, due to the lifetime of their cathodes. ECR ion sources on the contrary show excellent long term stability and reproducibility because of only two operating parameters, gas pressure and microwave power [6].

2 MODIFICATIONS

2.1 Source Description

A cross section of the source is shown in Fig.1. Due to the poor extraction efficiency in previous runs a new insulation flange with a larger opening and a tapered puller electrode assembly has been built. All intensities shown below are obtained using this set up [7].

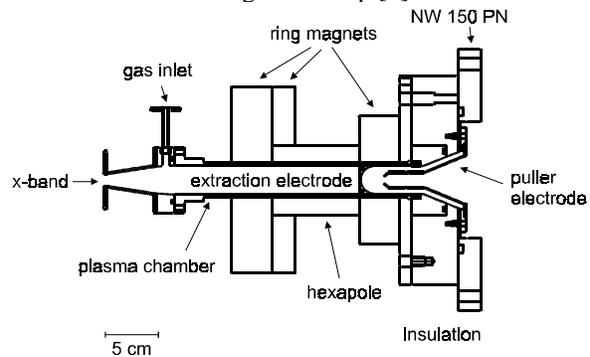


Fig. 1: Schematic view of the 10 GHz ECRIS

2.2 Magnetic Field

The axial magnetic confinement of the hot plasma electrons has been improved by using larger magnet rings at the microwave injection side. The axial mirror ratio B_{\max}/B_{\min} has been enhanced to 2.5 with a field maximum of 0.8 T and 0.5 T, respectively. The Halbach-type 24-segment hexapole magnet [8] (75mm long) gives a radial magnetic field of 0.94 T at the inner wall of the plasma chamber.

2.3 Frequency Dependence

The dependence of extracted intensities and charge states distributions on the applied microwave frequency has been investigated after installing the new magnetic system. The magnetron based microwave generator is tunable in the range of 8.75 to 10.5 GHz with a maximum output power of 275 watts c/w. Fig. 2 shows the change in the extracted Ar²⁺ ion current at different microwave frequencies together with the axial magnetic field distribution for this experiment. It can be clearly seen that the best result is obtained when the frequency is set to a value where the minimum of the magnetic field is close to the resonance magnetic field strength. This result could be verified by

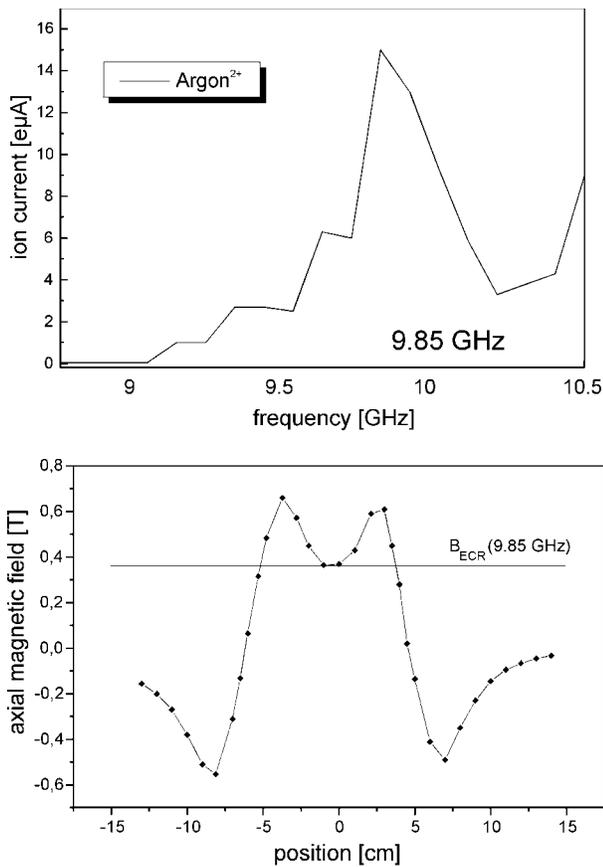


Fig. 2: Frequency dependence of the extracted Ar 2+ beam intensity with corresponding axial magnetic field using another permanent magnet configuration with a mirror ratios of 2.5 and 1.6, respectively. The best results were obtained at a frequency of 8.85 GHz, for which the resonance field was close to the minimum of the magnetic mirror.

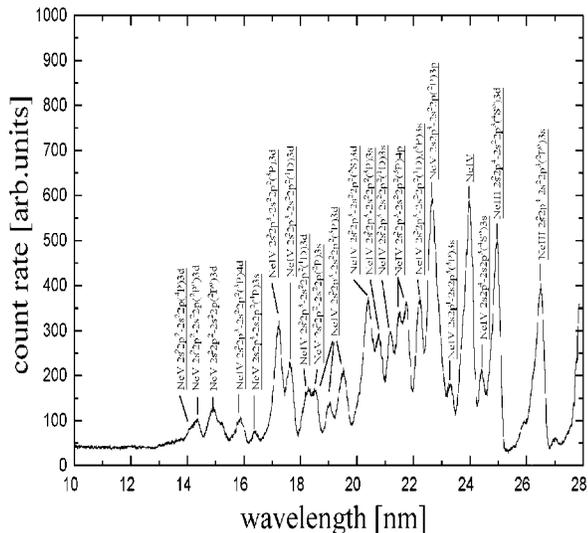


Fig. 3: Detailed line spectrum obtained from a Ne plasma using a 32cm grazing incidence spectrometer

2.4 VUV Spectroscopy

Measurements regarding the photon yield from an ECR plasma were performed by using a 32cm grazing incidence spectrometer with a grating of 550 g/mm with maximum efficiency at 15 nm. The resolution of the spectrometer was 0.4 nm at a dispersion of 2 nm/mm using an entrance slit of 100 µm. Fig. 3 shows a spectrum of a Neon plasma in the spectral range between 10 and 28 nm, where mainly Ne IV and Ne V transitions could be identified. The stability of the plasma was measured by monitoring a single Ne II transition line, $2s^2 2p^5 - 2s2p^6$ ($^2P - ^2S$), at 44.7 nm over a period of 8 hours. Using this transition line we also found an excellent reproducibility after extinguishing and reigniting the plasma by turning the microwave power off and on. Spectroscopy at higher resolution using a 5m grazing incidence spectrometer has been performed recently and showed intense lines down to 12 nm obtained from a Ne plasma. No detailed results can be presented at this time.

2.5 Beam Intensities

The maximum beam intensities obtained from the compact ECR ion source are shown in Fig. 4. All beam currents were optimized on the respective charge state and measured in a Faraday cup after a 90° analyzing magnet, at 9 kV extraction voltage using a 5 mm diameter extraction aperture. Recent experiments using calibrated leaks of Ne and CHF₃ for studies of the ionization efficiency have shown a poor transmission of the beam line used for these measurements. The ionization efficiency is an important factor in determining the usability for on line production systems in radioactive beam facilities.

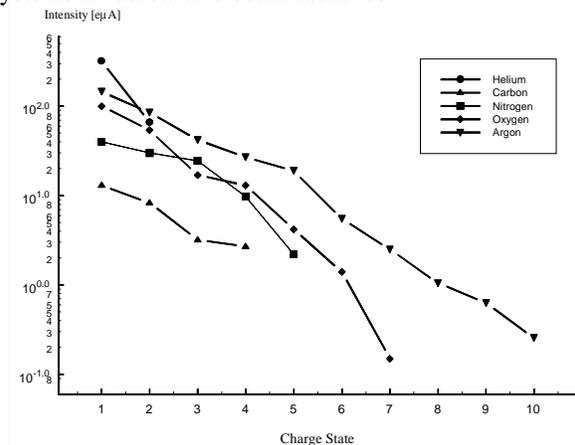


Fig. 4: Beam intensities for various gases at an extraction voltage of 9 kV.

3 OUTLOOK

Work is in progress to improve the residual gas pressure and the ion optical system which should result in higher charge states as well as in higher intensities. Recent measurements using calibrated leaks to determine the ionization efficiency have shown a preliminary value of approximately 30% for Neon. Identical measurements at

both ECR ion sources at Argonne National Laboratory, a 2 stage 10 GHz ECRIS and a newly constructed single stage 14 GHz ECRIS [9] will allow to compare the efficiency of a compact source to high performance ECRIS.

4 ACKNOWLEDGMENTS

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