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FREQUENCY ION SOURCE BY THE INJECTION OF
SUPPLEMENTAL ELECTRONS**

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Performance enhancement of a compact radio frequency ion source by the injection of supplemental electrons

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A versatile, high brightness, volume type, low power RF source, capable of producing positive ion beams with intensities as high as 1 mA from gaseous feed materials and microamperes of negative ion beams has been characterized. The source can also be operated as a plasma sputter negative ion source to generate up to 1 mA of a selected species. The performance of the source in the positive and negative volume modes of operation can be greatly enhanced by addition of a removable, water cooled filament assembly in place of the negative sputter probe. For example, the material utilization efficiencies of gaseous feed species can be more than doubled, total current intensities increased up to 40%, molecular dissociation fractions increased by 20% and minimum operating pressures reduced by a factor of four when operated in the volume mode. These added electrons also favorably effect, as a consequence of lower pressures, the emittance apparently through a reduction of scattering in the beam through the transport system. A brief description of the source and performance data for the positive volume mode of operation will be presented.

I. INTRODUCTION

The design features of the source are described in reference 1. Plasma sputter negative ion sources of this type have been utilized by several groups for a number of applications including accelerator based atomic and nuclear physics, material processing and isotope separation (see e.g. the references contained in ref. 1). In addition to the sputter mode of operation, both positive & negative ions can be extracted directly from the RF plasma when operated in the volume mode. The capability to operate in any of these three modes greatly

extends the number and variety of ionic species that can be generated by the source. Because of this versatility the source can be used for numerous applications [1]. Source reliability, multimode operation, high gas load tolerance, long lifetime, low emittance and high efficiency for dissociative ionization of molecules into positive and negative singly charged atomic ions also make the radio frequency ion source a candidate for Radioactive Ion Beam (RIB) generation. However issues concerning the ionization efficiencies when operated in the positive mode have not yet been resolved for these applications.

The effect of injecting electrons into a high frequency discharge ion source has been explored extensively for microwave ECR sources [2-9] and to a lesser degree in radio frequency ion sources [10]. Lynies has shown [2] that the performance of microwave ECR sources could be enhanced through the addition of injected electrons either from a gun or by a coating of SiO_2 on the metallic plasma chamber. Others employ a plasma cathode or biased disk technique to augment the electron density in the main stage of the source [8,9]. Abdelaziz et al [10] has explored the improvement to beam brightness of a magnetized radial extraction RF ion source, finding nearly an order of magnitude improvement in electron density, an increase in extracted beam current and a decrease in emittance resulting in a significant increase in ion beam brightness. In this work, we characterize the performance of a compact RF source for operation in the volume mode for the generation of positive ions. Total analyzed current yields, ionization efficiency, molecular dissociation and emittance have been measured with the filament on and off.

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Figure 1: Schematic view of ion source showing the removable filament assembly.

II. THE ION SOURCE AND FILAMENT PROBE ASSEMBLY

Fig. 1 shows a cross sectional view of the RF source with the removable filament assembly in place. Radio frequency power is coupled into the plasma through a copper coil shown in the figure, matching is achieved by a network controlled remotely and located adjacent to the RF feedthrough. Power is generated in a 0-1kW, 13.56 MHz supply. Atomic and molecular gas mixtures can be fed into the source from a system of variable and calibrated leaks through an opening directed through the RF coil windings. A converging helical tantalum element of thickness 1.5 mm is raised to emission temperature by a current of ~ 70 A flowing through a water cooled copper central conductor and out through a copper shield. High temperature components are isolated from the copper by a tantalum cylinder which forms a shield about the filament to prevent direct bombardment of the copper RF coil. The entire assembly can be biased with respect to the plasma.

III. EXPERIMENTAL RESULTS

Total extracted argon current, nitrogen dissociation fractions and trace flow (9×10^{-5} sccm) Xe efficiencies were measured with the filament on and off as a function of operating pressure, RF power and extraction voltage. Optimal

conditions of filament operation were 70A heating current, -10V bias and an emission current of 1.5A. The variation of the ion current, dissociation fractions and Xe efficiencies with RF power is shown in fig. 2. In each case, the source was maintained at the lowest pressure that allowed reliable operation. Use of the filament resulted in a lowering of the normalized emittance from 2.4 to $2.12 \pi \text{ mm mrad (MeV)}^{1/2}$ for the 90% contour of the beam. In addition, the minimum pressure for stable plasma operation was reduced on the average by a factor of four.

IV. CONCLUSION

This work quantifies the performance enhancement that can be expected with the addition of a relatively simple filament structure to an inductively coupled RF ion source. Measurements were geared to both accelerator (injector) ion source applications where intensity is desired and ISOL (radioactive beam) applications where ionization efficiency of trace material and molecular dissociation is most important. Under optimal conditions, the ionization efficiency of a trace flow of Xe was found to increase from 8% to 16%. The electrons appear to benefit the source plasma in three important respects: (1) the minimum operating pressure is lowered four fold (to 4×10^{-4} Torr in the source), (2) the emittance is improved and (3) the electron density is increased which subsequently lowers the plasma potential, as observed in ref. 2 and 7.

Figure 2: Performance enhancement of the ionization efficiency, beam current, dissociation and emittance achieved through filament operation. Emittance is given in $\pi \cdot \text{mm} \cdot \text{mrad} \cdot (\text{MeV})^{1/2}$

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PAC'95 Keyword Selection

Suggested Keywords - Please select up to 5 keywords & indicate with a checkmark

Keyword	✓	Keyword	✓	Keyword	✓
acceleration		hadron		polarization	
accelerator-theory		heavy-ion	✓	positron	
accumulation		higher-order-mode		power-supply	
alignment		impedance		proton	
antiproton		incoherent-effects		pulse-stretcher	
background		induction		pulsed-power	
beam-beam-effects		industrial-accelerators		quadrupole	
beam-cooling		injection		radiation	
beam-loading		injector		radio-frequency	✓
beam-losses		insertion		radio-frequency-quadrupole	
beam-transport		insertion-device		radio-frequency-gun	
beat-wave		instrumentation		radioactivity	
betatron		interaction-region		recirculation	
booster		inverse-free-electron-laser		resonance	
brightness		ion	✓	RF-structure	✓
brilliance		ion-effects		scattering	
bunching		ion-source	✓	secondary-beams	
cathode		isotope-production		separation-scheme	
chromatic-effects		kaon		septum	
civil-engineering		kicker		sextupole	
closed-orbit		klystron		shielding	
coherent-effects		laser		simulation	
collective-effects		lattice		single-bunch	
collider		lepton		site	
collimation		light-ion		space-charge	
controls		linac		storage-ring	
coupling		linear-collider		superconducting-magnet	
cryogenics		linear-dynamics		superconducting-RF	
cyclotron		longitudinal-dynamics		superconductivity	
damping		luminosity		survey	
diagnostics		magnet-design		synchro-cyclotron	
dipole		man-machine-interface		synchrotron	
dumping		medical-accelerators		synchrotron-radiation	
dynamic-aperture		micro-particles		tandem-accelerator	
electromagnetic-fields		microtron		target	
electron		monitoring		transverse-dynamics	
electrostatic-devices		multi-bunch-effects		undulator	
emittance		multipole		vacuum	
energy-calibration		neutral-beams		Van-der-Graaf	
extraction		non-linear-dynamics		wakefield	
factory		octupole		wiggler	
feedback		operational-performance			
fibre-optics		optical-matching			
focusing		optics			
free-electron-laser		permanent-magnet			
ground-motion		photon			
gun		pick-up			
H-minus		plasma			

Accelerator name (please fill in)