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# Beam Instabilities in Electron Cyclotron Resonance Ion Sources

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## Abstract

*Accelerator facilities for radioactive beams and low energy nuclear physics such as FRIB require intense, stable ion beam currents in order to achieve required reaction rates for rare and undiscovered isotopes. Presently, the only way to produce intense Continuous Wave beams of highly-charged, medium to heavy-mass ions is with Electron Cyclotron Resonance Ion Sources (ECRIS). The complex nature of these devices causes temporal instabilities to occur, most notably: slow and fast instabilities. Slow instabilities and drifts, occurring over hours, decay the beam current intensity due to variations in ambient and hardware conditions. These drifts require beam operators to constantly monitor and tune ECRIS plasma parameters in order to maintain experimental beam requirements. Fast instabilities, in the form of ms oscillations, occur at operational parameters needed for high-intensity, high-charge state beams. These oscillations cause sudden drops in beam current of the order of 30%. We present here initial results of recent measurements to investigate these instabilities. Results for slow instabilities indicate a linear decay of beam intensity following a sharp current drop due to a brief source conditioning period. Results for fast instabilities show a relationship between the frequency and amplitude of beam oscillations and the electric potential of the plasma chamber bias disk.*


## Apparatus

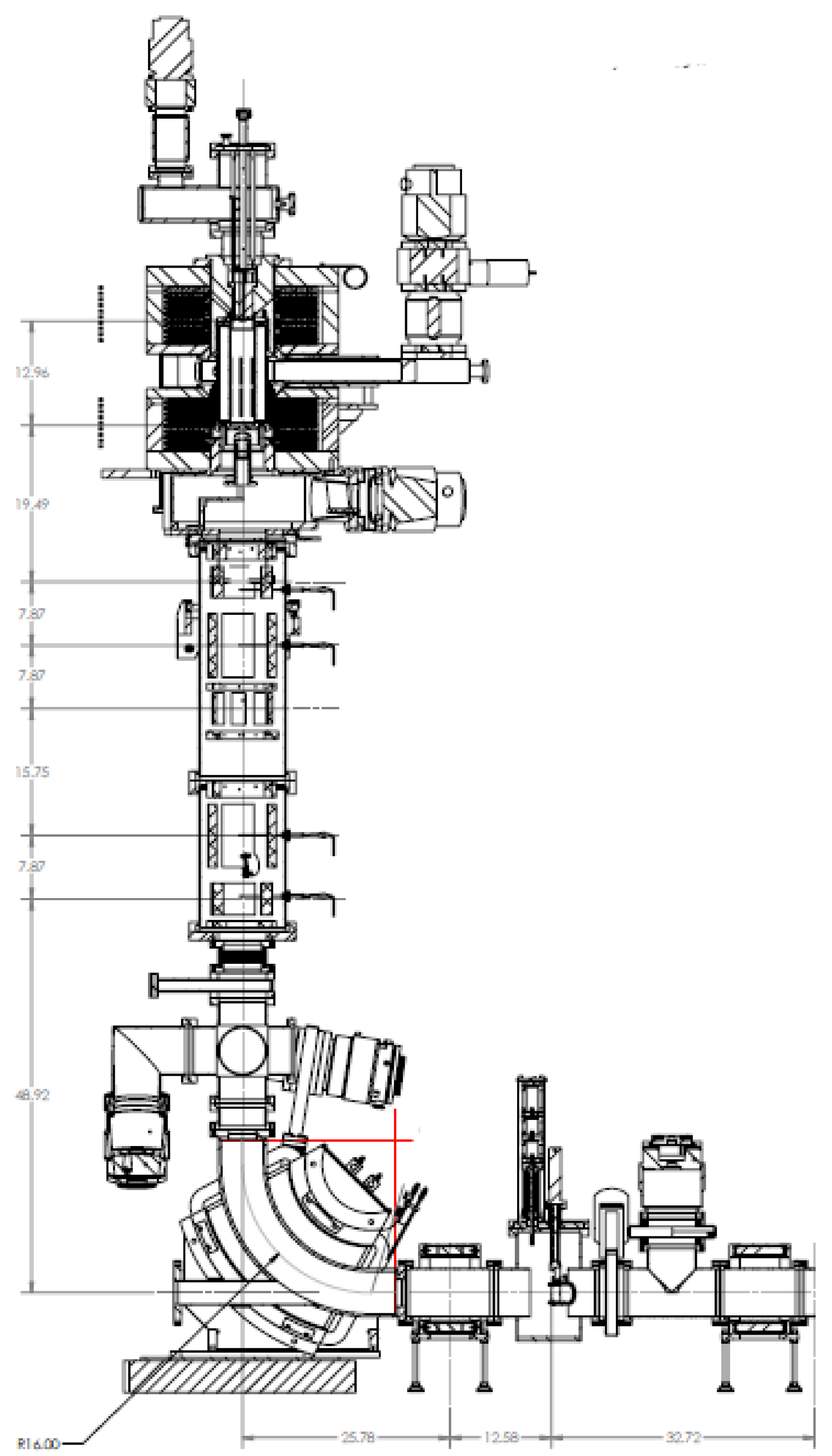

**Figure 1:** Sketch of ARTEMIS beam line up to the first faraday cup.

Measurements were taken using an AECR-U type source, known as ARTEMIS, powered by a 14.5 GHz klystron source [1]. A 90° analyzing magnet steered the beam to a faraday cup 14 feet downstream of the ion source (Figure 1).

## Slow Beam Drift

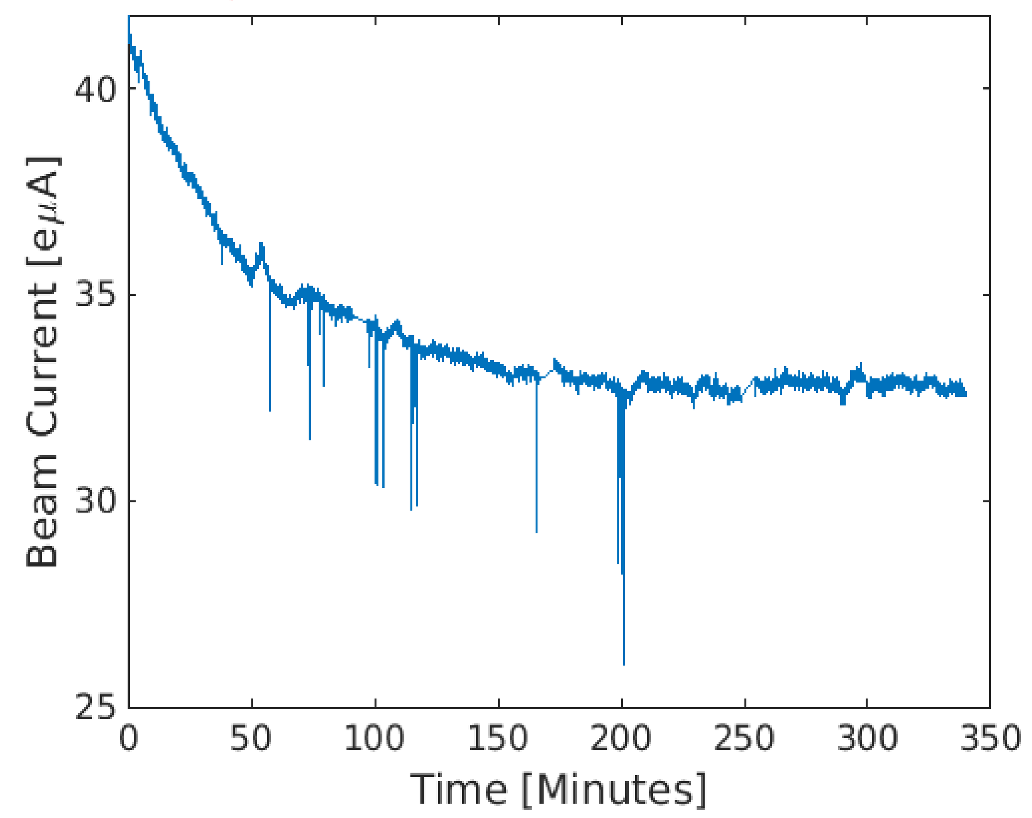


**Figure 2:** Beam current profile for $Ar^{8+}$ over 5.5 hours. The downward fluctuations were a result of dead time due to supplementary measurements.

The slow intensity drift is characterized by a steady continuous change in beam current Intensity, typically a decrease, occurring on the order of hours. Significant enough drifts lead to increased experimental uncertainty and dead time in beam applications as the constantly changing beam must be tuned regularly. Several measurements using an argon beam were taken in order to evaluate this effect, each time the system was allowed to evolve for several hours following the plasma's ignition.

### *Results*

Our slow drift measurements showed an asymptotic decay after several hours (Figure 2). Temperature sensors and parameter space values remained constant throughout.

## Beam Current Oscillation

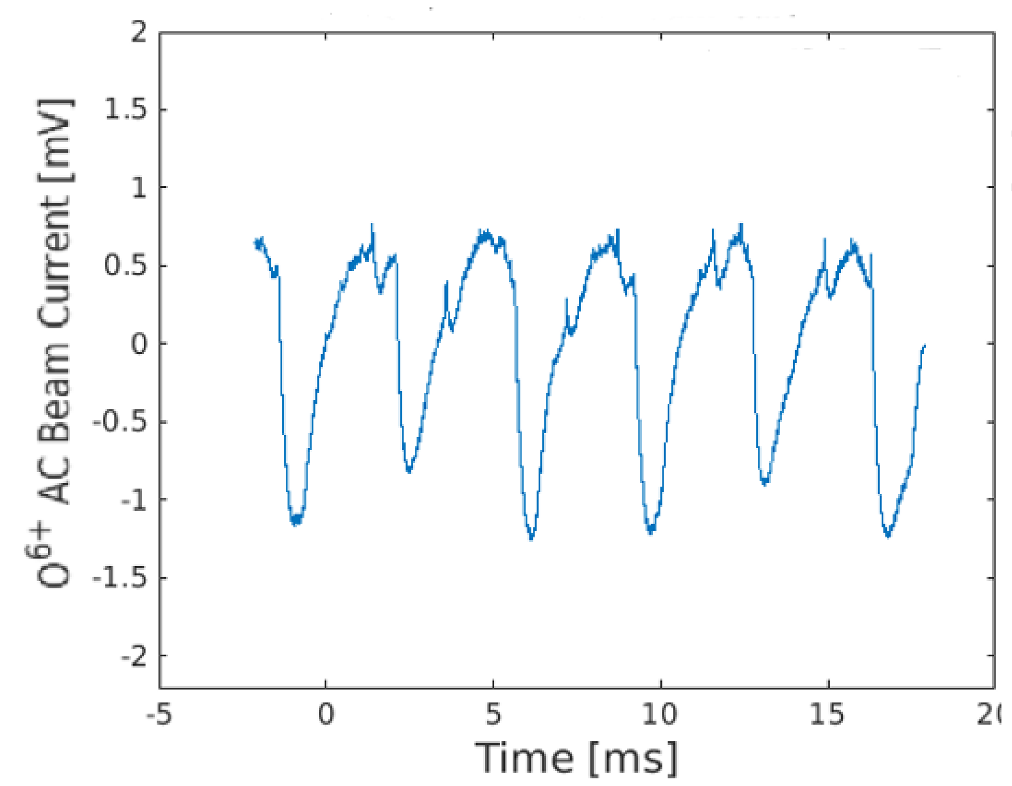


**Figure 3:** Pictured above is an example instability waveform for $O^{6+}$ with a frequency of 300 Hz measured in AC mode.

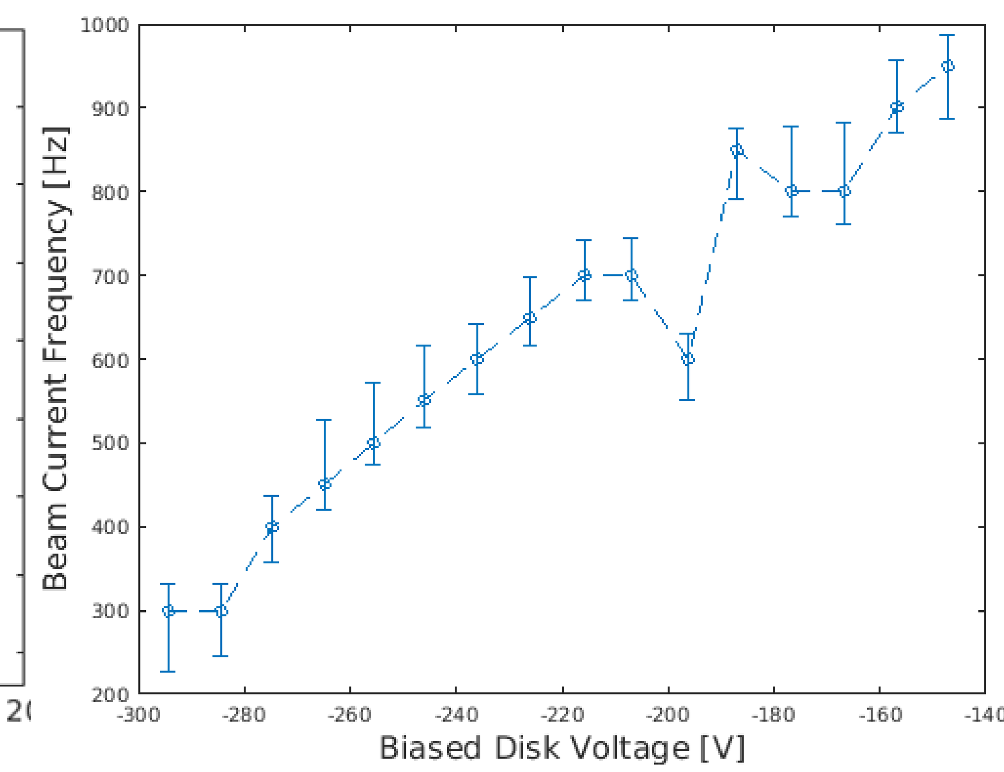


**Figure 4:** Pictured above is the relationship between beam oscillation frequency for $O^{6+}$ beam and the biased disk voltage.

Periodic beam oscillations caused by plasma instabilities within the ion source plasma cause catastrophic losses of beam intensity on the order of 30% on ms time scales. These instabilities are characterized by emission of microwave, bremsstrahlung, and visual light radiation from the plasma and ultimately a characteristic drop in measured beam current [2]. The ECR parameter space was set to force the plasma into the unstable regime with 500 A powering both injection and extraction coils, 20 kV potential at extraction aperture, -300 V biased disk potential, and 400 W input microwave power using an oxygen beam.

### *Results*

The periodic beam current profile observed displayed a sawtooth like profile consisting of a brief emission period and slower electron recovery period (Figure 3). As the biased disk voltage increases from -300 to -150 V the frequency of beam oscillations followed the set voltage (Figure 4).

## Future Work and Project Goals

Further investigation will involve systematic measurements of slow beam drifts following the completed analysis of the presented work and further investigation of beam current oscillation causing plasma instabilities using a superconducting ion source. Fast RF and Bremsstrahlung detection systems must be developed to study the coincidence of beam current oscillations and plasma emission of radiation. Determination of the primary causes of beam drifts and plasma instabilities will allow for the implementation of automated feedback mechanisms that can suppress the instabilities within the ion source.

## References


[1] G. Machicoane et al., "ARTEMIS-B: A room temperature test electron cyclotron resonance ion source for the National Superconducting Cyclotron Laboratory at Michigan State University", Rev. Sci. Instrum. 77, 03A322 (2006)

[2] O. Tarvainen et al., "Beam current oscillations driven by cyclotron instabilities in a minimum-B electron cyclotron resonance ion source plasma" , Plasma Sources Sci. Technol. 23 (2014)


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