Measurement of the Plasma Diamagnetic Current in the LBNL 6.4 GHz ECR Ion Source

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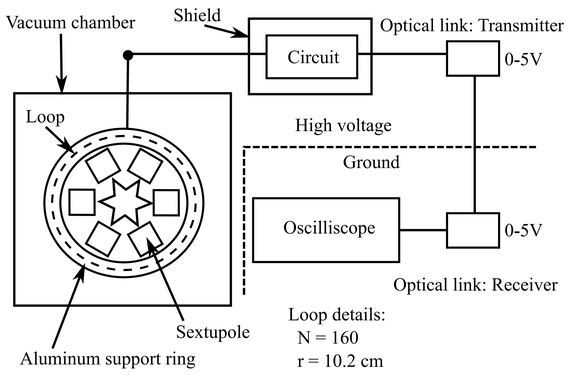
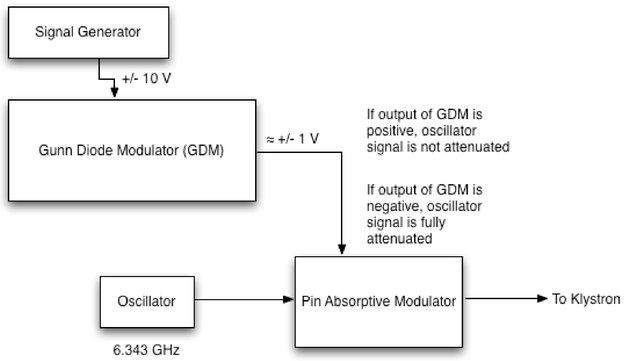
Abstract

A method of measuring the diamagnetic current on the LBNL 6.4 GHz ECR ion source is described. The diamagnetic signal is proportional to the rate of plasma formation and decay. Furthermore, the integrated signal can be used to estimate the total plasma pressure, or energy density, and can thus be used to study the warm and hot electron populations in an ECR plasma.

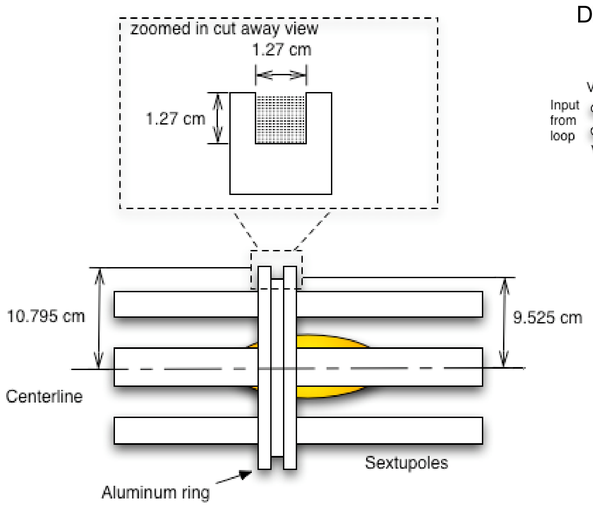
Experimental Setup



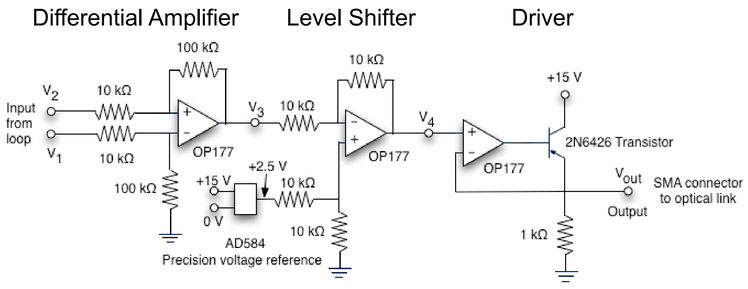
Schematic of diamagnetic loop signal chain.



Schematic of RF pulsing circuit.



Schematic showing approximate location of the diamagnetic loop and aluminum support ring.

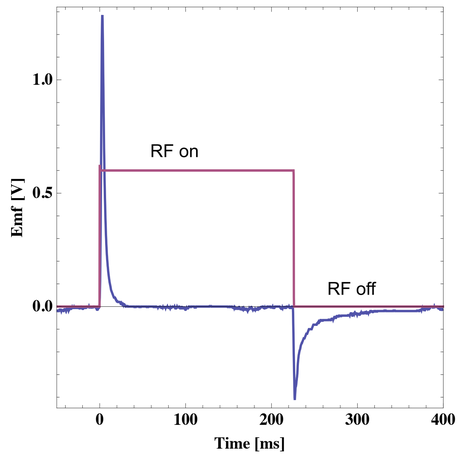


$$V_{out} = -10\,(V_2 - V_1) + 2.5$$

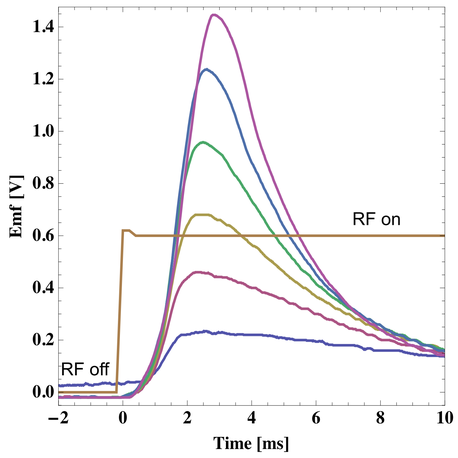
Schematic of diamagnetic loop circuit.

Offset voltage of 2.5 V is required because the optical link transmitter and receiver operate correctly within a voltage range of 0-5 V. However, the diamagnetic signal can be either positive or negative

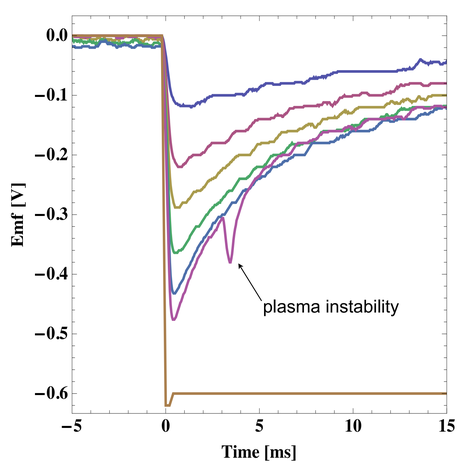
Estimate of Plasma Energy Density



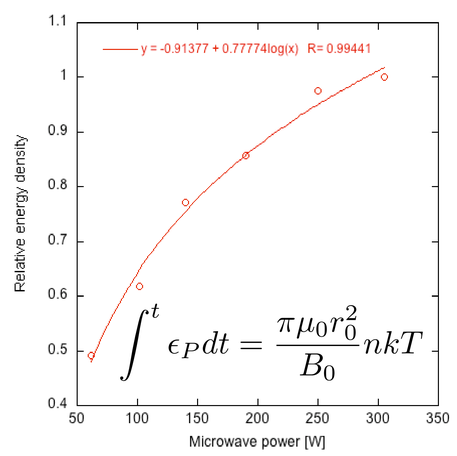
Example of full, unintegrated diamagnetic signal.



Leading edge (RF on) of diamagnetic signal.



Trailing edge (RF off) of diamagnetic signal.

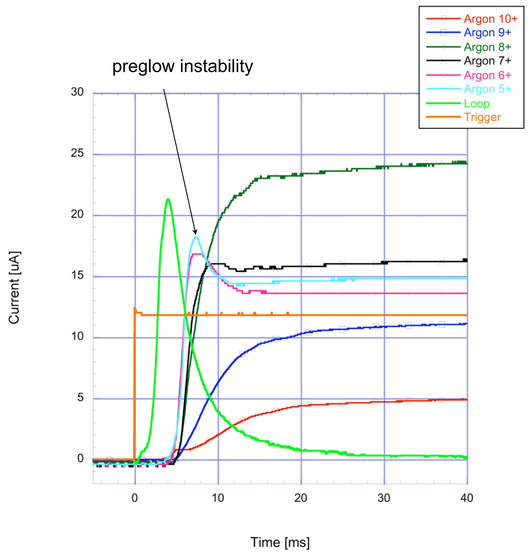


$$\int^{t} \epsilon_P dt = \frac{\pi \mu_0 r_0^2}{B_0} nkT$$

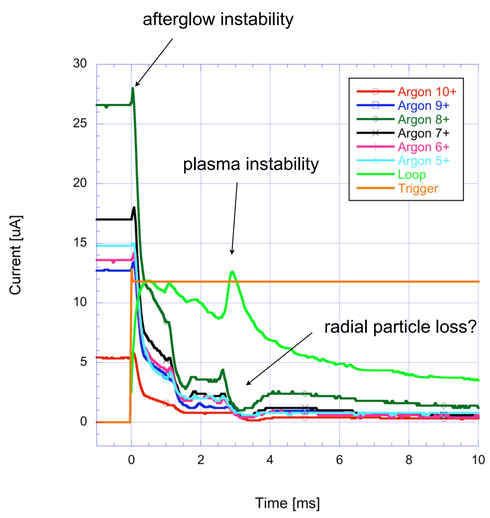
Relative plasma energy density. Obtained by integrating leading edge of diamagnetic signal.

1) The plasma in the ECR forms at a faster rate than it decays at.
2) There is a delay of approximately 3 ms before the maximum rate of plasma formation occurs.
3) The maximum rate of decay occurs almost immediately as the RF power is turned off.
4) Plasma energy density increases logarithmically as microwave power is increased.

Comparison of Faraday Cup Currents and Diamagnetic Loop Signal



F.C. currents and diamagnetic loop signal at plasma ignition.

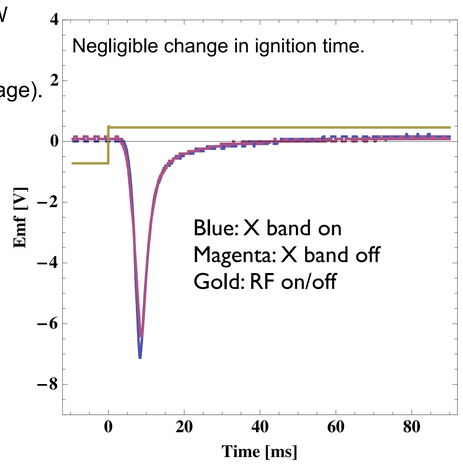


F.C. currents and diamagnetic loop signal as plasma decays.

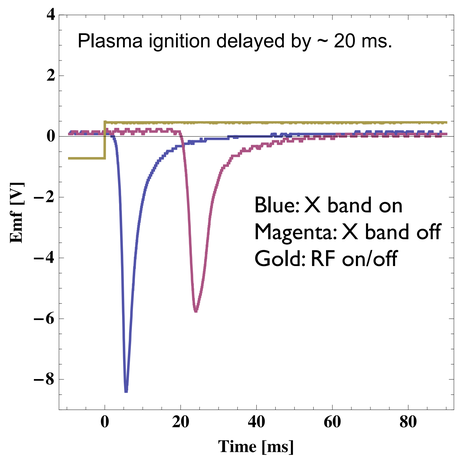
1) Faraday cup currents start to increase as the plasma energy density is decreasing.
2) Higher charge state currents take longer to reach steady state.
3) The presence of a radial particle loss has been observed.

Effect of ECR First Stage on Plasma Ignition

C-band power: 260 W
X-band power: 2-3 W
Argon plasma
2E-6 Torr (1st stage)
3-4E-7 Torr (Main stage).



Plot of leading edge of diamagnetic signal. 600 ms/ 600 ms RF on/off times.



Plot of leading edge of diamagnetic signal. 3 s/ 3 s RF on/off times.

1) Electrons are present in the vacuum chamber on the order of seconds after RF power is turned off: Magnetic confinement of hot electrons.

Acknowledgments

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