Retarding Field Energy Analyzer Measurements of Ion Velocity Distributions in a Helicon Plasma Source

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Abstract

A four grid retarding field energy analyzer (RFEA), with a fifth grounded entrance grid, has been constructed based on published design criteria [Charles et al. Phys. Plasmas 7, 5232 (2000)]. A fast amplifier is used to sum the current collected by the suppressor grid and the collector current. The best fit to the RFEA measurement is shown in the top figure at the right. The derivative of this expression, which has a full width at half maximum of \( \Delta \Phi = \pm \sqrt{E_b} \), is often described as the “energy distribution function” and is given by:

\[
I(E) = \frac{e^2}{2\pi m} \sqrt{2m(E + \Phi)} 
\]

where \( I(E) \) is the collector current, \( E \) is the energy, and \( \Phi \) is the potential of the retarding field. The derivative of the collector current \( dI/dE \) is collected on a flat plate and measured as a current. As the retarding field is increased the collected current decreases until all the particles are rejected. The denominator of the retarding potential is called the discriminator voltage \( V_d \) which is otherwise interpreted as the particle energy corresponding to the voltage difference between the front grid of the RFEA and the plasma, i.e., the plasma potential. The interpretation is not entirely correct as drifts of particles back to the source must be accounted for. In the energy space the distribution is measured as an energy range. For a drifting Maxwellian ion population, the measured RFEA current as a function of discriminator voltage, \( V_d \), is given by:

\[
I(E) = \frac{en \sqrt{2m(2E + \Phi)}}{\sqrt{\pi m}} \left( \frac{2mE}{2mE + \Phi} \right)^{3/2} \]