Design of a Retarding Field Energy Analyzer for the Large Plasma Device

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***Abstract*— This article details the construction of a retarding field energy analyzer (RFEA) designed to measure the ion energy distribution function (IEDF) in a moderately dense laboratory plasma, such as that produced in the Large Plasma Device (LAPD). The RFEA was specifically developed to study ion acceleration in a magnetic reconnection experiment involving two kink-unstable flux ropes. It features four independently biasable grids, an electrically and thermally insulating exterior, a mesh grid stack as the entrance grid to collect more current, a solder-less design for easy assembly, and is constructed with readily available off-the-shelf materials for quick turnaround time. In this experiment, the RFEA demonstrated continuous operation for several days under LAPD conditions. It measured low-energy thermal ions with energies below 20 eV and observed field-aligned ion beams with energies between 9 and 15 eV near the reconnection region between the two ropes. For brevity, a detailed analysis of the ion beam and supporting 3-D gyrokinetic simulations are presented in a related manuscript [Tang et al., Phys. Plasmas 30, 082104 (2023)]. Ion temperature measurements of thermal ions within the flux ropes from the RFEA were consistent with those inferred from the spectroscopy of Doppler-broadened helium II spectral lines (320.3 nm).**

***Index Terms*— Energy measurement, ion energy distribution function (IEDF), magnetic reconnection, plasma diagnostics, plasma measurements, retarding field energy analyzer (RFEA).**

I. Introduction

A RETARDING field energy analyzer (RFEA), an instrument used to determine the temperature and velocity distribution of low-energy ions in a plasma [1], [2], was constructed to measure the acceleration of ions during the

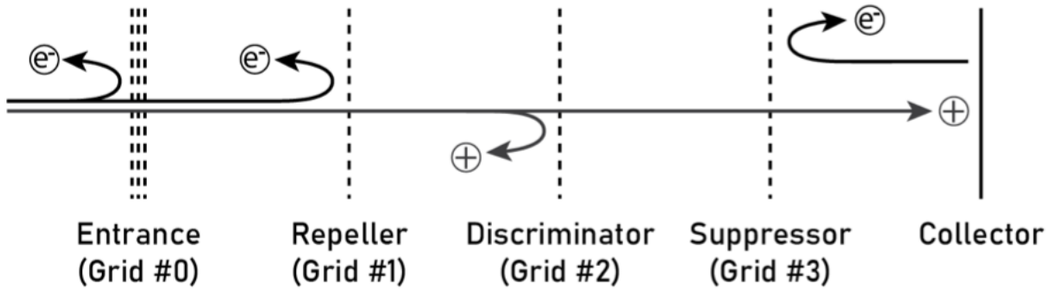

Fig. 1. Diagram illustrating the basic operation of the ion RFEA is shown. The discriminator grid repels ions, while the entrance, repeller, and suppressor grids repel electrons.

numerous observations of ion acceleration near Earth's magnetosphere and in related numerical simulations [7], [8], [9], [10], [11], [12], [13], [14], as well as in laboratory experiments that merge spherical or toroidal-shaped plasmas to observe it [15], [16]. However, despite these observations, the exact mechanism that accelerates ions in three dimensions remains poorly understood. This is due to the increased theoretical and computational complexities when describing the reconnection process in three dimensions instead of two [17]. In addition, the experiments that demonstrate the 3-D nature of magnetic reconnection are rare [10], [18], [19]. Thus, given the scarcity of such experiments, this motivates the construction of an RFEA to study ion acceleration within the two flux rope system on the LAPD, a well-characterized experiment where magnetic reconnection is inherently three-dimensional [3], [20].

An RFEA operates by guiding ions through a series of paral-