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Time Dependent Measurements and Calculations of Field Profile in the PBFA-II Ion Diode

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The reduction of the effective anode cathode (AK) gap during an applied-B ion diode pulse is driven by the diamagnetic effect of EXB drifting electrons in the sheath between the virtual cathode and the anode, and may be assisted by fluctuations that enable electrons to cross magnetic field lines. The dynamics of the sheath and the resulting AK gap are manifested in the time and space dependence of the electric field across the gap. We are studying the electric field profile in the PBFA-II ion diode with a goal of improving our understanding of acceleration gap dynamics, leading to improved power coupling to the ion beam.

The cylindrically-symmetric PBFA-II ion diode accelerates ions radially inward, using a LiF ion source to generate a lithium beam with approximately 9 MeV peak energy, current densities up to 1 kA/cm^2, and a pulse fwhm of about 20 nsec. The initial AK gap is typically 20 mm. We measure the accelerating electric field from the Stark shift of the LiI 2s-2p transition. The line emission is collected at four radii in the AK gap using fiber optics and the light from each radius is injected into a streaked spectrograph. Thus, on a single PBFA-II shot we acquire four spectra, each with 1 nsec time resolution, approximately 1 A spectral resolution, and each corresponding to a different radial location with a resolution of about 2 mm in the AK gap. The electric field is obtained from the measured Stark shift using calculations of the emission pattern that take into account both the electric and magnetic field and polarization. The electric field is typically constant across the gap at the onset of ion current growth. When the ion current becomes large, the field becomes larger on the anode side of the gap as the electron sheath thickness grows. The peak field observed is greater than 10 MV/cm, the highest field ever measured with the Stark effect.

We compare the field profile measurements with calculations performed using two different computer codes. The three dimensional, fully electromagnetic QUICKSILVER code calculates the field profile using the applied accelerator power pulse, treats the ions and electrons in the gap self-consistently, and includes the effects of fluctuations. The two-dimensional code TWO-QUICK is more practical for simulating many different experimental configurations, but requires an ad-hoc fluctuation model. Initial comparisons demonstrate an encouraging level of agreement. We expect that more detailed comparisons will provide insight into the complex physics of the acceleration gap.

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Three-dimensional Particle-in-Cell Simulations of Ion Diodes on PBFA II*

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We are now using the 3-D particle-in-cell code QUICKSILVER to simulate applied-B ion diode configurations on the PBFA II accelerator. These simulations are done in cylindrical coordinates, using realistic diode geometries (with "stair-stepped" conductors), together with the externally applied magnetic field actually used for the given geometry. The external field itself is azimuthally symmetric, since it is computed with a 2-D magnetic diffusion solver, but the dynamic field solver and particle kinematics are fully three-dimensional. Qualitatively, the results of these new simulations are similar to those done previously in Cartesian coordinates with a uniform applied field.[1] They show an instability with two distinct phases. Early in time, a diocotron instability grows rapidly, driven by the **E x B** drift of the electrons in the sheath. The frequency of the diocotron instability, f, is high compared to the ion transit time, τ_i, and the resulting beam divergence is low (10 - 15 mrad). However, as the diode continues to evolve towards higher current enhancement, a transition to a lower frequency ($f\tau_i < 1$) phase with an unacceptably high beam divergence (>30 mrad) occurs.

Preliminary results of these new simulations indicate that the overall performance of the diode is sensitive to the magnetic field shape. Previous 2-D simulations have already shown that the axial profile of the ion beam current density depends strongly on the field shape.[2] In the 3-D simulations, the instability is sensitive to the field shape, which affects not just the beam divergence, but the electron distribution in the diode. This in turn affects diode efficiency, impedance and current uniformity. We will present results of these simulations, and comparison with experimental data from PBFA II.

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