Ion-Imaging Plasma Diagnostics

by ***E. V. Barnat and P. A. Miller***

Motivation—Sandia is developing a 3-D unstructured-mesh plasma code which will provide unprecedented capabilities for modeling plasma and charged-particle flows. This will greatly improve Sandia's computational capabilities for design and manufacturing of critical components that employ plasma for ion generation. In parallel with this code work, we are developing novel plasma diagnostic techniques and conducting experimental tests for code validation. The diagnostics and tests are designed to isolate key pieces of plasma physics that the code must be able to treat accurately for eventual success.

Accomplishment—A plasma "sheath" is a region in which plasma properties change abruptly with spatial position. Plasma sheaths have been studied for decades, and their properties under different plasma conditions continue to be scientifically interesting and computationally challenging. The initial focus of our experimental studies is the extraction of an ion beam from quasi-neutral plasma. This effort tests the ability of the code to treat flowing, field-free plasma, its interaction with surfaces, and the transition in a sheath from plasma to a high-electric-field region in which an ion beam forms.

Advanced diagnostic capabilities have been developed to examine the interaction between flowing plasma and a structured electrode. Both the concept and realization of the diagnostic technique are illustrated in Figure 1. Ions are extracted from plasma generated by a vacuum arc ion source. The accelerated ions impact a meshed electrode, which in turn generate 'secondary' electrons. These electrons are then accelerated towards a fast responding phosphor screen (P47, with ~ 50 ns decay time). Spatial distribution of the photons generated by the electron beam is imaged using a gated, intensified CCD (ICCD) camera. Time evolution of the ion beam is obtained by scanning the gated ICCD over the period of plasma generation.

Representative images formed by ion flow through three structured electrodes, for three accelerating voltages are illustrated in Figure 2. The different structured electrodes demonstrate a transition from symmetric (round hole) to more complex (plus shaped hole) geometry. Accelerating potentials are varied from low voltage, where the plasma pushes through the hole to high voltage where the accelerating fields penetrate into the plasma. The resulting distribution of ions is observed to clearly depend on the coupling of the plasma to the applied electric fields. The 3-D predictive capabilities of the plasma code are being tested by measurements like these presented here.

Significance—Diagnostic techniques that we developed are being used for validation of Sandia's new plasma code. We are comparing the observed and predicted dynamics of ion beam formation and propagation through structured electrodes. Through this iterative procedure, we can understand the interaction between the species generated in the plasma and the structured electrodes that the plasma flows through. These measurements address sensitive and critical physics that will need to be implemented into the code. Successful validation will give confidence in use of the developed code towards aide in design and manufacturing.

Sponsors for various phases of this work include: Nuclear Weapons Program

Contact: Paul Miller, Lasers, Optics, & Remote Sensing, Dept. 1126
Phone: (505) 844-8879, Fax: (505) 844-5459, Email: pamille@sandia.gov

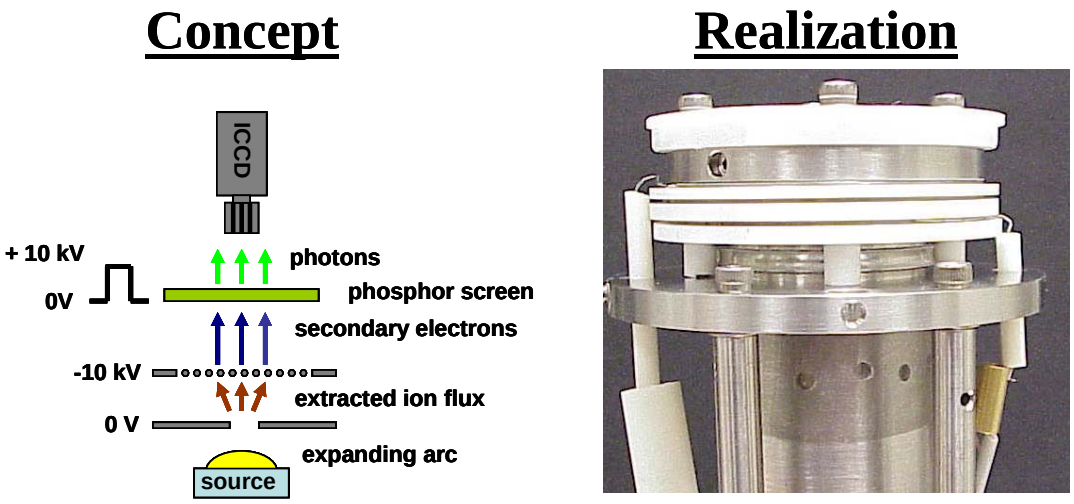

Figure 1. Concept and realization of ion imaging diagnostic used to study ion flow from plasma through structured electrodes.

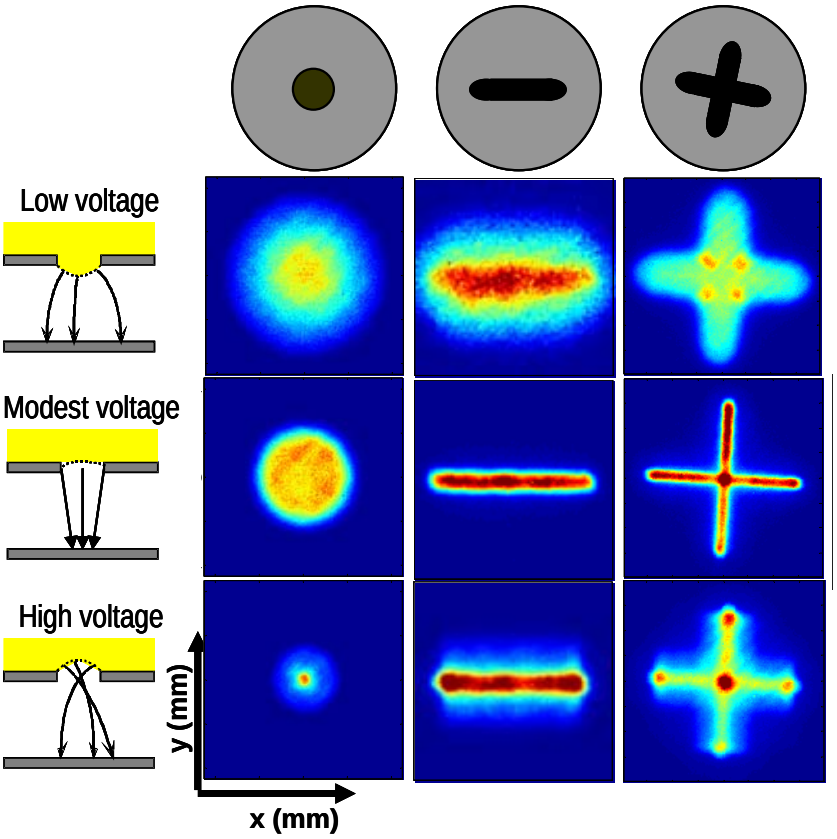

Figure 2. Representative images of the ion beam obtained with ion imaging diagnostic for various structured electrodes (illustrated above each column) and accelerating voltages (illustrated to the left of each row).