LIST OF FIGURES

FIG. 2.1 High Power Electron beam Diode. Schematic geometries of typical sites of field enhanced electron emission.

FIG. 2.2 Luminosity of anode and cathode plasmas for the AK gap length of 5 mm using an annular cathode of outer radius 1.5 cm, 1mm thickness and an aluminum (Al) foil anode of 15 µm in thickness (300 kV, 35 kA, 50 ns) [11].

FIG. 2.3 Expanding plasma boundaries in the diode region as a function of time. Expanding plasmas are observed by their luminosity as shown in the previous figure [11].

FIG. 2.4 Side-view images of plasma movement within the diode for the bare carbon fibre cathode. The anode appears on the right and the cathode on the left. Images (a), (b) and (c) were, respectively, captured at ~ 100 ns, ~ 200 ns and ~ 300 ns after the beginning of the HV pulse. The initial AK gap was 50mm and the anode was a stainless steel disc [39].

FIG. 2.5 Light emission from the diode with the CsI-coated carbon fibre cathode. Images (a), (b) and (c) were captured at ~100 ns, ~ 200 ns and ~ 300 ns after the beginning of the HV pulse, respectively. The anode appears on the right and the cathode on the left. The AK gap was 50 mm. Note that the light intensity increased only slightly as the voltage increased [39].

FIG. 2.6 Plasma expansion velocity calculated from diode perveance. A best fit was obtained when the plasma velocity was set equal to 2.8 cm/μs [40].

FIG. 2.7 Variation of the diode perveance $P$ normalized to Child–Langmuir values $P_{CL}$ with the dimensionless geometrical parameter $d_{ak}/R_k$. Data obtained with 20 (open
circles), 60 (full circles), and 100 mm (triangles) diameter velvet explosive emission cathodes are shown. The fitting curve (solid line 1) is calculated in accordance with Eq. (2) in Ref. 36. The dashed line 2 is a result of a PIC modeling of the finite width, infinite length diode (See Ref. 32). The dotted curve 3 is calculated from Eq. (2.7).

FIG. 2.8 Geometry and relevant parameters for the baseline 2D emission simulation [33].

FIG. 2.9 Simulated normalized current density emitted at cathode versus position (normalized to gap distance) for a variety of emission strip widths (W) and gap distances (D) in cm; each trace is labeled with its corresponding (W, D) value [33].

FIG. 2.10 Reduction of total emitted current due to the reduction of an allowed emission area on a 4-cm-wide cathode strip. The current is normalized to the simulation result for emission from 100% of the cathode area. The cathode is divided into 40 individual sections which are gradually turned off (discrete patches), or a sole nonemitting hole is allowed to expand from the cathode center (central hole) [33].

FIG. 2.11 Optical images showing the electron beam uniformity for each cathode: (a) the velvet cathode, (b) the tufted carbon fiber cesium iodide cathode, and (c) the carbon slat cathode. Note that the slatted cathode has very nonuniform emission, although the current wave form for it is nearly identical to the two cases of more uniform emission.

FIG. 2.12 Current and voltage traces from the experiment: (a) applied diode voltage, (b) current traces for the three cathodes. A is the velvet cathode, B is the tufted carbon fiber cesium iodide cathode, and C is the carbon slat cathode. Note the similarity in the current wave forms for the same applied voltage.
FIG. 2.13 (a) Diode current and (b) diode voltage drop obtained from Particle in Cell simulation for case with spatially uniform plasma density $n = 10^{13} \text{ cm}^{-3}$ hydrogen plasma fill and SCL electron emission from cathode surface [24].

FIG. 2.14 PFD configurations tested on Gamble II. Dashed lines indicate current flow direction [25].

FIG. 2.15 Data from the highest dose-rate PFD shot on Gamble II (solid lines), compared with data from a shot with no plasma (dashed lines). (a) Generator current waveforms. (b) Diode voltage waveforms. (c) Diode impedance waveforms. (d) X-ray (dose rate) signals. The vertical line indicates the time of maximum X-ray signal for the PFD shot [25].

FIG. 2.16 Modelled (a) Marx-Blumlein charging voltage and (b) raw prepulse voltage on the Blumlein inner conductor, for a peak operating voltage of 1.7MV on PIM machine [54].

FIG. 2.17 (a) Needle-shaped annular carbon fiber cathode. (b) Photo of nylon target bombarded once by beam emitted by a stainless steel cathode. (c) Photo of nylon target bombarded once by beam emitted by a needle-shaped annular carbon fiber cathode [2].

FIG. 2.18 (a) Macroscopic photograph and (b) SEM image of the CsI carbon fiber cathode. The cathode consists of carbon fibers that have been attached to a carbon surface. These fibers are then coated with a CsI salt. The SEM is at 50-times magnification with the fibers of 6-$\mu$m diameters [59].

FIG. 2.19 AFRL relativistic magnetron normalized average (rms) RF power waveforms for the cases of POCO graphite, CsI-coated carbon velvet on a graphite substrate
(conventional processing), and uncoated low-hydrogen carbon velvet on a graphite substrate (high-temperature processing) cathodes [59].

FIG. 2.20 Uniformity data from an uncoated (a) and a CsI coated (b) carbon-on-epoxy cathode. Regions of intense are red and regions of low emission are blue. The uncoated cathode shows flaring, or nonuniform emission [58].

FIG. 2.21 False-color images of the cathode plasma generated by explosive emission processes in a vircator high-power microwave source (300 kV, 5-8 kA, 60 ns). Three different cathode materials are shown. The camera intensifier gate width was 200 ns. Each cathode was attached to a brass plate which is located at the top of each image. The anode structure is seen at the bottom of each image. The spacing between the anode and cathode was 10 mm. The images show the plasma formation to be fairly uniform across the surface of all three cathode types. The light emission from the brass attachment plate in the milled aluminum cathode case indicates that differences in either the delay time or peak voltage required for emission for this particular cathode design allowed points on the brass to explosively emit [75].

FIG. 2.22 Images of the anode scintillator: (a) with magnetic field; (b) without magnetic field. Line profiles shown were taken along horizontal diameters [76].

FIG. 2.23 Histogram showing the variation in current for a carbon velvet, cesium-iodide-coated cathode. Other cathode produces similar results with variation in standard deviation and skewness [31].

FIG. 2.24 Axial virtual cathode oscillator.

FIG. 2.25 An axial vircator with HPM diagnostics [81].
FIG. 2.26 (a) Vircator microwave power and (b) frequency versus various initial AK gap distances $d$ [81].

FIG. 2.27 Microwave signal and time-varying effective AK gap distance $d_{eff}$ along with the diode voltage $V_d$ and diode current $I_d$ under initial AK gaps $d$ are (a) 2 mm and (b) 5 mm, respectively [81].

FIG. 2.28 Coaxial virtual cathode oscillator.

FIG. 2.29 A coaxial Vircator with HPM diagnostics [88].

FIG. 2.30 Typical oscilloscope traces of the diode voltage, current, and microwave [37].

FIG. 2.31 Field magnitude of FFT at the output port [37].

FIG. 2.32 Plot of (a) microwave frequency and (b) power according to the variation of AK gap distance in the coaxial vircator without a reflector [37].

FIG. 2.33 Plot of (a) microwave frequency and (b) power according to the variation of the reflector position [37].

FIG. 3.1 The schematic of the KALI-5000 system.

FIG. 3.2 A Photograph of the KALI 5000 system.

FIG. 3.3 A photograph of the KALI 1000 system.

FIG. 3.4 Schematic of the KALI 1000 system.

FIG. 3.5 Schematic of the planar electron beam diode with the beam diagnostics.

FIG. 3.6 A planar graphite cathode.

FIG. 3.7 Schematic of the cylindrical electron beam diode and coaxial vircator.

FIG. 3.8 Annular graphite cathodes of various diameters.

FIG. 3.9 Schematic of the rogowski coil.
FIG. 3.10 Calibration curve of the KALI 5000 rogowski coil.

FIG. 3.11 B-Dot Probe.

FIG. 3.12 Coaxial vircator graphite annular cathode.

FIG. 3.13 Coaxial vircator copper anode mesh.

FIG. 3.14 HPM diagnostics setup.

FIG. 4.1 Waveform of the electron beam voltage and current for 11.3 mm Gap, 70 mm dia cathode.

FIG. 4.2 Marx generator output voltage with impedance mismatch.

FIG. 4.3 Waveform of the electron beam voltage and current for 21 mm Gap 70 mm dia cathode.

FIG. 4.4 Marx generator output voltage with matched impedance.

FIG. 4.5 Waveform of the electron beam voltage and current for 31 mm Gap 70 mm diameter cathode.

FIG. 4.6 Diode impedance and beam perveance with time.

FIG. 4.7 Diode impedance for various Marx Voltage / (Anode Cathode Gap)$^2$ at the diode.

FIG. 4.8 Diode perveance for various Marx Voltage / (Anode Cathode Gap)$^2$ at the diode.

FIG. 4.9 Marx generator output and Prepulse waveform along with the main voltage pulse for 280 kV diode voltage in Phase I experiment with 67 mm diameter planar cathode.

FIG. 4.10 (a) The temporal behavior of the diode impedance in Phase I experiment with 67 mm diameter planar cathode. (b) Experimental perveance for Phase I experiment.

FIG. 4.11 The diode voltage and current waveform in Phase I experiment with 98 mm diameter planar cathode for (a) $\phi_m = 334$ kV, (b) $\phi_m = 306$ kV.
FIG. 4.12 (a) The temporal behavior of the diode impedance in Phase I experiment with 98 mm diameter planar cathode for two different Marx generator voltages. (b) Experimental perveance for Phase I experiment for two different Marx generator voltages.

FIG. 4.13 The diode voltage and current waveform in Phase II experiment with 40 mm diameter annular cathode for (a) $\varphi_u = 278$ kV, (b) $\varphi_u = 320$ kV.

FIG. 4.14 The temporal behavior of the diode impedance in Phase II experiment with 40 mm diameter annular cathode for two different Marx generator voltages.

FIG. 4.15 The diode voltage and current waveform in Phase II experiment with 70 mm diameter annular cathode for (a) $\varphi_u = 320$ kV, (b) $\varphi_u = 348$ kV.

FIG. 4.16 The temporal behavior of the diode impedance in Phase II experiment with 70 mm diameter annular cathode for two different Marx generator voltages.

FIG. 4.17 (a) Voltage waveform in the Phase I experiment. (b) Current waveform in the Phase I experiment.

FIG. 4.18 (a) The temporal behavior of the diode impedance in Phase II experiment. (b) Experimental and theoretical perveance for Phase II experiment. Solid triangle represent perveance for 310 kV Marx voltage and open circles represent 240 kV Marx voltage. Continuous line represents theoretical perveance.

FIG. 4.19 (a) The temporal behavior of the diode impedance in Phase III experiment. (b) Experimental and theoretical perveance for Phase III experiment. Solid circles represent perveance for 250 kV Marx voltage and open circles represent 320 kV Marx voltage. Continuous line represents theoretical perveance.
FIG. 4.20 Prepulse waveform along with the main voltage pulse for 240 kV Marx voltage in Phase II experiment.

FIG. 4.21 Prepulse waveform along with the main voltage pulse for 250 kV Marx voltage in Phase III experiment.

FIG. 4.22 Prepulse waveform along with the main voltage and current waveform for 320 kV Marx voltage in Phase III experiment.

FIG. 4.23 (a) The diode voltage waveform. (b) The diode positive and the second negative voltage waveform with the corresponding current waveform.

FIG. 4.24 The temporal behavior of the diode perveance for positive voltage pulse. The dashed line is the perveance calculated from Langmuir-Blodgett law.

FIG. 4.25 The temporal behavior of the diode perveance for negative voltage pulse. The dashed line is the perveance calculated from Langmuir-Blodgett law.

FIG. 4.26 (a) The temporal behavior of the diode impedance for positive voltage pulse. (b) The temporal behavior of the diode impedance for negative voltage pulse.

FIG. 4.27 Schematic of the experimental setup showing Perspex cathode holder and the electron beam diode.

FIG. 4.28 Diode voltage and current waveform for 18 mm AK gap and 35 mm Perspex insulator.

FIG. 4.29 Diode voltage and current waveform for 18 mm AK gap and 35 mm Perspex insulator with a higher Marx generator voltage.

FIG. 4.30 Diode voltage and current waveform for 25 mm AK gap and 40 mm Perspex insulator.
FIG. 4.31 Diode voltage and current waveform for 25 mm AK gap and 40 mm Perspex insulator with a higher Marx generator voltage.

FIG. 4.32 Marx output and Prepulse waveform along with the main voltage pulse with an inductance added to the charging circuit of the Blumlein line.

FIG. 5.1 (a) Diode voltage and current waveform for 18 mm AK gap. (b) The temporal behavior of the diode impedance and perveance for 18 mm AK gap. Continuous line represents theoretical perveance.

FIG. 5.2 (a) Diode voltage and current waveform for 25 mm AK gap. (b) The temporal behavior of the diode impedance and perveance for 25 mm AK gap. Continuous line represents theoretical perveance.

FIG. 5.3 (a) Diode voltage and current waveform for 31 mm AK gap. (b) The temporal behavior of the diode impedance and perveance for 31 mm AK gap. Continuous line represents theoretical perveance.

FIG. 5.4 The temporal behavior of the diode impedance and perveance for 18 mm AK gap and 35 mm Perspex insulator. Continuous line represents theoretical perveance.

FIG. 5.5 The temporal behavior of the diode impedance and perveance for 18 mm AK gap and 35 mm Perspex insulator with a higher Marx generator voltage. Continuous line represents theoretical perveance.

FIG. 5.6 The temporal behavior of the diode impedance and perveance for 25 mm AK gap and 40 mm Perspex insulator. Continuous line represents theoretical perveance.

FIG. 5.7 The temporal behavior of the diode impedance and perveance for 25 mm AK gap and 40 mm Perspex insulator. Continuous line represents theoretical perveance.
FIG. 5.8 The temporal behavior of the diode impedance and perveance for Phase I experiment.

Continuous line represents theoretical perveance.

FIG. 5.9 (a) The temporal behavior of the diode gap in Phase I and Phase III experiment. (b) The temporal behavior of the diode gap in Phase II experiment.

FIG. 6.1 Diode voltage and current waveform for 6 mm AK gap 70 mm diameter graphite cathode.

FIG. 6.2 The temporal behavior of the diode perveance and impedance for 6 mm AK gap.

FIG. 6.3 HPM signal recorded from axial vircator.

FIG. 6.4 Coaxial vircator diode voltage (Top 100 kV/Div) and diode current (Bottom 10kA/Div) (Time 200 ns/Div).

FIG. 6.5 Marx output voltage (Bottom 80 kV/Div) and diode current (Top 10 kA /Div) (Time 200 ns/Div).

FIG. 6.6 HPM signal from coaxial vircator detected by diode detector and horn antenna setup.