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SIMULATION AND DIAGNOSTIC MODELING OF HERMES III

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Abstract: The HERMES III gamma ray simulator has been in operation since the 1980's, yet a complete system model has not been developed to simulate diagnostic waveforms for the system. This paper describes a simulation method using Stella Bertha to generate waveforms for the accelerator.

Introduction

- The High Energy Radiation Megavolt Electron Source (HERMES) III pulsed power accelerator is a gamma ray simulator which produces bremsstrahlung radiation.
- HERMES III is useful in performing radiation effects science experiments on test articles ranging from individual circuit board components to a military tank.
- Diagnostic modeling and simulation capabilities have not been developed to obtain a comprehensive set of voltage and current waveforms for the system.
- Figure 1 includes elements from the MARX generators through the Cavity, known as the HERMES Combined Aspects (HCA). The simulation runs through 10 iterations of the HCA sending the output to the MITL adder section through the Electron Beam Diode of Figure 2.

Motivation

- Modeling and simulation of the HIII pulse is necessary to understand the physical processes that influence the radiation output, operation, and reliability of the accelerator.
- In times of operational failure the model is useful in understanding how the failed element will impact the expected energy output decreasing the downtime of HERMES III.
- This model allows experimenters and operators to note performance creep. This research sets the foundation for modeling other pulsed power systems to obtain a comprehensive set of voltage and current waveforms.

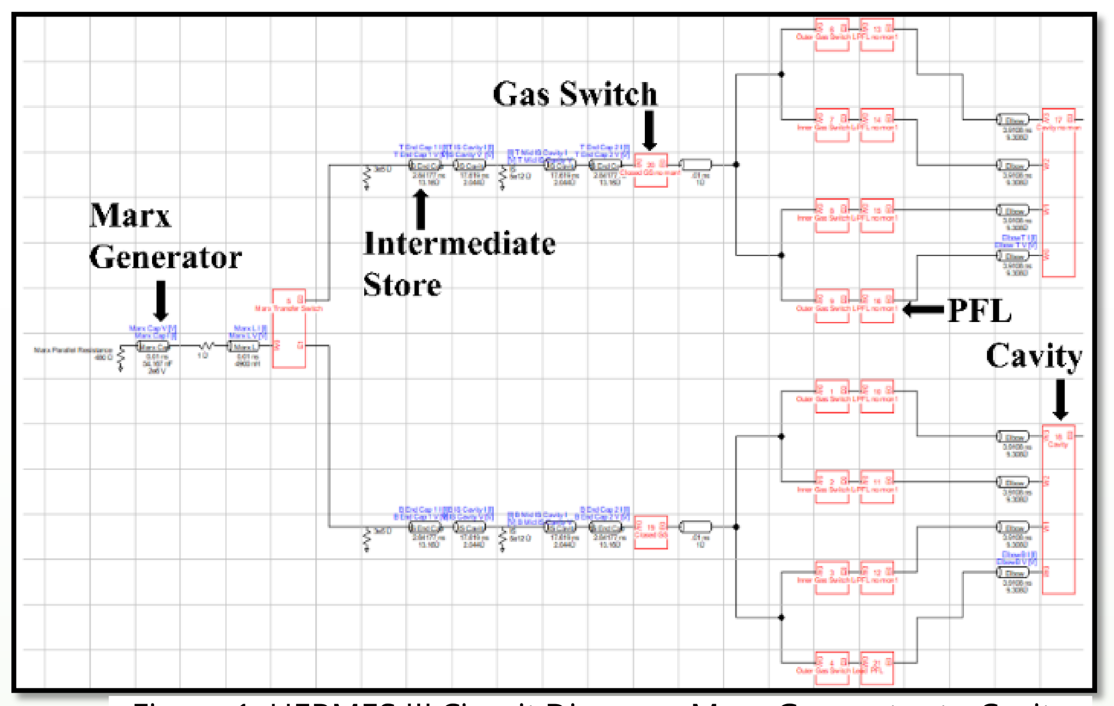

Figure 1. HERMES III Circuit Diagram, Marx Generator to Cavity

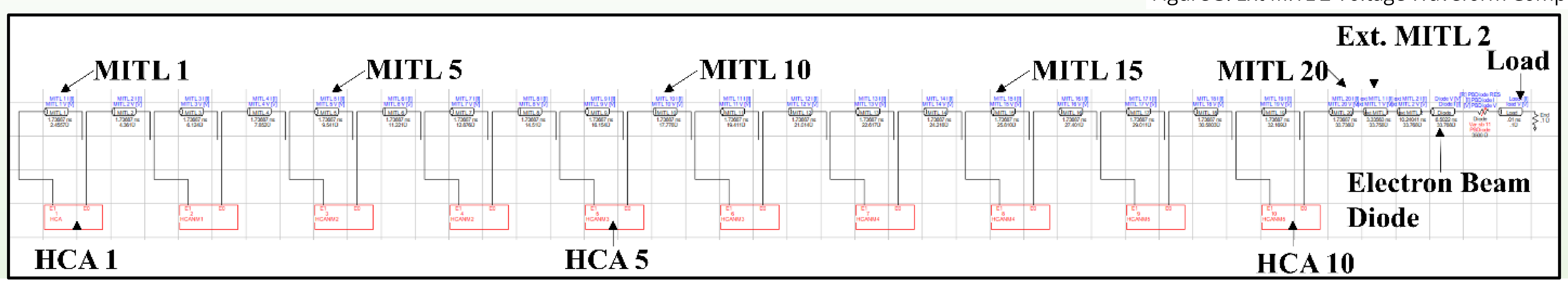

Figure 2. HERMES III Circuit Diagram, MITL to Electron Beam Diode

Results

- The main areas of interest for comparison of simulation and experiment waveforms are the Intermediate Store (IS), Pulse Forming Line (PFL), Magnetically Insulated Transmission Line (MITL) and Extension (Ext.) MITL 2 which is near the end point of HERMES III.
- At Ext. MITL 2, shown in Figure 3, the experiment voltage peaked at 16.19 MV with a FWHM of 45.90 ns, and the peak simulated voltage was 16.51 MV with a FWHM of 28.60 ns. The peak voltage magnitudes in this section are in the same range, but the experiment voltage waveform has a wider FWHM than the model prediction.
- In Figure 4, the MITL 16 experiment peak current was 310.76 kA with a FWHM of 60.60 ns, and the peak simulated current was 274.30 kA with a FWHM of 25.60 ns. While the peak currents were in the same range the simulated waveform had a smaller FWHM.
- While there are 80 PFL sections, PFL 1 is used as the representative plot shown in Figure 5. The peak experiment voltage at PFL 1 was 1.62 MV with a FWHM of 115.80 ns, and the peak simulated voltage was 1.09 MV with a FWHM of 139.60 ns.
- At IS 1, shown in Figure 6, the experiment voltage peaked at 1.70 MV with a FWHM of 509.60 ns, and the simulated peak voltage was 1.63 MV with a FWHM of 567.70 ns. The peak voltage magnitudes in this section were better matched, but the simulated FWHM was wider than the experiment.

Discussion

- The simulated waveforms from the Stella Bertha Simulation are most accurate for the voltage waveforms in the IS and Ext. MITL 2 regions. The simulated peak voltage of PFL 1 was lower than the experiment signal but close to the mean peak output of 1.10 MV from the original design analysis. The simulated MITL current was slightly lower than the value measured in the experiment, but the pulse FWHM in the simulation is much shorter than in the experiment.
- Variations between simulation and experiment waveform results are attributed to the fact that the simulation does not consider parameters such as mismatched electrical impedance or radiation drive induced effects on the components within HERMES III. The simulation also does not consider the effects of EMP radiation. These parameters could add additional noise to the EM pulse of HERMES III that the Stella Bertha simulation tools fail to incorporate in the simulation.
- Another source of discrepancy in the simulation and experiment values may come from the parameters used in the set up of the simulation. The values used in the simulation are based on historical design parameters, and actual values may differ over time due to modifications to the HERMES III accelerator. The simulation also has not accounted for the potential of any detrimental component aging effects from multiple decades of machine operation.
- A system model using Stella Bertha offers the ability to capture diagnostic performance at any point in the system where they placement of physical diagnostic equipment is not practical. This approach provides simulation data that is easy to generate and enables the performance of HERMES III to be modeled for the entire system.

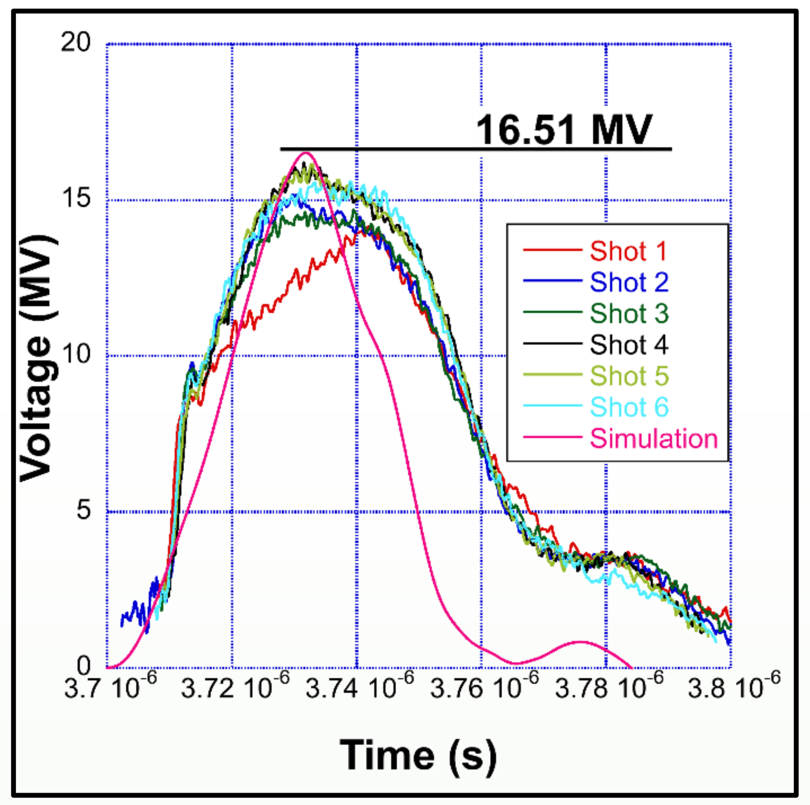

Figure 3. Ext MITL 2 Voltage Waveform Comparison

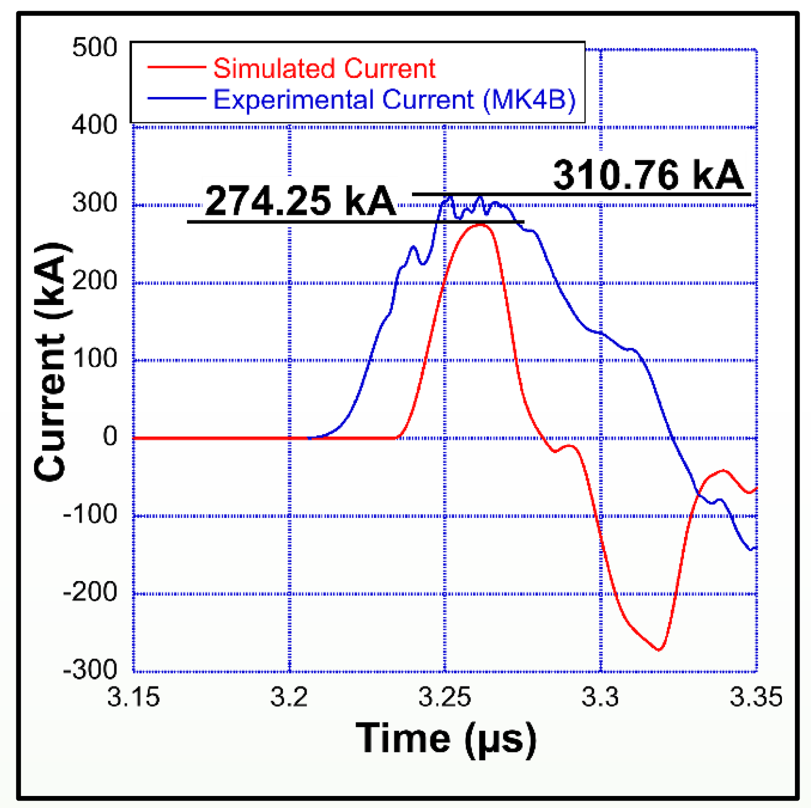

Figure 4. MITL 16 Current Waveform Comparison

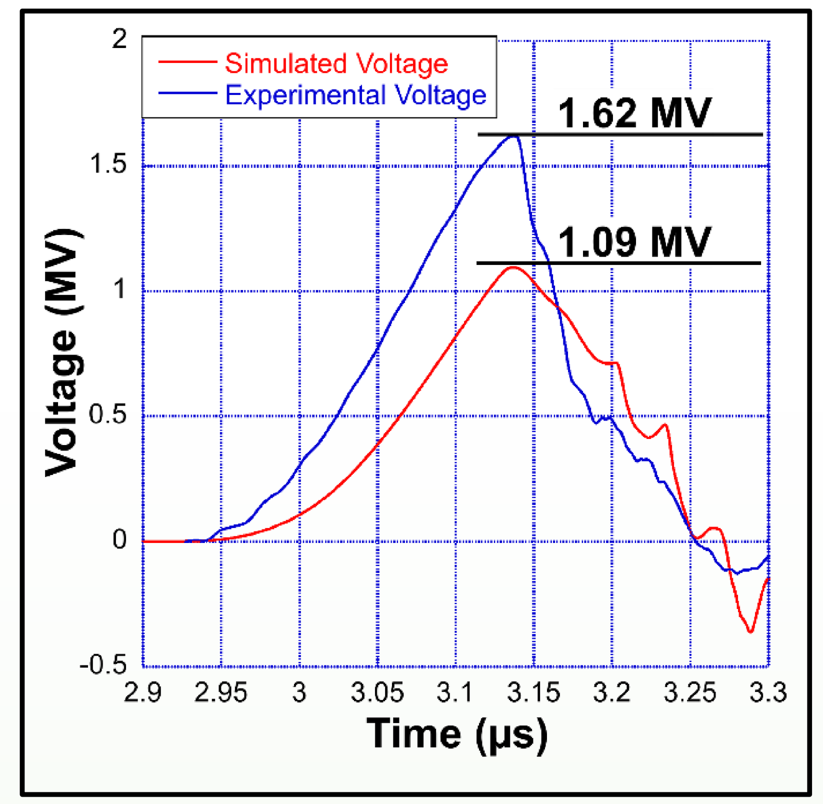

Figure 5. PFL 1 Voltage Waveform Comparison

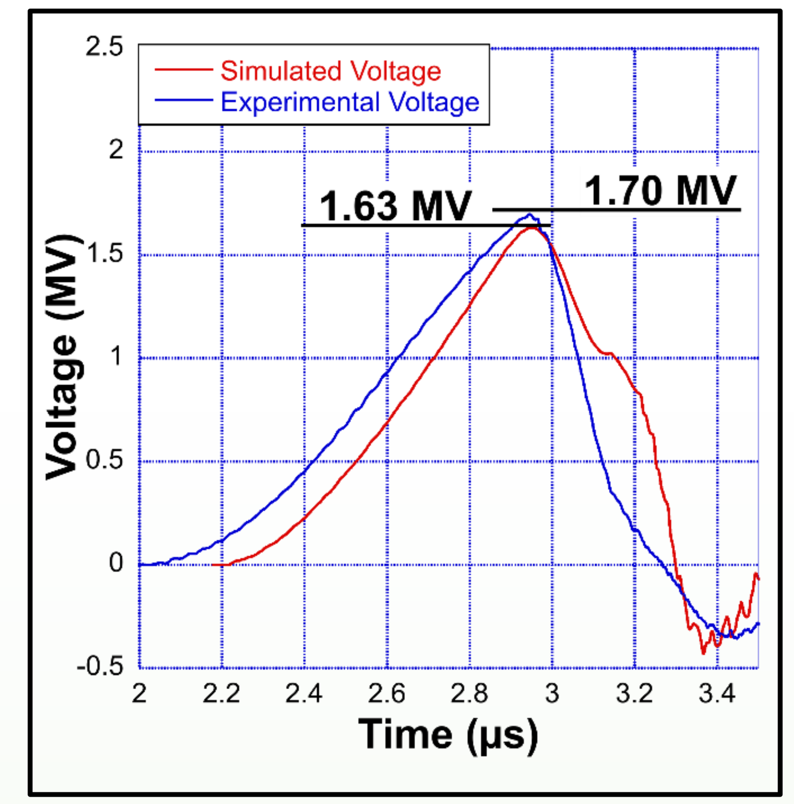

Figure 6. IS 1 Voltage Waveform Comparison

Summary

- Voltage and current waveform comparisons for the main component section of HERMES III show that a reliable pulsed power model in Stella Bertha is a promising tool.
- Future work on the HERMES III model in Stella Bertha include fine tuning the components between the IS and Ext. MITL 2 to better match the simulation waveforms to known experiment ranges.
- Further use of the HERMES III model in Stella Bertha would be to use the final waveform produced from the simulation to feed into models to characterize the end point radiation output.

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