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Title: PARTICLE-IN-CELL SIMULATIONS OF ELECTROMAGENTIC POWER-FLOW IN A COMPLEX 3D GEOMETRY*

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CTA: CFD

Computer Resources: SGI Altix ICE, [NRL, DC]

Research Objectives: The goal is to assist experimental designs which are being developed to create an azimuthally uniform terawatt electron beam with comparable current densities in each of the 3 ring diodes.

Methodology: Modern pulsed-power architectures feature multiple modules whose voltages and currents must be added to create the desired electron-beam or radiation source. One geometry that is commonly used to add currents is called a convolute by the pulsed-power community which features a series of rods which pass through a series of holes. This allows the currents from each module to be added together while tying a common conductor to a similar potential. A double convolute geometry is being designed to drive a 3-ring electron-beam diode. The geometry shown in Fig. 1 uses an anode (red) convolute to add the anode currents and ties them all to a common conductor. A cathode (blue) is also used for a similar purpose. Three dimensional electromagnetic particle-in-cell simulations are being used to design a 3-ring-diode electron-beam source. At the desired ~1 MV diode voltage the cathode surfaces become space-charge-limited emitters of electrons. These electrons move in self-consistent electric and magnetic fields which are computed by the particle-in-cell code. There are two main issues that are being addresses by the simulations: the symmetry and location of the electron beam that strikes the anode in the ring diode and current losses in the convolute sections as a result of electron emission.

Results: For most applications it is desirable to have the electron beam generate in each of the ring diodes strike the anode with shallow angles. Large imbalances in the electromagnetic power-flow caused by the inductance imbalances that feeds each side of each diode can have a profound effect on the electron beam the location and quality of the beam that strikes the anode. Figure 2 shows a comparison of a 3-ring diode where the inductances of all the gaps are balanced with one where the inductance of the inner diode is imbalanced. Another issue being addressed by the simulations is the degree of asymmetry in the power-flow introduced by the convolutes. Figure 3 shows the magnetic field contours at different z location indicating differing amounts of asymmetry. These results suggest that a larger separation between the convolute and the diode is needed to achieve the desired symmetry.

Significance: Electron beams generated in modern high-power devices can be used to simulate the effects of nuclear weapons. These sources either use the electrons directly or the electrons are used to create a bremsstrahlung radiation source by striking a high-atomic-number anode.

Productivity Measures: The simulations are influencing designs for future experiments.

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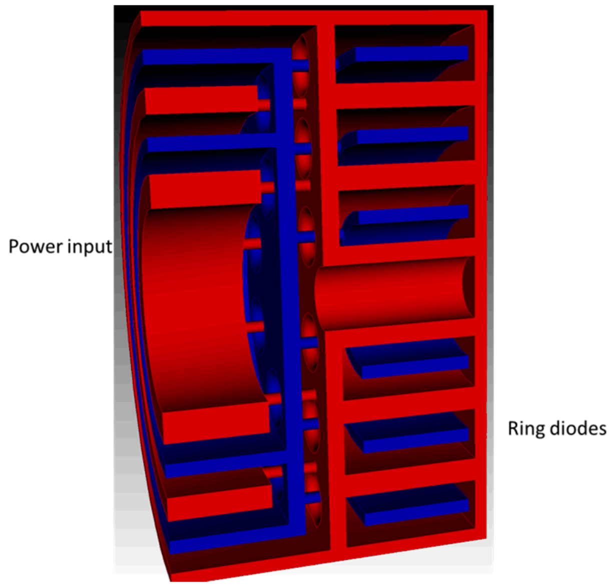

Figure 1. The simulation double-convolute setup to add the currents from four power-flow input gaps and to equalize the voltage on three ring diodes. The anode is shown in red and the cathode is shown in blue.

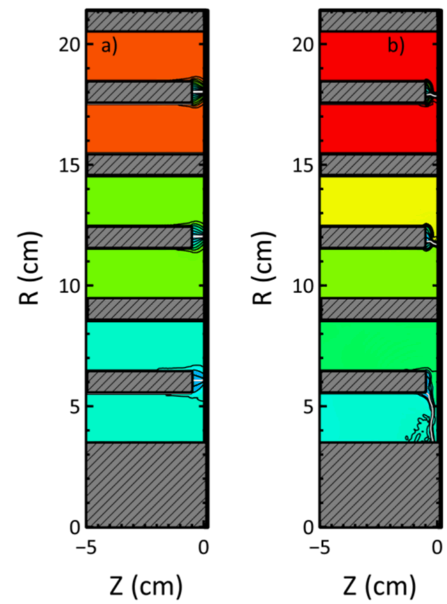

Figure 2. A comparison of electron current-flow patterns for a) balanced and b) the inner diode with imbalanced inductances.

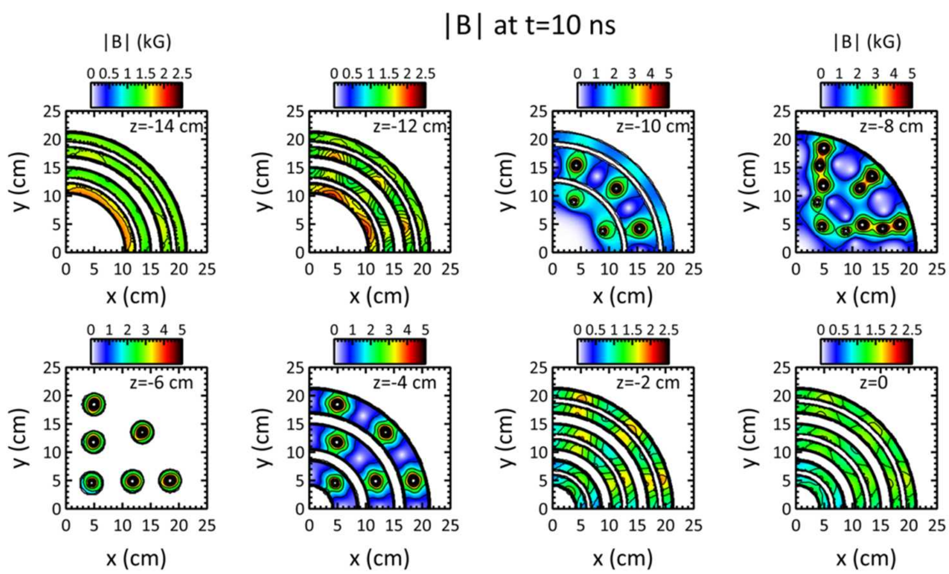

Figure 3. Contour plots of the magnitude of the magnetic field at different z locations showing the amount of azimuthal asymmetry at different z-locations in the convolute structure.