A Coupled 1-D Transmission Line and Particle-in-Cell Model to Simulate Electron Flow in the Z and ZR Accelerators

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The refurbishment of the Z accelerator at Sandia National Laboratories, the "ZR" project [1], is scheduled for completion in FY06. An important issue for the success of ZR is controlling electron losses to the anode in the vacuum section. The ZR vacuum section will be topologically similar to Z; four magnetically insulated transmission lines (MITLs) are coupled in parallel, with a double-post-hole convolute, into the final MITL delivering the full current to the load.

We are using electromagnetic particle-in-cell (PIC) simulation codes to improve the MITL design for ZR, adjusting the gap as a function of radius to minimize electron flow into the convolute. It is simply not feasible to model the entire vacuum section with a full 3-D simulation. However, 3-D simulations of the Z convolute [2,3], using a geometry in which the MITLs extend out to only a fraction of their full radius, have provided insight into the electron flow. First, they show that almost all the electron loss occurs in the convolute. Second, these electrons are all emitted out in the MITLs; as they **E x B** drift into the convolute, their space-charge inhibits emission in the convolute itself. Third, although the convolute has significant azimuthal structure, the electron flow in the MITLs even slightly upstream of the convolute is essentially azimuthally symmetric.

Based on these results, we are simply modeling each MITL in 2-D down to the convolute radius. The applicability of this approach depends on having an inner boundary that allows the electrons to flow through it, without greatly perturbing the fields upstream. Because we also need to couple all four MITLs together, we are using a boundary that connects to a 1-D transmission line. The convolute is modeled with a transmission line network that ties the four MITL lines in parallel into a final load transmission line, terminated with either an inductive or Z-pinch load.

We are currently working on the transmission line boundary model. It is very stable, even with particles flowing through it. The current in the transmission line is computed from a surface integral of the magnetic field over the boundary plane, filtering out the non-TEM component. However, with particles, this algorithm sets the line current to an average of the anode and cathode currents. We are studying ways to extract the anode and cathode currents seperately, using surface integrals rather than line integrals for stability.

1. D. H. McDaniel, *et al., Proc. 5th Int'l. Conf. on Dense Z-pinches*, Albuquerque, NM, edited by J. Davis, *et al.* (AIP, New York, 2002), p. 23.

2. T. D. Pointon, *et al.*, Phys. Plasmas **8**, 4534 (2001).

3. T. D. Pointon and W. A. Stygar, *Proc. 13th IEEE Int'l. Pulsed Power Conf.*, Las Vegas, NV, edited by R. Reinovsky and M. Newton (IEEE, New York, 2001), p. 1696.

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