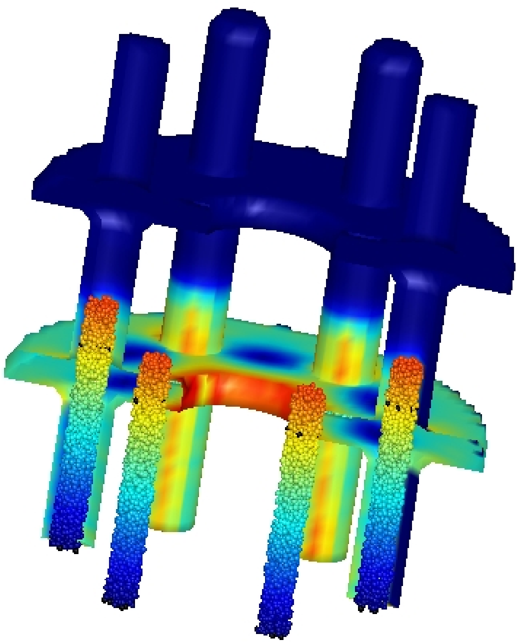
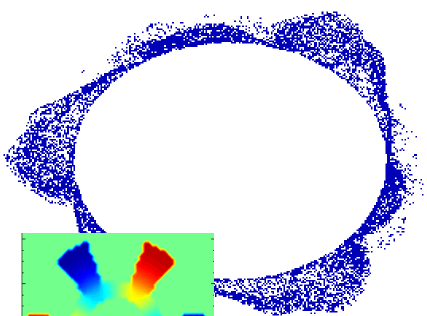
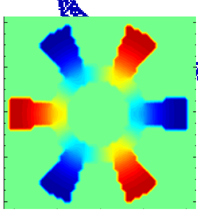
Modeling Vacuum Electronics with VORPAL



Klystron

A klystron is a linear-beam vacuum tube used as an amplifier at microwave and radio frequencies. VORPAL simulations of a multi-beam klystron (right) show particle beams moving up the tubes and the resulting magnetic field on the structure. VORPAL is capable of describing highly complex geometries through importing CAD models in the STL format or user-defined Python expressions. VORPAL uses a cut-cell algorithm to give more accurate fields than a stair-step approach used in many other particle-in-cell codes.

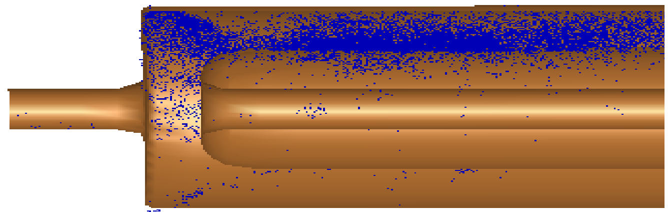




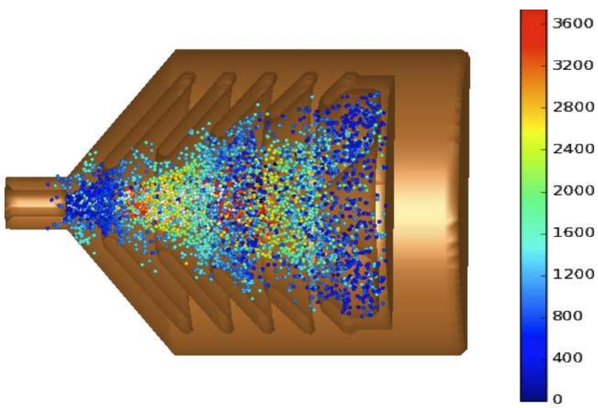
Magnetron

Cavity magnetrons are high powered vacuum tube devices that generate microwaves. VORPAL is a fully self-consistent particle-in-cell code, so it is ideally suited to modeling the nonlinear behavior of these devices. VORPAL simulation results (left) show the interaction of electrons with a magnetic field for the A6 configuration. Also, VORPAL has an integrated post-processing script to extract and reconstruct the eigenmodes of a cavity. The lower left image shows the pi-mode of the A6 magnetron reconstructed through VORPAL.

Multipacting



Multipacting occurs when an oscillating field in a cavity or waveguide resonates with the periodic motion of electrons traveling between and colliding with the walls, leading to an exponential increase in secondary electrons. Multipacting is often the factor that limits the performance of high-power RF devices. The image at right shows VORPAL simulation results with a substantial increase in the number of electrons over time near power levels where multipacting barriers are seen in experiments. Emission models in VORPAL include simple emission (where one electron is emitted if the primary electron falls within the required secondary emission yield energy), and the Furman-Pivi model for secondaries (where multiple electrons can be emitted with varied energies and angles). VORPAL is also capable of modeling elastically scattered electrons and user defined secondary electron yield curves. VORPAL has particle tracking to allow resonant trajectories to be identified.



Collectors

Traveling-Wave-Tube efficiency depends strongly on the efficiency of the electron beam collector. Multistage depressed collectors (MDCs) are highly efficient collectors that use several electrodes at different potentials to selectively collect electrons at different energies. VORPAL simulation results (left) show the collection of electrons on the various electrode surfaces. VORPAL gives the user the capability to optimize collector efficiency by modeling many different collector voltages. It also allows the user to study the transient effects of the depressed voltages on the MDC efficiency, the effects of unregulated behavior of the collector powers, and the effects of secondary electrons.

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