The design of modern, high-performance vacuum electron devices relies on the use of advanced numerical simulation tools to achieve high performance operation while reducing development time and cost. For specific classes of slow-wave amplifiers, 1D and 2D large-signal simulation codes, such as CHRISTINE [1] and TESLA [2] developed at NRL, provide accurate predictions of amplifier performance over a wide range of conditions. These are widely used as design tools due to their speed of execution, ranging from a few seconds per simulation point in 1D to typically tens of minutes in 2D. There are, however, many situations when these 1D and 2D codes cannot capture the either the simulation geometry or the essential physics sufficiently well. In these cases, full 3D modeling is possible using well-tested electromagnetic particle-in-cell (PIC) codes such as MAGIC [3]. For these simulations, however, speed of execution is typically measured in hours per simulation point, even using parallel computation across a multiple-CPU cluster, making such codes less effective as design tools.

To address this situation we have developed a new general-purpose 3D electromagnetic PIC simulation code, ‘Neptune’, which accelerates simulations using high-performance Graphics Processing Unit (GPU) hardware. A typical high-end graphics card can contain 512 or more computational cores, combined with fast memory addressing, at the relatively low cost of ~$1/core. In Neptune we take advantage of this parallelism to accelerate electromagnetic simulations by up to 70-80 times compared to a single CPU core. Alternatively, Neptune can perform parallel simulations on multi-core CPUs when a GPU is not available, showing almost linear speed-up for calculation on a 12-core system. We report on the application of this new capability to achieve rapid 3D PIC simulation of vacuum electronic amplifiers.


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