HIGH ACCURACY ELECTRON BEAM MODEL DEVELOPMENT IN MICHELLE: EBEAM*

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We present a new MICHELLE [1,2] software module (eBEAM) that is capable of high accuracy simulations of electron beams with stochastic space charge effects. In modeling low current electron beam systems such as electron beam lithography, nanolithography and electron microscopy, it is necessary to simulate ensembles of individual electrons to account correctly for the statistical effects of inter-particle interactions. The MICHELLE–eBEAM simulation is accomplished via a CPU/GPU hybrid code that runs on multiple platforms.

Electron and ion beam simulations such as those applicable to charged particle beam lithography and nanolithography present challenges to particle-in-cell, mesh-based simulation codes due to the requirement to achieve high accuracy. For instance, blur simulations in lithography columns require nanometer spatial accuracy while the applicable device size is on the order of a meter. These disparate scales put unrealistic constraints on the mesh size in cell-based simulations.

To accurately model stochastic space charge, Coulomb interactions must be efficiently evaluated for a large number of particles. Current densities in lithography applications are sufficiently low that each simulated particle may represent a single electron or a single ion, for example. Direct calculation of these particle-particle interactions has $O(n^2)$ computational complexity, and therefore requires either substantial computing power or use of a tree algorithm that reduces the complexity to O(n log n). In our present approach the former is accomplished by using high performance GPU hardware which acts as a co-processor to the host CPU-based program.

We report on our progress on the MICHELLE–eBEAM development and present illustrative examples of applications in charged particle optics for modeling lithographic beamlines.

1. John Petillo, et al., "The MICHELLE Three-Dimensional Electron and Collector Modeling Tool: Theory and Design", IEEE Trans. Plasma Sci., vol. 30, no. 3, June 2002, pp. 1238-1264.
2. John Petillo, et al., "Recent Developments in the MICHELLE 2D/3D Electron Gun and Collector Modeling Code", IEEE Trans. Electron Devices Sci., vol. 52, no. 5, May 2005, pp. 742-748.

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