VORPAL Used to Design a High-Efficiency Smith-Purcell THz Amplifier

Problem Description

The Smith-Purcell Free-Electron Laser [1] operating as a backward wave oscillator [2,3] is proposed as a high-gain, tunable amplifier for TeraHertz (THz) radiation, as needed for medical imaging and security purposes. For these applications, THz is ideal because of its ability to penetrate organic matter without the ionizing damage associated with radiation such as X-rays. The problem has been to find the optimal operating parameters without the expense of building multiple amplifiers and running expensive tests.

Solution

Researchers at Northern Illinois University and Fermi National Accelerator Lab improved Smith-Purcell configurations for THz generation. Beginning with extensive benchmarking, they showed VORPAL could accurately model these configurations. They were then able to use VORPAL to demonstrate a more effective way to bunch the beam compared to the standard SPFEL configuration explored so far by other researchers, by using a dual grating configuration. VORPAL is now being used to provide a start-to-end model [4] to predict the performance of a complete table-top THz light source.

Why VORPAL?

Simulating the THz regime is demanding: wavelengths are on the order of 100s of microns, requiring simulation cell sizes to be on the order of 10s of microns, while the simulation domain spans centimeters. Modeling millions of cells in three dimensions requires distributed parallel computing to achieve reasonable run times, and VORPAL provides this kind of computational horse-power.

"We felt VORPAL was the best tool for helping understand the important issue of how to make a compact TeraHertz radiation source," says Philippe Piot of Northern Illinois University and Fermi National Accelerator Laboratory. "We needed to take advantage of the full power of our Linux cluster computers available at the Northern Illinois Center for Accelerator and Detector Development (NICADD), and VORPAL provided us with the way to do that. We also received tremendous technical support from Tech-X Corporation staff to help us get started with our modeling."

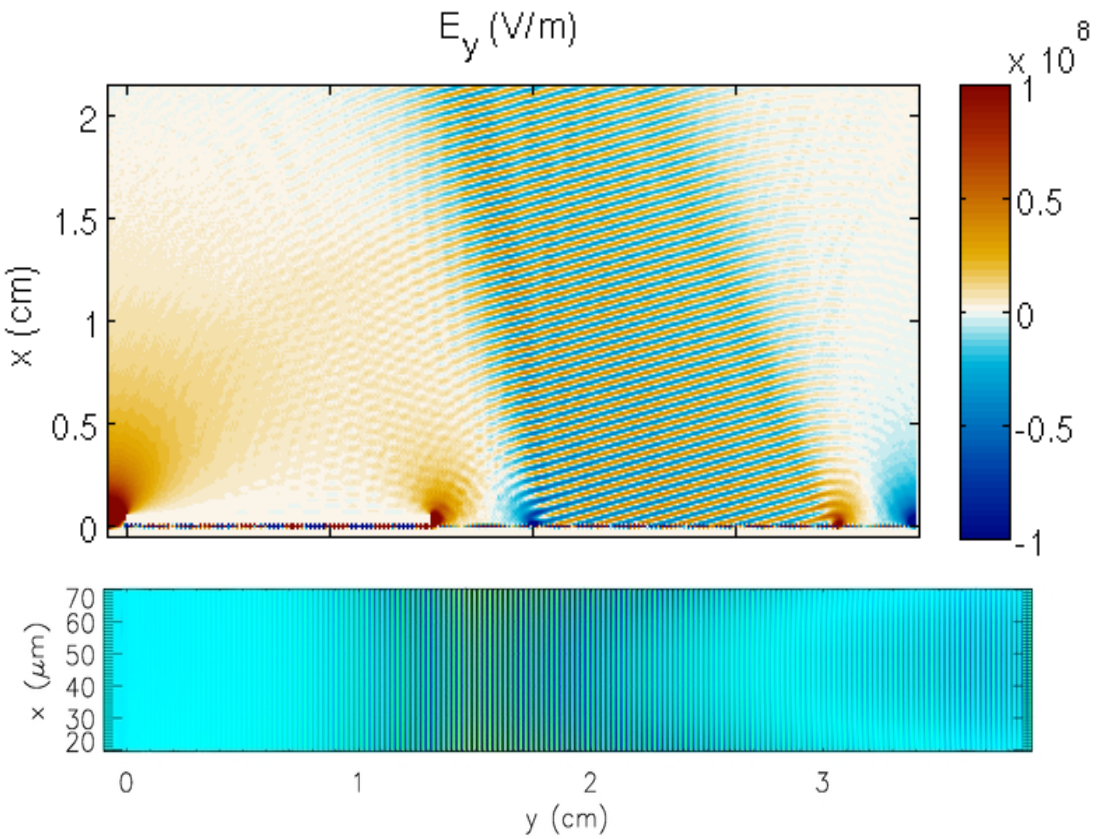

Figure 1: VORPAL simulation results show enhanced radiated power (top) due to the more efficient beam bunching (bottom) via the dual-grating design.

References

[1] J. M. Wachtel, J. Appl. Phys., 50 (1) (1979).

[2] H. L. Andrews and C. A. Brau, Phys. Rev. ST-AB 12, 070701 (2004).

[3] V. Kumar and K.-J. Kim, Phys. Rev. E 73, 026501 (2006).

[4] C. Prokop, P. Piot, M. C. Lin and P. Stoltz, Numerical modeling of a table-top tunable Smith-Purcell terahertz free-electron laser operating in the super-radiant regime, *Applied Physics Letters, 96*, 151502 (2010)