A DGTD Algorithm with Dynamic h-Adaptation and Multirate Time Integration Techniques for EM–Plasma Interaction Simulations

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Interactions between electromagnetic (EM) fields and plasmas result in many interesting physical phenomena (J. Bittencourt, *Fundamentals of Plasma Physics*. New York: Springer-Verlag, 2004), including high-power microwave air breakdown, plasma shielding effect, and plasma streamer discharge. The Lorentz forces exerted by EM fields provide plasmas with the energy for their generation and annihilation. The physically competing ionization–diffusion mechanism usually results in an abrupt change of the plasma density at the edges of plasma bulks, which requires an extremely high spatial resolution in a numerical simulation. Providing such a high spatial resolution by increasing the mesh density uniformly in the entire simulation domain will result in a dramatic increase of the total number of unknowns and a significant decrease of the computational efficiency. In time-domain simulations, the use of an explicit time integration method limits the largest time step size by the smallest mesh element, making the numerical simulations impractical for most of the problems.

To provide a sufficient spatial resolution while maintaining a reasonably low computational cost, it is desirable to develop a technique that can identify regions requiring a higher resolution from the rest. Once identified, the mesh grids in these regions can be refined to increase the spatial resolution. Since the physical interaction under consideration is progressing in space and time, such an identification procedure must be both efficient and effective, in order for it to be applicable in the real time of a simulation. In the meanwhile, the numerical method that adopts such an identification procedure must be highly flexible so that it can handle the time-varying meshes in a highly efficient manner.

In this talk, we present a discontinuous Galerkin time-domain (DGTD) algorithm with a dynamic h-adaptation technique (S. Yan, C.-P. Lin, R. R. Arslanbekov, V. I. Kolobov, and J.-M. Jin, *IEEE Trans. Antennas Propag.*, 65(6), 3122–3133, 2017) to handle non-conformal, time-varying, and automatically adjustable meshes. Identification procedures with different criteria are analyzed, compared, and discussed for their effectiveness and robustness in the mesh refinement automation. A multirate time integration technique is employed to perform an efficient time marching by permitting different time step sizes in elements with different scales. The implementations of both the EM–plasma diffusion and the EM–five-moment plasma fluid models enable the presented techniques to be applicable in a wide range of EM–plasma simulations. Several numerical examples are given to demonstrate the application of the proposed method in the simulation of practical problems with the computational efficiency and the numerical accuracy highlighted.