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Extension of adaptive mesh refinement to simulations of high-power plasma experiments*

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Large-scale numerical simulations play a crucial role in the modeling of modern high-power pulsed particle, microwave and laser sources. Inadequate spatial resolution of realistic features (wall boundaries, injectors, targets, pulse shapes etc.) may give rise to unacceptable errors in critical simulation results. Structured adaptive mesh refinement (AMR) has been successfully applied to increase numerical resolution of fluid dynamics and MHD simulations. Unfortunately, straightforward extension of AMR (e.g., applying standard interpolation and flux matching techniques) to problems involving electromagnetic and particle-in-cell (PIC) descriptions proves to be nontrivial due to a number of severe numerical difficulties arising due to the presence of fine-coarse mesh interfaces: (i) spurious wave reflection, (ii) macro-particle self-force, and (iii) violation of charge conservation (Gauss' law). The approximation errors due to these numerical effects typically result in loss of simulation accuracy, energy/momentum non-conservation and long-time instabilities. We review our progress in developing specialized techniques that resolve these issues by way of introducing buffer zones and absorbing (PML) boundaries around the fine-coarse interfaces. We demonstrate the efficiency and accuracy of these techniques on realistic examples related to simulations of the generation and propagation of high-power microwave (HPM) pulses, lasers and energetic particle beams.

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