Long-term PIC simulations of relativistic shocks using the magic CFL method

*Yosuke Matsumoto[1], Naoki Ikeya[1]

1.Graduate School of Science, Chiba University

Mitigating so-called the numerical Cherenkov instability (NCI) has been a critical issue in studying particle accelerations at relativistic collision-less shocks by means of the particle-in-cell simulation. We have studied the stability property of the NCI in relativistic plasma flows employing particle-in-cell simulations. Using the implicit finite-difference time-domain method to solve Maxwell equations, we found that the nonphysical instability was greatly inhibited with a Courant-Friedrichs-Lewy (CFL) number of 1.0 (Ikeya and Matsumoto, 2015). The present result contrasts with recently reported results (Vay et al., 2011; Godfrey and Vay, 2013; Xu et al., 2013) in which magical CFL numbers in the range 0.5–0.7 were obtained with explicit field solvers.
Using the newly found stability property of the NCI, we successfully solved long-term evolutions of relativistic collision-less shocks. For relativistic, un-magnetized shocks in pair plasmas, we found that magnetic field turbulence generated by the Weibel instability saturated at much larger levels than those found in the previous studies. As results, particles’ maximum energy increased linearly in time with the energy spectral slope $\gamma^{-1.8}$, which compares with the previously-reported relation as $\gamma_{max} \propto \sqrt{t}$ with $\gamma^{-2.4}$.

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