Progress and challenges in constructing structure-preserving particle-in-cell methods for the regular and drift-kinetic Vlasov-Maxwell systems

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This contribution discusses the progress that has been made over the recent years and some of the challenges that still await us in constructing structure-preserving particle-in-cell discretizations for the regular and the drift-kinetic Vlasov-Maxwell systems. Regarding the structure-preserving aspects of a numerical algorithm, it would be preferable to achieve at least an electromagnetically gauge-invariant variational integrator for this would imply local charge conservation, preservation of the multisymplectic two-form, and typically good behaviour of the global energy functional. For the full Vlasov-Maxwell system, explicit synchronous variational integrators exist that achieve all these properties but trying to implement subcycling to speed up the computations appears to always lead to an implicit scheme. For the drift-kinetic system, no stable, gauge-invariant variational integrator exists yet and the root cause of the problem appears to lie in the so-called parasitic modes. Furthermore, the traditional way of enforcing quasineutrality in the drift-kinetic formalism renders the system uninvertible for the electric field. Per these obesrvations, significant progress could be made if (i) stable gauge-invariant variational integrators for phase-space systems could be invented, (ii) a parallel polarization term for the drift-kinetic theory would be found to make the quasineutral limit of drift-kinetics invertible, and (iii) explicit subcycling schemes were found for variational geometric particle-in-cell algorithms. The purpose of this contribution is to discuss these particular topics.

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