Multisymplectic Integration for Beam and Plasma Simulations

STEPHEN WEBB, RadiaSoft, LLC, RADIASOFT, LLC TEAM — Particle-in-cell methods are a standard tool for simulating charged particle systems such as fusion plasmas, intense beams, and laser- and beam-driven wakefield accelerators. Conventional methods have been successful in studying short-term dynamics, however numerical instabilities and artifacts such as grid heating make long-time simulations unreliable. A similar issue existed in single particle tracking for storage rings in the 1980s, which led to the development of symplectic algorithms. The essential insight that if the physical equations of motion derive from a least-action principle, then so too should the numerical equations of motion. The resulting update sequence preserves a symplectic 2-form, which is a strong constraint on the numerical solutions. The resulting algorithms are stable and accurate over very long simulation times. This same structure exists for field theories as well as single-particle dynamics. Such multisymplectic integrators have good stability properties and naturally encode conservation laws, making them ideal for simulations over many oscillations of the system. We present here a number of examples where multisymplectic algorithms have been used over very long time scales.

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