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Research paper

Conservative semi-Lagrangian kinetic scheme coupled with implicit finite element field solver for multidimensional Vlasov Maxwell system

Hongtao Liu[a,b], Xiaofeng Cai[c], Giovanni Lapenta[b], Yong Cao[a,*]

[a] School of Mechanical Engineering and Automation, Harbin Institute of Technology, Shenzhen 518055, China
[b] Department of Mathematics, Center for Mathematical Plasma Astrophysics, KU Leuven, University of Leuven, 3001, Belgium
[c] Research Center for Mathematics, Beijing Normal University at Zhuhai, and Division of Science and Technology, United International College (BNU-HKBU), Zhuhai, 519087, P.R. China

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ABSTRACT

In this paper, a conservative semi-Lagrangian (CSL) kinetic scheme coupled with an implicit finite element method (IFEM) is developed for multidimensional electromagnetic plasma simulations. The present method (CSL-IFEM) enjoys the respective advantages of the CSL and IFEM, including mass conservation, high-order spatial accuracy, as well as being free from the Courant-Friedrichs-Lewy (CFL) condition. In present CSL-IFEM, the CSL scheme with a general high order positivity-preserving limiter is utilized for the spatial discretization of the Vlasov equation, which enables the proposed method to remove the CFL limitation in phase space, exactly conserve mass, and preserve the positivity of the distribution function. The IFEM solver is developed for the spatial discretization of the Maxwell equation, which makes the current method free from CFL limitation induced by the speed of light and easily handles general field boundary conditions. To make the proposed CSL-IFEM more efficient in multidimensional simulations, the dimensional splitting procedure and sparse matrix technology are implemented in CSL and IFEM, respectively. Then the Vlasov solver CSL and Maxwell solver IFEM are coupled via the current density calculated from the general Ohm law. Finally, several numerical experiments, including electromagnetic wave (2d0v), particle gyromotion (0d2v), streaming Weibel instability (1d2v) and magnetic reconnection (2d3v), are performed to demonstrate the capabilities of the proposed method.

1. Introduction

Electromagnetic plasma has a large number of applications, including space propulsion, plasma sources for material processing, solar wind, magnetospheric and magnetically confined fusion devices [1]. Owing to the large variety of physical situations, the numerical simulation of plasma is still a great challenge for the scientific community. Roughly speaking, two large classes of physical models are available to describe plasma dynamic: fluid and kinetic models. The fluid models evolve

* Corresponding author.
E-mail addresses: liuhongtao@stu.hit.edu.cn (H. Liu), xfcai@udel.edu (X. Cai), giovanni.lapenta@kuleuven.be (G. Lapenta), yongc@hit.edu.cn, yongc@hitsz.edu.cn (Y. Cao).

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