Hamiltonian particle-in-cell methods for the Vlasov-Maxwell equations

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Since 2012 [1-7], structure-preserving geometric algorithms for the Vlasov-Maxwell (VM) system have been an active research area. Variational [1-3], non-canonical [4,5] and canonical [6] symplectic particle-in-cell methods for the VM system have been successfully developed and applied. Recently, we have developed a Hamiltonian particle-in-cell method for the VM system by employing finite element methods in space and splitting methods in time [7]. Specifically, the discretization preserves the non-cannonical symplectic structure of the VM equations given by the Morrison-Marsden-Weinstein bracket. In order to derive the semi-discretized system which possesses a discrete non-canonical Poisson structure, we present a criterion for choosing the appropriate finite element spaces. It is confirmed that some conforming elements, e.g., Nédélec's mixed elements, satisfy this requirement. When the Hamiltonian splitting method is used to discretize the semi-discrete system in time, the resulting algorithm is explicit and preserves the discrete Poisson structure. The structure-preserving nature of the algorithm ensures its long-term accuracy and fidelity.

[1] J. Squire et al., Phys. Plasmas 19, 084501 (2012).

[2] J. Xiao et al., Phys. Plasmas 20, 102517 (2013).

[3] J. Xiao et al., Physics of Plasmas **22**, 092305 (2015).

[4] J. Xiao et al., Physics of Plasmas **22**, 112504 (2015).

[5] He et al., Physics of Plasmas **22**, 124503 (2015).

[6] H. Qin et al. Nuclear Fusion **56**, 014001 (2016).

[7] He et al., arXiv:1606.05716 (2016).