New Developments of the Energy Conserving Semi Implicit (ECsim) method

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The Energy Conserving Semi Implicit (ECsim) method [1, 2] is a new approach to particle in cell plasma simulation based on a exactly energy conserving formulation. The method uses a new implicit particle mover and a mass matrix formation of the current to discrete the coupled particle-field equations with a semi-implicit temporal scheme.

The new lines of investigation reported are: sub-cycling of the particle motion with respect to the field solution, stabilisation of spurious instabilities present in a drifting plasma, preservation of the Poisson constraint and detailed local charge conservation.

Subcycling is the process whereby particles are moved multiple times during a field evolution time step. In the present case, this feature can be implemented in a different way for each particle and leads to a modification of the algorithm to compute the mass matrix. The procedure is beneficial in three ways: it increases the accuracy, it can lead to charge conservation and it can be modified to lead to a gyro-averaged approach

Drifting cold plasmas are notoriously hard to model with PIC because of the insurgence of the finite grid instability. We report a new method developed within our ECsim approach to eradicate this nuisance.

The *Poisson eqaution* and the solenoidal condition for the magnetic field are constraints that need to be valid at all times. In kinetic particle in cell the second is trivially enforced by choosing a discretisation of the curl whose discretised divergence is zero. But the first is a more complex matter, requiring to design an interpolation method for the charge and the current consistent with each other via the local charge conservation equation. We report our approach to resolve this issue.

References

[1] Lapenta, G. (2017). Exactly energy conserving semi-implicit particle in cell formulation. Journal of Computational Physics, **334**, 349-366.

[2] Lapenta, G., Gonzalez-Herrero, D., & Boella, E. (2017). Multiple-scale kinetic simulations with the energy conserving semi-implicit particle in cell method. Journal of Plasma Physics, **83**(2).