Simulations of magnetic reconnection with Parsek2D-MLMD, a new Multi-Level Multi-Domain Implicit-Moment-Method Particle-in-Cell code

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The Aim
Reducing the computational effort of PIC simulations by simulating different sections of the domain with different resolutions chosen according to the local physics of interest

The Method
MLMD system:
1: BC interpolation C2R
2: updated interpolation C2R
3: particle repopulation C2R

Fig 3: sketch of the proposed MLMD system

Notable points:
- multiple levels, same physics, different resolution
- the IMM algorithm is used
- the native coarse grid info is not discarded, but integrated into the coarse grid updated solution
- particles are simulated at all levels → no particle coalescence, but particle repopulation in the refined grid

Projection strategy:
$$E_{\text{proj}} = \frac{1}{2} \left( E_{xL} + \sum_{i=1}^{N_{g}L} W_{i} (x_{p} - x_{g_{i+1}}) \right)$$

Particle repopulation strategy:
$$\psi_{p_{i+1}} = \psi_{p_{i}} + \delta_{m} \psi_{p_{i}} / RF^2$$

Fig 4: particle repopulation strategy [R6]

Particles are repopulated in an area bigger than the ghost cells, the PRA, to enforce particle motion consistency at the refined grid boundaries

Abbreviations
BC: boundary conditions - N_ops: number of operations
C2R: coarse to refined - R2C: refined to coarse
W: interpolation function
N: native field - P: projected field - S: single grid
RF: refinement factor - L: number of levels - I: level index
PRA: particle repopulation area

References
[R2]: W. Daughton, J. Scudder, H. Karimabadi, PoP, 13, 072101, 2006
[R6]: G. Lapenta, JCP, 181: 317-337, 2002

Conclusions
- a MLMD method is developed to reduce the computational costs of IMM PIC simulations by resolving portions of the domain with the local resolution of interest
- the method is successfully applied to a simulation of magnetic reconnection