Project review, Physics highlights, and Perspectives

Mickael Grech

SMILEI training workshop
November 6-7, 2017
Maison de la Simulation

Smilei's philosophy

- **Open-Source & Collaborative**

- **High-Performance-Computing (HPC) relevant**
  co-development between HPC specialists & physicists

- **User-friendly**
  3 user-levels: basic, advanced, expert

- **Multi-purpose & Physics-oriented:**
  advanced physics modules
  extensive diagnostics & post-processing tools

Project timeline

Open-Source & collaborative HPC relevant User-friendly Multi-physics

2013	2014	2015	2016	2017
Project Kick-Off	Architecture validation	Advanced HPC strategy	Full 3D operational	Smilei v3.3

1D & 2D geom.
1st physics studies
CeCILL B License

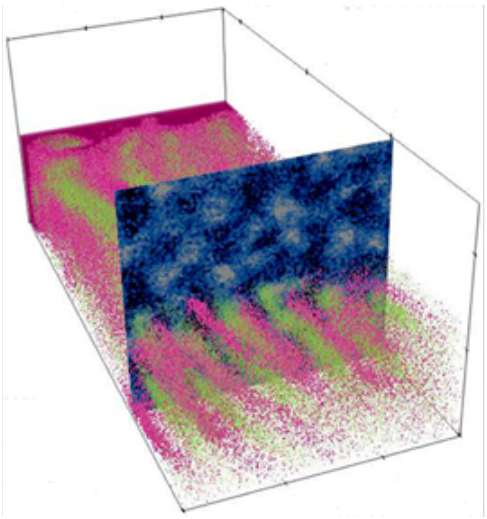
Hybrid MPI/OpenMP
Dynamic Load Balancing

Field ionization
Binary collisions

Web documentation

1st Grand Challenge (GENCI/IDRIS)

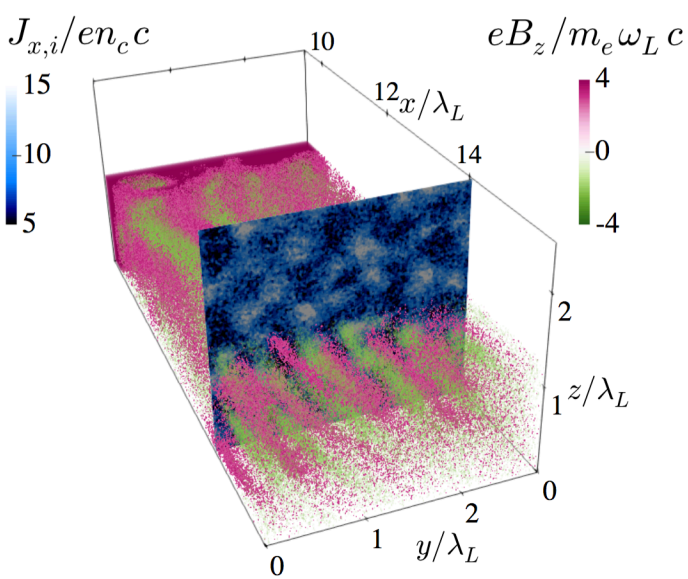
1st Master teaching at UPMC



Impact ionization
Advanced Maxwell solvers
Filtering techniques

Work on vectorization started
GitHub & Continuous integration
Python I/O management
1st papers published!

Current release: SMILEI v3.3



Code, processing tools and documentation avalaible online at: www.maisondelasimulation.fr/smilei

1D, 2D, 3D Cartesian geometries

Advanced physics modules

- Charge conserving current deposition (Esirkepov)
- Advanced Maxwell solvers & filters
- Antenna & external electromagnetic fields
- Binary collisions & impact ionization
- **High-emission photon emission & back-reaction**
- **Breit-Wheeler electron-positron pair production**

User friendly

- Full (updated) doc
- Python I/O management
- Extensive (built-in) diagnostics
- Python post-processing tools

High-Performance oriented

- Hybrid MPI/OpenMP
- Dynamic Load Balancing
- HDF5 parallel I/O (OpenPMD compliant)
- Vectorization (available soon)

A teaching & research platform

A teaching platform:

- Plasma physics numerical hands at the Master level (UPMC)
- Training workshops (1st Nov. 2017)

7 PhD thesis in various fields:

M. Chiaramello (LULI, UPMC), *Short laser pulse amplification* (2016)
A. Grassi (LULI, UPMC), *Relativistic lab. astrophysics* (2017)
J. Dargent (LPP/IRAP), *Magnetic reconnection in astrophysics* (2017)
G. Bouchard (LIDyL, Paris-Saclay), *High-harmonic generation* (2018)
F. Niel (LULI, UPMC), *QED processes at extreme light* (2018)
H. Kallala (MdlS, Paris-Saclay), *HPC-relevant Spectral solvers* (2019)
I. Zemzemi (LLR, Paris-Saclay), *Laser wakefield acceleration* (2020)

3 Postdoctoral fellows:

A. Sgattoni (LULI, UPMC), *Solar wind astrophysics* (since 2015)
F. Massimo (LULI, UPMC), *Laser wakefield acceleration* (from 2017)
S. Marini (LULI, UPMC), *Surface plasma waves* (from 2018)

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11 papers in peer-reviewed international journals

Dérouillat *et al.*, Comp. Phys. Comm. (2017)

Grassi *et al.*, Phys. Rev. E (2017)a

Niel *et al.*, arXiv:1705.05402 (2017)

Dargent *et al.*, J. Geophys. Res.: Space Phys. (2017)

Grassi *et al.*, Phys. Rev. E (2017)b

Dargent *et al.*, J. Plasma Phys. (2016)

Chiaramello *et al.*, Phys. Plasmas (2016)

Beck *et al.*, Nucl. Inst. Meth. in Phys. A (2016)

Lancia *et al.*, Phys. Rev. Lett. (2016)

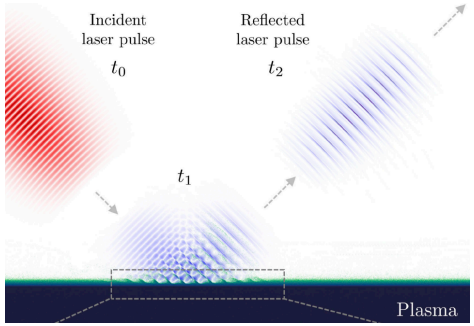
Golovanov *et al.*, Phys. Plasmas (2017)

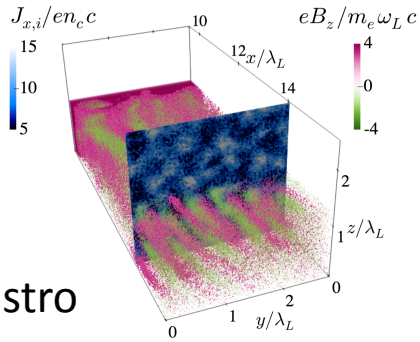
Fedeli *et al.*, Phys. Plasmas Control. Fusion (2017)

Current physics studies & HPC ressources

Laser plasma interaction

- short pulse amplification
- high-harmonic generation
- laser wakefield acceleration
- high-field physics & QED processes



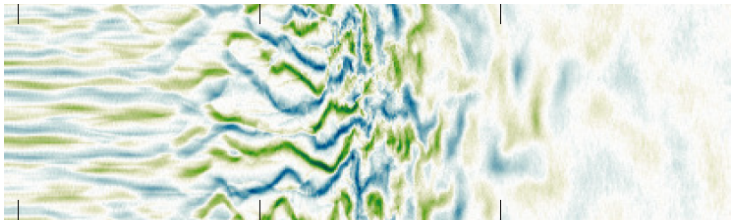


Laboratory astrophysics

- radio burst type III
- collisionless shocks: toward relativistic astro

Astrophysics

- magnetic reconnection
- earth bow shock
- relativistic collisionless shocks



HPC resources

- 2 Grand Challenges: IDRIS 2015 (Turing BG/Q) 13 Mh, CINES/Occigen (2016) 14 Mh
- LAser PLasma Accelerator for Cilex & Eurpraxia (12 Mh for SMILEI)
- 3 years in GENCI calls: LULI (5 Mh/yr), IRAMIS (2 Mh/yr), LLR (>2 Mh/yr)

Ongoing developments

Advanced boundary conditions for EM fields

- FDTD/PML
- Tightly focused pulses

Additional physics modules

- Incoherent/coherent high-energy radiation package
- Bremsstrahlung
- Pair production processes in Coulomb fields (Bethe-Heitler & Trident processes)

LULI: M. Grech, F. Niel, F. Pérez, T. Vinci

Coupling to the PICSAR library

HPC-relevant pseudo spectral methods for Maxwell's equations

MdlS: J. Dérouillat & H. Kallala, IRAMIS: H. Vincenti

Quasi-axisymmetric geometry

Wakefield acceleration studies

LLR: A. Beck, I. Zemzemi, F. Massimo

Acknowledgments

Partners: directly involved in developing SMILEI

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