Exascale Laser Plasma Physics - From Computational Speed to Predictions

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Since the very beginning, simulations have been an integral part of laser plasma research. With the advance of high-power lasers, non-linear effects on ultra-short time scales require extensive control in experimental setups, theoretical assumptions and simulation stability alike. For the latter, Particle-in-Cell simulations have been established as a scalable method to cover kinetic effects with long-range potentials at affordable computational costs.

Within the next years, supercomputers with the capability of calculating an ExaFlop/s will emerge for the scientific community. In order to fit in a power-envelope of approximately 10 MW per system, traditional computing architectures are replaced with highly parallel, RISC architectures that demanded a reinvention of our algorithms for a higher degree of parallelism. Driven by the urge to exploit these computational advances for precise modeling efforts, zero-cost methodological abstraction, cross-discipline collaboration, and the urgent need for reproducibility in simulation methods initiate a dawn of open source science and shared, data-intensive workflows.

Since 2013, the PIConGPU community converts that immense computational potential into robust predictions for laser plasma interaction within an open environment. We present our contemporary approaches to laser plasma modeling, starting from fast turn-around simulations to modeling of multi-physics effects to experimental uncertainty approximation, charging current and future challenges in our domain. Especially for high energy density plasmas, full-geometry runs in wide parameter spaces drive our long-term strategic developments, involving proper initial conditions under realistic laser contrasts and profiles, and stable modeling under extreme conditions such as X-FEL probe beams.

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