

Shocks, Interfaces and Flames Using Lattice Boltzmann Methods

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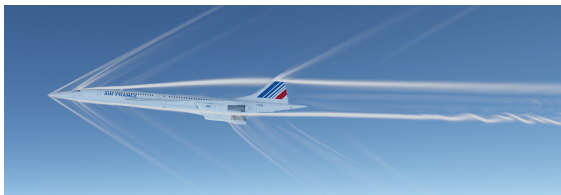
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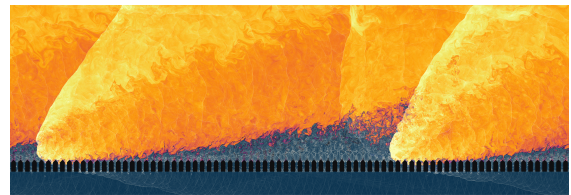
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ABSTRACT

Regarding Lattice Boltzmann Methods as a part of relaxation systems, arbitrary conservation laws needed for complex high-end engineering applications can be approximated [1]. By re-defining collision operators and utilizing advanced relaxation models, multi-population LBM efficiently handles extreme gradients and complex multiphysics interactions previously challenging for standard LBM formulations. We demonstrate the capability and versatility of this approach across diverse flow regimes, all implemented within the OpenLB framework [3]. Benchmarks and real-world applications include transonic turbulence via the Taylor-Green Vortex, highly compressible shock tubes [4], combustion and magnetohydrodynamic plasma flows [5]. Furthermore, we showcase industrial and astrophysical applications involving complex boundaries and phase interfaces, including asteroid interaction with solar wind [5], bubble columns, turbulent jets and rocket engines. This unified lattice relaxation approach provides excellent scalability and stability for multi-physics simulations on heterogeneous architectures [3].



Concorde at cruise (compressible Navier–Stokes).



Rotating detonation (reactive flow).

Fedor Bukreev is a mechanical engineer and researcher at the Karlsruhe Institute of Technology (KIT), working in the Lattice Boltzmann Research Group (LBRG). He studied mechanical engineering at RWTH Aachen University and Ruhr University Bochum before joining KIT in 2020, and completed his doctorate (Dr.-Ing.) in 2025 on the numerical investigation of crystallization processes using Lattice Boltzmann Methods (LBM). His research covers computational fluid dynamics, multiphase and reactive flows, chemical and electrochemical processes in porous materials, turbulent flows, and microfluidics, with a focus on high-performance simulation. He leads the LBRG Engineering Lab, which uses OpenLB to simulate complex engineering applications.

Adrian Kummerländer is a mathematician and software developer at the Karlsruhe Institute of Technology (KIT), working in the Lattice Boltzmann Research Group (LBRG). He holds a master's in mathematics from KIT and is pursuing a doctorate there. His research develops efficient numerical methods, including fluid-structure interaction and the automatic derivation of solvers from their governing equations. He is a core author of OpenLB, a widely used open-source C++ framework for multi-physics simulation using Lattice Boltzmann Methods. He contributes across the entire codebase, foremost its platform-transparent compute backend for CPUs and GPUs.

References

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