First Annual Meeting of the

# Gitter-Boltzmann-Arbeitskreis (GBA)

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Proceedings

Book of Abstracts

13–14 October 2026

Karlsruhe Institute of Technology (KIT)
Karlsruhe, Germany

# PROGRAM

Karlsruhe Institute of Technology, Karlsruhe, Germany

Conference dinner (self-paid): 13 October 2026, 19:00, Pizzeria Il Caminetto

**Venue:** KIT, Building. 20.30, Seminar Room 1.067, Englerstraße 2, 76131 Karlsruhe

**Tuesday, 13 October 2026**

| Time | Item | Speaker |
|---|---|---|
| 12:00–12:20 | *Arrival, registration and coffee* | |
| 12:20–12:30 | Opening | Mathias J. Krause |
| **Method Development** | | **Chair: Martin Geier** |
| 12:30–12:50 | *The Frequency-Domain Lattice Boltzmann Method (FreqD-LBM): A Versatile Tool to Predict the QCM Response Induced by Structured Samples* | Diethelm Johannsmann |
| 12:50–13:10 | *Closed-Form Solution for Oscillatory Flow and Wall Shear Stress in Axisymmetric Corrugated Tubes* | Frederik Keil |
| 13:10–13:30 | *A Phase-Field Based Lattice Boltzmann Model for Multiphase and Multicomponent Fluids in the Capillary Regime* | Esteban Castro-Ávila |
| 13:30–13:50 | *Probabilistic Lattice Boltzmann Methods* | Stephan Simonis |
| 13:50–14:20 | *Coffee break* | |
| **Solid Mechanics** | | **Chair: Stephan Simonis** |
| 14:20–14:40 | *Multigrid LBM for 3D Elastostatics* | Oliver Boolakee |
| 14:40–15:00 | *Lattice Boltzmann Method for Solids: High-Performance 3D Elastodynamics Solver using NVIDIA Warp* | Julie Weverbergh |
| 15:00–15:20 | *Gradient-based Optimization with Lattice Boltzmann Methods for Solid Mechanics* | Johannes Grafen |
| 15:20–15:40 | *Towards a Lattice-Boltzmann Monolithic Approach for Fluid Structure Interactions* | Andreas Nettekoven |
| 15:40–16:10 | *Coffee break & group photo* | |
| **Multiphase and Particle-Laden Flows** | | **Chair: Fedor Bukreev** |
| 16:10–16:30 | *From Drying of Catalyst Ink to Bubble Dynamics in Porous Structures: Lattice Boltzmann Simulations for Water Electrolysis* | Qingguang Xie |
| 16:30–16:50 | *Effective Stresses Analyses in Unsaturated Granular Material via Multifluid LBM-DEM Coupling* | Clara M. Toffoli |
| 16:50–17:10 | *Stability Boundaries of Conservative Allen-Cahn Multiphase Simulations* | Tikhon Riazantsev |
| 17:10–17:30 | *Formation and Rheology of Particle-stabilized Emulsions* | Aaron De Clercq |
| 17:30–19:00 | *Open discussion / joint activities* | |
| 19:00 | *Conference dinner* | |

**Wednesday, 14 October 2026**

| Time | Item | Speaker |
|---|---|---|
| **Aeroacoustics and Compressible Flows** | | **Chair: Adrian Kummerländer** |
| 09:00–09:20 | *Direct Aeroacoustic Simulations with Lattice Boltzmann Methods* | Andreas Schneider / Claus Feuchter |
| 09:20–09:40 | *Aeroacoustics and Supersonic Flow at the University of Siegen and Bonn-Rhein-Sieg University of Applied Sciences* | Philipp Spelten |
| 09:40–10:00 | *Towards Realistic Airframe Noise Prediction: LBM Simulations at High Reynolds and Mach Numbers* | Malav Soni |
| 10:00–10:30 | *Coffee break* | |
| **High-performance Computing and Software** | | **Chair: Jens Harting** |
| 10:30–10:50 | *Lattice Boltzmann @ iRMB* | Martin Geier |
| 10:50–11:10 | *Coupling waLBerla and ESPResSo for Coarse-Grained Modelling of Particles and Flows* | Rudolf Weeber |
| 11:10–11:30 | *Offshore Aerodynamics across Accelerators with Platform-Transparent Lattice Boltzmann Methods* | Adrian Kummerländer |
| 11:30–12:00 | Closing discussion, open points and next meeting | Mathias J. Krause |
| 12:00 | *End of the meeting* | |

**Notes**

- Talks are 15 minutes + 5 minutes for questions.
- Registration for the conference dinner by 12 October.
- For adaptations to the program contact johannes.grafen@kit.edu.

# Contents

**Program** **1**

**Tuesday, 13 October 2026** **4**
**Method Development** . . . . . 4
The Frequency-Domain Lattice Boltzmann Method (FreqD-LBM): A Versatile Tool to Predict the QCM Response Induced by Structured Samples
*Diethelm Johannsmann, Paul Häusner, Arne Langhoff, Christian Leppin, Ilya Reviakine, Viktor Vanoppen* . . . . . 4
Closed-Form Solution for Oscillatory Flow and Wall Shear Stress in Axisymmetric Corrugated Tubes
*Frederik Keil* . . . . . 5
A Phase-Field Based Lattice Boltzmann Model for Multiphase and Multicomponent Fluids in the Capillary Regime
*Esteban Castro-Ávila* . . . . . 6
Probabilistic Lattice Boltzmann Methods
*Stephan Simonis* . . . . . 7
**Solid Mechanics** . . . . . 8
Multigrid LBM for 3D Elastostatics
*Oliver Boolakee, Julie Weverbergh, Martin Geier, Laura De Lorenzis* . . . . . 8
Lattice Boltzmann Method for Solids: High-Performance 3D Elastodynamics Solver using NVIDIA Warp
*Julie Weverbergh, Oliver Boolakee, Martin Geier, Laura De Lorenzis* . . . . . 9
Gradient-based Optimization with Lattice Boltzmann Methods for Solid Mechanics
*Johannes Grafen, Florian Kaiser, Stephan Simonis, Shota Ito, Mathias J. Krause* . . . . . 10
Towards a Lattice-Boltzmann Monolithic Approach for Fluid Structure Interactions
*Andreas Nettekoven* . . . . . 12
**Multiphase and Particle-Laden Flows** . . . . . 13
From Drying of Catalyst Ink to Bubble Dynamics in Porous Structures: Lattice Boltzmann Simulations for Water Electrolysis
*Qingguang Xie, Jens Harting* . . . . . 13
Effective Stresses Analyses in Unsaturated Granular Material via Multifluid LBM-DEM Coupling
*Clara M. Toffoli, Sina Sadeghi, Reihaneh Hosseini, Jürgen Grabe* . . . . . 14
Stability Boundaries of Conservative Allen-Cahn Multiphase Simulations
*Tikhon Riazantsev* . . . . . 15
Formation and Rheology of Particle-stabilized Emulsions
*Aaron De Clercq* . . . . . 16

**Wednesday, 14 October 2026** **17**
**Aeroacoustics and Compressible Flows** . . . . . 17
Direct Aeroacoustic Simulations with Lattice Boltzmann Methods
*Andreas Schneider, Claus Feuchter* . . . . . 17
Aeroacoustics and Supersonic Flow at the University of Siegen and Bonn-Rhein-Sieg University of Applied Sciences
*Philipp Spelten, Mario Christopher Bedrunka, Ben Picard, Holger Foysi, Dirk Reith* . . . . . 18
Towards Realistic Airframe Noise Prediction: LBM Simulations at High Reynolds and Mach Numbers
*Malav Soni, Roland Ewert* . . . . . 21
**High-performance Computing and Software** . . . . . 22

Lattice Boltzmann @ iRMB
*Martin Geier, Konstantin Kutscher, Martin Schönherr, Ang Ye, Patricio Yescas Frangos* . . . 22
Coupling waLBerla and ESPResSo for Coarse-Grained Modelling of Particles and Flows
*Jean-Noël Grad, Ingo Tischler, Alexander Reinauer, Hideki Kobayashi, Michael Kuron, Frederik Hennig, Markus Holzer, Christian Holm, Rudolf Weeber* . . . . . 23
Offshore Aerodynamics across Accelerators with Platform-Transparent Lattice Boltzmann Methods
*Adrian Kummerländer, Fedor Bukreev, Leonardo Dorneles, Marcio Dorn, Shota Ito, Neale A. Watson, Ieuan Owen, Mathias J. Krause* . . . . . 25

# The Frequency-Domain Lattice Boltzmann Method (FreqD-LBM): A Versatile Tool to Predict the QCM Response Induced by Structured Samples

*Diethelm Johannsmann* [*a], *Paul Häusner,* [b] *Arne Langhoff* [a], *Christian Leppin,* [a,c] *Ilya Reviakine,* [d] *Viktor Vanoppen* [b]

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## Abstract

The quartz crystal microbalance with dissipation monitoring (QCM-D) is routinely used to investigate structured samples. Here, a simulation technique is described, that predicts the shifts of frequency and half bandwidth, $\Delta f_n$ and $\Delta\Gamma_n$, of a quartz resonator operating on different overtone orders, $n$, induced by structured samples in contact with the resonator surface in liquid. The technique, abbreviated as FreqD-LBM, solves the Stokes equation in the frequency domain. The solution provides the complex amplitude of the area-averaged tangential stress at the resonator surface, from which $\Delta f_n$ and $\Delta\Gamma_n$ are derived. Because the dynamical variables are complex amplitudes, the viscosity can be complex, as well. The technique naturally covers viscoelasticity. Limitations are linked to the grid resolution and to problems at large viscosity. Validation steps include viscoelastic films, rough surfaces, an oscillating cylinder in a viscous medium, and a free-floating sphere above the resonator. Application examples are soft adsorbed particles, stiff adsorbed particles, and a large, immobile spherical cap above the resonator, which allows to study the high-frequency properties of the material in the gap. Freq-DLBM runs on an office PC and does not require expert knowledge of numerical techniques. It is accessible to an experimentalist.

## References

Johannsmann, Diethelm, Paul Häusner, Arne Langhoff, Christian Leppin, Ilya Reviakine, und Viktor Vanoppen. „The Frequency-Domain Lattice Boltzmann Method (FreqD-LBM): A Versatile Tool to Predict the QCM Response Induced by Structured Samples“. *Advanced Theory and Simulations* 8, 7 (2025): 2401373. https://doi.org/10.1002/adts.202401373.

Sievers, Philipp, Arne Langhoff, und Diethelm Johannsmann. „Simulation of the QCM response to particle adsorption with varied degree of lateral clustering“. *Colloids and Surfaces A: Physicochemical and Engineering Aspects* 743 (2026): 140550. https://doi.org/10.1016/j.colsurfa.2026.140550.

# CLOSED-FORM SOLUTION FOR OSCILLATORY FLOW AND WALL SHEAR STRESS IN AXISYMMETRIC CORRUGATED TUBES

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Dinner Attendance (self-paid): ☒ Yes ☐ No

## ABSTRACT

Pulsatile flow in corrugated tubes arises in hemodynamics and microfluidics, where oscillatory forcing and geometric constrictions jointly determine transport and wall loading. We extend Womersley's classical solution for oscillatory flow in a rigid circular tube [1] to rigid axisymmetric tubes of slowly varying radius. Within the lubrication approximation, we derive closed-form expressions for the axial velocity profile, volumetric flow rate, phase lag, and wall shear stress at an arbitrary Womersley number. Three-dimensional lattice Boltzmann simulations are used to assess the regime of validity of the theory. The analysis shows that the local velocity profile varies strongly along the tube, ranging from plug-like in wide sections to more parabolic near bottlenecks. The cycle-maximum flow rate decreases with increasing corrugation, but this reduction weakens as pulsatility increases, reflecting a crossover from the quasi-steady scaling $\langle R^{-4}\rangle^{-1}$ to the high-frequency scaling $\langle R^{-2}\rangle^{-1}$. The wall shear stress is maximal at the bottleneck and decreases with Womersley number. For sinusoidal corrugations, the bottleneck wall shear stress depends non-monotonically on the corrugation because of the competition between local shear amplification and global hydraulic resistance. Closed-form expressions for the time-averaged wall shear stress and oscillatory shear index further connect the theory to standard hemodynamic metrics.

## REFERENCES

[1] Womersley J. R., *Method for the calculation of velocity, rate of flow and viscous drag in arteries when the pressure gradient is known*, J. Physiol., Vol. 127, pp. 553-563, 1955.

# A PHASE-FIELD BASED LATTICE BOLTZMANN MODEL FOR MULTIPHASE AND MULTICOMPONENT FLUIDS IN THE CAPILLARY REGIME

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Dinner Attendance (self-paid): ☒ Yes ☐ No

## ABSTRACT

In this work, we present a phase-field based lattice Boltzmann methodology to simulate multiphase and multicomponent fluid mixtures. We use an effective free energy model to reproduce the phase separation between two phases and between components. To simulate wetting phenomena on complex boundaries, the methodology incorporates a surface free energy penalty, based on the work from Ju et al. [1]. The model successfully reproduces the established phase separation behavior and coarsening kinetics of the single-component Flory-Huggins model [2]. For two-component systems, the methodology accurately recovers the Laplace law for both a droplet in its own vapor and a droplet submerged in a secondary liquid phase. Furthermore, dynamic validations recover the Taylor law of deformation for droplets in shear flows at low Capillary numbers, and static contact angles on flat substrates align precisely with theoretical predictions. Finally, complex three-phase scenarios are showcased, including liquid lens simulation, ternary spinodal decomposition and the nucleation of a gas bubble using a reactive substrate. These results demonstrate the model's capability to study the intricate multi-phase, multi-component reactive flows present in applications such as hydrogen electrolyzers.

## REFERENCES

[1] Ju, L., Guo, Z., Yan, B., Sun, S., *Implementation of contact line motion based on the phase-field lattice Boltzmann method*, Physical Review E, **109**, 045307, 2024.

[2] König, B., Ronsin, O.J.J., Harting, J., *Two-dimensional Cahn–Hilliard simulations for coarsening kinetics of spinodal decomposition in binary mixtures*, Phys. Chem. Chem. Phys., **23**, 24823-24833, 2021.

# PROBABILISTIC LATTICE BOLTZMANN METHODS

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Dinner Attendance (self-paid): ☐ Yes ☒ No

## ABSTRACT

Global well-posedness for three-dimensional fluid flow equations remains a profound open problem. Recent efforts have shifted toward statistical solutions as a robust and physically meaningful framework for describing turbulence; yet, efficient computational tools to explore these solutions in three dimensions are scarce. To this end, we develop novel probabilistic lattice Boltzmann methods to compute and analyze statistical solutions for three-dimensional incompressible fluid flows. We combine various types of lattice Boltzmann methods with probabilistic approaches, such as Monte Carlo [1] and stochastic Galerkin methods [2]. Through accelerated implementations on heterogeneous high-performance computers, we efficiently target application-relevant flow configurations. We present numerical results demonstrating the computational exploration of statistical solutions and their associated observables. We validate the Wasserstein convergence of these statistical measures in periodic regimes and demonstrate the computational feasibility of extracting statistical solutions for initial-boundary value problems where deterministic simulations are nonunique. Finally, we verify that the same pushforward construction extends to the compressible, inviscid regime as well [3]. Specific parts of the developed methodologies are implemented in the open-source framework OpenLB-UQ [4] to ensure public accessibility and sustainable reusability, enabling applications such as training generative diffusion models [5].

## REFERENCES

[1] Grafen J.L., Rohner, T., Simonis S., *Computing statistical Euler limits of the Navier–Stokes equations in three dimensions*, arXiv preprint, 2026, doi: 10.48550/arXiv.2608.23786.

[2] Zhong M., Xiao T., Krause M.J., Frank M., Simonis S., *A stochastic Galerkin lattice Boltzmann method for incompressible fluid flows with uncertainties*, Journal of Computational Physics, Vol. 517, p. 113344, 2024, doi: 10.1016/j.jcp.2024.113344.

[3] Simonis S., Wissocq G., *Computing statistical solutions of a Mach 2000 astrophysical jet*, arXiv preprint, 2026, doi: 10.48550/arXiv.2605.25282.

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# MULTIGRID LBM FOR 3D ELASTOSTATICS

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## ABSTRACT

Inspired by gas kinetic theory, the lattice Boltzmann method has emerged as a powerful alternative to conventional CFD methods. Specifically, the lattice Boltzmann method is well-known for its algorithmic simplicity, ease of parallelization and low numerical dissipation [1]. Adopting a more broad interpretation of the lattice Boltzmann method as a general-purpose discretization technique for partial differential equations, we seek to benefit from these advantageous properties in solid mechanics as well. In this spirit, we propose second-order accurate lattice Boltzmann formulations for both the linear elastostatic [2, 3] and elastodynamic [4] problems. In this contribution, we extend the linear elastostatics formulation for 3D problems. Additionally, the novel formulation is combined with a geometric multigrid algorithm, which significantly reduces the time until solution. The derivations are verified with a numerical convergence analysis and the performance as well as the multigrid acceleration is demonstrated on GPUs.

## REFERENCES

[1] Lallemand, P., Luo, L.-S., Krafczyk, M. and Yong, W.-A. The lattice Boltzmann method for nearly incompressible flows. *J. Comp. Phys.* (2021) **431**:109713.

[2] Boolakee, O., Geier, M. and De Lorenzis, L. A new lattice Boltzmann scheme for linear elastic solids: periodic problems. *Comp. Meth. Appl. Mech. Eng.* (2023) **404**:115756.

[3] Boolakee, O., Geier, M. and De Lorenzis, L. Dirichlet and Neumann boundary conditions for a lattice Boltzmann scheme for linear elastic solids on arbitrary domains. *Comp. Meth. Appl. Mech. Eng.* (2023) **415**:116225.

[4] Boolakee, O., Geier, M. and De Lorenzis, L. Lattice Boltzmann for linear elastodynamics: Periodic problems and Dirichlet boundary conditions. *Comp. Meth. Appl. Mech. Eng.* (2025) **433**:117469.

# LATTICE BOLTZMANN METHOD FOR SOLIDS: HIGH-PERFORMANCE 3D ELASTODYNAMICS SOLVER USING NVIDIA WARP

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Dinner Attendance (self-paid): ☒ Yes ☐ No

## ABSTRACT

The Lattice Boltzmann Method (LBM) has recently been developed to solve problems in solid mechanics, starting with linear elastostatics [1, 2] and continuing with linear elastodynamics [3] in two dimensions. Based on these works, we propose an extension of LBM for linear elastodynamics in three dimensions. Using the asymptotic expansion technique, we prove second-order consistency for periodic, Dirichlet and Neumann boundary conditions for 3D prismatic domains. The scheme is stable under a CFL-like condition. Numerical experiments are conducted to verify our theoretical derivations. Furthermore, we assess the computational performance on a GPU architecture using XLB [4], an accelerated Lattice Boltzmann library based on the NVIDIA Warp backend. We show that, for a prescribed relative L2 error in the stress field, the proposed LBM approach reaches the solution faster than a conventional explicit FEM scheme.

## REFERENCES

[1] Boolakee O., Geier M., De Lorenzis L., *A new lattice Boltzmann scheme for linear elastic solids: periodic problems*, Computer Methods in Applied Mechanics and Engineering, Vol. 404, pp. 115756, 2023

[2] Boolakee O., Geier M., De Lorenzis L., *Dirichlet and Neumann boundary conditions for a lattice Boltzmann scheme for linear elastic solids on arbitrary domains*, Computer Methods in Applied Mechanics and Engineering, Vol. 415, pp. 116225, 2023

[3] Boolakee O., Geier M., De Lorenzis L., *Lattice Boltzmann for linear elastodynamics: Periodic problems and Dirichlet boundary conditions*, Computer Methods in Applied Mechanics and Engineering, Vol. 433, pp. 117469, 2025

[4] Ataei M., Salehipour H., *XLB: A differentiable massively parallel lattice Boltzmann library in Python*, Computer Physics Communications, Vol. 300, pp. 109187, 2024

# GRADIENT-BASED OPTIMIZATION WITH LATTICE BOLTZMANN METHODS FOR SOLID MECHANICS

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Dinner Attendance (self-paid): ☒ Yes ☐ No

## ABSTRACT

Gradient-based optimization (GBO) of problems constrained by partial differential equations is central to optimal control, parameter identification and topology optimization in computational physics. Gradients can be computed with adjoint methods, where the cost is independent of the number of control variables, or with forward-mode automatic differentiation (f-AD), where the cost grows with the number of controls. The advantage of f-AD becomes clear for complex boundary conditions: while adjoint methods require the derivation of the adjount forumlation of the boundary conditions, f-AD differentiates them directly. The lattice Boltzmann method (LBM) is attractive in this context as it is computationally efficient, and its explicit operator-split formulation exposes the Jacobians needed for adjoint analysis [4]. Existing adjoint LBM approaches, however, mostly rely on manual, case-specific derivations, while generic AD frameworks often sacrifice performance.

We present a framework for GBO in the open-source library OpenLB [5] that offers both f-AD and adjoint approaches for gradient computation [4]. Discrete adjoint LBM (ALBM) collision kernels are generated automatically from their primal implementations. AD is applied locally to evaluate the adjoint Jacobians, and code generation with common subexpression elimination removes the overhead of AD tapes [4]. Alternatively, f-AD differentiates the primal solver directly by operator overloading.

We apply the framework to recently derived LBM schemes for linear elastic solids [1, 2] and propose the first optimization benchmarks for solid LBM [3]. These cover body force identification on a periodic domain, where f-AD and ALBM gradients are compared, and Young's modulus identification on an elliptic domain with Dirichlet and Neumann boundaries.

## REFERENCES

[1] Oliver Boolakee, Martin Geier, and Laura De Lorenzis. Dirichlet and Neumann boundary conditions for a lattice Boltzmann scheme for linear elastic solids on arbitrary domains. *Computer Methods in Applied Mechanics and Engineering*, 415:116225, October 2023.

[2] Oliver Boolakee, Martin Geier, and Laura De Lorenzis. A new lattice Boltzmann scheme for linear elastic solids: Periodic problems. *Computer Methods in Applied Mechanics and Engineering*, 404:115756, February 2023.

[3] Johannes L. Grafen, Florian Kaiser, Stephan Simonis, Shota Ito, and Mathias J. Krause. Benchmark cases for gradient-based optimization in linear elastic solid mechanics using lattice Boltzmann methods, September 2026.

[4] Shota Ito, Adrian Kummerländer, Julius Jeßberger, Johannes L. Grafen, Ecem Öz, Nicolas R. Gauger, Max Sagebaum, and Mathias J. Krause. Generation of efficient adjoint lattice Boltzmann methods with algorithmic differentiation, 2026.

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# TOWARDS A LATTICE-BOLTZMANN MONOLITHIC APPROACH FOR FLUID STRUCTURE INTERACTIONS

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Dinner Attendance (self-paid): ☒ Yes ☐ No

## ABSTRACT

We present a new approach to simulate entire fluid-structure interaction (FSI) problems in a monolithic way, leveraging only lattice Boltzmann methods (LBM). This innovative method couples a homogenized lattice Boltzmann scheme on the fluid side with the vector-based lattice Boltzmann scheme introduced by Boolakee et al. [1], for elastodynamics on the solid side. A new representation of moving surfaces is introduced, enabling the definition of arbitrary, movable geometries that serve as the coupling interface.

This approach is implemented entirely within the open-source LBM framework, openLB. To validate its effectiveness, the method is tested on a newly introduced numeric benchmark case specifically designed to evaluate the performance of explicitly coupled FSI solver combinations on linear elastodynmic problems. The results obtained from our LBM-based approach are compared against a traditional setup using OpenFOAM paired with the finite-element code deal.II, which are coupled through the coupling-library preCICE.

The results demonstrate that our new method exhibits strong convergence behavior and good agreement with the classical solver setup, highlighting its potential as a robust and efficient alternative for FSI simulations.

## REFERENCES

[1] “Lattice Boltzmann for linear elastodynamics: Periodic problems and Dirichlet boundary conditions”, Oliver Boolakee, Martin Geier, and Laura De Lorenzis, Computer Methods in Applied Mechanics and Engineering 433 (2025), p. 117469.

# From drying of catalyst ink to bubble dynamics in porous structures: lattice Boltzmann simulations for water electrolysis

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Dinner Attendance (self-paid): ☒ Yes ☐ No

Water electrolyzers play a crucial role in green hydrogen production for the energy transition. However, optimizing their performance requires a fundamental understanding of the complex processes involved in catalyst ink drying, as well as bubble formation and transport within porous electrodes. We employ lattice Boltzmann simulations to investigate the drying dynamics of particle suspension films. We develop theoretical models to predict surface coverage fractions for monolayer deposits [1] and characterize the porous properties of multilayer deposits under varying particle-particle interactions. Additionally, we study the dynamics of bubble nucleation [2], growth and detachment at catalytic surfaces. Our results show that the departure radius of bubbles growing on both horizontal and vertical surfaces aligns well with theoretical predictions. Beyond detachment, we analyze the subsequent transport of bubbles through a porous transport layer, systematically evaluating transport efficiency by considering key factors such as reaction rates and pore wettability. Our findings offer valuable insights for optimizing the design of porous structures, potentially leading to enhanced electrolyzer performance and improved efficiency in other gas-evolving systems.

## References

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# EFFECTIVE STRESSES ANALYSES IN UNSATURATED GRANULAR MATERIAL VIA MULTIFLUID LBM-DEM COUPLING

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Dinner Attendance (self-paid): ☒ Yes ☐ No

## ABSTRACT

Building on previous work comparing multiphase Lattice Boltzmann Method (LBM) models for unsaturated granular materials [1], we develop a coupled LBM–Discrete Element Method (DEM) framework to investigate effective stress in partially saturated granular systems. The gas and liquid phases are modeled using an in-house multiphase Shan–Chen LBM, while particle dynamics are resolved using the open-source DEM solver Yade [2]. Two-way coupling is achieved using a momentum exchange method, with particles initially represented as spherical. The framework enables direct resolution of fluid distribution within the pore space, allowing computation of capillary forces arising from surface tension and suction (defined as the difference between gas and liquid pressures, respectively $u_a$ and $u_w$). These forces play a central role in the effective stress ($\sigma'$) of unsaturated soils, where Bishop's parameter $\chi$ [3] is commonly introduced, as shown in Eq. 1. This term is employed specifically for unsaturated media, not being present for fully saturated materials, context in which the concept of subtracting water pore-pressure ($u_w$) from total stress ($\sigma$) was initially developed. Because of that, Bishop's factor remains poorly understood in terms of its dependence on saturation, permeability, and grain-scale properties.

$$\sigma' = \sigma - u_a + \chi(u_a - u_w) \tag{1}$$

Preliminary results of this study demonstrate stable coupling between the methods and consistent fluid–particle interaction. The ongoing work focuses on quantitative analysis of capillary effects and their contribution to effective stress, in an environment in which grains are allowed to move. The proposed approach provides a pore-scale numerical tool for investigating unsaturated granular materials, with future applications in unsaturated geotechnical systems such as slopes, pavements, and tailings storage facilities.

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# STABILITY BOUNDARIES OF CONSERVATIVE ALLEN-CAHN MULTIPHASE SIMULATIONS

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## ABSTRACT

Phase-field lattice Boltzmann models built on the conservative Allen–Cahn (CAC) equation have become a standard route to immiscible two-phase flow at liquid–gas density ratios. In the widely used formulation of Liang et al. (2018), two coupled lattices are advanced: a CAC lattice, whose relaxation time $\tau_f$ sets the interface mobility, and an incompressible Navier–Stokes lattice, whose relaxation time $\tau_g$ sets the viscosity. For a given physical problem both remain free numerical choices, and in practice they are found by trial and error. Published studies report the pair that worked. The pairs that diverged, or ran stably but inaccurately, are rarely documented, so anyone pushing such a solver to higher Reynolds numbers rediscovers its limits one crashed run at a time.

This talk maps those limits. The Liang model, with the equilibrium and forcing corrections of Otomo et al. (2019), is implemented in the open-source framework OpenLB. It is first validated against the quantitative rising-bubble benchmark of Hysing et al. (2009) at density ratios of 10 and 1000. We then turn to a dense drop launched into quiescent gas at the water–air density ratio in a periodic domain, the elementary setting of jets, sprays and sloshing, where liquid moves relative to gas. We sweep the $(\tau_f, \tau_g)$ plane at fixed resolution and interface thickness for $\mathrm{Re} \in \{100, 1000, 5000\}$, with both the BGK and the regularized collision operator. Every point is classified as stable or diverged, with points on the stability boundary examined and classified.

We show how the stable window contracts as the Reynolds number increases, and whether lowering $\tau_g$ to keep the Mach number down drives spurious momentum transfer from the liquid into the gas at high cell Reynolds numbers. We also show how much of the window the regularized operator recovers relative to BGK. The result is a set of practical guidelines for choosing $\tau_f$ and $\tau_g$ in conservative Allen–Cahn simulations. The case files will be released so that the maps can be reproduced and extended to other configurations.

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# FORMATION AND RHEOLOGY OF PARTICLE-STABILIZED EMULSIONS

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## ABSTRACT

Adsorption of solid particles at an interface between two immiscible fluids yields highly stable biphasic materials. Their resistance to mechanical stress make particle-stabilized emulsions promising candidates as a biopesticide carriers, with the potential to endure severe shear during spraying.

However, predicting how formulation parameters—such as fluid-fluid ratio, particle volume fraction and particle wetting properties—determine the material's rheological properties remains a key challenge. To establish these links, we perform Color-Gradient Lattice-Boltzmann simulations to systematically characterize the structural formation and rheological response of particle-stabilized emulsions across varying formulation parameters.

Spinodal decomposition simulations of a random mixture of two immiscible fluids with suspended particles reveal that the interplay between fluid-fluid ratio and particle contact angle dictates the structural topology and stability, while the particle volume fraction controls the domain size. Specifically, fluid ratios close to 1:1 combined with a neutrally wetting particles yield stable bicontinuous structures, whereas asymmetric fluid ratios and non-neutral contact angles result in the formation of discrete particle-stabilized droplets. Furthermore, initial rheological characterization under simple shear demonstrates pronounced shear-thinning behaviour, providing a proof of concept for the prediction of how formulation parameters influence the materials rheological properties.

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# DIRECT AEROACOUSTIC SIMULATIONS WITH LATTICE BOLTZMANN METHODS

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Dinner Attendance (self-paid): ☒ Yes ☐ No

## ABSTRACT

The direct simulation of aeroacoustic phenomena, also known as direct noise computation (DNC), remains one of the major challenges in computational aeroacoustics (CAA) to this day. In this context, modern Lattice Boltzmann methods have proven to be extremely efficient, particularly in terms of computation time, stability, and accuracy. The Lattice Boltzmann Method (LBM) is a numerical method for solving the compressible Navier-Stokes equations at low Mach numbers, i.e., for weakly compressible flows, which can be demonstrated using the Chapman-Enskog expansion. The LBM is characterized by low numerical dissipation and dispersion and is therefore suitable for direct noise calculations. The presentation first introduces some specifics of the LBM and its implementation, such as collision models, grid refinement, and rotating reference frames. The influence of these numerical components on DNC will also be discussed. Finally, the capabilities and the potential of the LBM will be analyzed based on calculation results for simulation cases of engineering interest or from an industrial context.

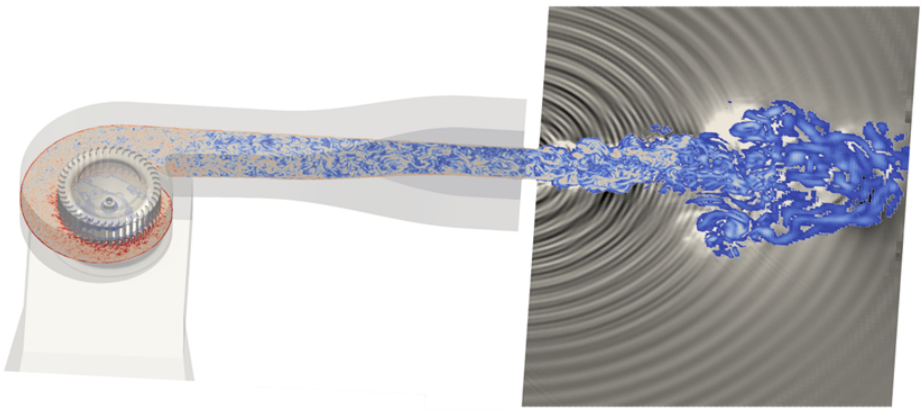

**Figure 1**: Jet & Sound Propagation into Plenum (Colored: Vorticity; Grayscale: Static Pressure) [1]

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# AEROACOUSTICS AND SUPERSONIC FLOW AT THE UNIVERSITY OF SIEGEN AND BONN-RHEIN-SIEG UNIVERSITY OF APPLIED SCIENCES

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Dinner Attendance (self-paid): ☒ Yes ☐ No

## ABSTRACT

The presentation will cover the latest findings in the supersonic regime for a 2D NACA-0012 test case and the benchmarking of non-reflecting boundary conditions.

**Aeroacoustics** Non-reflecting boundary conditions are indispensable for simulating aeroacoustic phenomena. In the LBM, a number of such boundary conditions exist, such as the characteristic boundary condition (CBC) [1] or absorbing boundary conditions [2, 3]. The presentation compares the results of different boundary conditions in a series of benchmark cases (convected Gaussian pulse [4], convected vortex [1, 5], and many more).

**Supersonic Flow** In the simulation of supersonic flows, using adaptations of the LBM, the case of a 2D NACA-0012 airfoil at Mach 1.5 and Reynolds number 10000 is a standard test case. The presentation compares the results of the Semi-Lagrangian LBM (SLLBM) [6] with the results of other LBM adaptations [7, 8, 9], as well as with the finite volume method (FVM) in `OpenFOAM` [10].

**Background** The research group of the University of Siegen (USi) and Bonn-Rhein-Sieg University of Applied Sciences (HBRS) has been working with lattice Boltzmann methods for a decade. Its focus lies on method development and on applications in the energy transition and climate adaptation. Current research directions of the group are:

- **Aeroacoustics** In the open-source code `OpenLB` [11], (aero-)acoustic benchmark cases are used to test non-reflecting boundary conditions against each other. The goal is the aeroacoustic simulation and optimization of the trailing-edge noise of a wind turbine airfoil [12].
- **Supersonic Compressible LBM** In the Semi-Lagrangian LBM (SLLBM), the streaming step is solved by interpolation from the equidistant Cartesian grid [13]. This allows cubature rules to be used to reduce the number of distribution functions [14]. The method is implemented in the open-source code `NATriuM` [15]. Most recently, several test cases in the supersonic regime and with strong compressibility effects have been demonstrated [6].
- **Augmenting the LBM with neural networks**

  - *Neural Collision Operator (NCO)* A convolutional neural network prescribes the relaxation times of the higher-order moments based on the distribution functions $f_i$. For example, it reproduces the energy spectrum and the dissipation of the Taylor-Green vortex better than other common collision operators. [16]
  - *Neural Boundary Condition (NBC)* A neural network is used to serve as an outlet boundary condition. In the wake of a cylinder, it avoids reflections better than the characteristic boundary condition (CBC) and drastically reduces the required domain size. [17]

- **Development of LBM code** The research group has created and maintains two LBM implementations:
  - **`lettuce`** [18]
  - **`NATriuM`** [15]

- **Urban Flows** In the open-source code `lettuce`, forward-mode gradients were used to compute the sensitivity of flows around a house geometry [19]. In addition, a multi-fidelity approach is being developed to provide different levels of granularity for urban planning in the areas of pollutant dispersion and cold-air flows for climate adaptation.

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**First Annual Meeting of the Gitter-Boltzmann-Arbeitskreis (GBA)**
**13–14 October 2026, Karlsruhe Institute of Technology (KIT), Germany**

# TOWARDS REALISTIC AIRFRAME NOISE PREDICTION: LBM SIMULATIONS AT HIGH REYNOLDS AND MACH NUMBER

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Dinner Attendance (self-paid): ☒ Yes ☐ No

## ABSTRACT

Airframe noise from high-lift devices and landing gear is a major contributor to aircraft noise during approach and landing. Accurate prediction requires resolving unsteady, complex flows at high Reynolds numbers and moderate Mach numbers; conditions that challenge conventional methods. This work presents a comprehensive LBM-based study using the ProLB solver to simulate airframe noise from key components: high-lift wings, slat tracks, and complex landing gear configurations. Wall-modelled LES (WM-LES) simulations are conducted at Reynolds numbers up to $10^7$ and Mach numbers up to 0.2, capturing the flow unsteadiness responsible for noise generation. A Direct Noise Computation (DNC) approach is employed that aims at resolving flow and acoustics simultaneously within one computation up to the microphone positions in the far-field. Comparison of numerical results with measurements reveal a close to accurate prediction of both aerodynamic and acoustic quantities. The LBM framework demonstrates robustness in handling complex geometries and high-fidelity flow physics, enabling accurate prediction of both broadband and tonal noise components. These results highlight the potential of LBM as a scalable, physics-based tool for advancing realistic airframe noise prediction; a critical step toward quieter aircraft design.

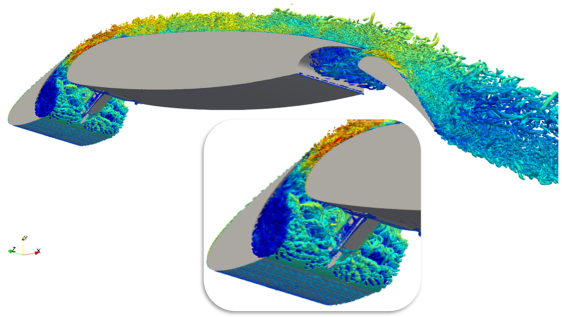

Figure 1: F16 high-lift wing section with slat-track, Q-criterion colored with velocity magnitude (m/s)

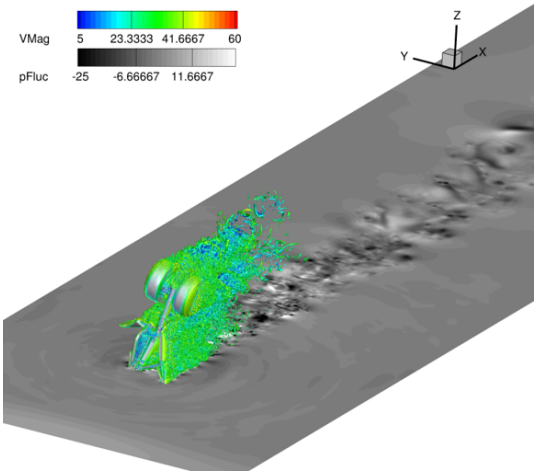


Figure 2: Main landing gear, Q-criterion colored with velocity magnitude (m/s) and sound pressure fluctuations (Pa)

# LATTICE BOLTZMANN @ IRMB

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Dinner Attendance (self-paid): ☒ Yes ☐ No

## ABSTRACT

The Institute for Computational Modeling in Civil Engineering (iRMB) has been engaged in the development and implementation of new lattice Boltzmann models for 25 years. This presentation will briefly review the theory of the cumulant lattice Boltzmann method [1], which is the workhorse in our open source Lattice Boltzmann solver VirtualFluids [2]. Some technical aspects of VirtualFluids regarding the EsoTwist and EsoSplit population handling will be discussed. The presentation will also cover some of the online teaching resources on the lattice Boltzmann method provided by the iRMB, including full lectures and shorter videos explaining one topic at a time.

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# COUPLING WALBERLA AND ESPRESSO FOR COARSE-GRAINED MODELLING OF PARTICLES AND FLOWS

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## ABSTRACT

ESPResSo is an open-source package for coarse-grained particle simulations in soft matter, statistical and biological physics, and process engineering [1]. On the mesoscale, a solvent is often present, and the hydrodynamic interactions it mediates govern the particle dynamics, as, e.g., in biofilm initiation in porous media flow [2] or nanoparticle–polymer coupling in magnetic gels [3]. Such models commonly couple molecular dynamics for the particles with the lattice-Boltzmann (LB) method for the solvent.

For a code centred on particle methods, maintaining a custom LB implementation is costly: accuracy, performance, and portability across CPU and GPU architectures must be sustained by developers whose work does not necessarily focus on LBM, and customising the method or adding coupled solvers, e.g., for electrokinetics, adds to that cost.

We therefore coupled ESPResSo to waLBerla, an established HPC framework for LB and other stencil methods. Our choice was guided by the proven scalability of waLBerla and its automated code generation capabilities: waLBerla's companion packages pystencils and lbmpy translate the mathematical definition of a stencil method's fields and kernels into hardware-adapted C++ or CUDA kernels [4]. In this way, ESPResSo obtains consistent CPU and GPU implementations of LB, and of a finite-volume solver for electrokinetics [5], from largely one code base, and gained multi-GPU support for those solvers. Due to the automated code generation, method changes largely stay at the level of the method definition; thermal fluctuations and Lees–Edwards boundary conditions were added this way. Two-component flows coupled to particles, based on the colour-gradient method, are currently being added.

On a technical level, the coupling is implemented as a bridge library that hides waLBerla behind a narrow interface and is largely independent of ESPResSo. This opens the way for re-use in other MD codes as is currently done by the National Institute of Chemistry in Ljubljana for open-boundary molecular dynamics in LAMMPS.

The multi-GPU support for lattice-Boltzmann required changes on the particle side which currently runs on the CPU. To avoid GPU contention, only one MPI rank per GPU should be launched. Therefore to fully use the remaining CPU cores for the particle side, shared-memory parallelism needs to be used. This was introduced to ESPResSo via the performance portability frameworks Kokkos and Cabana, which will also allow for GPU-offloading of the particle-side in the future. With these changes, weak-scaling multi-GPU benchmarks on MareNostrum 5 give 96% parallel efficiency for LB, 84% with a coupled diffusion-advection-reaction solver for solutes, and 70% for a coupled, highly dilute suspension of particles [6]. Further work now focusses on the particle side, to improve scalability for dense systems.

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# OFFSHORE AERODYNAMICS ACROSS ACCELERATORS WITH PLATFORM-TRANSPARENT LATTICE BOLTZMANN METHODS

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Dinner Attendance (self-paid): ☒ Yes ☐ No

## ABSTRACT

Offshore wind raises two flow problems: turbine wakes that cost energy, and platform airwakes that limit helicopter access. We address both with wall-modeled large eddy simulations (LES) in OpenLB. These use a homogenized lattice Boltzmann method in which moving blades and complex walls enter through a porosity field instead of a body-fitted mesh. On a model rotor, the method predicts thrust within 5.6% at a resolution coarser than an actuator line that misses by 14% [1]. For the helideck of a generic offshore platform, a statically refined grid of 1.3 billion cells runs on a single node with four H200s. It reaches the same CAP 437 safety verdict as a delayed detached eddy simulation (DDES) on 128 CPU cores, about 100 times faster per simulated second [2]. All models are implemented using OpenLB's hardware abstraction layer and run unchanged on AMD, NVIDIA and Intel GPUs as well as CPUs. A rotor-resolved wind farm of 5.94 trillion cells reaches 51.2 trillion cell updates per second on 12,288 GPUs of Aurora [3].

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