Spectral Simulation of Light Propagation in Participating Media by Using a Lattice Boltzmann Method for Photons

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Abstract

For engineering of photocatalytic or photosynthetic reaction systems, local reaction rates need to be known, which depend directly on the spatial distribution of light intensity [1,2]. Usually, in such systems fluids are present and light propagation depends on their local optical properties, which again are affected by transport of scattering, absorbing or emitting substances in the fluid. The kinetic equation for photons is the Radiation Transfer Equation (RTE), which is a Boltzmann-type transport equation [3]. To solve the RTE, different numerical methods can be applied. However, these methods cause either high computational costs or require different numerical grids from those used in Computational Fluid Dynamics. Thus, the interpolation of information between different grids becomes a necessity for the determination of optical properties of fluids. A new approach is to use lattice Boltzmann methods to calculate radiative transfer [4,5]. Those methods potentially enable the usage of the same grids for the calculation of flow and radiative fields. Recently, a new lattice Boltzmann method was presented to solve the monochromatic RTE in three dimensions in isotropically and anisotropically scattering media [6]. The subject of the present contribution is the extension of this method to spectral simulations of light. In the frequency space, photons equilibrate by interaction with matter via absorption and isotropic emission. In contrast to gases, the equilibrium distribution is given by a Planck distribution. The method is implemented by discretizing the frequency space into discrete frequency bands with constant optical properties. Photons in the discretized frequency space are computed in parallel to calculate local temperatures and thermal equilibrium states.

References

1. M. R. Hoffmann and S. T. Martin and W. Choi and D. W. Bahnemann. Environmental Applications of Semiconductor Photocatalysis. Chem. Rev. 95 (1995) 69-96.
2. A. D. Jassby and T. Platt. Mathematical formulation of the relationship between photosynthesis and light for phytoplankton. Limnol. Oceanogr. 21 (1976) 540-547.
3. J. Oxenius. Kinetic Theory of Particles and Photons. Springer (1986).
4. Y. Ma and S. K. Dong and H. P. Tan. Lattice Boltzmann method for one-dimensional radiation transfer. Phys. Rev. E 84 (2011) 016704.
5. H. Bindra and D.V. Patil. Radiative or neutron transport modeling using a lattice Boltzmann equation framework. Phys. Rev. E 86 (2012) 016706.
6. C. McHardy and T. Horneber and C. Rauh. Lattice Boltzmann Method for the Simulation of Radiation Transport in Microalgae Biosuspensions. Proceedings der GALA-Fachtagung "Lasermethoden in der Strömungsmesstechnik" GALA 2015, Dresden 2015.