Lattice Boltzmann Model (LBM) inspired radiative heat transport modeling with applications to crystal growth

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Radiative heat transport is of high importance in melt crystal growth systems since these typically operate at high temperatures, almost always contain transparent regions, and sometimes contain semitransparent regions. For example, in the case of Czochralski (CZ) crystal growth of oxide materials, the growing crystalline material (and sometimes the melt) is often semitransparent in nature, while the gas phase, above the melt and surrounding the crystal, can typically be considered transparent to thermal radiation. Although these issues have been addressed in the literature, comprehensive analyses of radiative transport in participating crystal growth media are typically two-dimensional in nature and, to the best of our knowledge, no attempt has been made to address three-dimensional radiative transport, combined with all other heat transfer modes using LBM in a crystal growth system. The advantages of LBM (e.g. linear and explicit, often efficient and amenable to parallelization) render it an attractive option for the three dimensional analysis of multi-mode heat transport in melt growth systems.

In this contribution we will present our efforts at developing an LBM inspired algorithm for the analysis of radiative transport showing, among other things, features introduced and aimed at achieving increased accuracy, stability and versatility of this approach. These include (but are not limited to) improved higher-accuracy and more versatile angular discretization, as well as a modified unconditionally stable and higher accuracy collision frequency. Two-and three dimensional analysis of simplified systems will be presented and the question of specular surfaces as well as spectral effects will be discussed as will initial efforts at incorporating this approach in our algorithm [1], for the three dimensional analysis of anisotropic shape evolution in CZ growth of Oxide crystals.

[1] Weinstein O, Miller W and Brandon S. Modeling anisotropic shape evolution during Czochralski growth of oxide single crystals. J. Cryst Growth. 2019;509;71-86.