A web-based interface for modeling laser-induced incandescence (LIISim)

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In this study we present a model for laser-induced incandescence (LII). Different heat conduction models can be selected and mono- or poly-disperse particles can be chosen as well as isolated, single particles or aggregates. We present a web interface that allows the scientific community to directly use this model. This will simplify the comparison of LII models developed by different research groups.

Introduction

Laser-induced incandescence (LII) has emerged as a useful tool to measure volume fractions and sizes of particles in the sub-micron region. The determination of particle sizes relies strongly on the use of models that accurately describe the micro-physical mechanisms of particle heating and cooling. However, recent comparisons have shown that large discrepancies exist between different approaches [1]. The motivation for the present study was to develop a model for LII that includes the recent advancements in the theoretical understanding of LII and to make it available to the scientific community by a web interface. This will simplify the comparison of different models and reveal deficiencies in the underlying sub models.

Heat and mass transfer in modeling LII

The basis for “LIISim” is the energy and mass balance of a single spherical particle including the absorption of laser energy and heat loss due to vaporization, heat conduction, radiation and change in internal energy.

The change of internal energy is given by $d(m_p c_p T_p)/dt$ [2]. Here, m_p is the particle mass, c_p the particle heat capacity, T_p the particle temperature and t the time. It should be noted that most models use the expression $m_p c_p dT_p/dt$ for the change in internal energy. This expression ignores the change in internal energy due to the temperature dependence of the particle’s heat capacity which can have a significant influence on the temperature decay.

The expressions used for vaporization in the transition regime are given in [3].

Different heat conduction regimes can be selected when running the model: The free molecular regime, the continuum regime and the transition regime. In the latter case, the heat conduction model of McCoy and Cha [4] or Fuchs [5] can be used. In this way, the model can be applied to any Knudsen condition, i.e. low, atmospheric and high pressure.

Particles can be chosen to be mono-disperse or poly-disperse, following a lognormal distribution.

The effect of aggregation of primary particles on the heat conduction has been taken into account as described by Liu et al. [6]. The effects of aggregates on the evaporation term are neglected and aggregates should be only considered if the laser fluence is below the vaporization threshold.

The web interface

The web interface for LIISim is available at http://www.liisim.com. It enables the user to choose between different general settings for solving the energy- and mass balance, e.g. particle-size distribution, heat-conduction model and aggregate sizes. Parameters for the absorption of laser radiation can be set as well as for particle and gas-phase properties, e.g. particle diameter, gas pressure and energy accommodation coefficient. The values entered by the user are read in by a perl script which generates the input files for the LIISim executable. Solving the energy- and mass balance with a fourth order Runge-Kutta algorithm with the user-specified settings results in a new frame that shows a graph of the calculated LII signal as well as a link to the corresponding data file. In the data file, the time histories of the LII signal, the particle temperature, the particle diameter as well as the contributions of the different heat-loss mechanisms are listed. In this way, users can compare the LIISim results with own model predictions.

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