Numerical analysis of ballistic imaging for revealing liquid breakup in dense sprays

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Abstract

This work demonstrates the capacity of a Ballistic Imaging (BI) instrument to suppress diffuse photons and improve image contrast, making it possible to view fluid structure in a spray where a fog of droplets occludes the near-field. Analysis of the system is performed by means of a numerical system model. The model simulates light propagation and scattering in the measurement volume using a Monte Carlo based solution to the radiative transfer equation, and includes treatment of the full system optics using a custom ray-tracing code. Simulation results for the validation case where source light illuminates a test chart inside a turbid (optical depth = 14) solution of monodisperse polystyrene spheres (d = 0.7 μm) show good agreement with experimental images. The model is further applied by replacing the solution of polystyrene spheres with a spray-like scattering medium. Here, we investigate the temporal characteristics of an ultrashort (100 fs) laser signal crossing a volume containing a polydisperse distribution of fuel droplets with a representative Sauter mean diameter, d_{32} = 23 μm. These quantitative predictions allow the effectiveness of both the spatial and temporal filtering of the BI instrument to be estimated. Results from the model demonstrate that the spatial filtering and time gating effects of the BI system significantly improve image contrast, revealing information that is not available with conventional imaging techniques.

Key words: diagnostics, modeling, simulation and validation

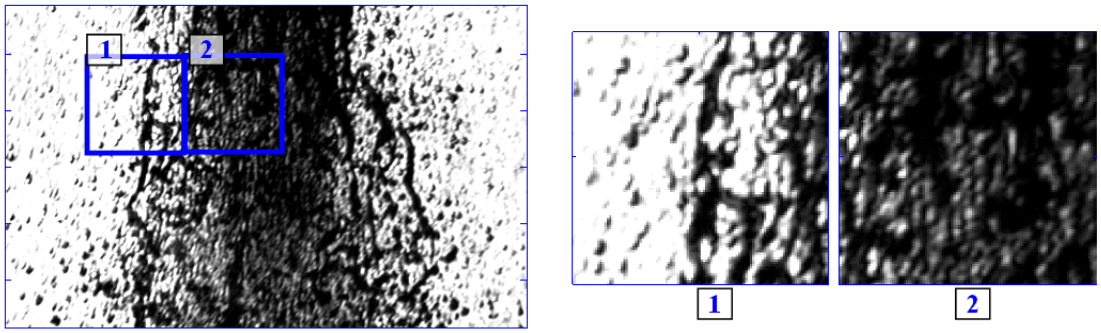

Figure 1. Example of an experimental time-gated ballistic image for an aerated water spray, 2 mm downstream from the nozzle orifice. Border tick marks indicate 1 mm image distance. Liquid structures appear as dark regions on a light background field. Magnified image regions are shown in (b).

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