Simultaneous Planar Fluorescence, Phosphorescence, and Mie Scattering in Pressure-Atomized Sprays

Barry V. Kiel and James R. Gord
Air Force Research Laboratory, Propulsion Directorate
Wright-Patterson AFB, OH 45433, USA

Jacob B. Schmidt, Joseph D. Miller, and Terrence R. Meyer*
Department of Mechanical Engineering
Iowa State University, Ames, IA 50011, USA

Abstract

While Mie scattering is sensitive only to the liquid phase within a spray, fuel fluorescence is sensitive to both the liquid and vapor phases. Hence, subtraction of Mie scattering from fluorescence signals could theoretically be used to qualitatively distinguish the liquid and vapor phases within a spray. Unfortunately, subtraction of these two signals is subject to significant error in polydisperse sprays because scattering is sensitive to droplet surface area (D^2) while fluorescence is sensitive to droplet volume (D^3). An improvement to this approach may potentially be achieved by employing phosphorescence for subtraction rather than Mie scattering since phosphorescence is proportional to droplet volume (D^3) and can, therefore, more accurately track the liquid volume distribution under polydisperse conditions. This approach relies on the fact that fluorescence will track both the liquid and vapor phases, whereas phosphorescence will yield signals only from the liquid phase because its signals from the vapor phase are quenched by the presence of oxygen. Previous efforts have explored the use of fluorescence and phosphorescence of acetone for vapor imaging. In the current work, we implement simultaneous fluorescence, phosphorescence, and Mie scattering and compare the relative merits of using a combination of techniques for vapor imaging in pressure-atomized sprays. Tests are performed using both acetone and a multicomponent fuel, and it is shown that image subtraction of phosphorescence from fluorescence can be achieved in polydisperse sprays on a droplet by droplet basis. Hence, the simultaneous detection of these three techniques can yield new information regarding atomization and vaporization, although regions prone to multiple scattering present a significant challenge in signal interpretation. Data from cold and heated sprays are analyzed, and methods to improve and advance the approach are suggested.

Key words: Fluorescence, phosphorescence, Mie scattering, pressure-atomized sprays

*Corresponding author, trm@iastate.edu