Two-camera dual-band collection Toluene PLIF Thermometry in supersonic flows

V. A. Miller\textsuperscript{1*}, M. Gamba\textsuperscript{1}, M. G. Mungal\textsuperscript{1, 2}, R. K. Hanson\textsuperscript{1}

\textsuperscript{1}: Department of Mechanical Engineering, Stanford University, Stanford, California, United States
\textsuperscript{2}: School of Engineering, Santa Clara University, Santa Clara, California, United States
* correspondent author: vamiller@stanford.edu

Keywords: Toluene PLIF, expansion tube, supersonic flow imaging and diagnostics

This work presents the application of two-camera dual-band collection toluene planar laser-induced fluorescence (PLIF) temperature imaging in an expansion tube flow facility. Toluene exhibits a high fluorescence quantum yield in oxygen-free environments compared to similar aromatic tracers, such as 3-pentanone or acetone, and toluene fluorescence is exceptionally sensitive to temperature. These qualities make toluene an ideal tracer for imaging compressible flow fields in which large temperature gradients may exist. Furthermore, it has been shown that toluene fluorescence has a red shift with increasing temperature \cite{Koban2004}, enabling temperature imaging in flow fields with non-uniform pressure or tracer seeding via a two-camera, single-wavelength excitation imaging scheme, for which each camera images a different spectral region of the fluorescence, and the ratio of these images is converted to temperature.

In this work, an expansion tube is used to generate supersonic flow fields. An expansion tube is an impulse facility typically used to generate moderate- to high-enthalpy flow. An expansion tube allows freedom of choice over the free stream test gas, and also allows for the seeding of tracers into the test gas. In this work, the expansion tube is operated at low- to moderate-enthalpy conditions, such that toluene does not pyrolize and it emits sufficient fluorescence for imaging. Toluene (0.5\% by volume) is seeded into nitrogen test gas, a 266nm pulsed light source is used to acquire single-shot images, and intensified CCD cameras are used to collect fluorescence over different spectral regions.

This work is organized as follows: first, a description of toluene spectroscopy and design of the two-camera imaging strategy are presented. Then, a description of the expansion tube flow facility and test conditions are provided. The thermometry strategy is validated by imaging flow behind incident shockwaves, where temperature is inferred from measured shock speeds. Finally, two canonical flow fields are imaged: supersonic flow over a wedge (Figure 1) and cylinder (Figure 2). A wedge offers both a uniform-pressure field upstream and downstream of an attached oblique shock, as well as a well-known solution across the shock. The cylinder offers variable temperature and pressure fields downstream of a bow shock, enabling further evaluation of the technique in a controlled but complex flow field, and to assess its suitability in more general flow configurations.

References