Ultrafast CARS and LITGS imaging in high-speed compressible flows

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Coherent anti-Stokes Raman scattering (CARS) and laser-induced thermal grating spectroscopy (LITGS) are two powerful nonlinear laser diagnostics techniques for scalar measurements in harsh gas-phase environments, such as reacting (i.e flames and plasmas) as well as high-speed compressible flows. These techniques operate on distinctly different timescales, providing complementary information. On the microscopic timescale (1 ps = 10^{-12} s), on which molecular collisions occur, CARS has become the gold standard for thermometry and species concentration measurements via Boltzmann statistics. In contrast, LITGS operates on macroscopic timescales, where inter-molecular interactions over tens-to hundreds of nanoseconds (1 ns = 10^{-9} s) give rise to larger-scale flow phenomena such as wave propagation in compressible gases (e.g. shock waves formation). The recent commercial availability of ultrafast laser amplifiers, providing high peak power and broad pulse bandwidth, has promoted the further development of both techniques. Hybrid femtosecond/picosecond (fs/ps) CARS now allows for one-dimensional (1D) and two-dimensional (2D) imaging measurements [1,2], while multiphoton absorption has been demonstrated to efficiently generate thermal gratings in nitrogen, air, and argon in fs-LITGS [3].

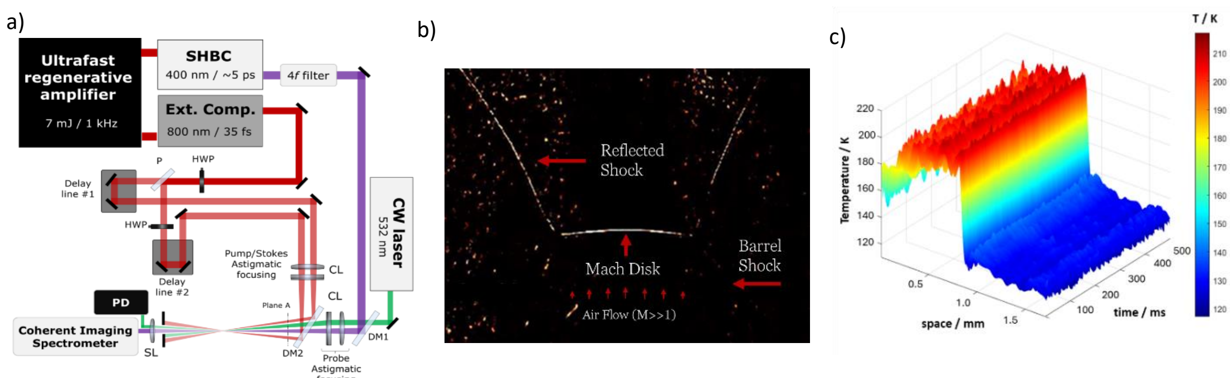

Figure: a) Experimental set-up for simultaneous CARS and LIGTS one-dimensional imaging. b) Single-shot shadowgraph image of the under expanded air jet. c) Temperature dynamic obtain from 1D-CARS experiments.

In this work, we demonstrated the simultaneous generation of these two non-linear diagnostic techniques across a 1D image, using a single laser source. A Ti: Sapphire amplifier (Astrella, Coherent) delivers 7 mJ/pulse 35 fs laser pulses at 800 nm at a 1 kHz repetition rate. A 65% beam split is used to generate the ps CARS probe pulse, while the remaining 35% is further split into two fs beams. The latter serves two purposes at one: they act as pump and Stokes lasers to impulsively excite the Raman coherence, and they generate a thermal grating via multiphoton absorption in nitrogen and oxygen. A CW laser is scattered by the grating resulting in the generation of the LITGS signal. This dual capability is demonstrated by measuring temperature and the speed of sound the across the Mach disk in the under expanded jet shown in Fig. 1(b).

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