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ACCURACY INVESTIGATION OF FILTERED RAYLEIGH SCATTERING FOR VELOCITY MEASUREMENTS

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Filtered Rayleigh scattering (FRS) is a measurement technique that uses the light scattered by fluid molecules to determine the density, velocity and temperature of the fluid non-intrusively. While the intensity of the scattered flow is proportional to the density of the fluid, the bulk and thermal movement of the molecules produce a Doppler shift of the scattered light that allows the flow velocity and fluid temperature to be determined. In this investigation, the accuracy of FRS when used for determining flow speeds has been evaluated in a setup using a Mach 2.22 free jet. The results showed that while it is feasible to employ FRS for this type of measurement, there are several factors that need to be considered in the design of an experimental setup as well as when the data are analyzed in order to attain the desired accuracy level. In the investigated setup, the accuracy was found to be ±40 m/s in well-seeded areas. The most significant source of error was laser drift, 35 m/s over 3 hours, followed by image matching, turbulent and thermal motions, shot noise, and white field corrections, each of which contributes on the

order of 10 m/s to the uncertainty. Using different laser wavelength setpoints, the velocity measured in a single point was found to vary by as much as 100 m/s, primarily due to non-monochromatic scattering in extreme cases. While careful experiment design and analysis can produce uncertainties of <10 m/s, it is suggested that for many flows, Doppler global velocimetry using controlled seeding may be better suited. Due to the small cross-section of gas molecules, the presence of impurities, e.g., water vapor, even in minute concentrations, may lead to uneven seeding when FRS is applied to a flow without deliberate seeding. This produces a signal level that varies significantly over the studied region, leading to sensor saturation or low signal-to-noise ratio in regions with high and low seeding density, respectively. FRS is an attractive alternative for measurements in clean fluids where interaction between seed particles and the fluid is unacceptable or when non-intrusive fluid density or temperature measurements are desired.