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Temperature and velocity imaging in a confined low-temperature gas flow using thermographic phosphor tracer particles

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Temperature measurements in turbulent gas flows are crucial to the design of efficient energy systems. A few optical diagnostic options for gas thermometry exist such as Rayleigh scattering, Laser Induced fluorescence (LIF), coherent anti-stokes Raman scattering (CARS), and thermographic PIV, presented here, which is a relatively new addition to the portfolio.

Thermographic phosphors are solid particles with temperature dependent luminescence properties. Upon excitation with UV light, they typically emit visible light, and the emission spectrum and lifetime is temperature dependent. By dispersing micron-size phosphor particles into the fluid stream, the temperature of the fluid can be measured. In contrast with organic LIF tracers, phosphor particles are inert, stable over a wide temperature range, and the luminescence properties are generally insensitive to the composition, pressure and phase of the surrounding fluid. Also, due to the large spectral shift between emission and excitation, both the laser light scattered by the particles and reflected from walls can be efficiently rejected, allowing simultaneous velocity measurements and in confined configuration.

In this study, ZnO phosphor particles are seeded into a high-pressure (120 bar) stream of argon, which expands through an orifice into an atmospheric pressure channel. Velocity and temperature measurements performed some distance downstream of the orifice in the confined channel are shown in Fig. 1. High velocity regions (~300 m/s) are present, which due to the conversion of thermal energy into kinetic energy are also associated with regions of cold gas (~160 K). In addition, the high-pressure difference leads to the real-gas Joule-Thomson effect so that even the slow moving fluid is about 60 K colder than the gas inlet temperature. This study shows the utility of this emerging optical diagnostic technique in the investigation of complex fluid phenomena.

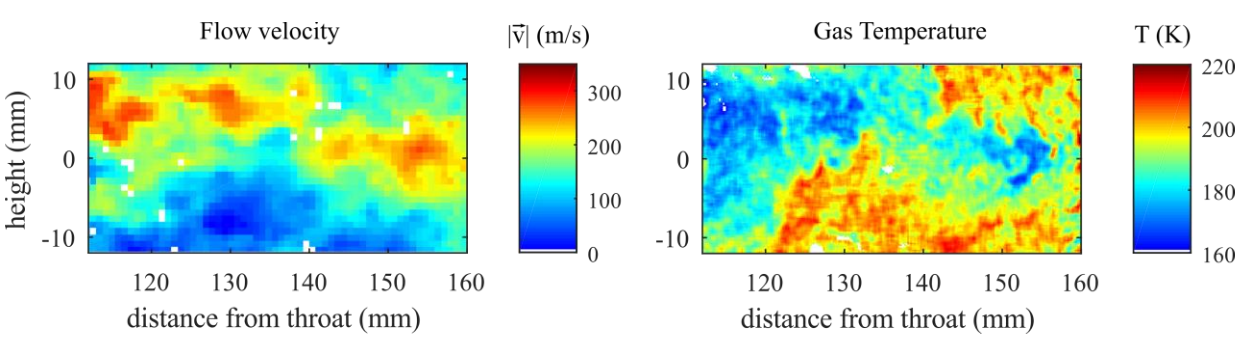

Fig. 1 Example of simultaneous single shot flow velocity and gas temperature measurements measured downstream of a high-pressure ratio expansion. Note that the digital resolution of the temperature image is higher.