# Particle image velocimetry measurements in highly luminescent flames

**Michael Schroll[1], Christian Willert[1], Joachim Klinner[1] and Manfred Beversdorff[1]**

[1] Institute of Propulsion Technology, German Aerospace Center, Cologne, Germany
michael.schroll@dlr.de

## ABSTRACT

This contribution describes recent efforts leading toward the successful application of particle image velocimetry (PIV) in highly luminescent flames avoiding saturation of the second frame of commonly available double shutter PIV cameras, which is usually inevitable when using their interline-transfer CCD sensors. In order to characterize the performance of modern aero engine combustors in correlation with emissions data, laser optical diagnostics are extensively utilized in specifically designed pressurized test rigs with good optical access. While spectroscopic techniques provide information on fuel placement, reaction zone, temperature field among other quantities, flow field data is of equal importance in providing insight into the convective transport of reactants and their products. The method of choice in providing this flow field data is PIV. But the successful application of PIV in pressurized combustion imposes a variety of challenges. Among these, strong flame luminescence - mainly stemming from localized soot production and burn-off - cannot be sufficiently suppressed with narrow banded laser line filters and result in the saturation of the second frame of commonly available double shutter PIV cameras. A useable solution to this problem is a dual sensor setup as shown in Figure 1 splitting the optical path with a beamsplitter cube. By exposing each sensor separately in the sub-microsecond range saturation due to flame luminosity can be sufficiently reduced to allow reliable measurement in pressurized combustion. Several different swirl burners were investigated; each mounted inside pressurized single sector combustors (SSC), which are designed for the optical investigation of aero-engine combustors operating at realistic (flight relevant) conditions (Fig. 2).

Because of the beam splitter configuration and mechanical tolerances in the camera module along with the presence of a beam splitter in the optical setup necessitate an inter-sensor offset correction. After several iterations procedures for proper in-situ offset corrections could be established and ultimately allowed successful PIV measurements in highly luminescent environments.

Fig. 3 shows representative image obtained in the flow field of a pressurized combustion chamber with a swirl nozzle located near the middle on the lower edge and mean flow propagating from bottom to top. Exposure time of the sensor is 500ns while the laser light pulse has a duration of ~5ns. The image is characterized by four types of light scattering: (1) from the glass liner walls left on the left and right edges, (2) Mie scattering by the dense fuel spray immediately downstream of the fuel nozzle, (3) Mie scattering by the inert seed particles (1 µm porous silica spheres) and (4) Rayleigh scattering by soot particles in the fuel rich combustion zones. Due to their fine structure the soot patches serve as flow markers and be tracked with conventional PIV processing algorithms. The comparison of “flow” fields obtained with and without particles revealed that the soot patches do not adversely affect the velocity estimates provided by the seeding particles. Soot tracking therefore is a promising alternative when the particle image signal is lost in flows with higher soot fractions.

**Figure 1**: Dual sensor PIV camera system with a large aperture medium format lens and remote focusing

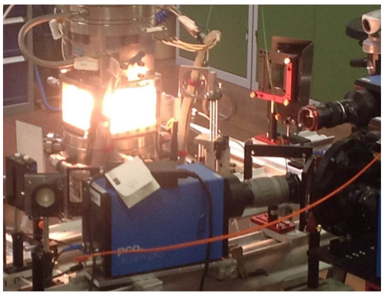

**Figure 2**: Pressurized single sector combustor operating at “moderate” fuel loading conditions

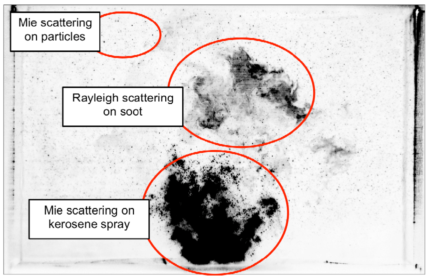


**Figure 3**: Single recording of the reacting flow field downstream of a kerosene swirl atomizer located at the bottom center at ~7 bar plenum pressure, CCD sensor exposure: 500 ns.