of the technique used, these properties of laser light allows for a controlled input to the experiment thereby providing an accuracy value often limited by the laser wavelength.

The point measurements of velocity, particle size and temperature utilize the LDA, PDA and Dual-band LIF techniques respectively. Because PDA and LIF hardware can be an extension of the LDA system, the simultaneous measurements of velocity, droplet size and temperature is possible. While point measurements provide sufficient accuracy and spatial resolution, often the global behaviour of the process is of interest. For this purpose, the laser beam is stretched into a thin sheet to illuminate a planar measurement area. In such planar measurements, often a high-quantum efficiency camera is used, thus the planar measurement techniques are also called the imaging techniques. These include Interferometric Particle Imaging (IPI), Shadow sizing and Spray geometry for droplet size and spray shape measurements and Particle Image Velocimetry (PIV) and Particle Tracking Velocimetry (PTV) for velocity measurements.

PIV has matured over a quarter century and is now an established tool in fluid diagnostics. The development of the technique has been tremendous due to relentless advances in laser, detector, and CPU processor technology: In 25 years, the technique evolved from the manual construction of a 2-component velocity field from a double-exposed particle image on a single photographic paper, to digital storage and computation of 3-component velocity fields in liter-sized volumes in a time resolved fashion. Along the way, several other sub-techniques and names, such as Digital-PIV, Micro-PIV, Nano-PIV, Holo-PIV, Stereo-PIV, Endoscopic-PIV have been introduced to describe certain variations of the technique.

With the availability of high-power-, high-repetition rate lasers and high-speed cameras the laser beam can be expanded to illuminate a 3-D volume for volumetric velocity measurements. This means, the measurement of unsteady, inertial and viscous terms of the Navier-Stokes equation is possible using time resolved volumetric velocimetry, allowing the estimation of the volumetric pressure distribution in the measurement volume.

Application examples and corresponding results will follow the presentation of each technique.

OPTICAL DIAGNOSTICS FOR AVIATION ENGINE RESEARCH: PART 2. COMBUSTION DIAGNOSTICS

F. Gökhan Ergin, PhD, Dantec Dynamics A/S, Skovlunde
Denmark, E-mail: Gokhan. Ergin@dantecdynamics.com

Laser-based imaging techniques have proven to be valuable tools in combustion research as well as in many other fields. Techniques such as Laser-Induced Incandescence (LII), Rayleigh Thermometry and Laser-Induced Fluorescence (LIF), can, correctly used, provide non-intrusive measurements with high spatial and temporal resolution of a range of combustion properties. All these techniques utilize ultra short exposure times, making them suitable for instantaneous imaging even in turbulent environments, such as in gas turbine combustors.

The need to reduce emissions of pollutants from combustion processes is becoming increasingly important due to their impact on global warming and human health. In many combustion applications soot is a result of incomplete combustion and a source of pollution in e.g. diesel engine combustion. Laser-Induced Incandescence is a laser-based imaging technique used for soot diagnostics. The technique allows for in-situ measurements of soot-volume-fraction to be made to reveal where in the combustion chamber the soot is formed.

Temperature is a key parameter in all combustion research and is directly related to the heat release from the fuel as a result of the chemical reactions taking place. In very clean combustion environments instantaneous temperature maps can be measured by means of Rayleigh Thermometry. As in the other laser-based imaging techniques presented, a light sheet is directed through the combustion process and the light is elastically scattered by the molecules in the gas. The light intensity recorded on the camera is directly related to the gas density, which can be converted to temperature.

Laser-Induced Fluorescence is one of the most powerful techniques available today for experimental diagnostics of combustion processes. Based on the physics of interaction between light and molecules, the technique allows for species-selective measurements with high sensitivity. Highly advanced and flexible system capable of measuring several combustion produced radicals and products are available. State-of-the-art equipment including narrow band, tuneable laser sources and sensitive, intensified CCD detectors integrated with advanced electronics for precise synchronization and powerful yet user-friendly acquisition software have been integrated in order to facilitate these measurements. The system is capable of measuring several combustion radicals such as OH for flame front visualization, is described.

By adding a fluorescent tracer species (e.g. acetone) to a non-fluorescent fuel (e.g. iso-octane, n-heptane, methane), studies of the combustion as well as the pre-combustion process can be carried out. Powerful yet easy-to-use tracer-LIF dedicated systems enables studies of a wide range of applications, from open flames to internal combustion engines and laboratory gas turbine combustors, for properties such as fuel distribution and injection behaviour.

Application examples of the techniques mentioned will be presented, as well as examples of combined measurements such as fuel visualisation combined with flame front tracking (OH) and PIV for further advanced analyses combining combustion chemistry and fluid mechanics.