Technology Transfer R&D Services

Combustion Diagnostics

Introduction

Laser techniques are suitable for low-interference, spatially and temporally resolved measurements of physical and chemical variables in matter which is transparent to laser light.
The Combustion Diagnostics Laboratory at PSI specializes in the laser-optical investigation of combustion processes, especially in gas turbines and in large internal combustion engines. PSI also offers its expertise for the determination of flow velocities, including measurements in non-reactive flows.

Services

- **Visualization of the spatial structure of the combustion zone (flame) and its temporal change by laser-induced fluorescence (LIF):** Uses determination of chemical components typically occurring in flames, such as OH. For the combustion of hydrocarbons, flame indicators such as CH_2O (formaldehyde) and CH are also used. In the combustion process these are usually completely oxidized; thus, in contrast to OH, they are absent after the combustion zone.
  Using laser light with a specifically tuned frequency, the molecules of the targeted species are excited. Pulse repetition rates of 20 Hz to 20 kHz can be realized at PSI. The excited molecules emit specific light within nanoseconds (ns), which is detected with a special camera, resolving the spatial location of the targeted molecules. It is therefore possible to determine the special distribution of the laser excited spacies (2-D LIF). This imaging technique is applicable to 20 bar and more.
- **Determination of substance concentrations with the 2-D LIF technique:** Compounds such as NO are also detectable with the LIF technique. Higher accuracy can be achieved by using the simultaneous measurement of light absorption.
- **Visualization of the distribution of unburned fuels with LIF.** For the combustion of liquid fuels, **Mie scattering** can be applied in addition, to determine the locations of non-evaporated oil droplets.
- **Determination of flame indicators by observing its Chemiluminescence (CL):** Spontaneous emission of light with characteristic frequency (CL) occurs for some compounds without any laser-induced excitation. The currently used technique at PSI registers the integral CL along the whole beam to the detector, i.e. CL in this form is only a limited spatial resolution technique.
- By means of **Raman spectroscopy,** the process of combustion, i.e. the transformation of fuel (e.g. methane or hydrogen) into combustion products (H_2O, CO_2), can be monitored in its spatial sequence. Simultaneous determination of the concentration of various species is possible. The accuracy of the measurement depends on the absolute value of the measured concentration – of the order of about 0.5 % to 3 %. In combustion with air, the Raman scattering of N_2 molecules is used to simultaneously determine the **temperature distribution** within the combustion chamber.
- **Coherent Anti-Stokes Raman Scattering (CARS)** at PSI allows pointwise temperature measurements during and after combustion, with an accuracy of about 50 K at approx. 2000 K. For the same purpose, advanced imaging techniques in 2-D LIF are currently being developed, using NO as tracer.
- **Particle imaging velocimetry (PIV)** deals with the subject of two dimensional (2-D) determination of **flow velocities.**
  Another technique for flow measurements uses laser-induced gratings (LIG). This new technique can, for instance, be applied for measurements in wind tunnels.

Examples

Laser spectroscopic investigation of combustion in a commercial gas turbine burner. Applied technique is 2-D LIF of OH.

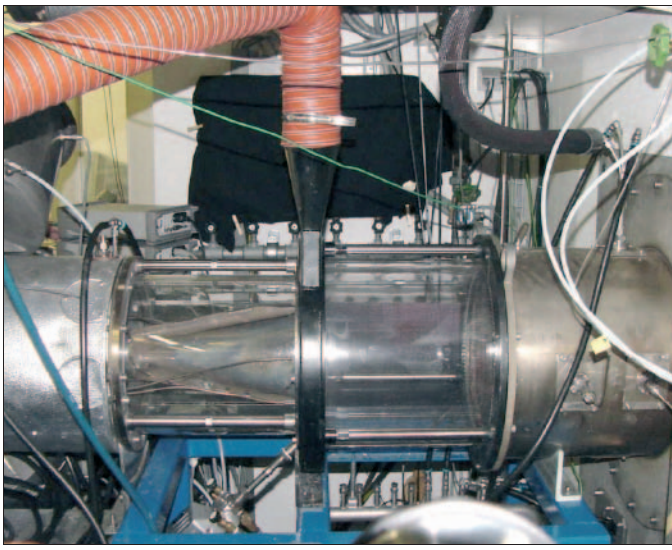
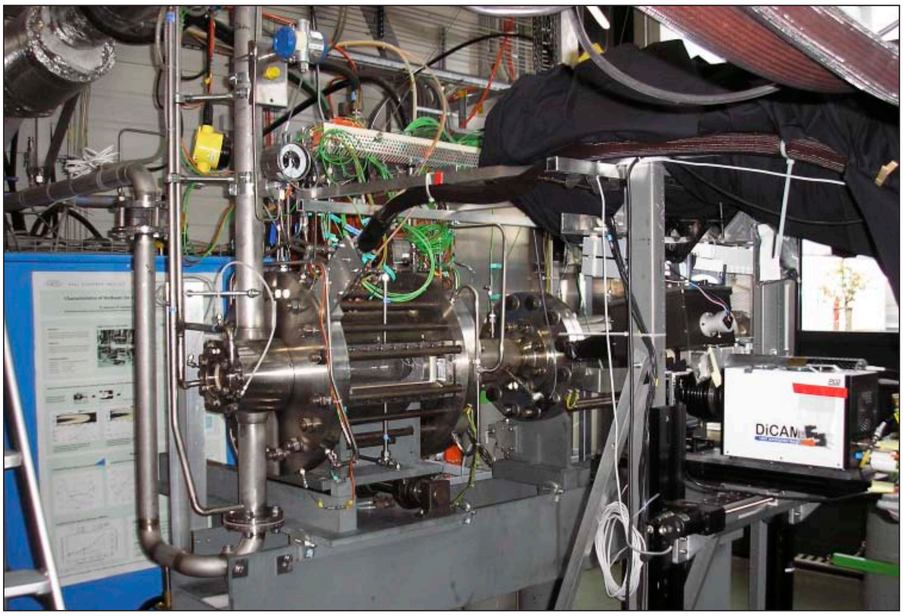


Figure1: **Experimental setup at the atmospheric test rig of Alstom (Schweiz) AG (photograph by courtesy of Alstom).**

The cone-shaped burner is located in the central part of the image. To the right is the partially transparent combustion chamber. The leaf-shaped laser beam (a “light sheet”) is directed from below into the combustion chamber. The camera which records the laser-induced fluorescence of the flame indicator OH is located at the image viewer. The light sheet had a transverse extension of about 11 cm. An important objective of this experiment was the visualization of time-averaged flames at different phases of the (dominant) acoustic oscillation generated by unstable combustion in the flame.

Figure 2: **Investigation of turbulent combustion at high pressure.**

Test rig at PSI for the investigation of turbulent combustion at high pressure. The combustion chamber, provided with windows, is situated in the centre of the Figure. Flow of the premixed gas is from the right. The laser beam is directed from the left, axially through the combustion chamber. The camera is seen at the right-hand side of the Figure.



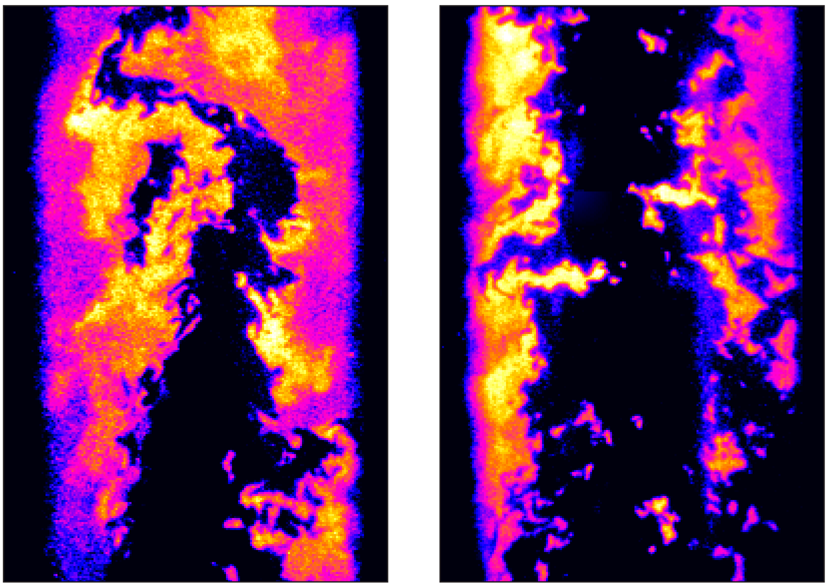


Figure 3: **Examples of flame pictures (OH LIF) obtained at the test rig of figure 2.**

For further information on combustion diagnostics at PSI, see cdg.web.psi.ch

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