Preliminary Investigations on Thermometry in Thermal Flows via Transient Grating Spectroscopy (TGS)

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Abstract

In combustion environments the temperature field is one of the very important basic quantities for diagnostic research. Especially in unsteady reacting flows the time-resolved measurement of temperature is of great interest in order to understand the complex interaction of the local chemistry, fluid dynamics, heat transfer and sound generation of combustion gases.

Conventional measurement techniques with thermocouples acquire mainly time-averaged values and are in addition highly intrusive. Other methods like *Coherent Anti-Stokes Raman Spectroscopy* (CARS) are highly-developed although they are still very demanding and require a tunable laser and the means to spectrally resolve and evaluate the signal.

Therefore, *Transient Grating Spectroscopy* (TGS) as a nonintrusive nonresonant laser-based technique has been investigated with respect to its application for local and time-resolved temperature measurements in thermal flows. TGS determines in a probe volume comparable to the *Laser Doppler Anemometry* (LDA) in a period of a few hundred nanoseconds the local speed of sound and therewith the temperature of the flow medium. The contrast modulation of a pulsed laser induced refraction index grating is used. In order to detect the grating a continuous wave probe laser beam is adjusted under Bragg angle conditions to the grating. The reflected signal beam is received by a photomultiplier and frequency modulated due to the local speed of sound. The speed of sound is given by the modulation frequency in combination with the grating spacing.

This work addresses the dependence of the signal strength and the signal-to-noise ratio on different parameters like ambient pressure, pulsed-laser energy and probe-laser power. The signal strength increases approximately quadratically with the ambient pressure and the pulsed-laser energy. Tests have been conducted and statistically analysed at laboratory temperature. The resulting accuracy seems to be sufficient for measurements in combustion flows where high temperature fluctuations are expected. The influence of gaseous combustion products on the speed of sound is discussed previously in literature and here ignored for the time being. The strong density or pressure dependence of the signal strength seems to be disadvantageous when measuring in hot environments like first tests in candle flame have shown. But this can be compensated by either increased pulsed-laser energy or higher ambient pressure in the medium, e.g. in high-pressure burners.

Possible design relevant improvements concerning the pulsed laser like the usage of a seeded Nd:YAG laser are discussed. The application of the infrared wavelength of a Nd:YAG laser (1064nm) for the grating generation could also be favorable.

These investigations are implemented within the framework of project no.5 "Investigation of the Correlation of Entropy Waves and Acoustic Emission in Combustion Chambers" of the DFG Research Unit 486 "Combustion Noise" supported by the German Research Foundation (DFG). In this project the main interests are correlation measurements between temperature and velocity or pressure fluctuations in combustion flows.