Single-shot CARS Imaging of Near-Wall Turbulent Reacting Flows

Bohlin, Alexis; El Sioufy, Karim; Jainski, C.; Dreizler, A; Patterson, B.D.; Kliewer, C. J.

Publication date
2019

Document Version
Final published version

Citation (APA)
Bohlin, A., El Sioufy, K., Jainski, C., Dreizler, A., Patterson, B. D., & Kliewer, C. J. (2019). *Single-shot CARS Imaging of Near-Wall Turbulent Reacting Flows*. Abstract from 18th European Conference on Non-linear Optical Spectroscopy (ECONOS), Rouen, France.

Single-shot CARS Imaging of Near-Wall Turbulent Reacting Flows

Alexis Bohlin[1], **Karim El Sioufy**[1]
Christopher Jainski[2], **Andreas Dreizler**[2]
Brian D. Patterson[3], **Christopher J. Kliewer**[3]

1. *Faculty of Aerospace Engineering, Delft University of Technology, Kluyverweg 1, 2629 HS Delft, The Netherlands*
2. *Institute of Reactive Flows and Diagnostics (RSM), Technische Universität Darmstadt, 64287 Darmstadt, Germany*
3. *Combustion Research Facility, Sandia National Laboratories, Livermore, CA 94551, USA*

In practical combustion devices featuring high power densities, the interaction between flames and walls may have a significant impact on the thermodynamic efficiency and the formation of pollutants (e.g. unburned hydrocarbons and carbon monoxide). The common understanding is that at the region near the wall ~ 1 mm, where the solid metal surface is generally much cooler than the impinging flames, steep temperature gradients exist which may result in incomplete combustion and local quenching of the flame. This has been investigated experimentally, by CARS monitoring of temperature- and major species profiles from premixed methane/air flames impinging against a cooled steel side-wall, performed at well-characterized quasi-stationary laminar conditions [1].

In these new experiments, we have employed the same generic burner and CARS imaging system [2], but now operating at significantly enhanced turbulence intensities induced by a turbulence generator grid (blockage ratio 45%, turbulence level $u'/\bar{u}$ = 6-7%). The complex interplay between the laser diagnostic and the turbulent reacting flow in the near-wall region has been overcome, for instance, with the balanced detection between CARS signals originating from unreacted- and reacted mixtures imaged on the same detector frame, the removal of the laser beams reflecting from the surface, and the suppression of background flame luminosity within the clear aperture of the coherent imaging system. A quick-fitting routine enabling rapid convergence of two-beam femtosecond/picosecond CARS signal analysis has been developed. Correlated statistics have been produced, for instance, on the instantaneous temperature gradients near the wall (position with magnitude). This temperature data supports the recent findings of velocity measurements [3], and adds to the database on this burner system which can be used as a benchmark to improve the fidelity of numerical simulation on near-wall turbulent reacting flows.

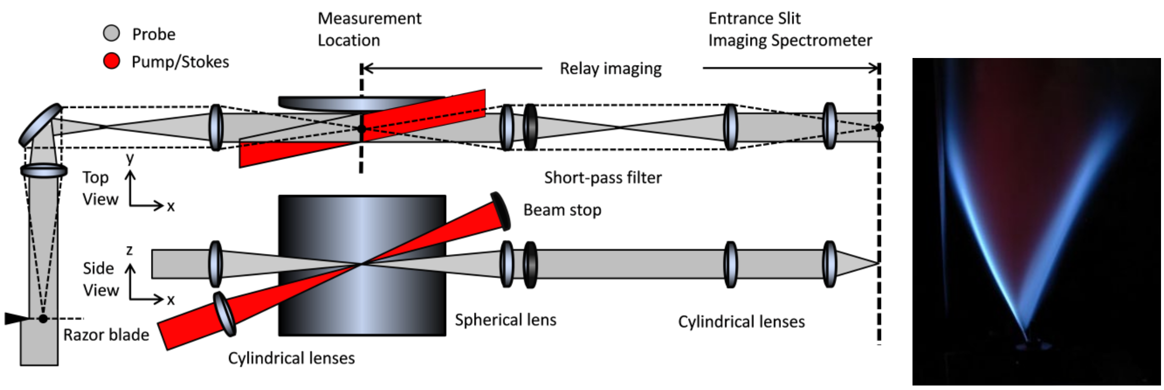

Fig. 1. (left) The single-shot CARS imaging system employed for direct temperature contour analysis of premixed methane/air turbulent flames impinging on a cooled steel side-wall. The probe and pump/Stokes beams originating from separate picosecond- and femtosecond regenerative amplifier laser systems, respectively, are combined at the measurement location utilizing a two-beam CARS phase-matching scheme. (right) The V-flame supported by the side-wall quenching burner, is operated in the wrinkled flamelet regime at some distance from the wall.

Acknowledgement:
The CARS imaging experiments was performed at Sandia National Laboratories on a generic SWQ burner provided by TU Darmstadt. The data analysis has been performed at TU Delft. KES, AB acknowledge NWO. CJ, AD acknowledge DFG. BDP, CJK acknowledge U.S. DOE.

References

[1] A. Bohlin, C. Jainski, B.D. Patterson, A. Dreizler, C.J. Kliewer, "Multiparameter spatio-thermochemical probing of flame–wall interactions advanced with coherent Raman imaging", Proc. Combust. Inst. **36**, 4557–4564 (2017).
[2] A. Bohlin, B.D. Patterson, C.J. Kliewer, "Communication: Simplified two-beam rotational CARS signal generation demonstrated in 1D", J. Chem. Phys. **138**, 081102 (2013)
[3] C. Jainski, M. Rißmann, S. Jakirlic, B. Böhm, A. Dreizler, "Quenching of Premixed Flames at Cold Walls: Effects on the Local Flow Field", Flow Turbul. Combust. **100**, 177-196 (2018)