

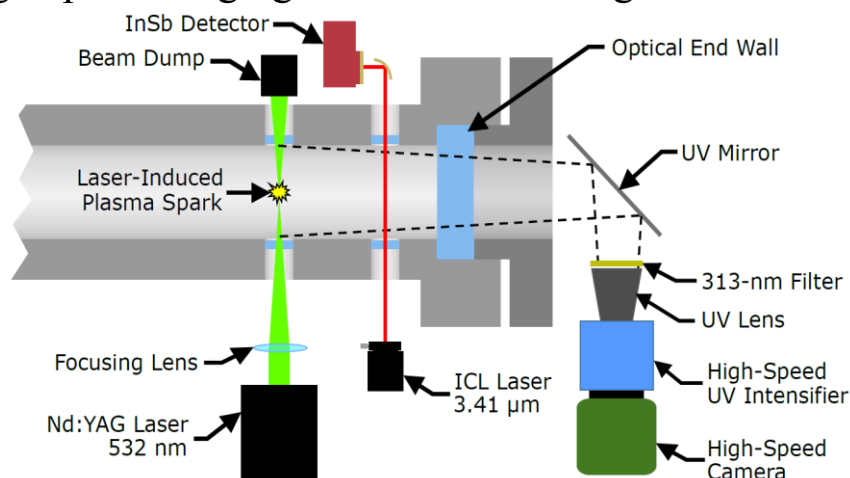
Recent progress characterizing high-temperature flames in a shock tube

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Introduction

The shock-tube flame speed method was introduced to enable the study of flames at high unburned-gas temperatures inaccessible to existing experimental methods ([CNF, 2019](#)). Near-instantaneous shock jumps allow fuel-oxidizer mixtures to be heated to reactive temperatures on timescales short relative to those of auto-ignition ($Da \ll 1$). Laser-induced breakdown non-intrusively ignites a flame, and high-speed imaging records the flame growth.

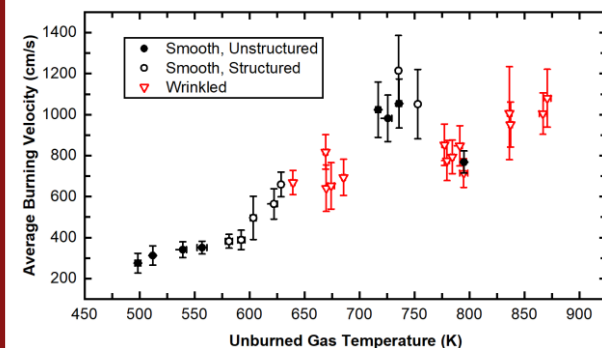


Prior Work

Negative Temperature Dependence

High-temperature burning velocity measurements of *n*-heptane ([SciTech, 2018](#)) and *iso*-octane ([AIAA, 2019](#)), revealed regions of negative temperature dependence for both fuels. These findings have since been studied through detailed numerical simulations by Zhang et al. for *n*-heptane double flames ([PROCI, 2020](#)) and Yang et al. for *iso*-octane overdriven flames ([CNF, 2021](#)).

Prior Work (cont.)

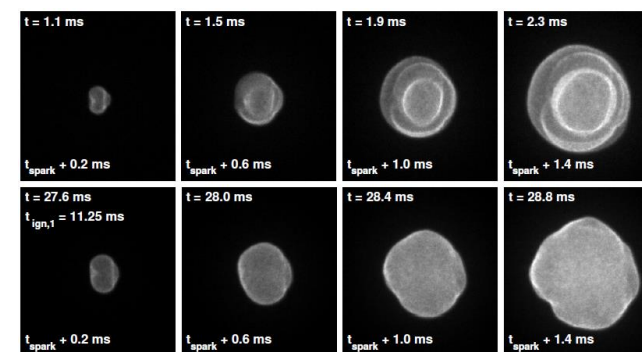


Observed *iso*-Octane Burning Velocities:
 $P_5 \sim 1$ atm
 $\Phi = 0.9$ in 18% O_2 /
41% Ar/41% He
([AIAA, 2019](#))

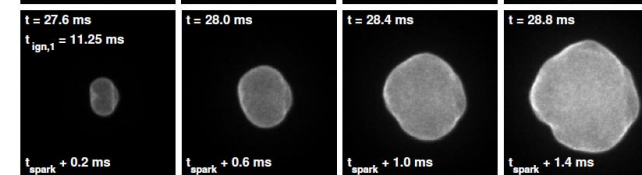
Flames at Variable Extents of Reaction

The shock tube has also allowed high-temperature flames to be observed after controlled extents of ignition chemistry occur in the unburned gas. These experiments showed significant changes in the appearance of *n*-heptane flames ignited prior to and following first-stage ignition. ([ISSW32, 2019](#))

Pre-1st-stage ignition



Post-1st-stage ignition



Recent Progress

Recent efforts have focused on characterizing residual motion in the post-reflected-shock gas and exploring the extremes of conditions at which flames may be studied in the shock tube. This work aims to develop the shock-tube flame speed method into a more refined technique while also exploring its capability to enable studies at novel conditions.

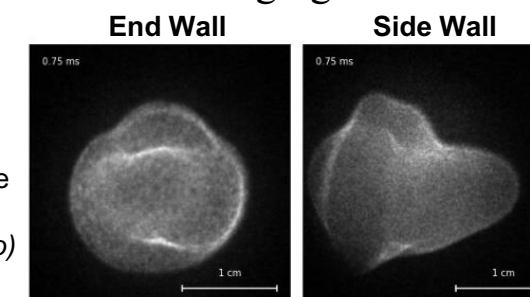
Recent Progress (cont.)

Dual-Perspective Emission Imaging

Adding a second high-speed camera, imaging laterally through a side-wall optical port, has provided new insight into the behavior of flames in the shock tube. Side-wall imaging clearly shows the structured appearance of flames noted in prior works results from axial flame distortion that could not be discerned from end-wall imaging alone.

Conditions:

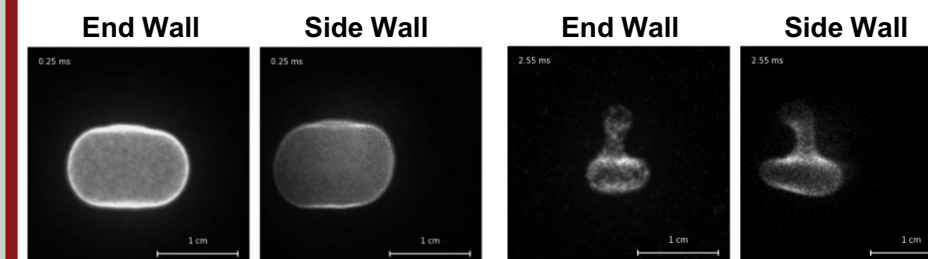
Fuel: *n*-C₇H₁₆ ($\phi = 0.9$)
Oxidizer: .18O₂/.41Ar/.41He
 $T_5 = 749$ K, $P_5 = 1.08$ atm
([click image for link to video](#))



Laterally viewing flames has additionally revealed bulk motion of flames in the direction of the end wall under some conditions. This effect is evident in the extreme-condition flame videos linked below.

Extreme Temperature, Fuel-Lean Conditions

The shock tube has also been used to observe flames at extreme temperature and near-limit conditions ($T_u > 1,000$ K, $\phi \sim 0.3$), demonstrating the promise of the shock-tube flame speed method to enable flame studies at difficult laboratory conditions.



C₃H₈ ($\phi = 0.8$) in .19O₂/.39Ar/.42He
 $T_5 = 1,028$ K, $P_5 = 1.06$ atm
([click image for link to video](#))

C₃H₈ ($\phi = 0.3$) in .21O₂/.79Ar
 $T_5 = 745$ K, $P_5 = 1.06$ atm
([click image for link to video](#))

PLIF of High-Temperature Flames

Efforts are presently underway to deploy PLIF to study the structure of high-temperature flames. A preliminary video result can be [viewed at this link](#).

Conclusions

Recent efforts have advanced the characterization of bulk motion of the unburned-gas and properties of flames in a shock tube. These results have improved the interpretation of previously obtained results and will inform the optimization of experimental design and procedures used in future flame studies in the shock tube. The demonstration of the shock-tube flame method at extreme conditions further motivates the value of enabling this new approach.

Future Work

Future efforts will be directed at assigning a strong theoretical basis to the observed phenomena such that future experiments might be designed to suppress non-ideal effects. Further refinement of additional diagnostics (e.g. PLIF, Schlieren) and expanding side-wall optical access will further support future studies of flame speed, structure, and novel phenomena at the extreme flame conditions enabled with the shock-tube method.

Acknowledgements

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