Supercritical $CO_2$
Power Cycles
Symposium

# Methane and Natural Gas Combustion and Ignition Measurements for $sCO_2$ Allam Cycles

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## Motivation

As demand for energy grows, concerns about carbon dioxide emissions highlight the need for low-carbon power generation technologies. Supercritical carbon dioxide ($sCO_2$) power cycles are of interest for their high efficiency and inherent carbon sequestration. Optimization of combustor designs requires validation of chemical kinetics mechanisms for the target fuel mixtures and conditions; however, extremely high working pressures pose challenges for experimental measurements.

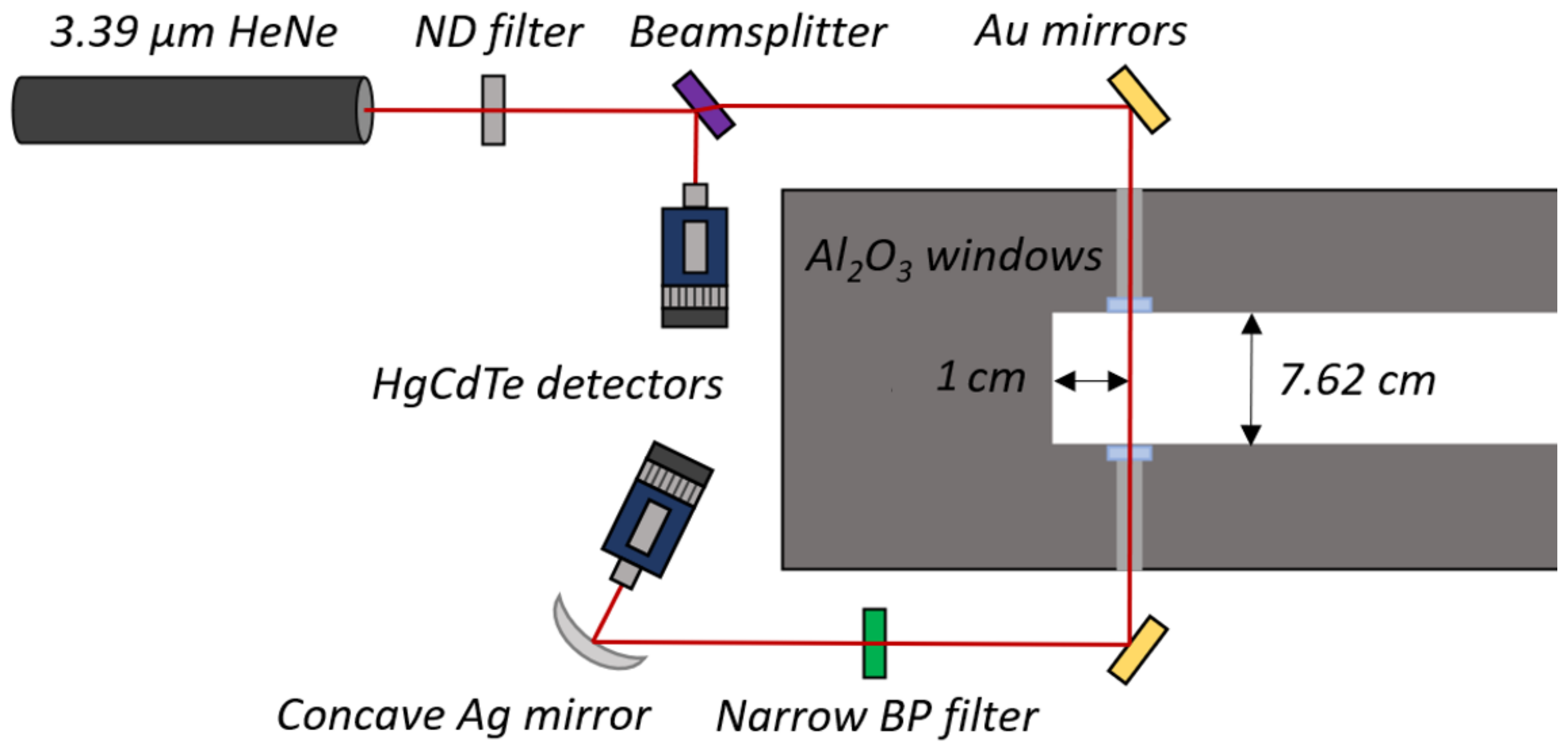
## Experimental Facility

Shock tubes are ideal combustion devices for studying combustion phenomena, such as ignition delay times (IDTs), to give insight into underlying chemical kinetics. A shock tube is separated by a diaphragm into a driver and driven section – the latter contains the oxy-fuel mixture, and the former is filled with an inert gas until the diaphragm bursts. A shock wave propagates through the mixture, raising its temperature and pressure, until it reaches the endwall, where it reflects and heats the mixture a second time. Experimental measurements are performed in the stagnant gas region behind the reflected shock.

Experiments were conducted at the High-Pressure Extended Range Shock Tube for Advanced Research (HiPER-STAR) at the University of Central Florida (UCF) which was designed to study ignition processes at reflected shock pressures of up to 1000 bar.

## Experimental Setup

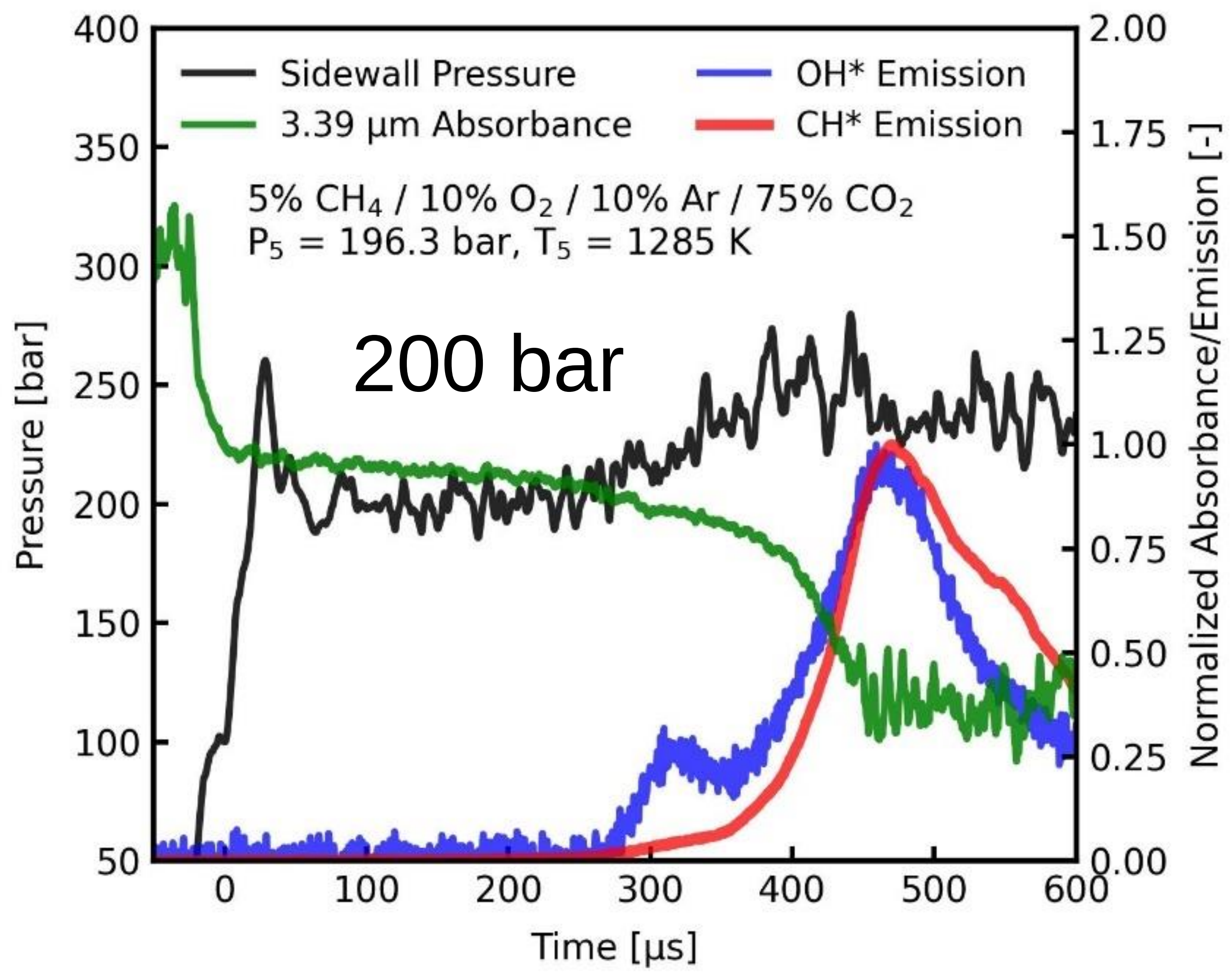
Sidewall pressure measurements were taken using fast-response piezoelectric pressure transducers. Laser schlieren data were collected using a Helium-Neon laser (632.8 nm) for time zero determination in the presence of reflected shock bifurcation. Another Helium-Neon laser (3.39 μm) was used for absorption measurements for methane decomposition to monitor ignition progress. Broadband detectors with bandpass filters were used for chemiluminescence detection at 306 nm targeting the A2Σ+ → X2Π ((0,0) band) of OH* and 432 nm targeting the A2Δ → X2Π transition of CH*.



## Results and Discussion

A comparison of ignition experiments for stoichiometric methane and natural gas with and without $CO_2$ dilution using the same fuel loading yielded the following observations:

- The ignition process is much more gradual in $CO_2$ versus an argon bath gas due to thermodynamic effects.
- Interpretation of OH* emission measurements can vary, resulting in uncertainty in IDTs, complicating comparisons with chemical kinetics mechanisms in similar studies.
- Maximum slope of CH* emission increase and methane concentration decrease provide the clearest definition of ignition delay time, in agreement with the approximate time of peak pressure.



## Conclusions and Future Work

Collecting and interpreting experimental data for methane and natural gas ignition with high $CO_2$ dilution at conditions relevant to the Allam cycle is challenging. This work employed a combination of optical diagnostics, including chemiluminescence and laser absorption spectroscopy, to increase the quality of data for experimental validation of chemical kinetics mechanisms beyond what is currently available in the literature. This work could be extended to pressures of 300 bar to further increase relevance to $sCO_2$ cycle optimization. Additionally, absorbance measurements at additional wavelengths would yield more even more useful data with which to refine chemical kinetics mechanisms for application to $sCO_2$ power cycles.

## Acknowledgements

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