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Sandia National Laboratories

LASER-BASED CHARACTERIZATION OF REFLECTED SHOCK TUNNEL FREESTREAM VELOCITY AND MULTI-SPECIES THERMAL NONEQUILIBRIUM WITH COMPARISON TO MODELING

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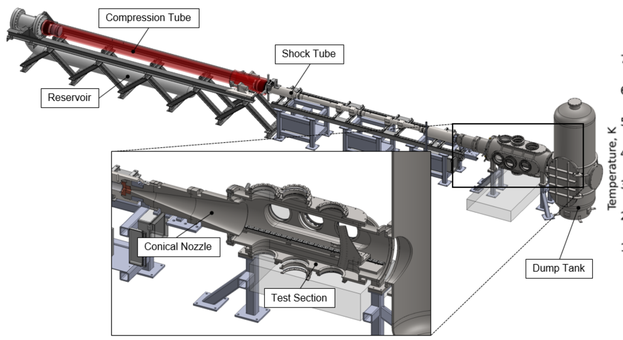
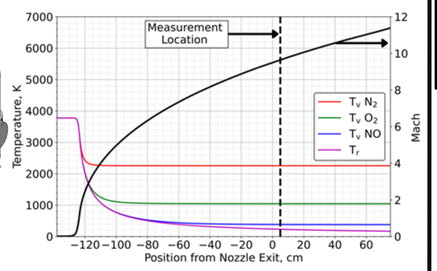
Motivation

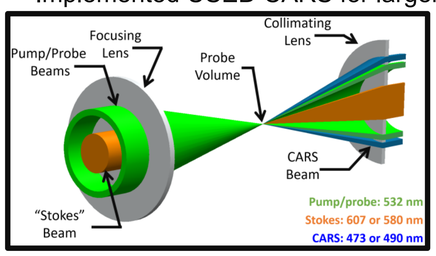
- Shock tunnels are able to replicate flow enthalpies of hypersonic flight but are out of thermal and chemical equilibrium.
- SPARC Hypersonic CFD simulation with 5-species air model (N_2, O_2, NO, O, N) with multiple vibrational temperature model.

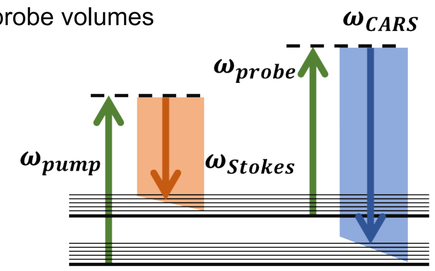




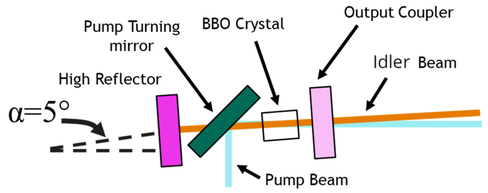
100 kHz Pulse-burst CARS

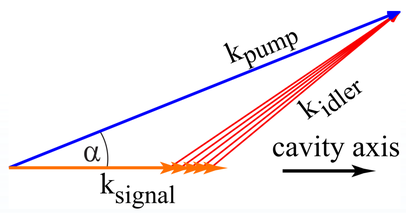
- Implemented USED CARS for larger probe volumes



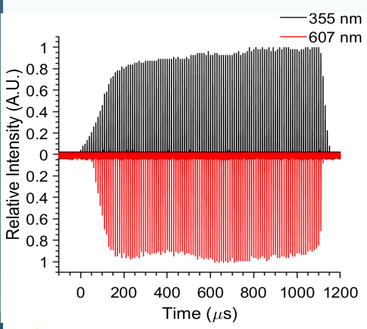


- Nanosecond Noncolinear Optical Parametric Oscillator (NOPO) used to generate broadband Stokes beam.

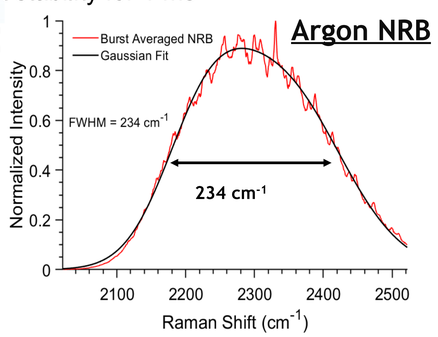




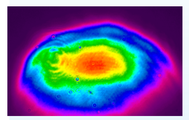
- Excellent OPO shot-to-shot stability for 1 ms



Argon NRB



OPO Beam Quality

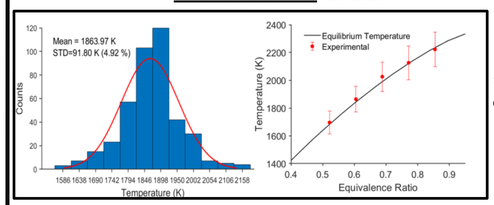


Spatial chirp

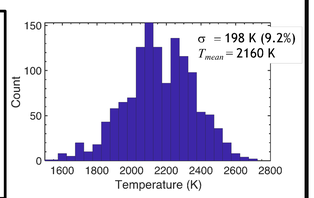
Comparison of *ps* to *ns* burst-mode CARS

- Improved SNR and single-shot precision with ns CARS in a flat flame burner

Nanosecond CARS

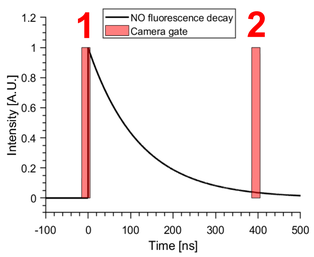


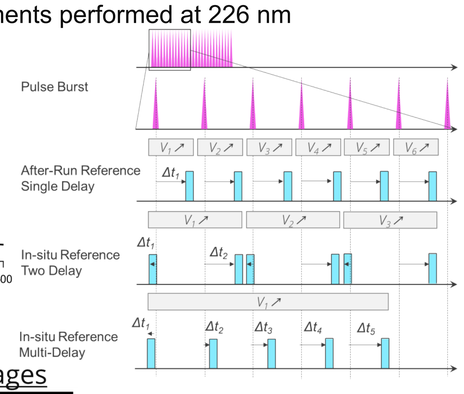
Picosecond CARS



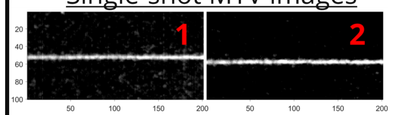
100 kHz Pulse-burst NO MTV

- NO(A-X) LIF measurements performed at 226 nm

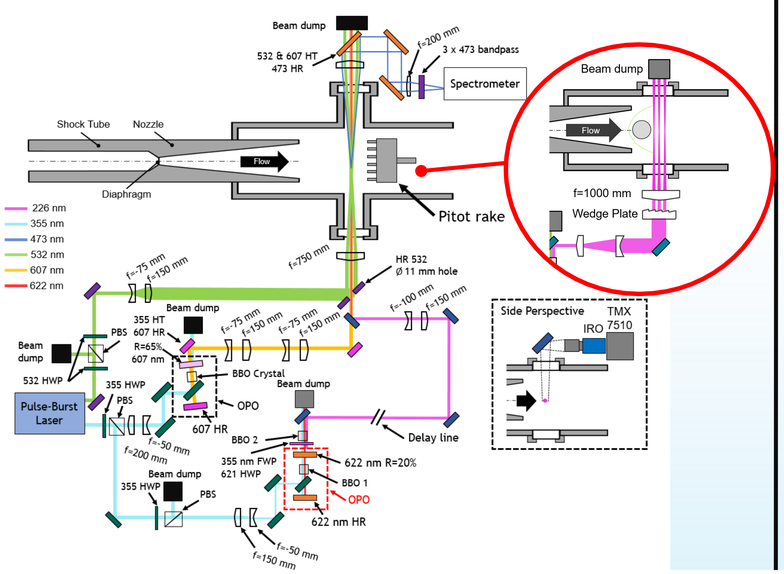




Single-shot MTV images

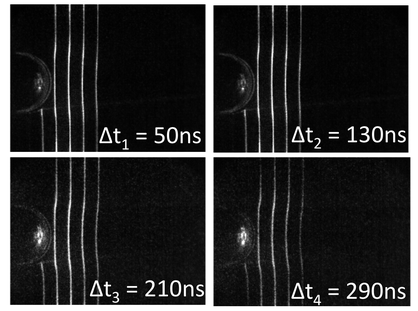


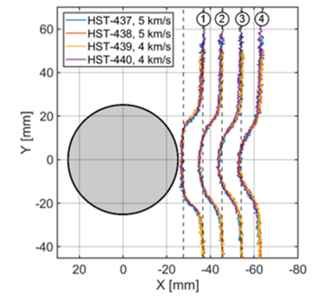
Experimental Set-up



Results: Free-flight wake measurement

- Wake measurements done with dry air at an enthalpy of 7 and 9 MJ/kg with a free-stream flow velocity of 4 and 5 km/s.

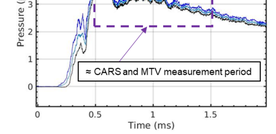




Results: Freestream measurements

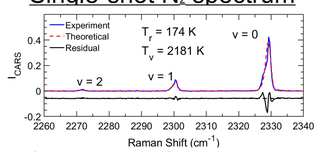
- Freestream measurements done with synthetic air at an enthalpy of 4.6 MJ/kg

Pitot Rake measurements

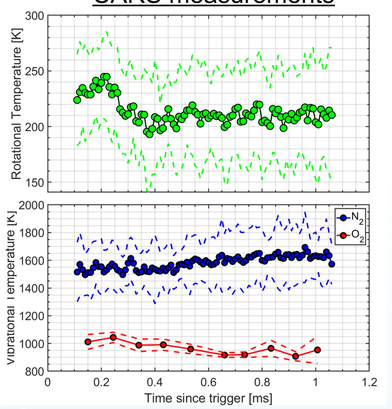


NO MTV Velocimetry

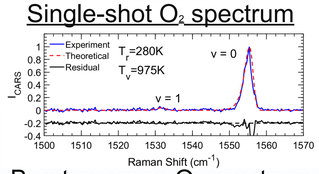
Single-shot N_2 spectrum



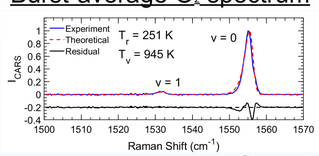
CARS measurements



Single-shot O_2 spectrum



Burst-average O_2 spectrum



Conclusions

- Characterization T_{rot} and T_{vib} for N_2 and O_2 in freestream via burst-mode ns-CARS.
- Disagreements of N_2 Tvib with CFD simulations suggest uncertainties in kinetic rates or presence of other species.
- Utilized NO MTV for freestream and wake velocity measurements, precision within 200 m/s

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