Title and Research Team

- *Title*: Ultrafast laser absorption spectroscopy (ULAS) for characterizing shock-heated gases
- *PI*: Prof. Christopher Goldenstein, Purdue University
- *Team Members*: The proposed work will be completed by the PI, two full-time (0.5 FTE), and 1 half-time (0.25 FTE) PhD students. The PI will gladly collaborate with NASA colleagues if deemed appropriate and valuable by NASA. A letter of support is provided by the PI's mentor, Prof. Robert Lucht, to simply indicate that he is supportive of continuing to share the ultrafast laser with the PI.

Research Objectives

- *Objectives:* Develop, validate, and apply *the first*: (1) One-dimensional (1D) mid-IR ULAS diagnostics for measuring rotational and vibrational temperatures and NO, CO, and CO_2 and (2) UV-Vis ULAS diagnostics for temperatures and populations of non-IR-active species (e.g., N, N_2).
- *Innovations*: Extend ULAS to provide *first:* (1) 1D ULAS measurements with sub-ns to 100-ns time resolution and (2) UV & Vis ULAS measurements of temperatures and non-IR-active species.
- *Key Advantages over SOA:* ULAS can measure multiple-temperatures and –all-requested-species with sub-ns time resolution and 1D spatial resolution.
- Start at TRL 2 and end at TRL 3 since the proposed effort will demonstrate proof-of-concept for the 1st time.

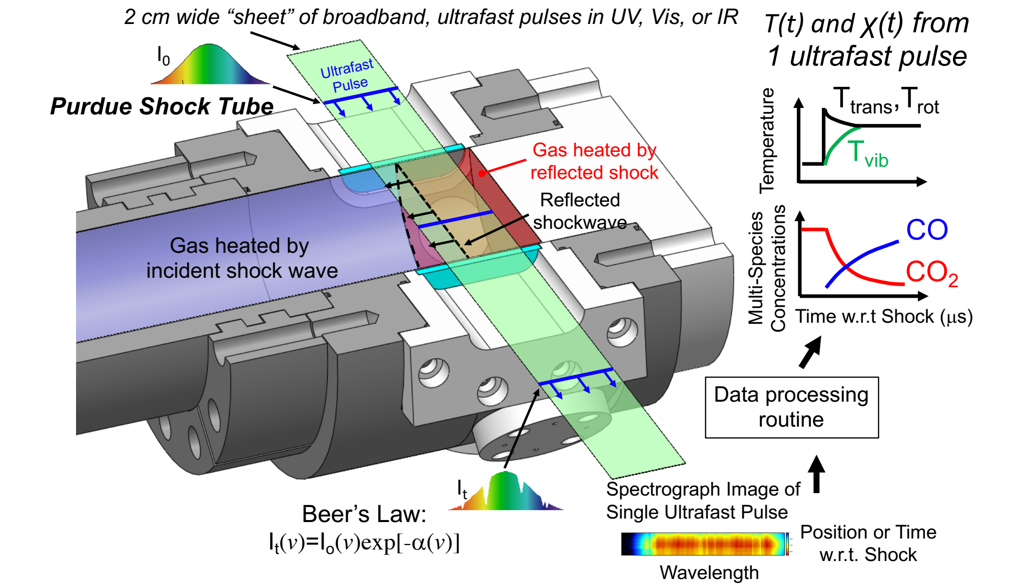

Fig. 1: ULAS diagnostic for 1D-, time-resolved, multi-temperature, and multi–species measurements in shock-heated gases using a broadband femtosecond pulse.

Approach

- Ultrafast (55 fs), broadband (600 cm^{-1}) pulses of light centered at wavelengths from 235 nm to 5.5 μm will be formed into a "sheet" and directed through the Purdue shock tube and onto a spectrograph to measure absorbance spectra and, ultimately, multiple-temperatures and –species (simultaneously) in 1D (behind shock waves) and with sub-ns to 100-ns time resolution. An established quantum-cascade-laser diagnostic will be used simultaneously to help validate the accuracy of the novel ULAS diagnostics in non-equilibrium gases. The test gas will be shock-heated to temperatures up to 10,000 K to evaluate the novel ULAS diagnostics at conditions relevant to atmospheric entry and NASA impulse facilities, and to study non-equilibrium processes (e.g., vibrational relaxation, dissociation, excitation of electronic states).

Potential Impact

- The proposed ULAS diagnostics will help optimize the heat-shield design process and reduce mission costs by advancing our understanding of non-equilibrium gases and plasmas encountered during atmospheric entry.
- ULAS will reduce ground-testing costs by providing temporally and spatially resolved measurements of multiple temperatures and multipl species per test, thereby reducing the number of required tests.
- ULAS measurements can also advance atmospheric entry models by revealing phenomena occurring on the shortest time-scales of interes (ns) which cannot be resolved with SOA absorption diagnostics.
- The proposed work will enable the PI to build a relationship with NAS and focus his research and career path on advancing NASA's missio