MICKEY LELAND ENERGY
FELLOWSHIP PROGRAM

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Rayleigh Scattering Combustion Diagnostic

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Introduction

Why energy research?

- The threat of global warming is real
- Energy independence, economy, national security

1824 – Joseph Fourier

- Terrestrial temperature related to atmospheric carbon

Today

- We know something needs to change

Renewable and sustainable energy

- Renewables – small piece of the pie
- Power plant retrofitting - improvements
  - Cleaner, more efficient ways to burn coal
  - Carbon capture and sequestration (CCS)
  - Engineering challenges

Introduction

Oxy-combustion

- Burning fuel in presence of high O_2 concentrations instead of air
- Less N_2 to heat (wastefully), reduced fuel consumption, high CO_2 concentration
  - CCS
- CO_2 gasification reaction enhances pulverized coal char burning rates

CRF Experiment

- Characterizing kinetic gasification rates in oxy-combustion of coal char
- Need to know temperatures, hard to measure
  - Thermocouples consumed by CO_2
  - Need for optical diagnostic, enter laser Rayleigh scattering

Rayleigh Scattering Theory

Scattering cross section (90°, isotropic)

$$\sigma_R = \frac{4\pi^2(n-1)^2}{{N_0}^2\lambda^4}$$

Scattering intensity from gas

$$I_R = C_0 I_0 \Omega l N \sum_{i=1}^{j} X_i \sigma_{R\,i}$$

Dependence on temperature

$$I_R \propto N \propto \frac{1}{T}$$

Applications

Rayleigh scattering combustion diagnostics

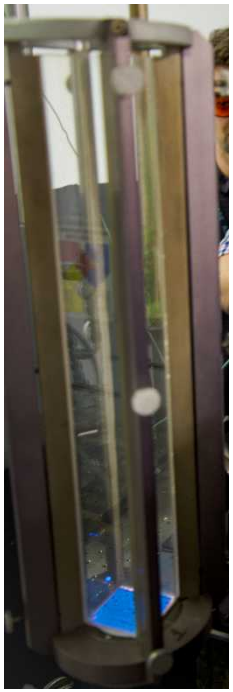
- Have been applied to many combustion processes
- Temperature, concentration, density

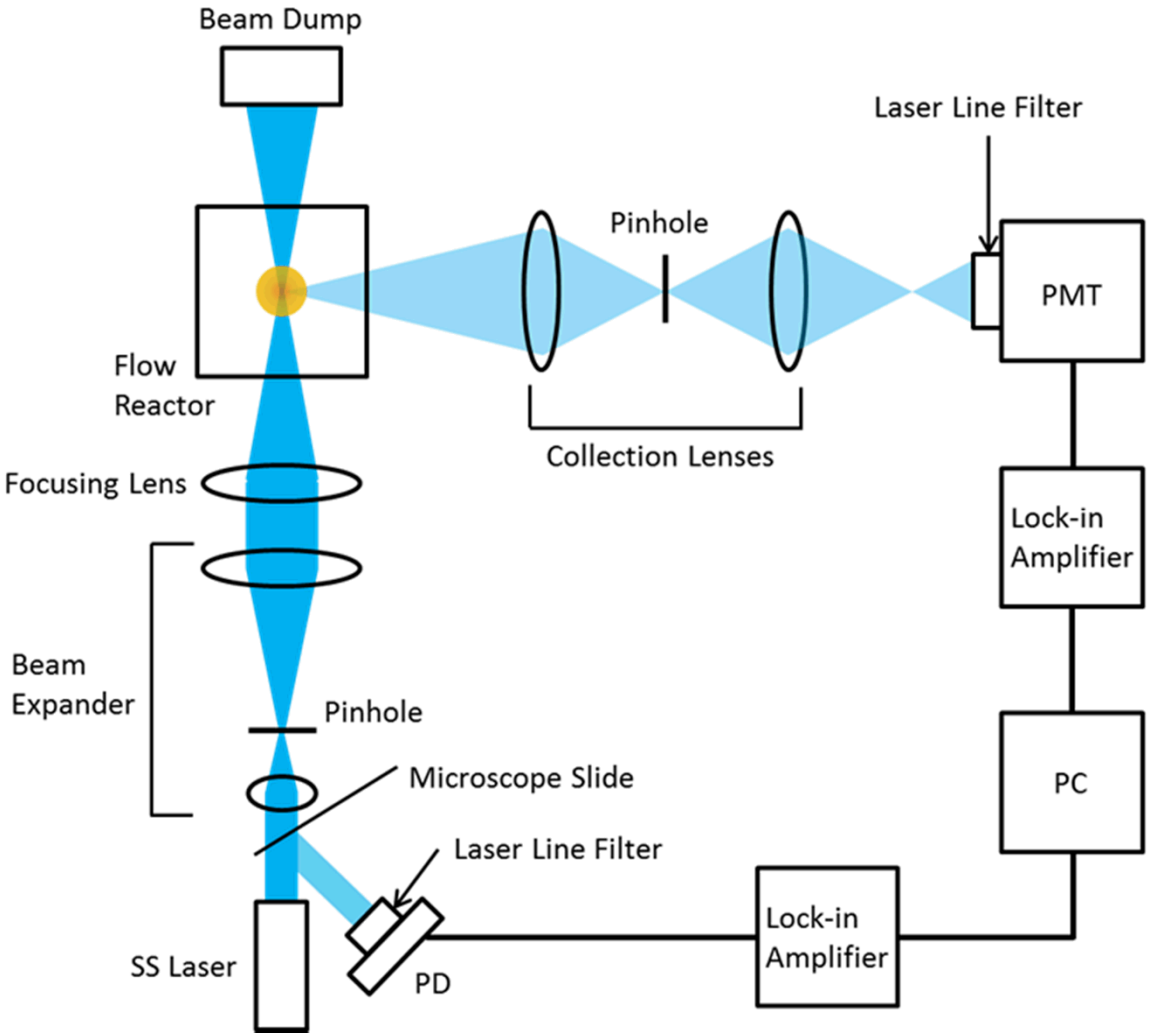
Oxy-combustion of coal

- New application of Rayleigh scattering to study gasification reactions in high temperature (>2000 K) oxy-combustion of coal
- Temperature information previously unavailable

LRS System

LRS system for temperature measurements inside flow reactor





Experiment

Calibrate LRS system

- Measure N_2 and CO_2 signals at room temperature to determine C

Measure “hot” signals

- Ignite combustion flame and measure scattering
- Again measure N_2 and CO_2 signals to determine background scattering level
- Repeat measurements at multiple heights to obtain profile

Perform analysis calculations

- Algorithm developed for LRS system

Interpret temperature results

- Accurate?
- What to adjust

Analysis

Measured signals

$$R = I_R + S_B$$

Optical calibration constant

$$C = \frac{R_{CO_2} - R_{N_2}}{1.4/T_{cal}}$$

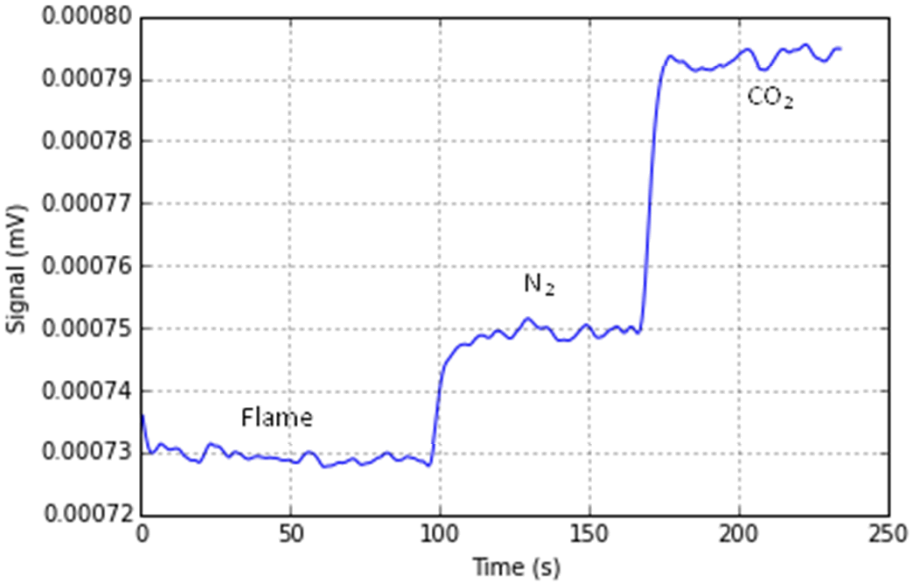
Background scattering

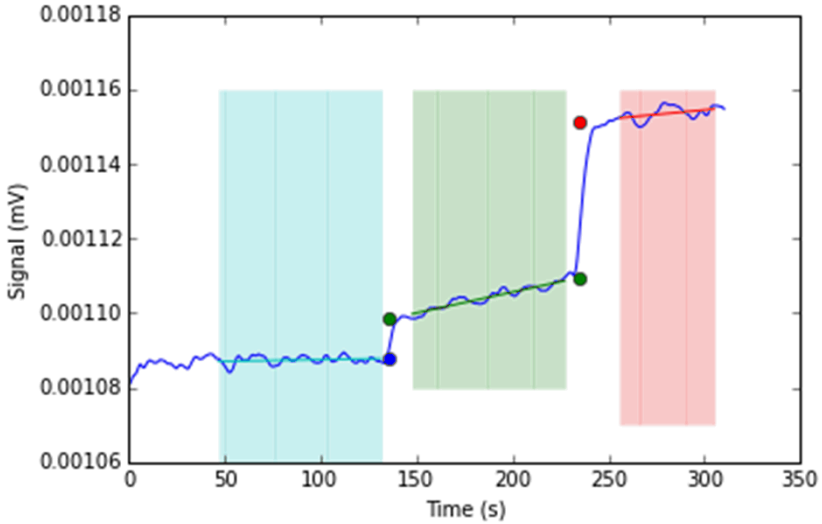
$$S_B = \frac{2.4R_{N_2} - R_{CO_2}}{1.4}$$

Temperature

$$T = \frac{C\sigma_{flame}}{R_{flame} - S_B}$$

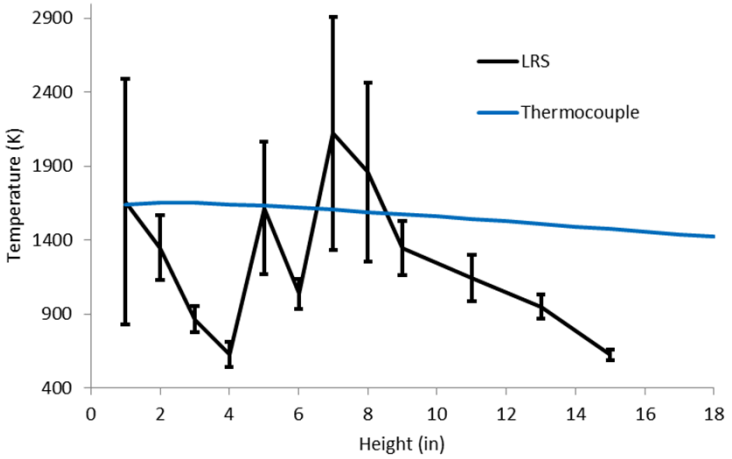
Results





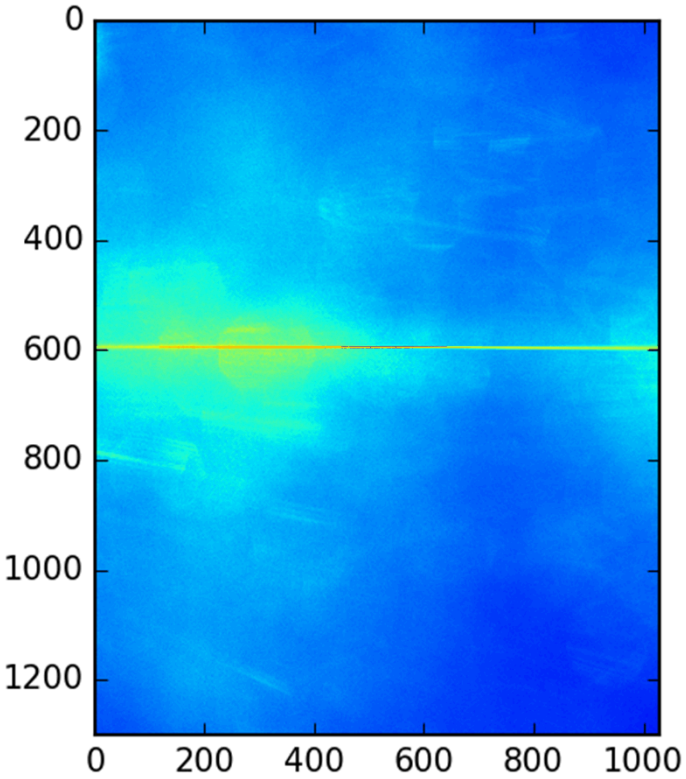
Measured signals follow expectations

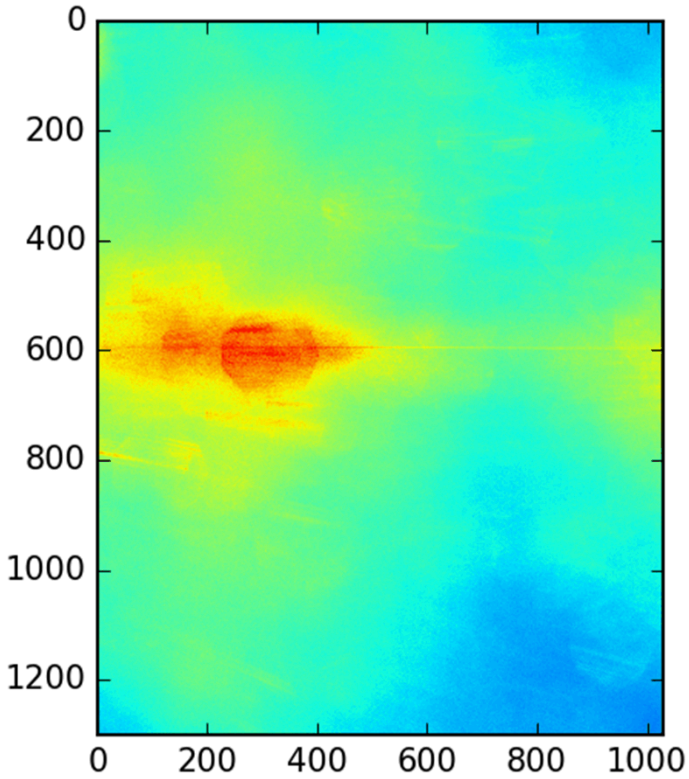
Inaccurate temperatures



CCD Images

- Attempt to solve inaccuracy issues





Conclusions

Diagnostic still in development

- Progress in 8 weeks
- Techniques developed can be used in future experiments

Signals obtained – didn't correlate to accurate temperatures

- Future work to determine why this is and how to correct it

Accurate temperature measurements will provide new, useful information

- Advance in understanding of oxy-combustion and gasification of coal
- Sustainable energy

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Questions