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Experimental Determination of the Kinetics of Pressurized Oxy-fuel Char Combustion

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Motivation

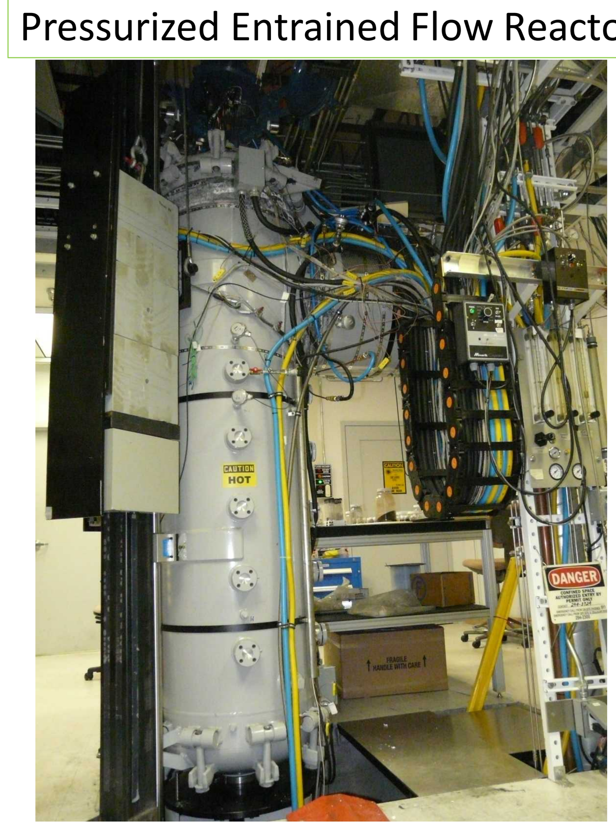
Oxy-fuel combustion of coal has received much attention recently as a promising way to continue to generate electrical power from coal while implementing carbon capture and storage (CCS) technology. Utilization of oxy-fuel combustion of coal with CCS could significantly reduce CO_2 emissions and thereby mitigate the climate change due to this greenhouse gas. The efficiency penalty associated with the implementation of oxy-fuel combustion with carbon capture as compared to air-fired combustion without capture (roughly 10 percentage points when using boilers operating at 1 atm) can be reduced by around 3 percentage points through better heat integration, which can be enabled by combusting the fuel in a pressurized environment. Oxy-fuel combustion of coal under pressure also prevents air leakage into the system and may produce lower NOx emissions than oxy-combustion under atmospheric pressure. Kinetic models and rates of pressurized oxy-fuel coal combustion can enable effective system design and process optimization, and thus facilitate rapid implementation of this promising technology.

Approach

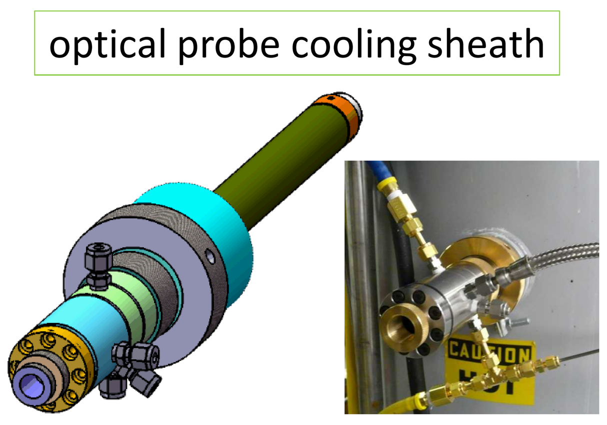
- Generate chars
  - Devolatilize in 1200 °C furnace under N_2
  - Sieve collected char into narrow size fractions
- React chars in Sandia's Pressurized Entrained Flow Reactor
  - Vary reaction environment
    - 12, 24, 36 vol-% O_2
    - N_2 and CO_2 diluents
    - 1200K and 1400K reactor temperatures
    - Atmospheric, 5, 10 bar pressures
  - Make in-situ optical particle temperature measurements
  - Collect and analyze particles for burnout extent
- Fit char consumption models to measured data

Experimental setup

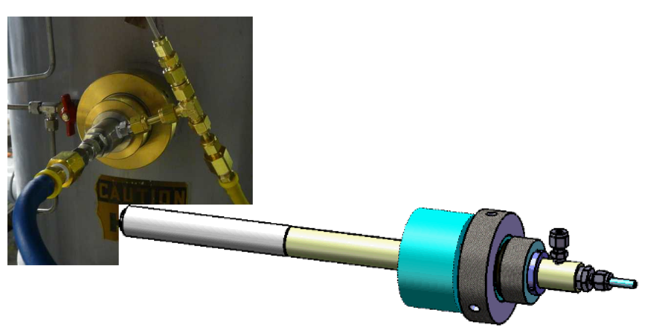
Pressurized Entrained Flow Reactor



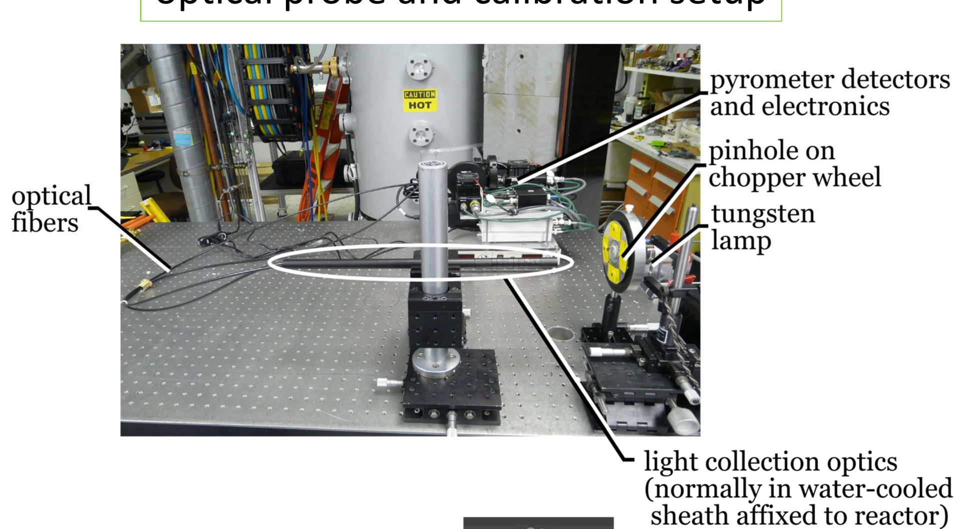
optical probe cooling sheath



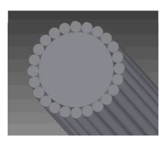
cold surface probe



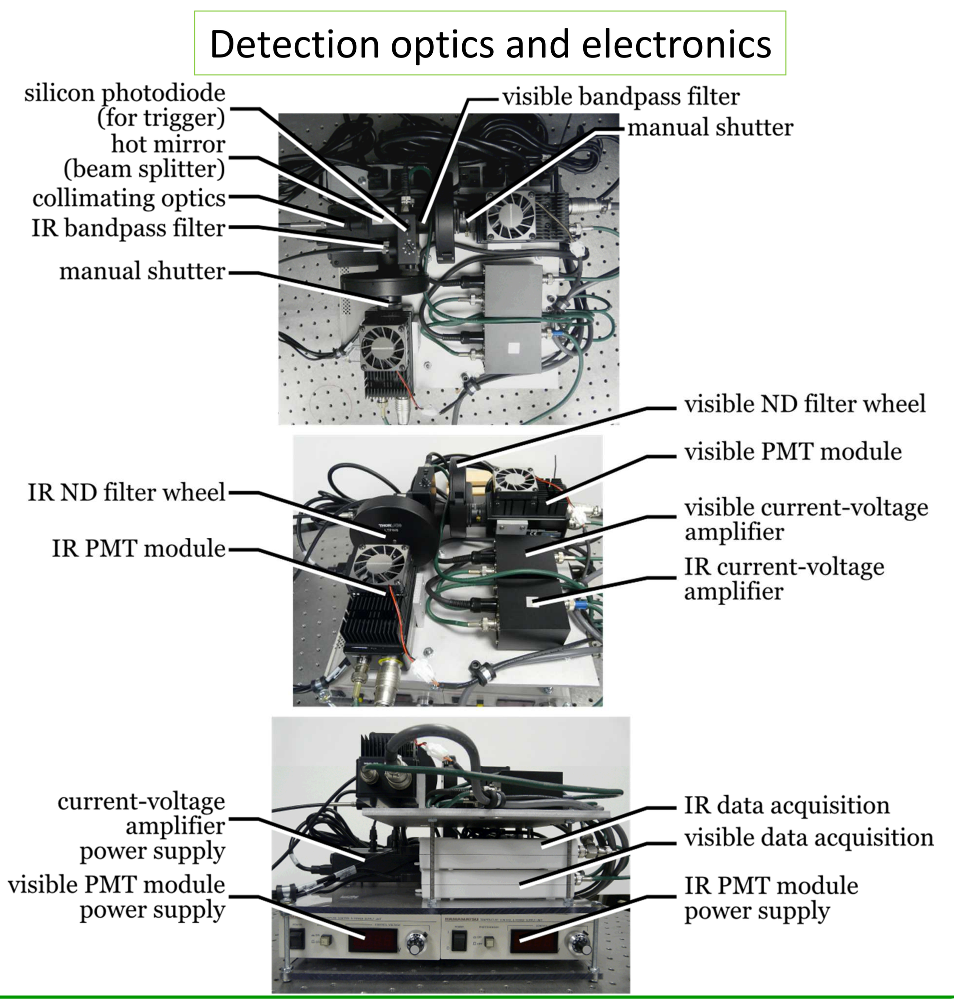
optical probe and calibration setup



Fiber bundle face

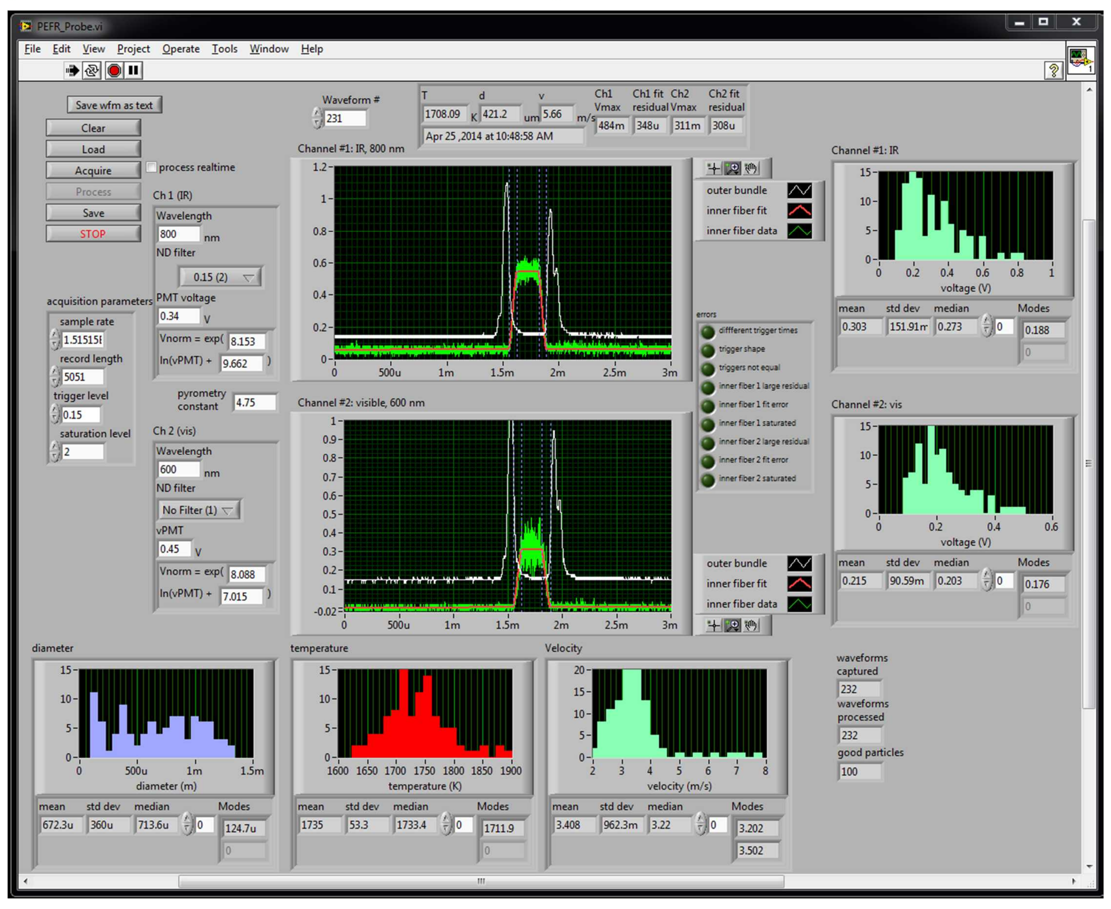


Detection optics and electronics

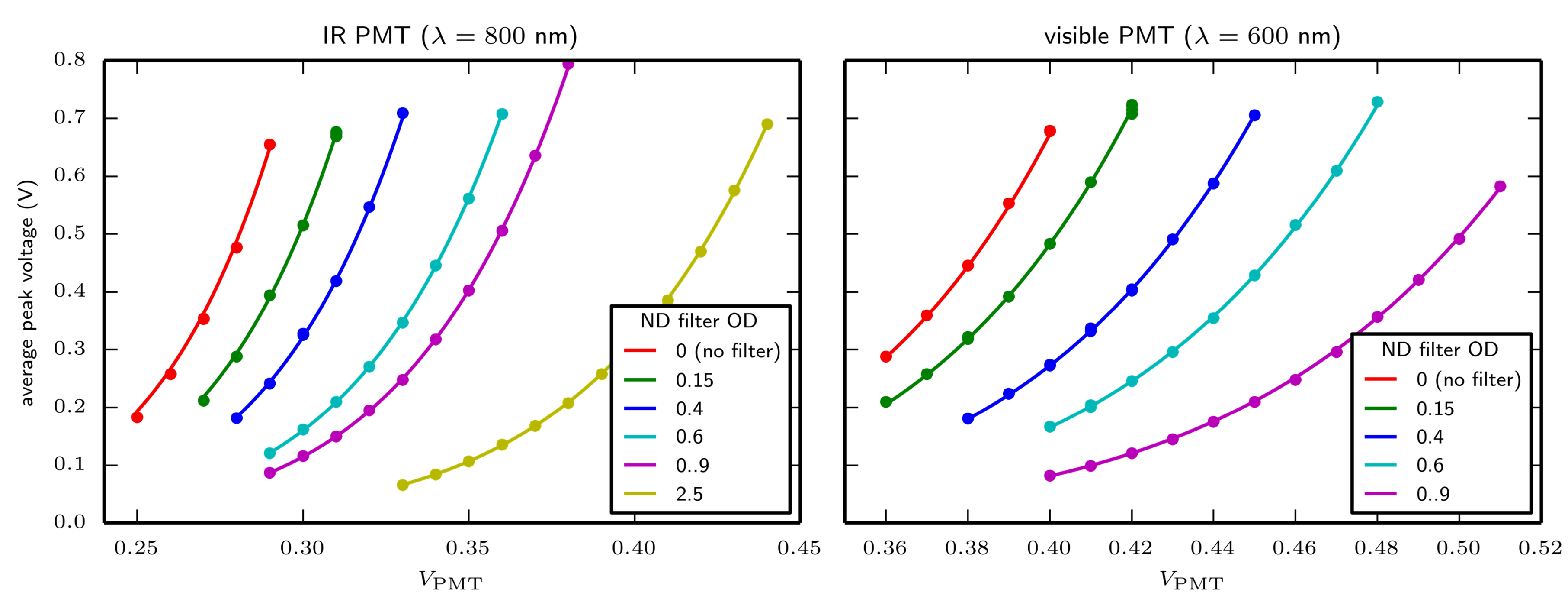


Data Acquisition and Analysis

- 2-color pyrometric temperature measurement on individual particles burning in isolation from each other
- Statistical analysis from 100's of particles passing through the measurement location (i.e. residence time)
- Real-time error checking
- Real-time signal fitting
- Raw and processed data saved
- Lack of focal point check makes size measurement challenging

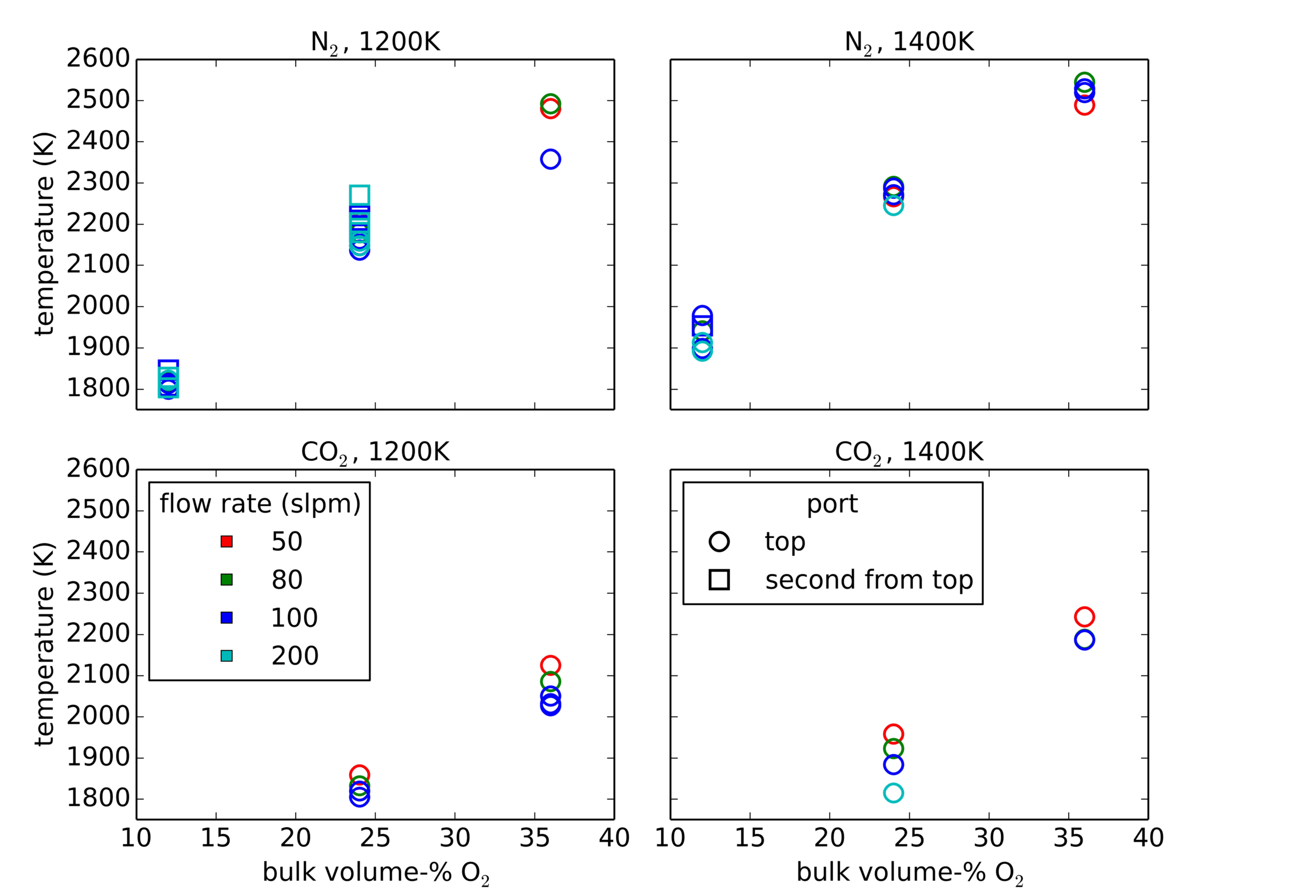


Calibrations



- Corrections for attenuation in neutral density filters and photomultiplier tube gain:
  - ND filter attenuation is wavelength dependent
  - PMT gain is logarithmically dependent on circuit voltage
- 1-point calibration for temperature yields system response constant

Results for a Subbituminous PRB Coal Char



- Residence time does not greatly affect combustion temperature (2 ports or flow rate)
- Particle temperatures nearly independent from reactor wall temperature
- Particle surface temperature significantly lower in CO_2 environment

Conclusions and future work

- Optical probe and cold-tip work well in oxy-combustion environment (based on tests up to 5 bar)
- Preliminary data at elevated pressure indicate higher particle temperature for same oxygen partial pressure with nitrogen diluent
- Next steps:
  - Complete data set for subbituminous and other rank coal chars at pressures up to 10 bar and higher
  - Collect and analyze samples of partially reacted chars
  - Analyze data to quantify kinetics rate parameters
  - Improve focal point discrimination through improved data analysis routines or laser trigger (additional perpendicular probe)

Acknowledgements

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