Mid IR Laser Sensor for Continuous SO_3 Monitoring to Improve Coal-Fired Power Plant Performance during Flexible Operations

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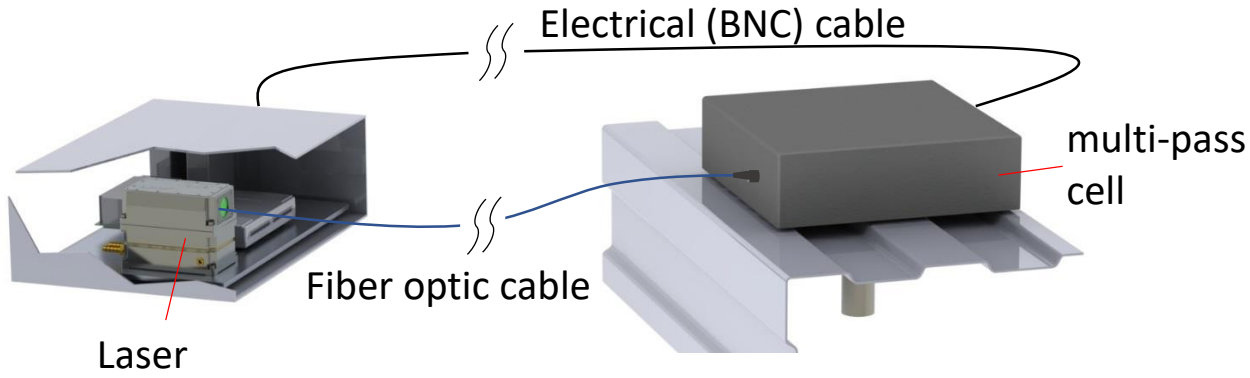
Project Description and Objectives

Purpose:

- Produce and demonstrate a continuous SO_3 / H_2SO_4 monitor for coal-fired power plants

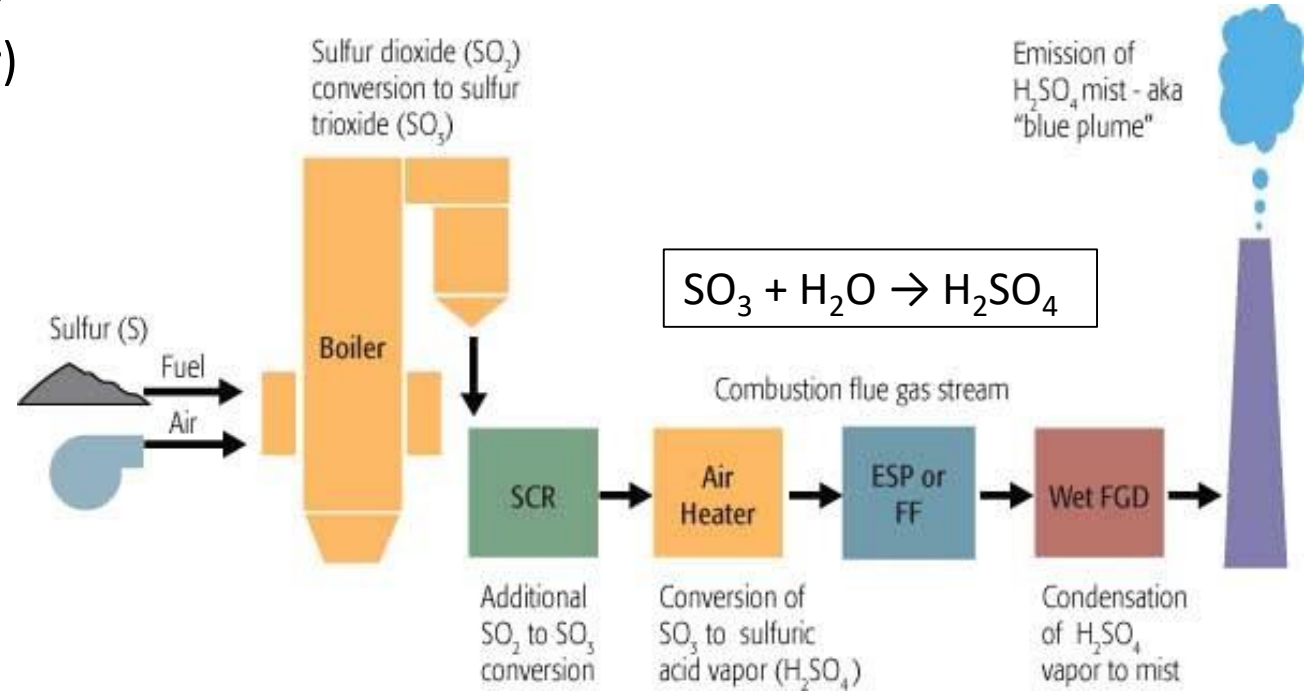


Alignment to Fossil Energy objectives

- Real-time information to optimized additive injection and minimize catalyst deactivation
- Without an SO_3 monitor, power plants over use sorbent => waste (typical sorbent costs $1M/yr)
- Sensor would enable cost savings ($100k/yr – $200k/yr) and improved flexible operations

Driving questions

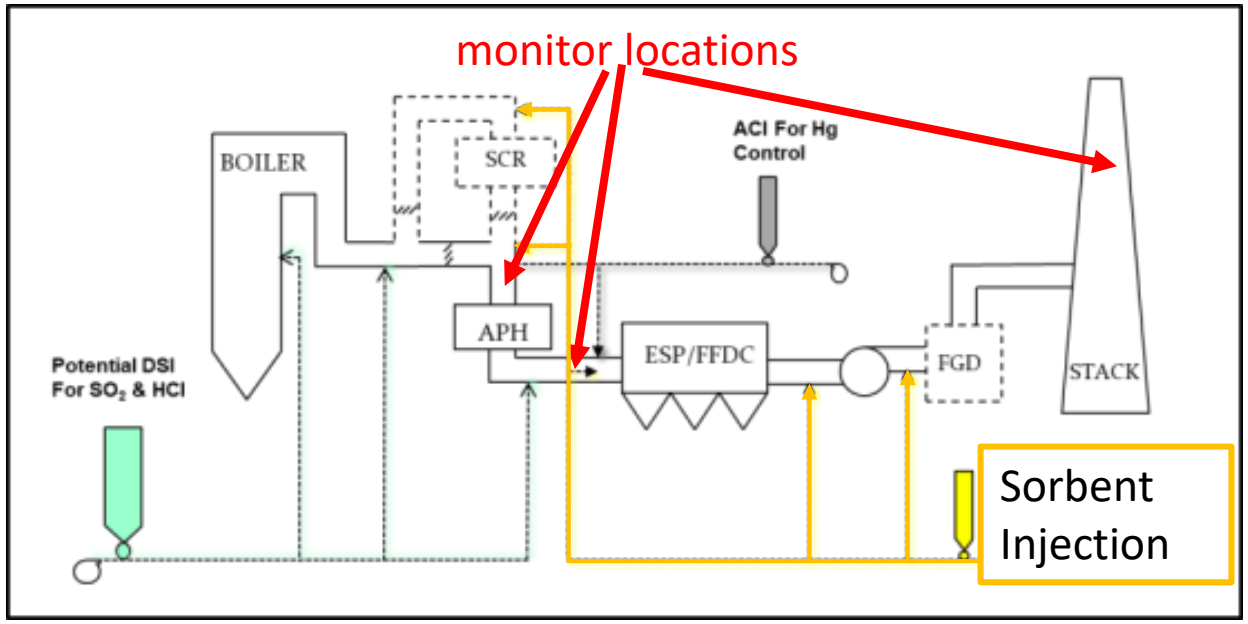
- Can the sensor provide sufficient sensitivity in a challenging environment?
- Do measurements accurately reflect the composition of the flue gas?



Alkali Sorbent Injection

Alkali sorbent injection uses include:

- Mitigation of H_2SO_4 'blue plume'
- Enhanced powdered activated carbon (PAC) efficiency in capturing mercury
- Mitigation of ammonium bisulfate (ABS) and SO_3 condensation impacts on air heater fouling
- Mitigation of duct corrosion due to SO_3 condensation

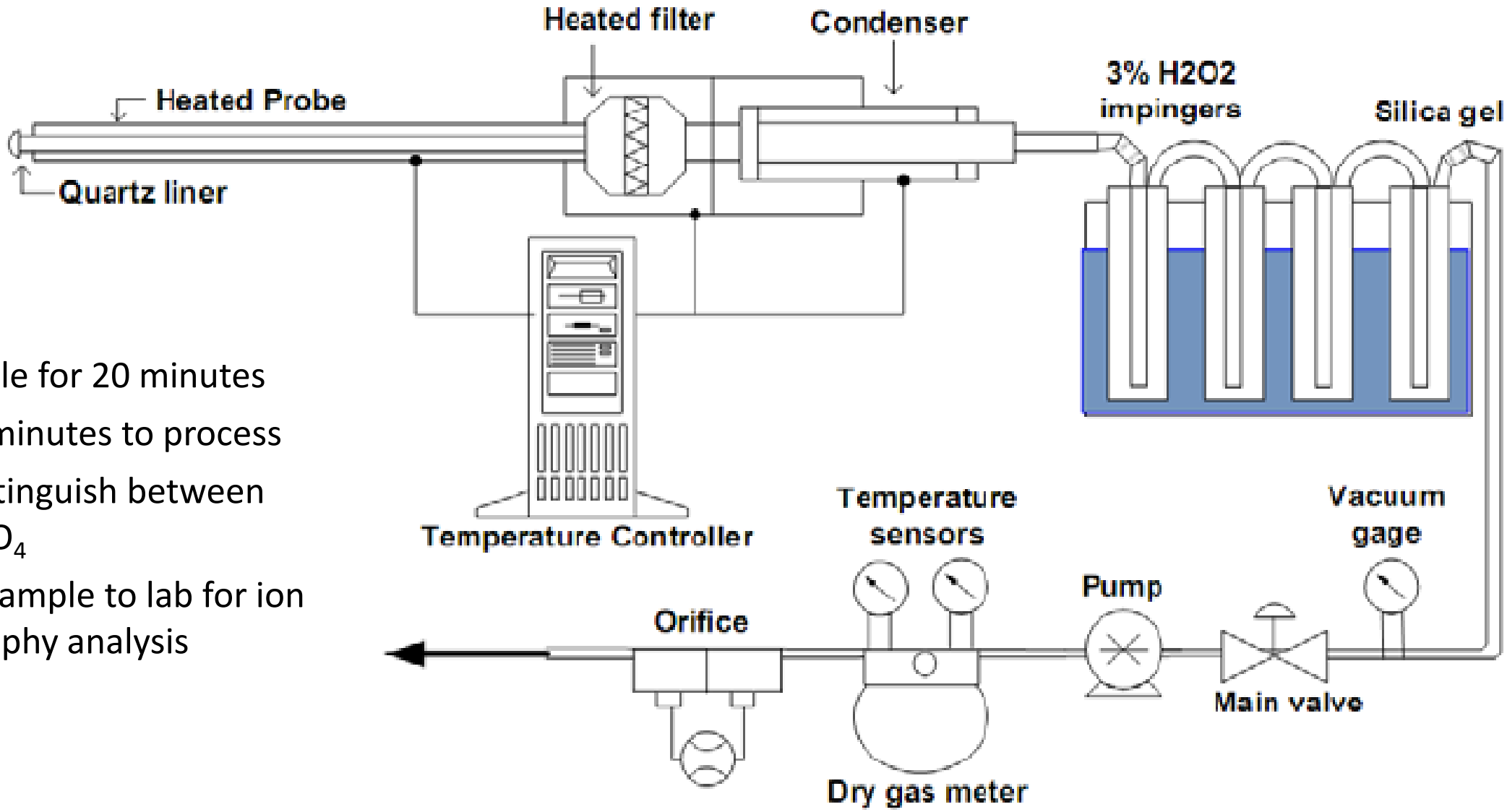


Alkali sorbent injection locations moving upstream:

- Originally downstream of air heater / upstream of particulate collection device
- Also between the Selective Catalytic Reduction (SCR) outlet and air heater
- Recently positioned upstream of the SCR

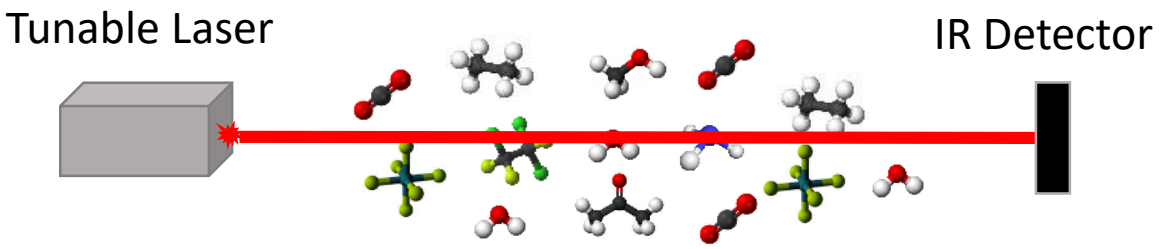
Lack of continuous SO_3 monitor limits ability to optimize sorbent injection rates

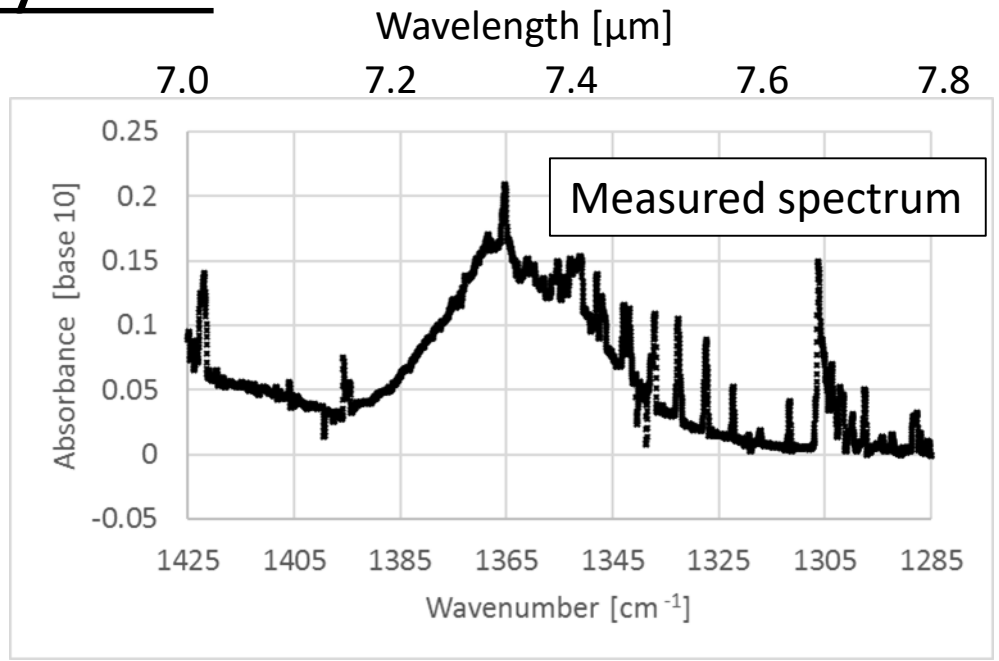
Current Technique for SO3 / H2SO4

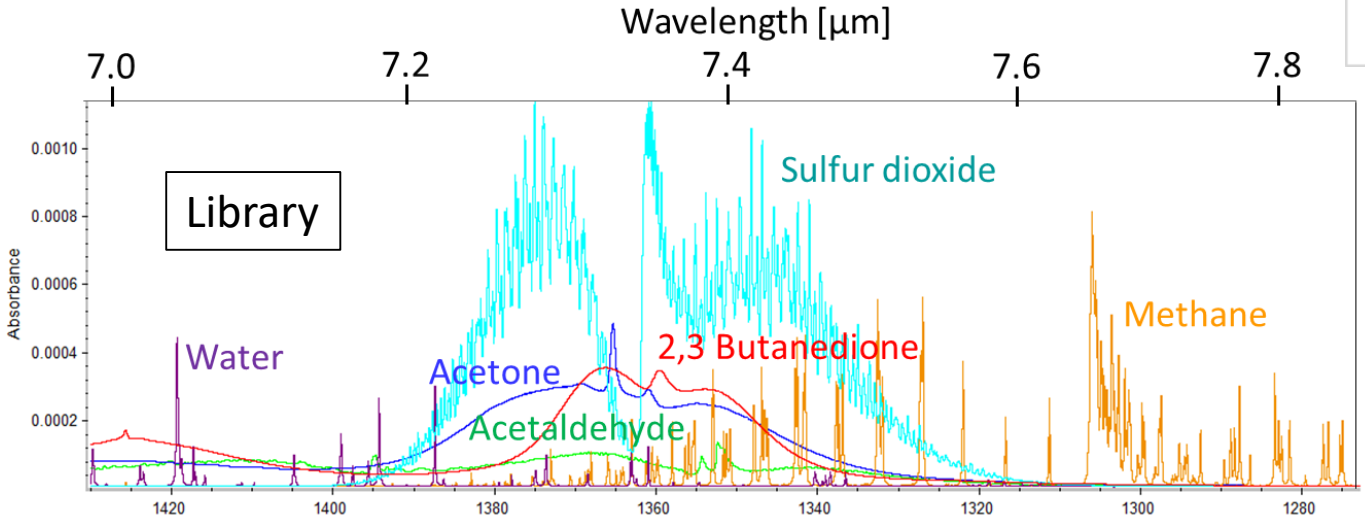


- Collect sample for 20 minutes
- Another 20 minutes to process
- Does not distinguish between SO_3 and H_2SO_4
- Send liquid sample to lab for ion chromatography analysis

Spectroscopy System



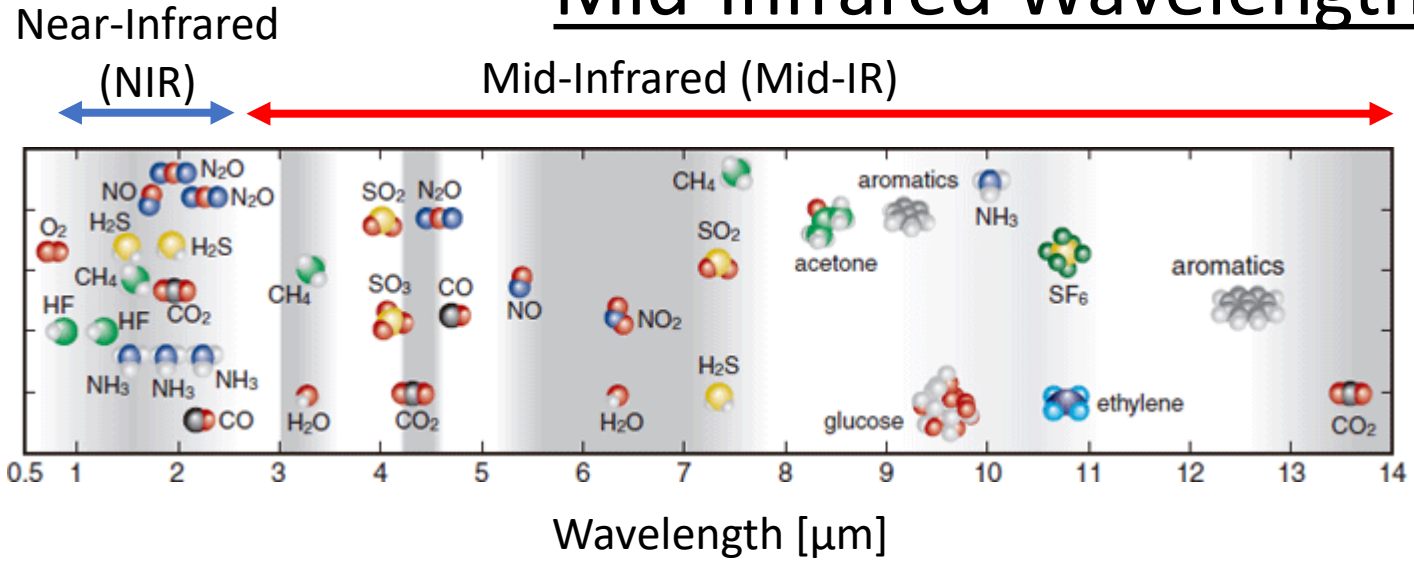


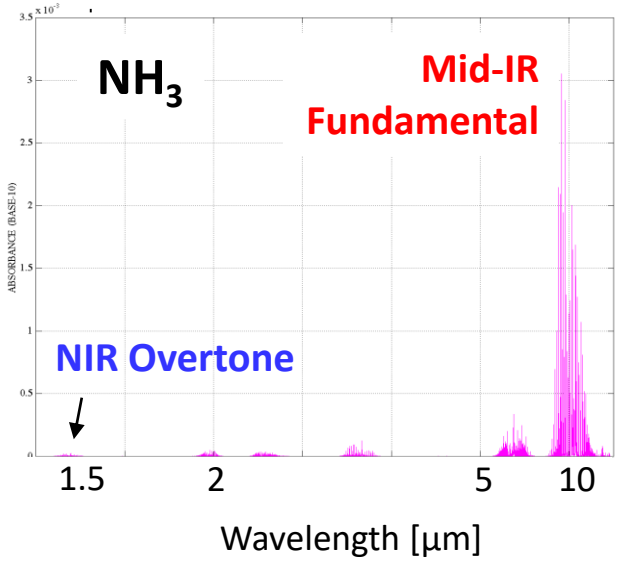


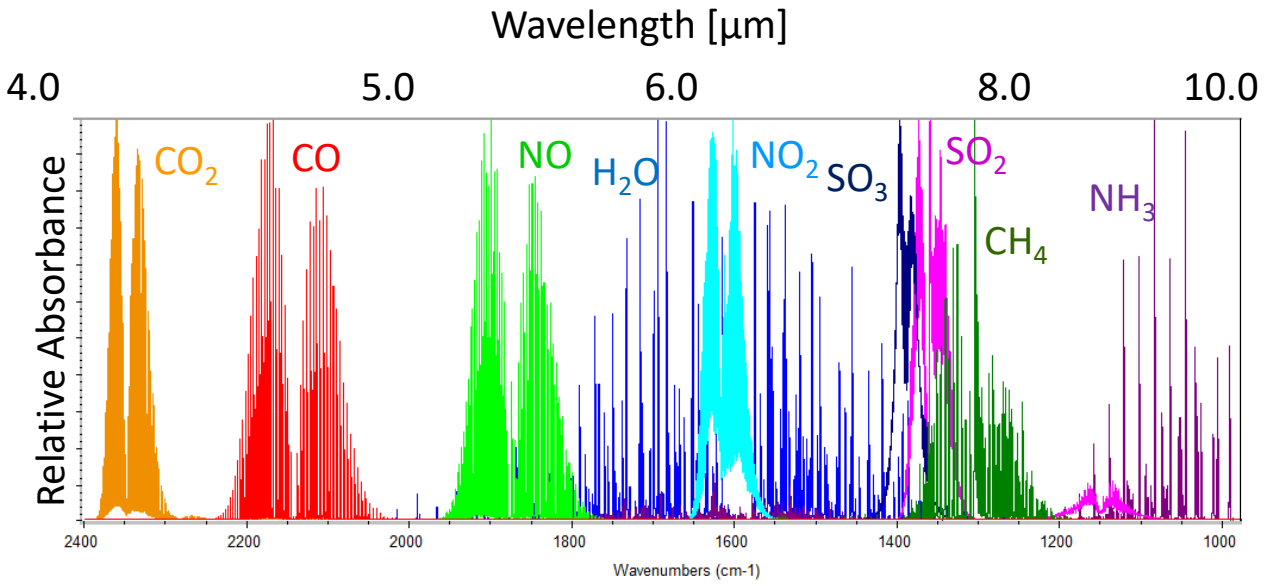
Species Concentration

2,3 Butanedione:	99.7 ppm
Acetaldehyde:	230.2 ppm
Acetone:	130.8 ppm
Methane:	259.3 ppm
Water:	-38.8 ppm
Sulfur dioxide:	2.5 ppm

Mid-Infrared Wavelength Range







Mid-IR Spectroscopy

- Fundamental transitions in Mid-Infrared (λ: 2 -12 µm) stronger than overtones in NIR (λ: 1 -2 µm)
- Molecular species uniquely identified and precisely quantified
- But….. NIR benefits from developed components (telecom investments)

Technology Development

- Extractive measurements are not representative of sample
- Cross-duct measurements suffer from alignment and transmission issues (soot)

→ Heated, close-coupled multi-pass cell

- SO_3 and H_2SO_4 absorption features are strongest in the Mid-Infrared
- Absorption feature are relatively broad spectrally

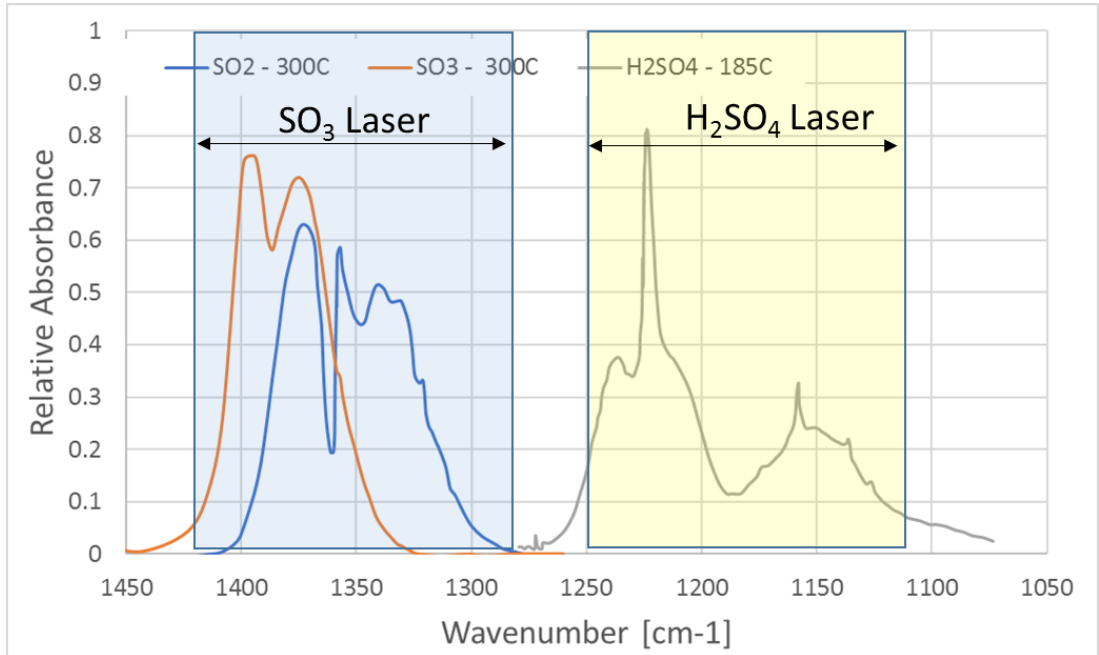
→ Custom, broad-tuning Mid-IR lasers

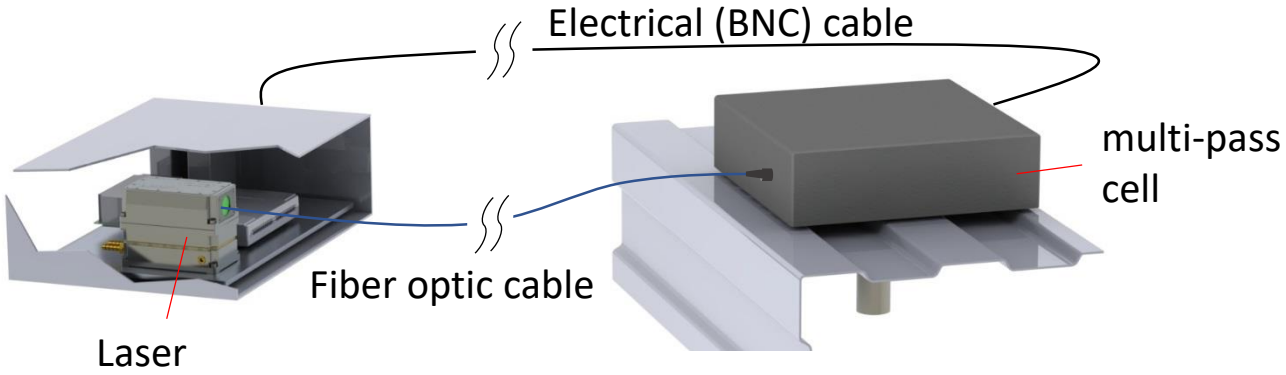
- Lasers should be remotely located from duct

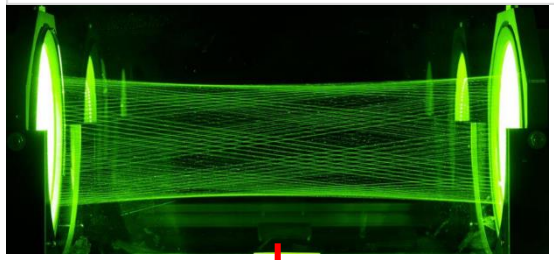
→ Proprietary, hollow-core fiber optics

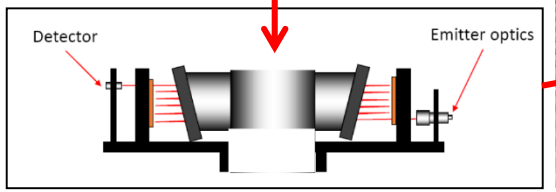
Technology Development

- Dual laser approach for SO_3 and H_2SO_4
- Need “broad” wavelength tuning lasers
- Use close-coupled heated multi-pass cell
- Mid-IR Fiber Optics for remote laser delivery









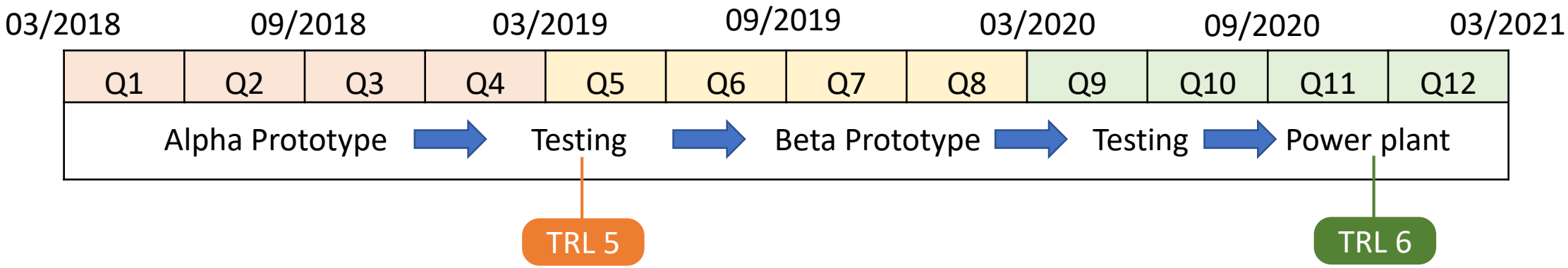
Project Overview and Status

Overview of Project

- Current in the final year of a 3-year project
- Two rounds of prototype development and testing to increase the Technology Readiness Level (TRL)
- Testing in both “laboratory” (UC Irvine) and “industrial” (FERCo) facilities

Project Status

- Successfully demonstrated ability to precisely measure SO_3 and H_2SO_4
- Planned testing / demonstration at a coal-fired power plant the week of October 12th, 2020
- Industry feedback: “We need a solution now”



Lab-based Flue Gas Test Facility

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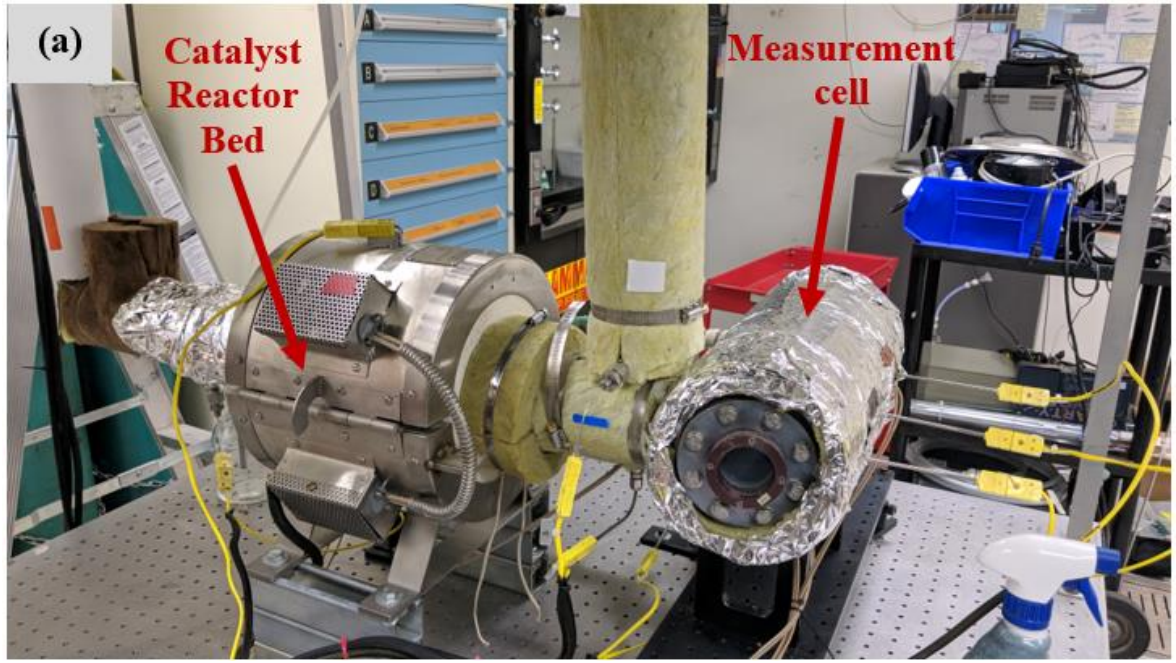
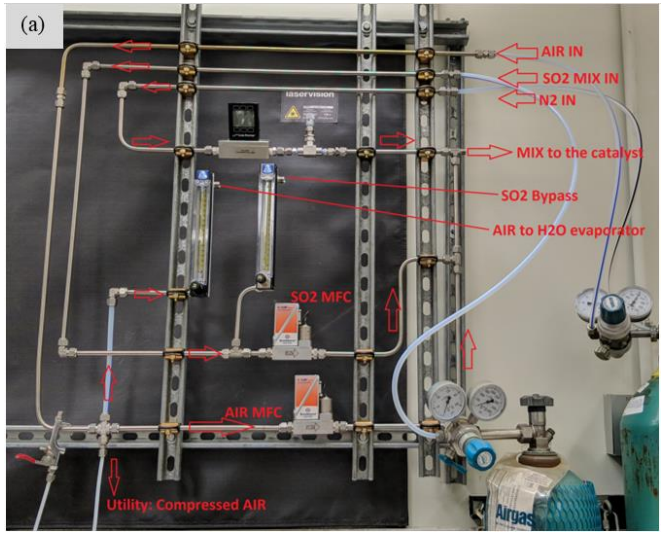
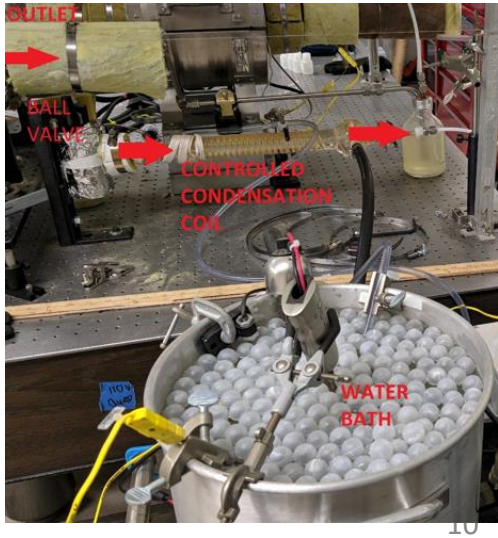
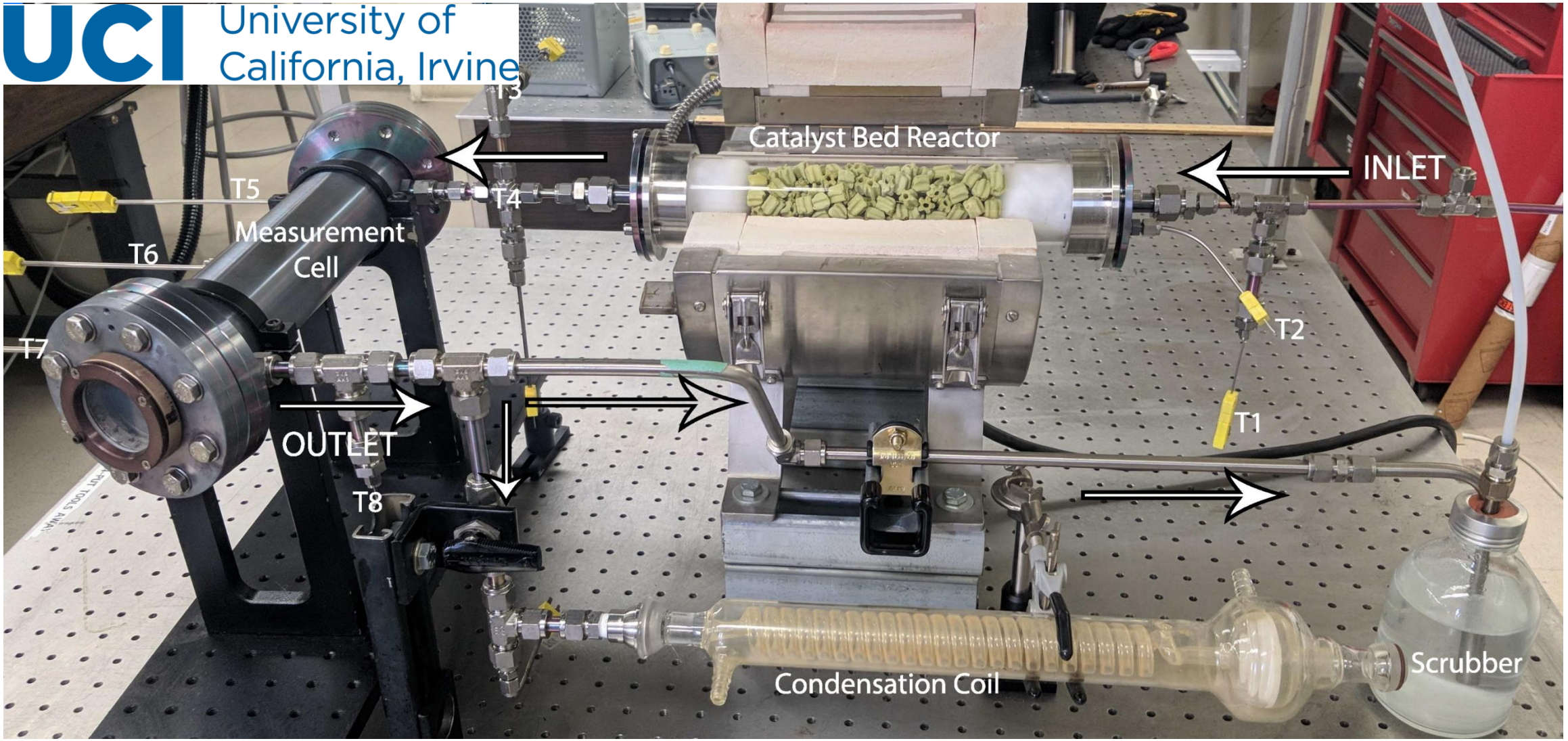
- Heated vanadium catalyst bed reactor
- Heated optical cell with windows: T = 400°C (750°F)
- Controlled condensation setup for validation







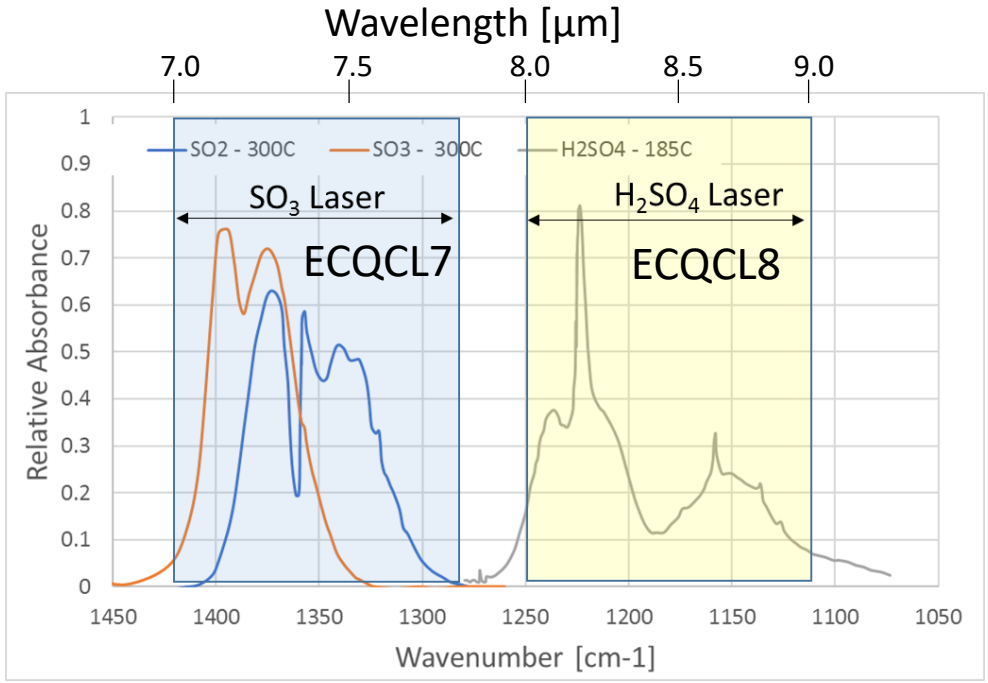
Lab-based Flue Gas Test Facility

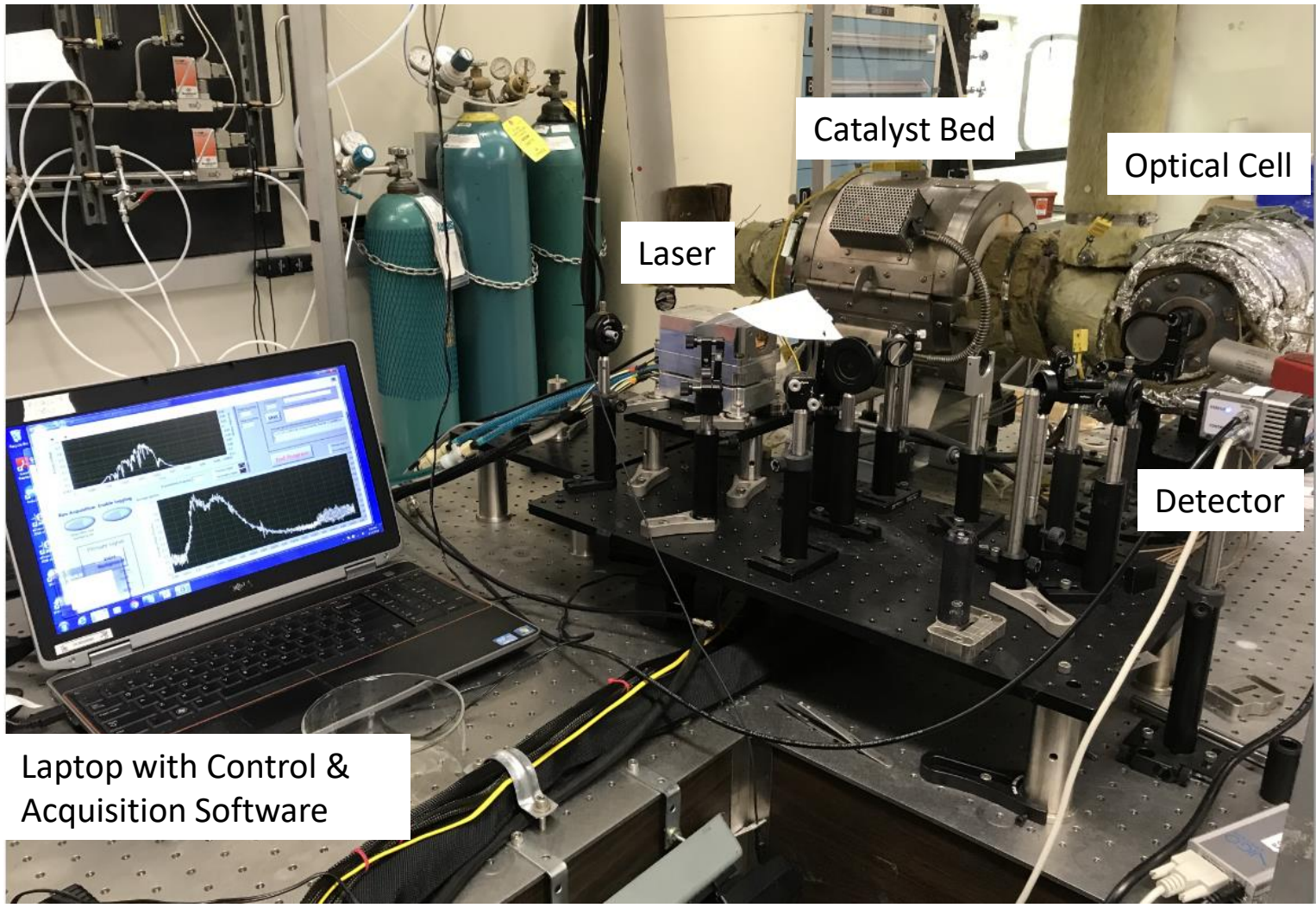


Lab-based Testing

UCI University of California, Irvine

- Controlled conditions with ability to vary: SO_2, SO_3/H_2SO_4, H_2O, Temperature
- Generate "library spectra"





Higher Fidelity Testing

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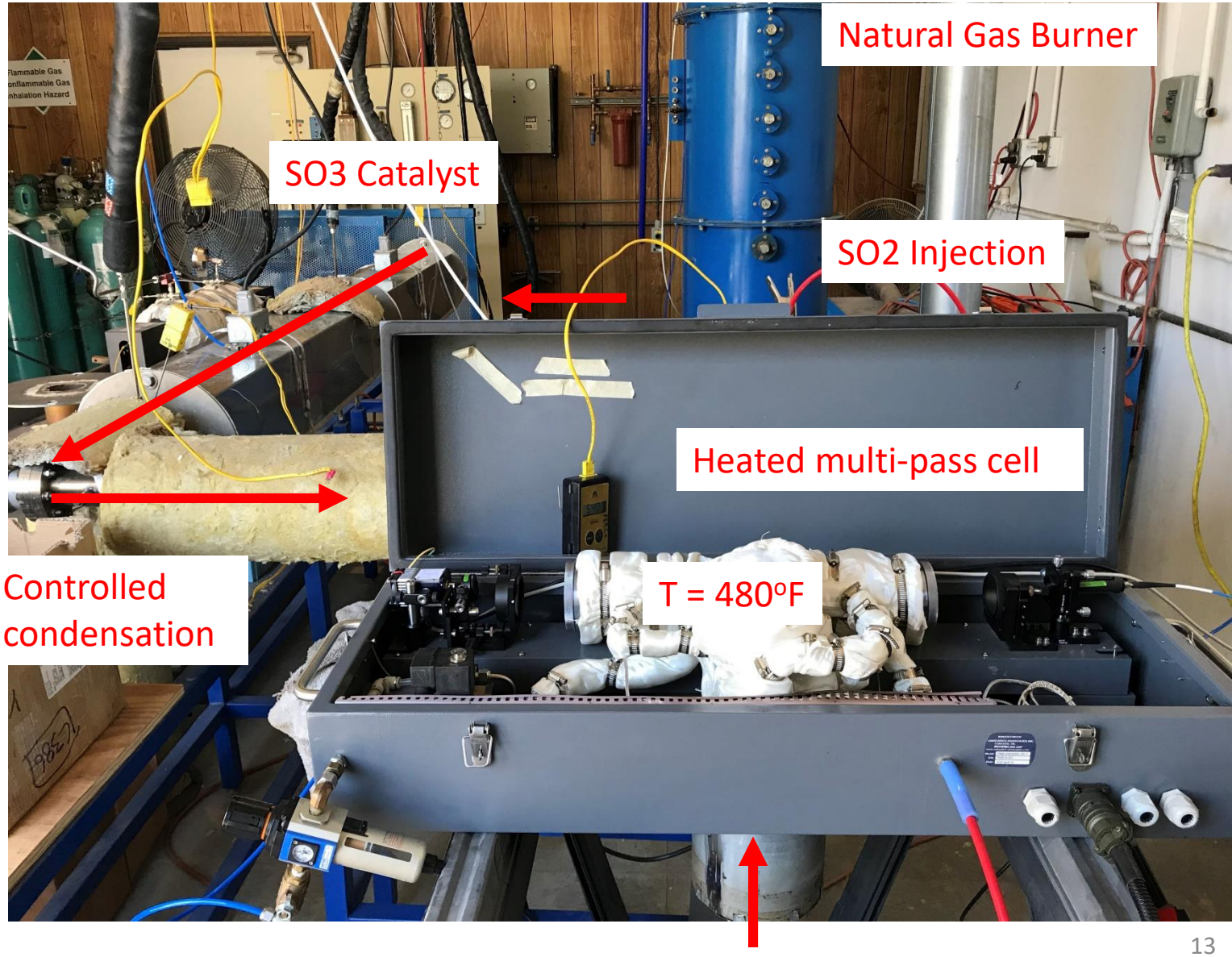
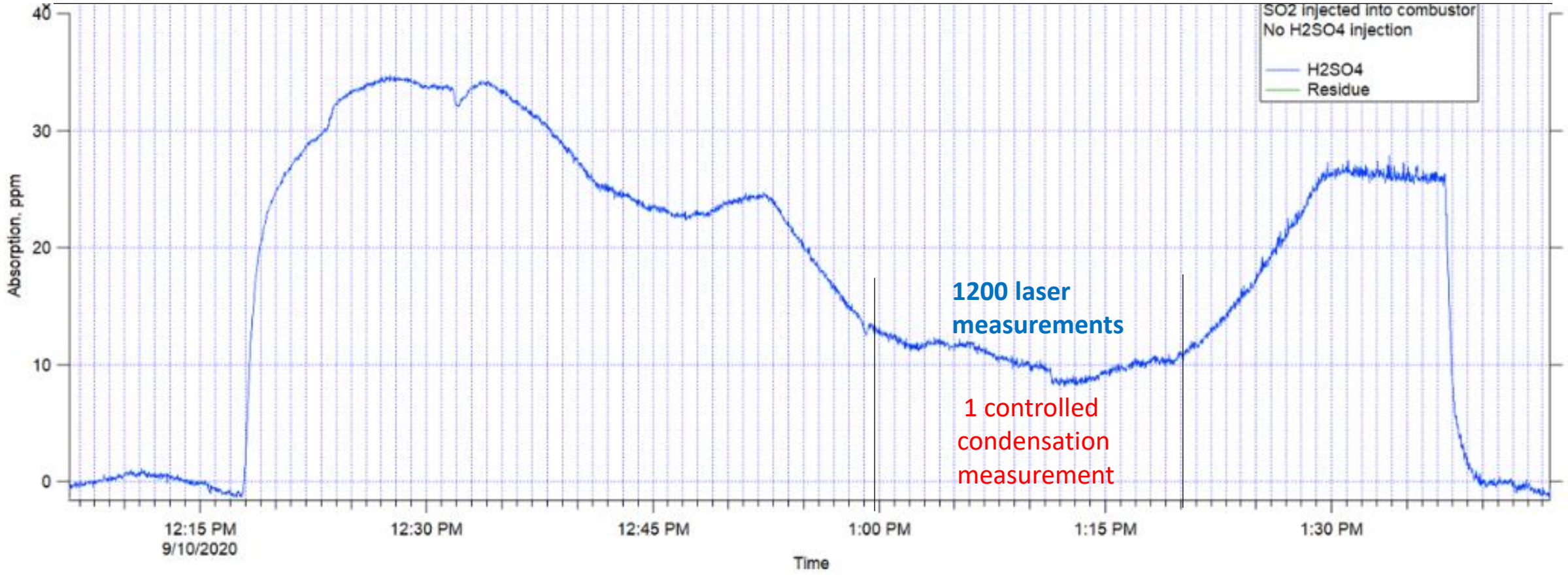
- Industrial facility for catalyst testing
- Hot flue gas with ability to add SO_2 and generate SO_3 / H_2SO_4
- Warehouse environment, ambient temperature up to 110°F
- Controlled condensation performed and utilized as “ground truth”

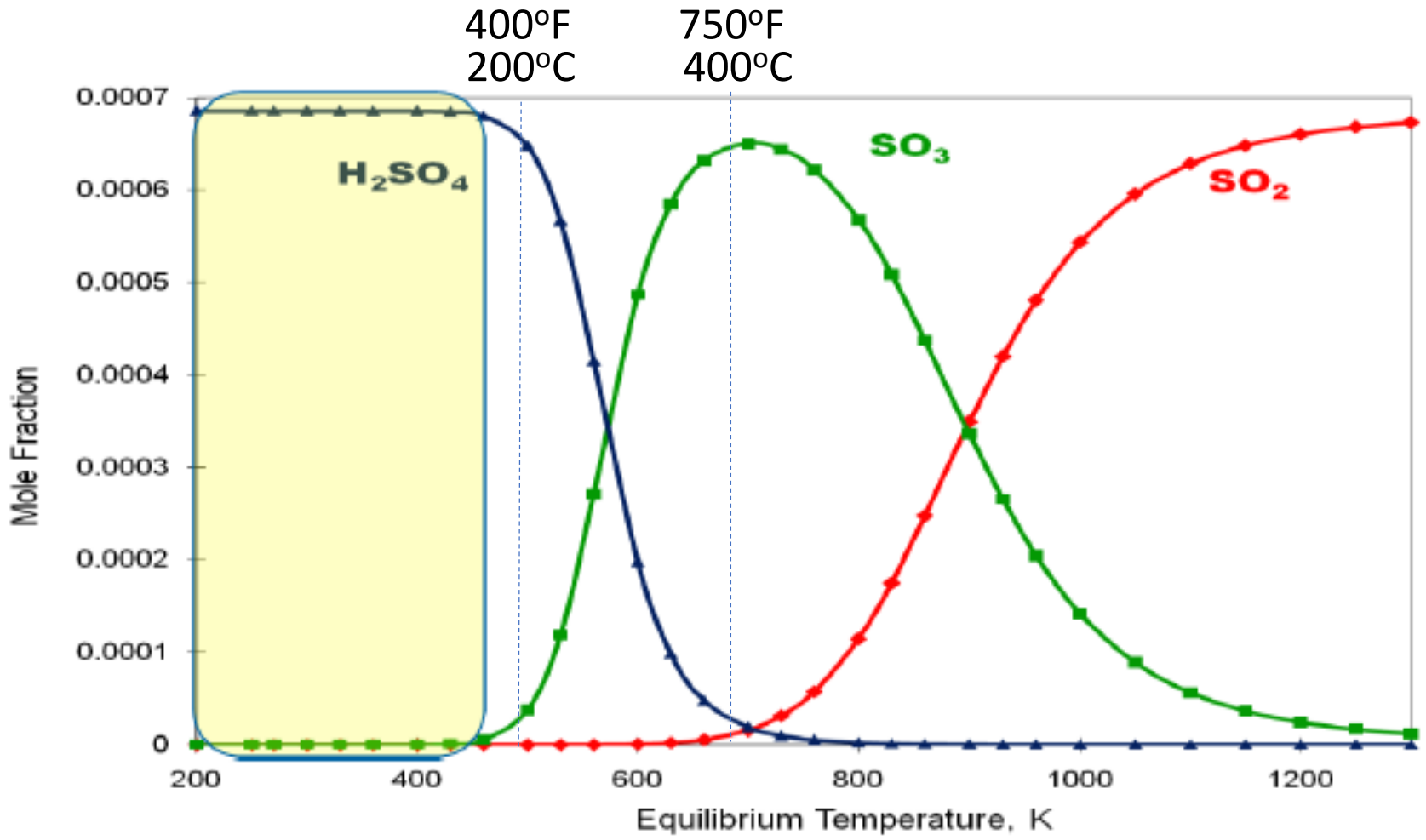


Real-time H2SO4 Measurements

- Laser measurements, real-time updated every second (1 Hz) – can observe dynamics
- Laser measurement precision better than 1 ppm at 1 Hz – better precision possible with averaging



Equilibrium Conditions vs Temperature



Power Plant Testing

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Week of October 12th

FirstEnergy Harrison Station host site

- 3 x 700 MW units equipped with:
  - SCR for NOx control
  - ESP for particulate control
  - FGD scrubbers for SO2 control

Initial proof-of-concept testing

- First test conducted between economizer outlet and SCR ammonia-injection grid
- Controlled condensate wet chemical tests to be obtained in parallel (SO3 + H2SO4)

Haywood, West Virginia

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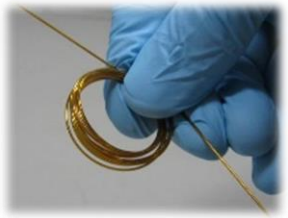
Related DOE/NETL SBIR



Hollow Fibers

Custom Laser

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DOE – RAPID STTR

Phase I | **Phase II**

Multi-Species Sensor

DOE – SO3

Coal power plant sensor

Air Force AEDC CRP

Test Center Combustion Diagnostic

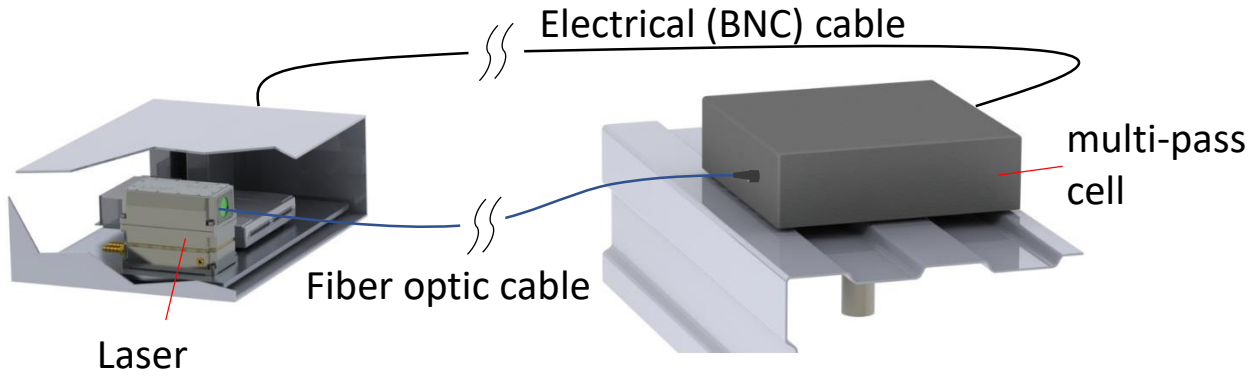
Air Force AFRL STTR

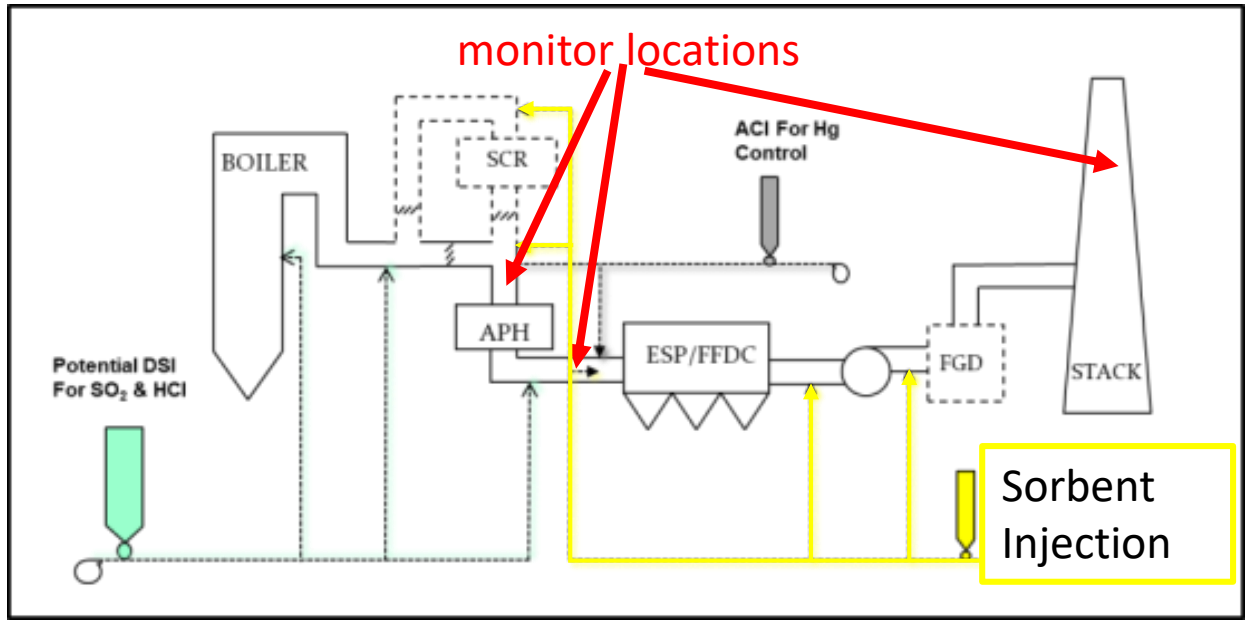
Rocket Engine Diagnostic

Gas Sensors for Harsh Environments

Summary

- A continuous SO_3 / H_2SO_4 monitor is needed to optimize sorbent injection
- Mid-IR Laser spectroscopy solution
- Advancing the state of the art
  - Broad tuning Mid-IR lasers
  - Hollow core fiber optics
  - Close-coupled, heated multi-pass cell
- Technology proven with 1 ppm sensitivity of H_2SO_4 at 1 Hz in representative conditions
- Power plant testing scheduled in 2 weeks
- Related SBIR to commercialize the technology





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