Expanded Measurement Needs for Process Control and Compliance

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EPRI - Technical Executive

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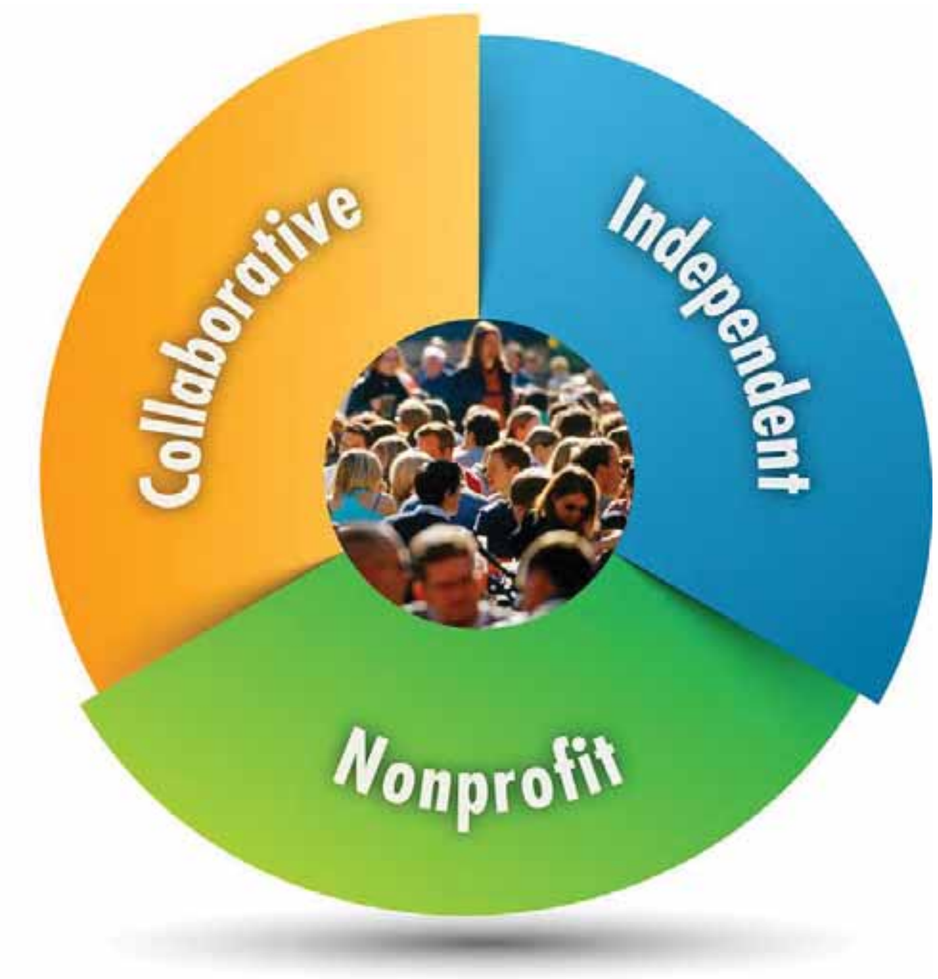
Three Key Aspects of EPRI



Independent

Objective, scientifically based results address reliability, efficiency, affordability, health, safety, and the environment

Nonprofit

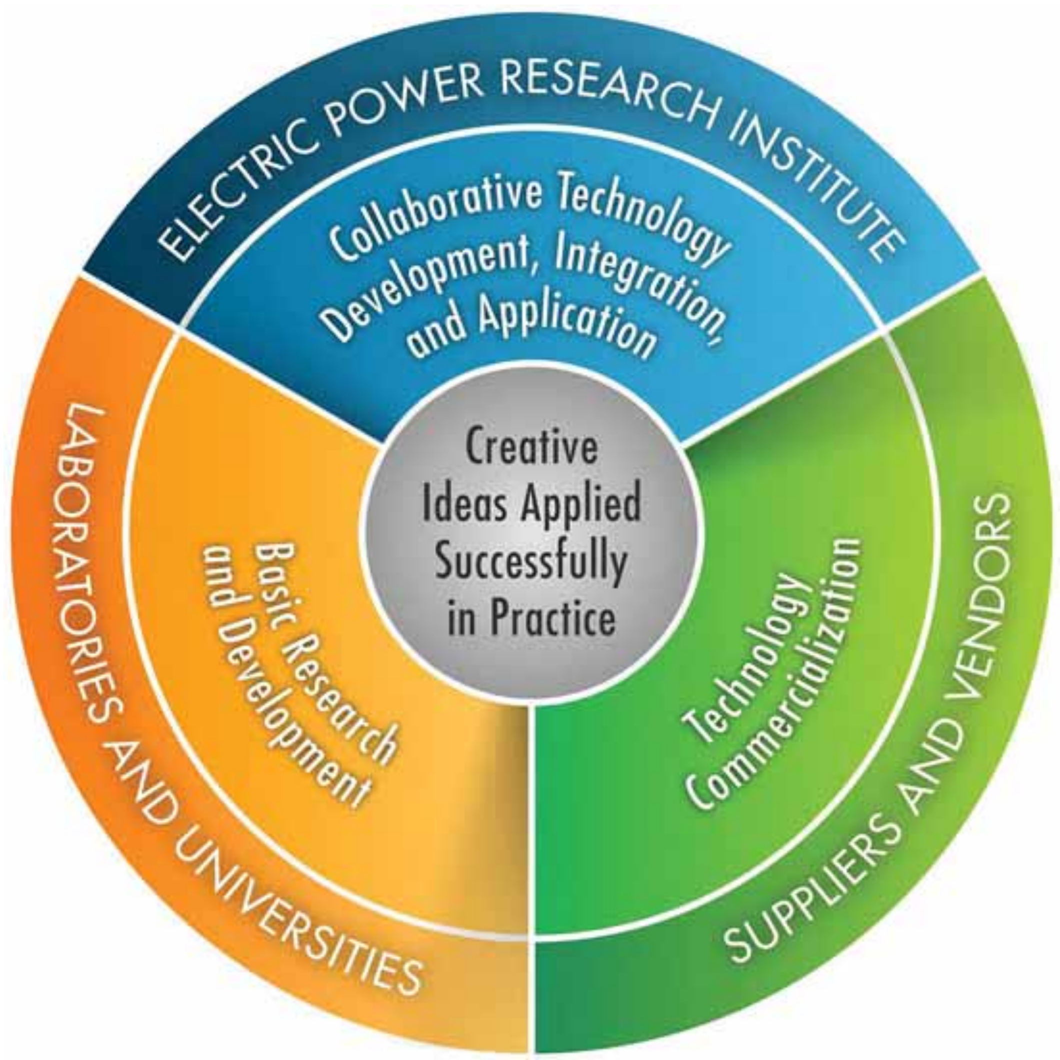
Chartered to serve the public benefit

Collaborative

Bring together scientists, engineers, academic researchers, and industry experts

EPRI's Role

Stimulate innovation; help accelerate technology development

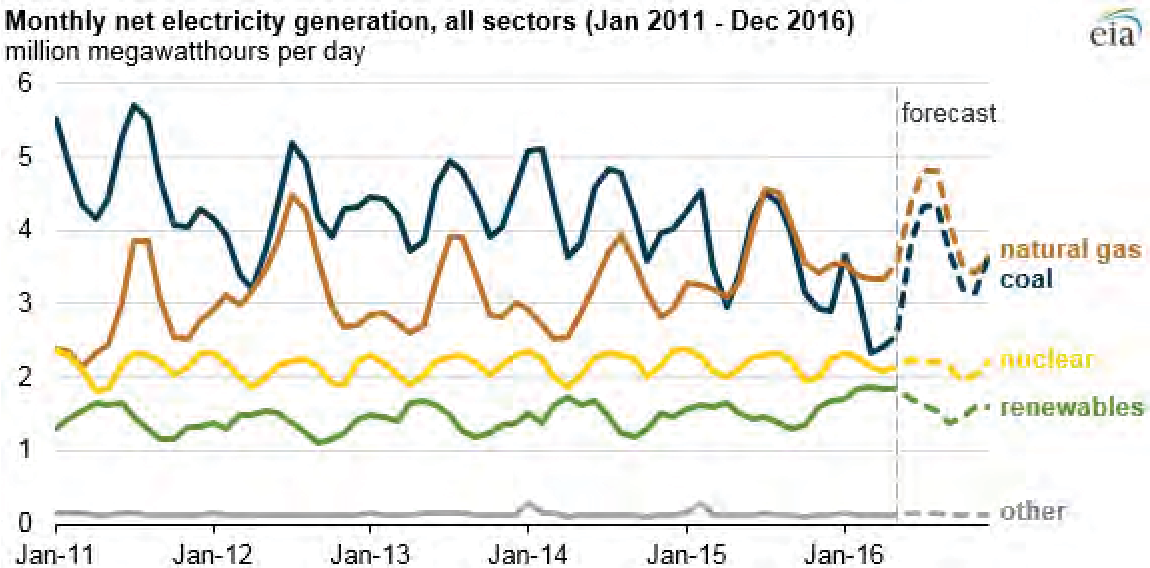


Agenda

- Impact of ‘disruptors’
  - Broadening scope of measurements
  - Changing approach
- Laser based measurements
- Applications examples
  - SCR tuning process control application
  - HCl compliance measurement example
- Summary

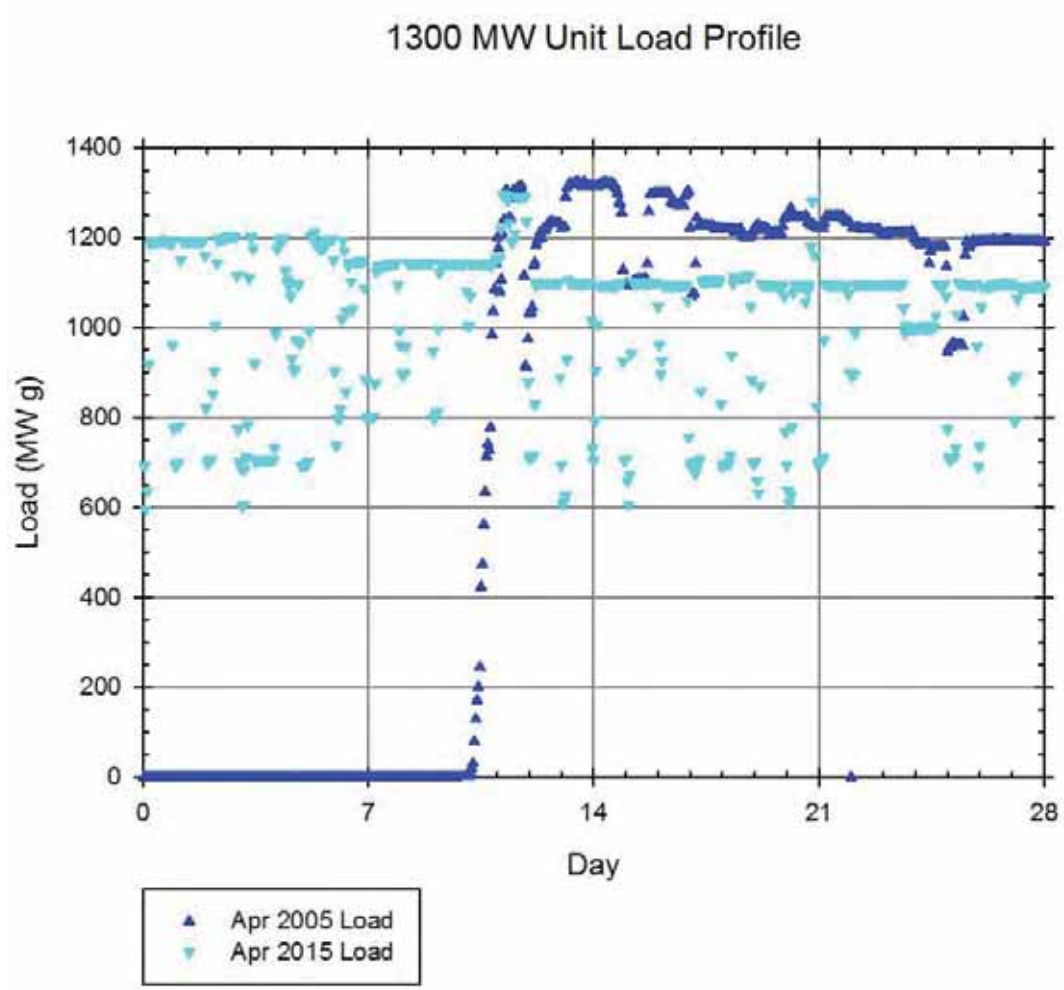
Disruptors Create Change

- Internet Example
  - Email communication
  - Smart phones
  - Commerce (e.g. Amazon)
  - Information (e.g. Google)
- Energy supply
  - Fracking drilling technology
  - Increased supply of oil and natural gas
  - Increased renewable generation
- Resultant change in coal generation
  - Economic stress
  - Reduced manpower
  - Drive to reduce commodity use/manpower



Change in Coal Generation Asset Dispatch

- Previous 'base load' dispatch coal generation assets 'cycled'
- Need for deeper reduced load capability
- Cycling requires more diagnostic measurements for efficient operation
  - Combustion control
    - Air/fuel distribution over range of conditions
  - Emissions control
    - Selective catalytic reduction for NOx control
      - Change in mill patterns and SCR inlet NOx distribution
      - Avoiding catalyst impacts from ABS condensation
    - SO_3 mitigation for optimizing Hg control with powder activated carbon (PAC)
    - FGD ORP impacts from higher excess O_2 operation



Broadening Scope of Utility Measurements

Process Control and R&D

- Combustion
  - O_2
  - CO
- Post Combustion NOx Control
  - NOx (NO + NO_2)
  - NH_3
  - CO_2
- Mercury Control
  - Speciated Hg
  - HCl
  - SO_3

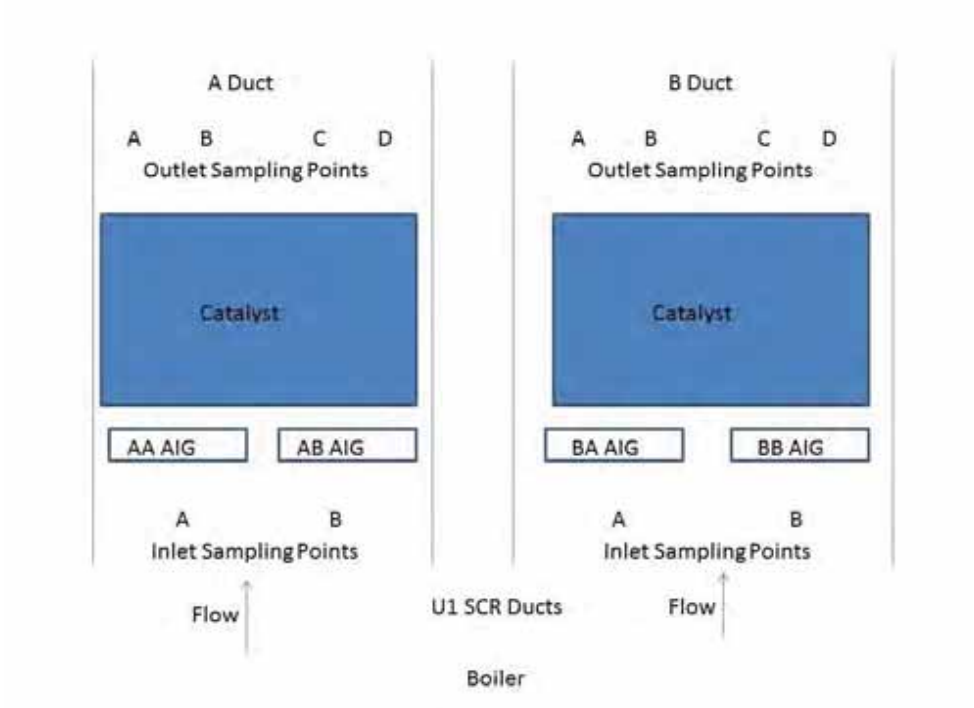
Compliance

- Criteria Pollutants
  - NOx
  - SO_2
  - Diluent for conversion from volumetric to mass basis
    - O_2 or CO_2
- Hg
- HCl
- NH_3 – implemented in some states
- SO_3 (?)

Additional process control measurements must provide cost/benefit

Traditional SCR Control Measurement Approach

- SCR outlet duct nominally 840 ft^2
  - One measurement point per ~210 ft^2



- SCR inlet duct nominally 1,000 ft^2
  - One measurement point per ~500 ft^2

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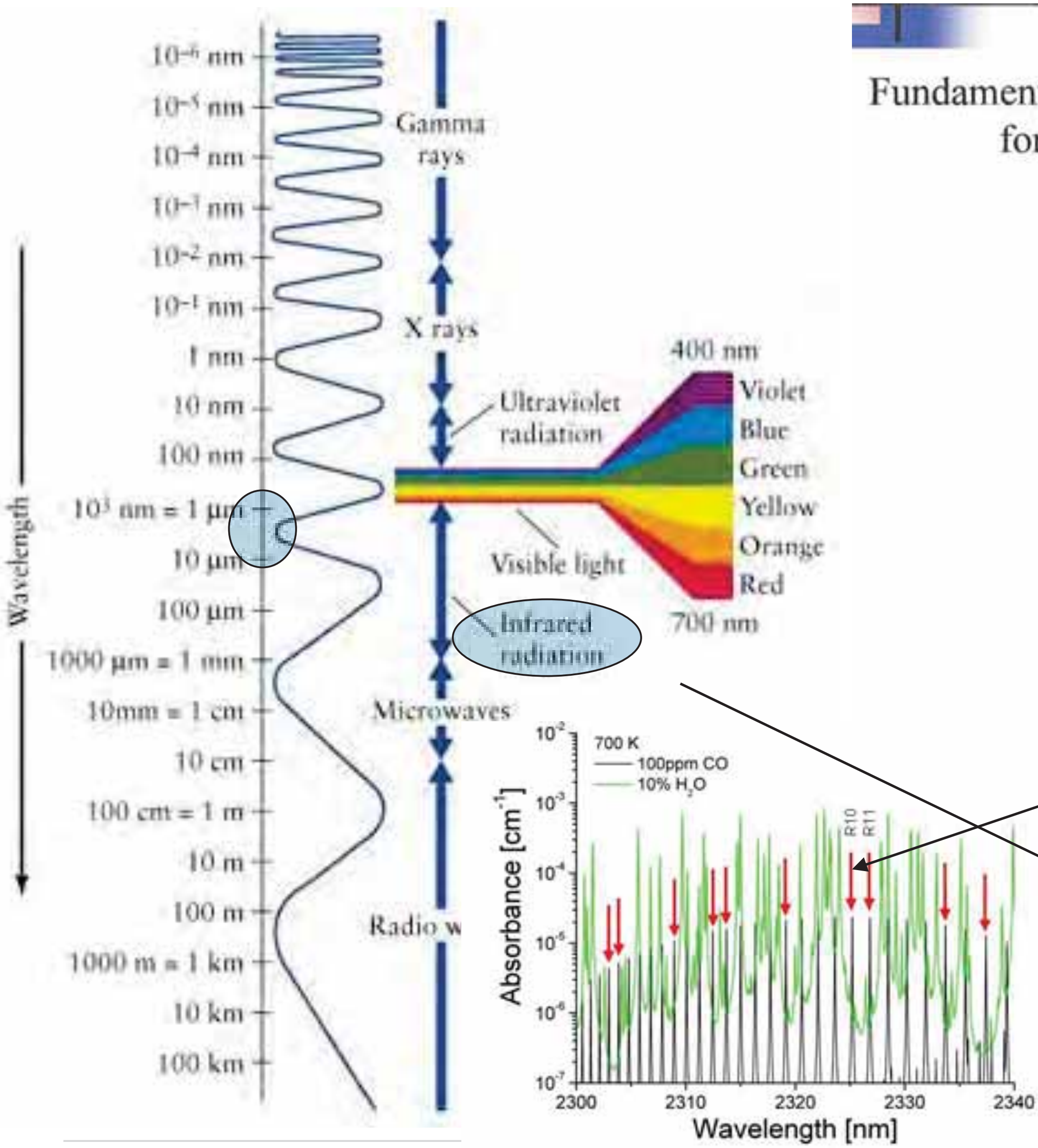
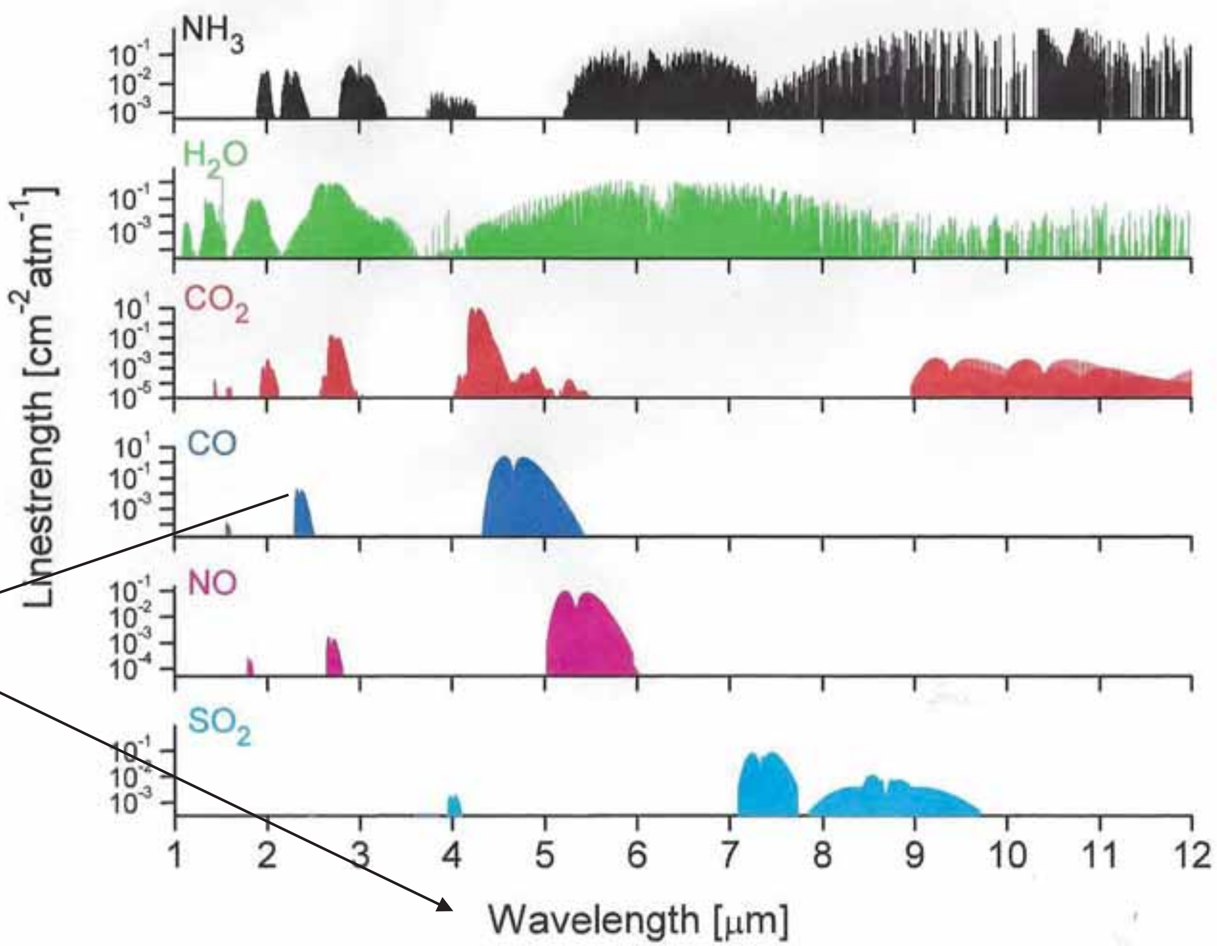
Laser Based Measurements

Molecules Absorb Light at Specific Wavelengths



Fundamental vibrations for NH_3

	Vibration	Frequency [cm^{-1}]	Type	Description
2.98 μm	ν_1	3357	∥	Symmetric Stretch
10.5 μm	ν_2	950	∥	Symmetric Bend
2.90 μm	ν_3	3444	⊥	Asymmetric Stretch (Degenerate)
6.14 μm	ν_4	1627	⊥	Asymmetric Bend (Degenerate)



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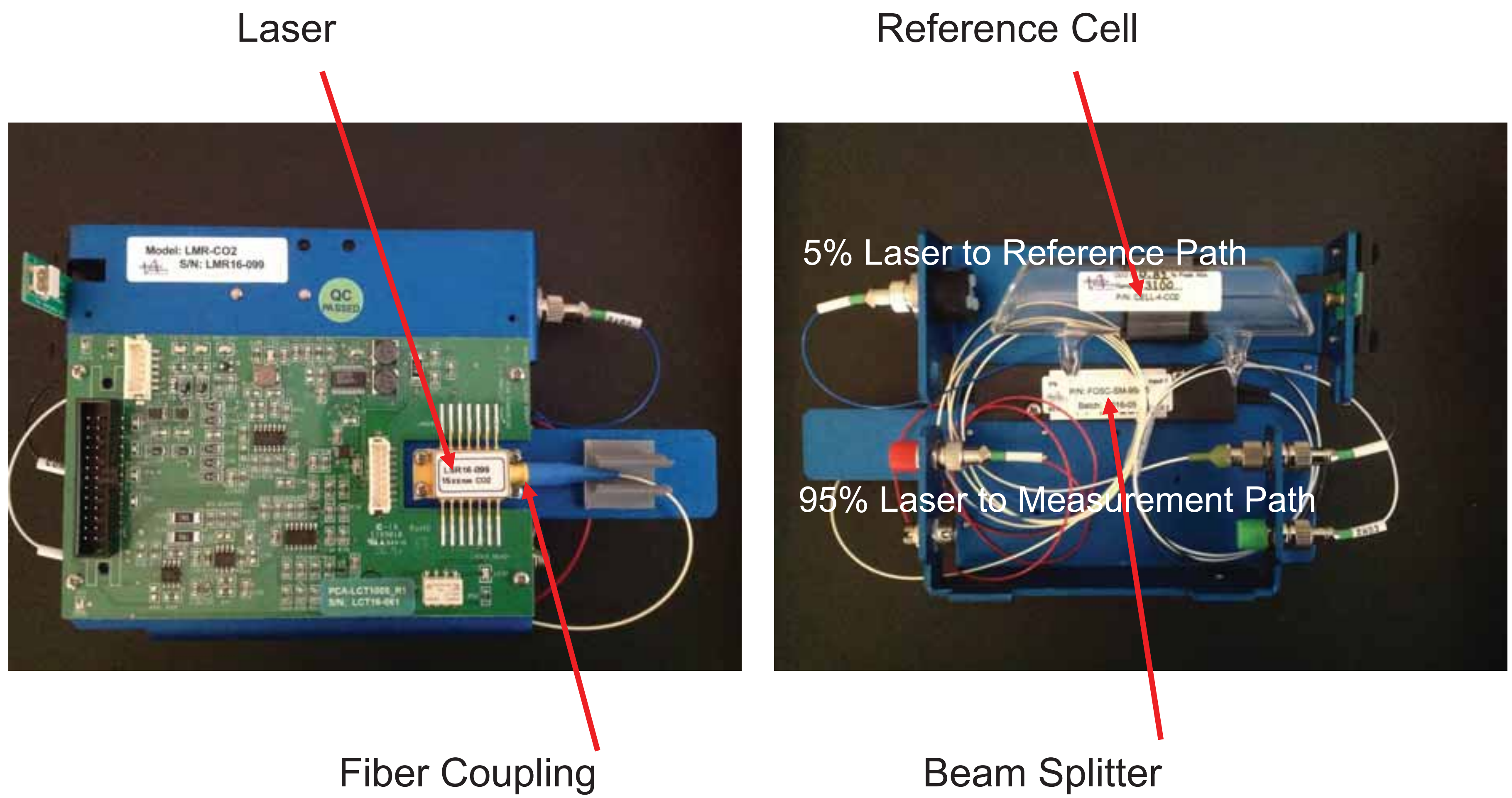
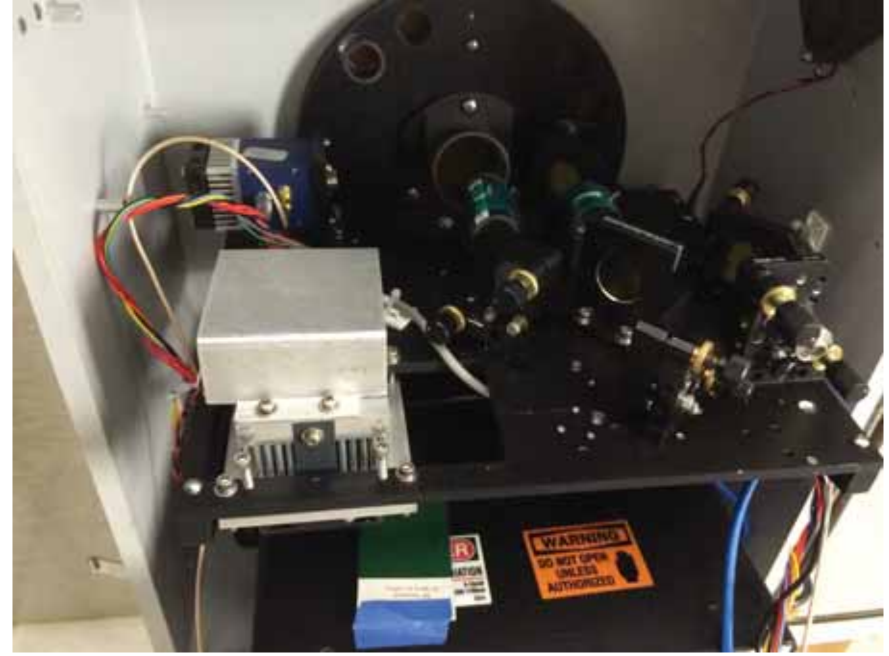
Fiber Coupled CO_2 Laser Package

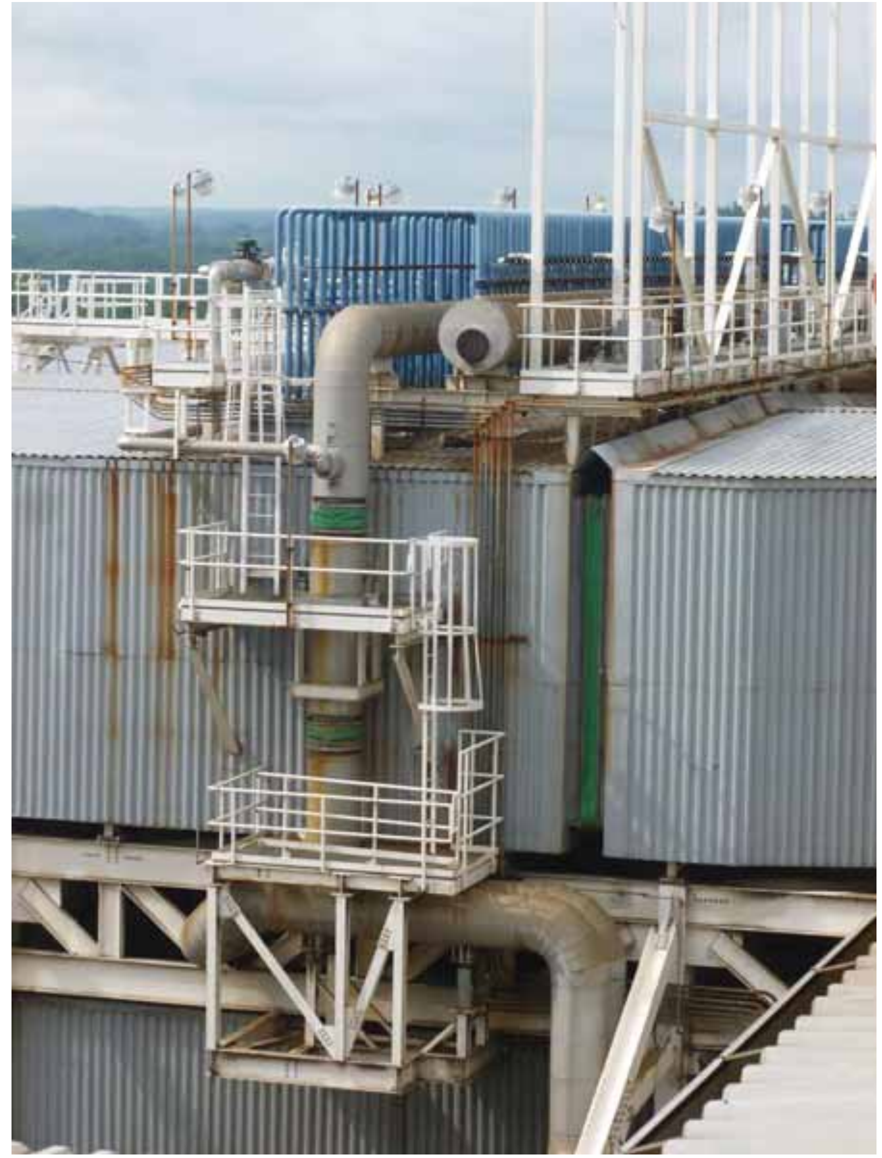


NO Laser Monitor Development Non-Fiber Coupled System

- EPRI R&D project with Stanford University
- Results used to develop commercial prototype with Unisearch Associates
- Completed laboratory tests confirming linearity, detection limits, and absence of interference
- Exploring approach to fiber couple laser to simplify operation



How to Implement? Not Always Easy



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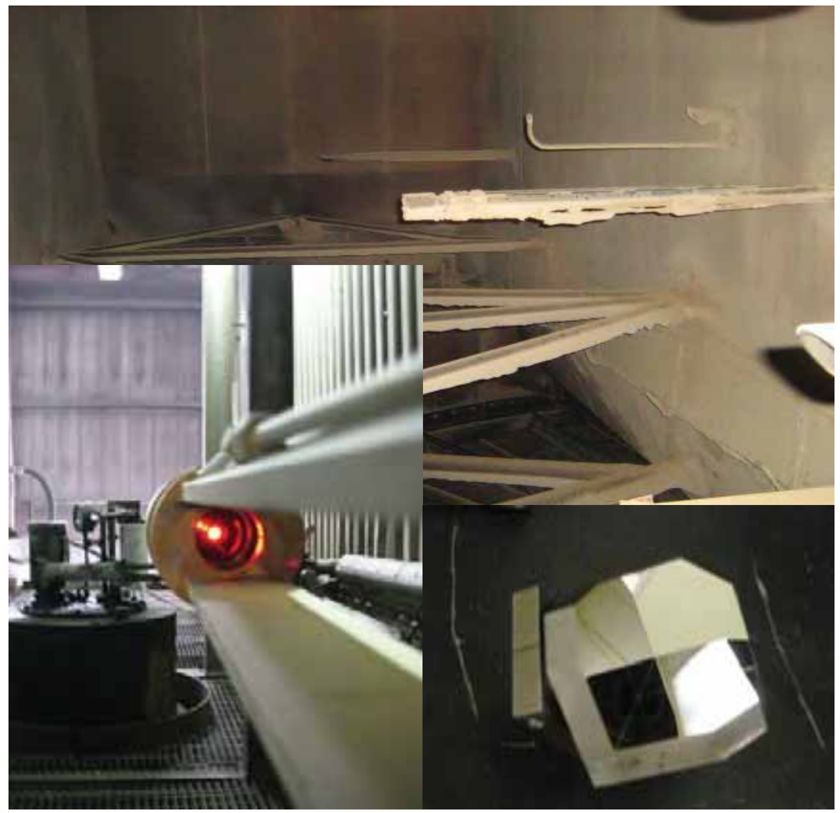
Range of Implementation Approaches

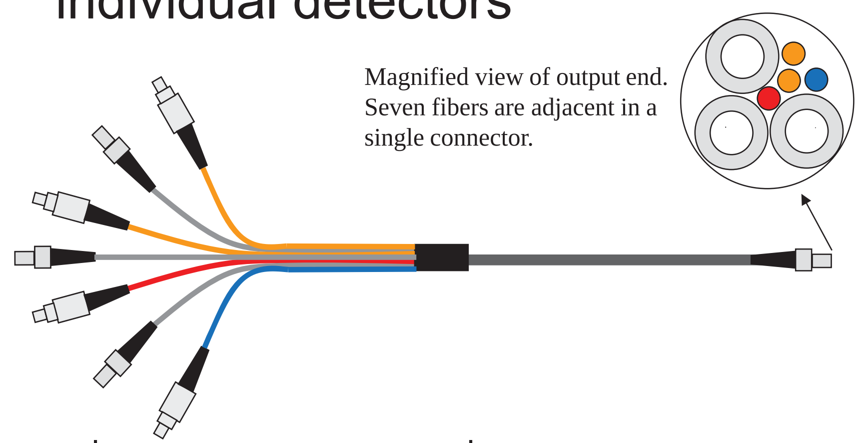


Emerging Laser Measurement Technologies

Multi-Path Cell

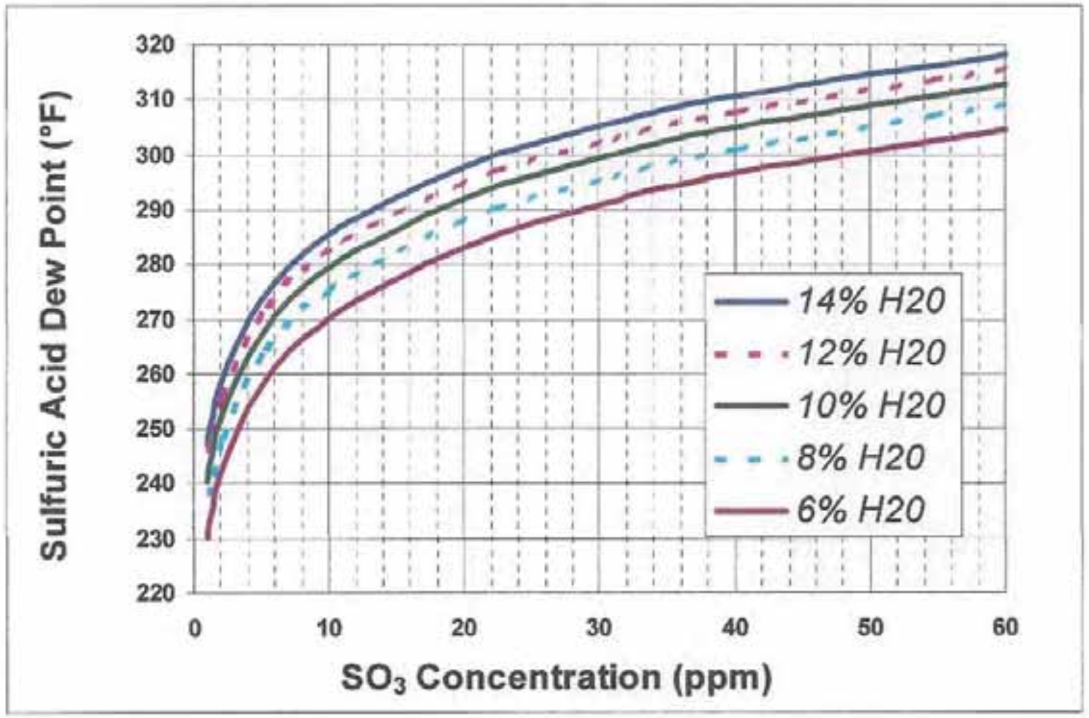
Multi-Fiber Bundle

- Enables lasers with different wavelengths to be combined over same path
- Issue of window material compatibility for different laser λ
- Requires separation of lasers to individual detectors



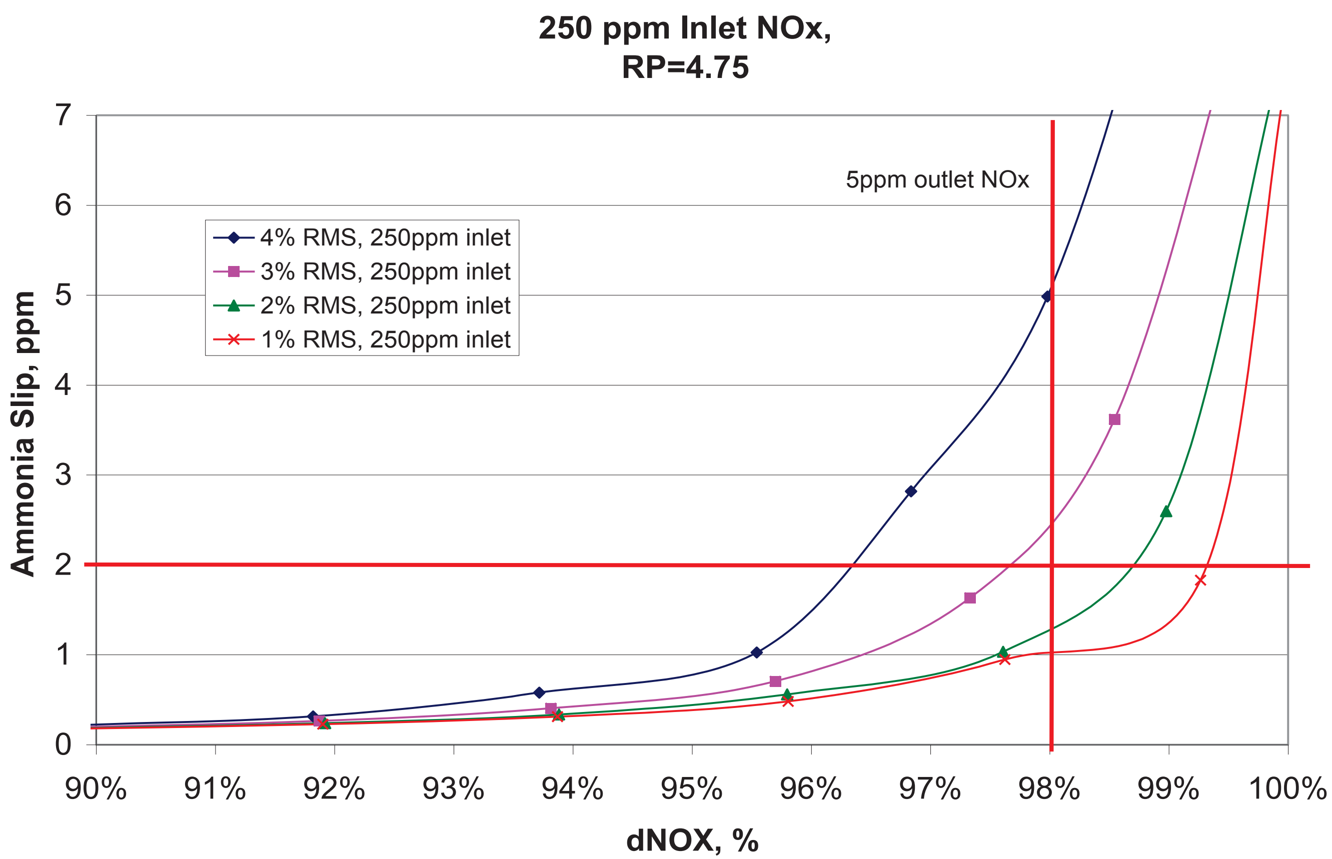
Potential Advantages of Optical Based Measurements

- In situ measurement can eliminate potential biasing reactions for reactive species
- Line-of-sight average can be more representative
- Potential for faster time response
- Reduced cost per measurement point
  - Situations where beam splitting or multiplexing available
- Alternative optical based measurement approaches can also provide species specific advantages
  - FTIR
  - UV-DOAS
  - External cavity quantum cascade lasers



Example of Process Control Application

SCR Tuning and Optimization



Diagnostic measurements enable measurement of NH_3/NOx volumetric ratios to enable more optimized SCR performance

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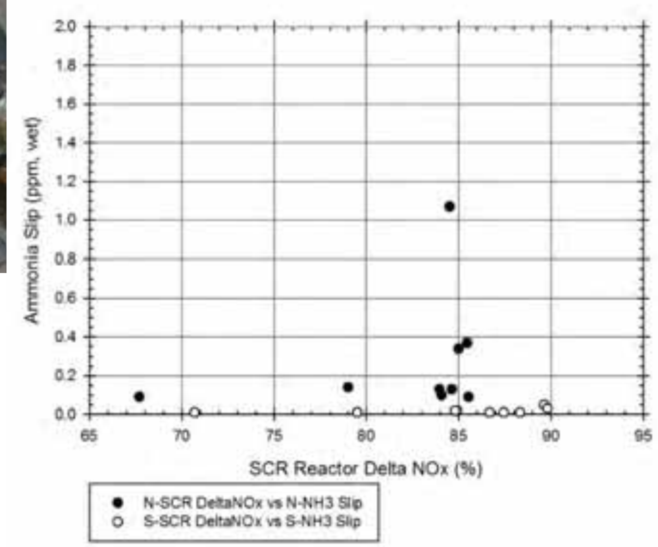
Manual/Automated SCR Tuning Approach

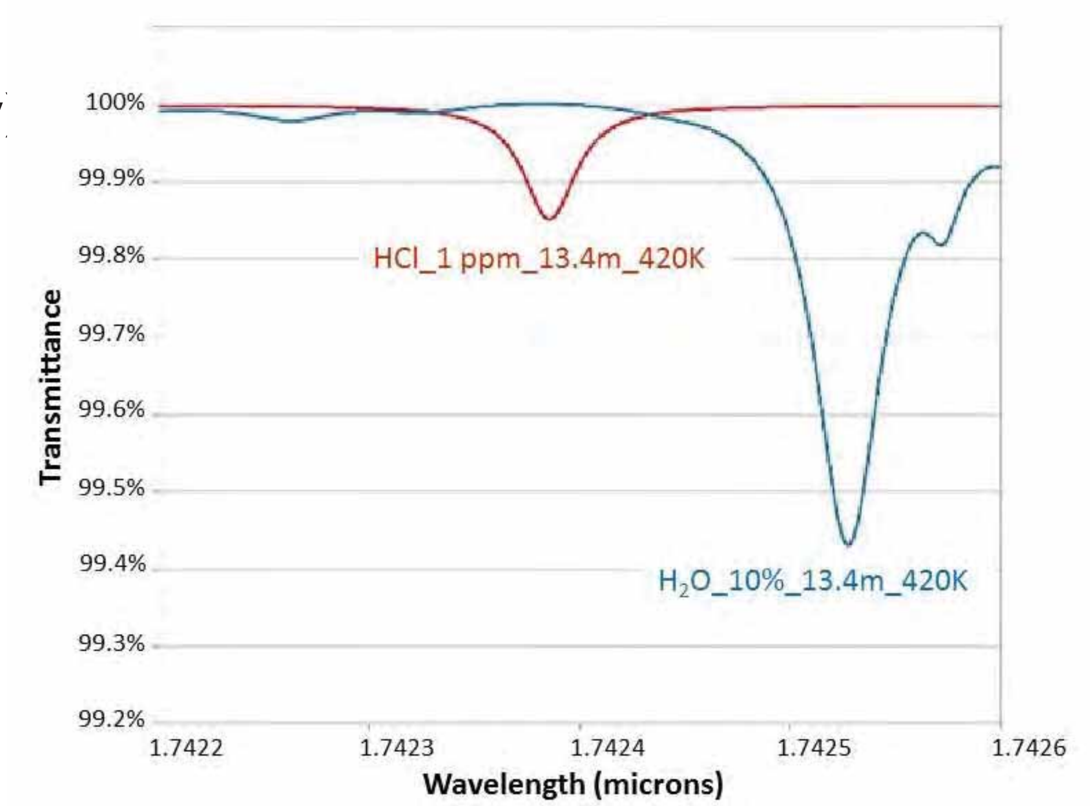
- SCR designed for inlet NOx of 0.40 lb/MBtu
  – Reactor design for 90% ΔNOx
  – Economizer bypass for flue gas temperature control
- Urea to ammonia reagent system
  – 16 Delta Wing points of reagent injection
  – 16 NH_3 TDL measurement lines of sight aligned with each Delta Wing
- Conducting test to explore NH_3 slip vs SCR ΔNOx >90%
  – Use NH_3 TDL to manually tune any regions observed with high NH_3
  – Identify maximum achievable ΔNOx while maintaining NH_3 slip target



Example of Compliance Measurement Application

HCl Compliance Measurements

- EPA PS-18
  - Interference test
  - Beam intensity test (IP-CEMS only)
  - Temperature verification procedure (IP-CEMS only)
  - Pressure verification procedure (IP-CEMS only)
  - Level of detection determination
  - Response time test
  - Measurement error test
  - Calibration drift test
    - Stability criterion
  - Relative accuracy test
- Nominal 50 HCl TDL applications
  - Wet, dry, and bypass stacks
  - Some issues with meeting zero/span criterion due to changing backgrounds on bypass stacks



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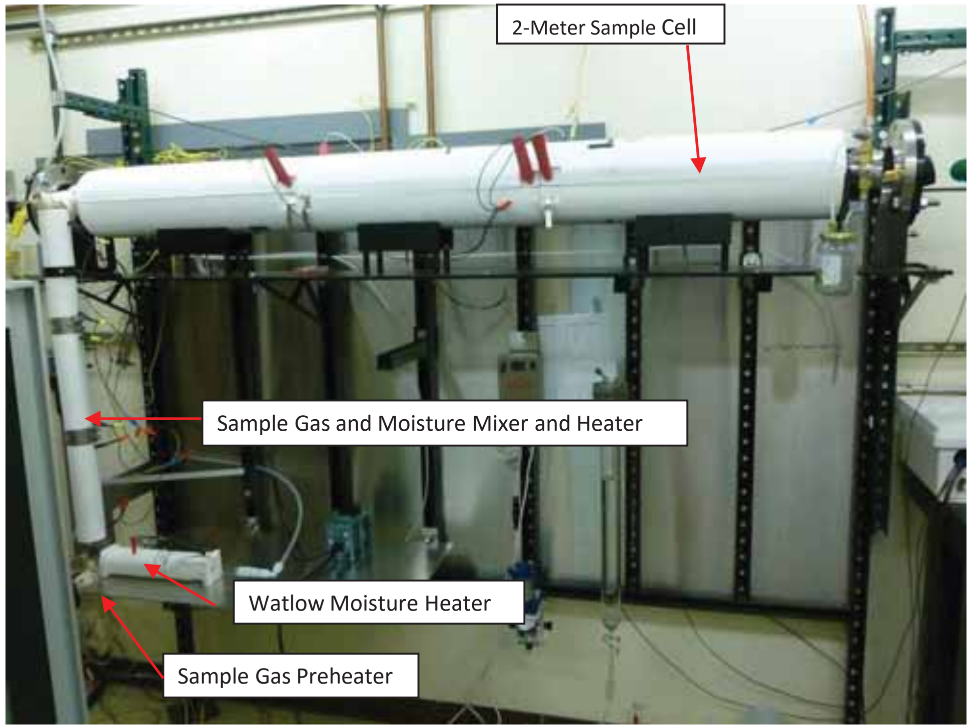
Laboratory Laser Test Facility

- Two meter laser test cell at UC Riverside
  - Built under EPRI sponsorship
    - Quartz lined for NH_3 tests up to 800 F
    - Teflon lined for HCl tests up to 375 F
  - Temperature control from ambient to 800 F
  - Moisture control up to 25%
  - Calibration gases for target species measured
- Laboratory used to evaluate TDL monitors
  - Ammonia (NH_3)
  - Nitric Oxide (NO)
  - Carbon Monoxide (CO)
  - Carbon Dioxide (CO_2)
  - Oxygen (O_2)
  - Hydrochloric Acid (HCl)



HCl Interference Tests

- Demonstrate monitoring system meets performance requirements
  - Sum of interference responses not greater than 2.5% of the calibration span, or +/-3.0% of the equivalent HCl concentration used for interference test
  - Also acceptable if sum of interference responses not greater than six times the LOD or 0.5 ppm for a calibration span of 5 – 10 ppm
- Interference test gas concentrations
  - CO_2 15%+/- 1% NO_2 250+/- 50 ppm
  - CO 100+/- 20 ppm SO_2 200+/- 20 ppm
  - CH_2O 20 +/- 5 ppm O_2 3%+/- 1%
  - CH_4 100+/- 20 ppm H_2O 10%+/- 1%
  - NH_3 10 +/- 5 ppm N_2 Balance

Interference Gas or Gas Combination	Cylinder Used	Date of Test	HCl Concentration (2 ppmv) in N2 Only	HCl Concentration (ppmv) w/Interference	Absolute Difference (ppmv)	Average Absolute Difference (ppmv)
CO, CH4, O2	A	22-Jan-16	2.015	1.948	0.067	
CO, CH4, O2	A	22-Jan-16	1.976	1.973	0.002	
CO, CH4, O2	A	22-Jan-16	1.983	1.991	-0.008	0.026
CO2, NO,SO2	D	22-Jan-16	2.029	2.027	0.002	
CO2, NO,SO2	D	22-Jan-16	1.981	2.003	-0.022	
CO2, NO,SO2	D	22-Jan-16	2.041	2.053	-0.012	0.012
HCHO	E	22-Jan-16	2.055	2.055	0.000	
HCHO	E	22-Jan-16	2.050	2.048	0.002	
HCHO	E	22-Jan-16	2.050	2.053	-0.003	0.002
SO2	H	23-Jan-16	2.052	2.045	0.006	
SO2	H	23-Jan-16	2.049	2.046	0.003	
SO2	H	23-Jan-16	2.054	2.045	0.010	0.006
CO2, O2	I	23-Jan-16	2.056	2.050	0.007	
CO2, O2	I	23-Jan-16	2.048	2.054	-0.005	
CO2, O2	I	23-Jan-16	2.058	2.058	0.001	0.004
NO2	K	10-Feb-16	2.122	2.015	0.107	
NO2	K	10-Feb-16	2.130	2.052	0.078	
NO2	K	10-Feb-16	2.142	2.022	0.120	0.102
H2O 10%	None	3-Feb-16	2.030	2.011	0.019	
H2O 10%	None	3-Feb-16	2.019	2.043	-0.024	
H2O 10%	None	3-Feb-16	2.022	2.018	0.004	0.015

Criteria results:

Percent of Baseline Concentration	4.18%	Maximum Limit	3.00%	-1.18%	FAIL
Percent of Span	3.34%	Maximum Limit	2.50%	-0.84%	FAIL
Sum of Interference Responses <6xLOD(ppmV)	0.167	Maximum Limit	1.2	1.033	PASS
Sum of Interference Responses (ppmV)	0.167	Maximum Limit	0.5	0.333	PASS
Percent of Span < 5.0 ppmV	0.167	Maximum Limit	0.2	0.033	PASS

Note: Interference test passed when at least one criteria is a pass.

Summary

- TDL monitors need to be evaluated under application conditions
  - HITRAN and HITEMP constantly being updated
  - No substitute for lab tests to assess potential interferences and accuracy of monitor analytical approach
- Significant potential benefits with TDL line-of-sight measurements
  - More representative (line-of-sight average vs. single point)
  - Faster time response (*in situ* vs. extractive)
  - Potentially lower cost (avoid filtration, sample line, conditioning, etc.)
  - Technology rapidly evolving to enable measurement of additional species
- Potential issues
  - Species interferences as a function of concentration and temperature
  - Establishing consistent monitor set up procedure that takes into account differences between lasers and application conditions
  - Viable methodology for incorporating PS-18 requirements (e.g. zero and span)

Summary

- Recent developments show promise regarding single port, close coupled, extractive measurements as option in addition to cross-duct
  - In addition, technology evolving that will enable multiple species measurement over single measurement path
- Conducting lab and field tests of additional lasers for O_2, CO_2, NO, and SO_3
- Projects being conducted to benchmark monitor performance in terms of:
  - Accuracy
  - Monitor reliability
  - O&M requirements
  - Cost effectiveness

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