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Development of a Real-Time Optical Sensor for Atmospheric Formaldehyde Monitoring

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OUTLINE

GCHSRC
Site Visit
Nov 18, 2002

- Motivation and Technology Issues
- Infrared Diode Laser-based Gas Sensor
- Formaldehyde Concentration Measurements in the Greater Houston Area
- Summary and Outlook

Motivation for Precision Monitoring of H_2CO

- **Precursor to atmospheric O_3 production**
- Pollutant due to incomplete fuel combustion processes
- Potential trace contaminant in industrial manufacturing products
- Medically important gas

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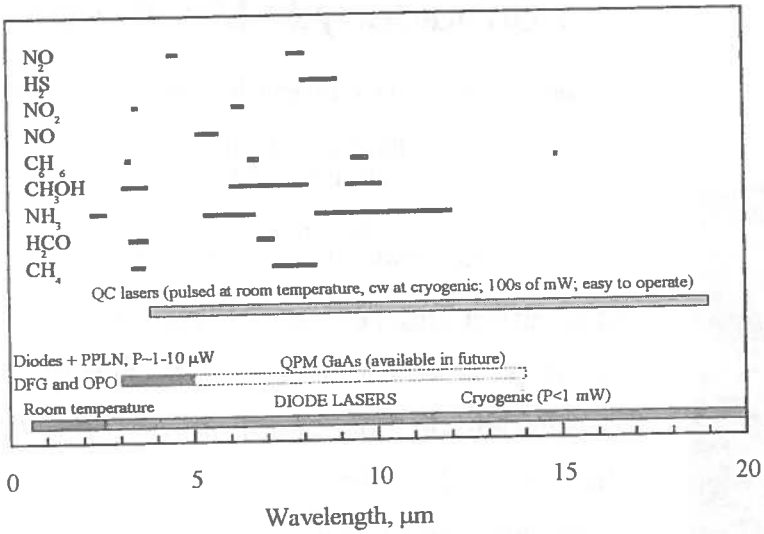
Spectral Coverage by Diode Lasers



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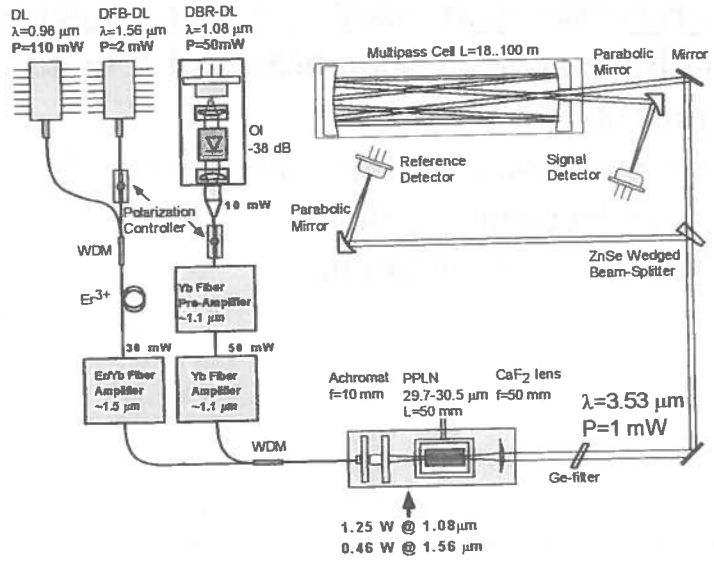
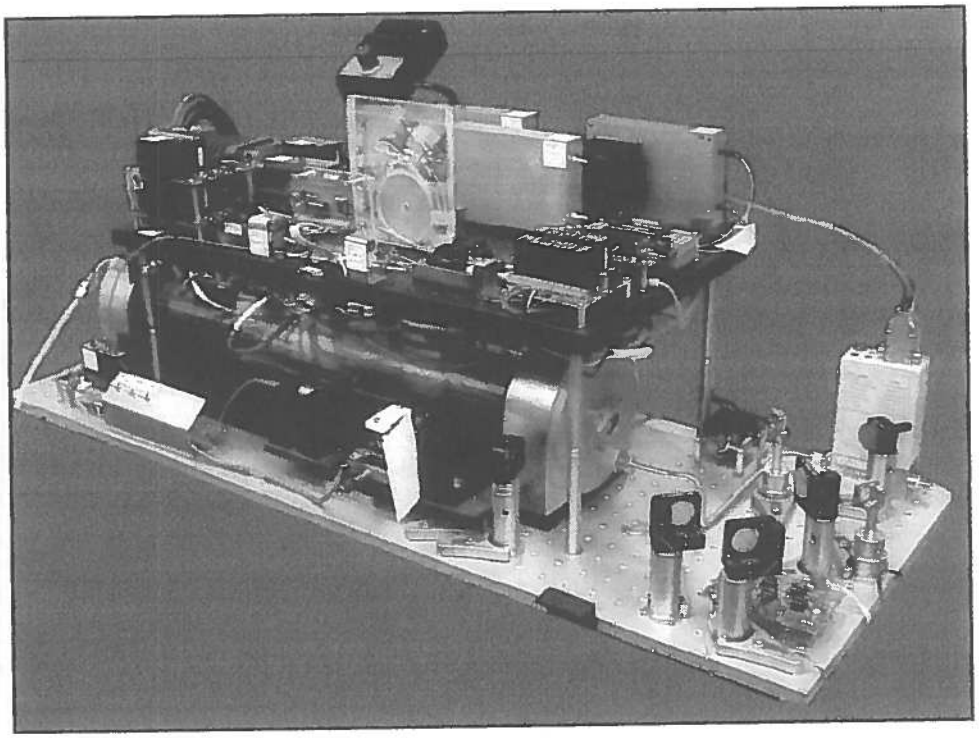
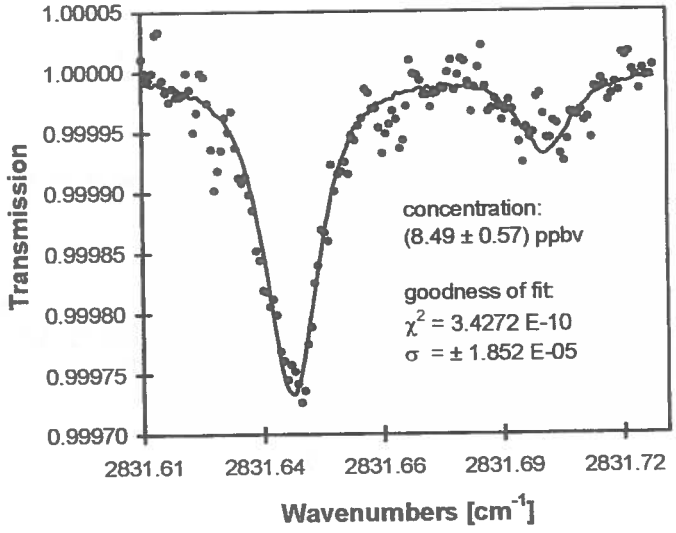
Diode Laser Based H_2CO Sensor

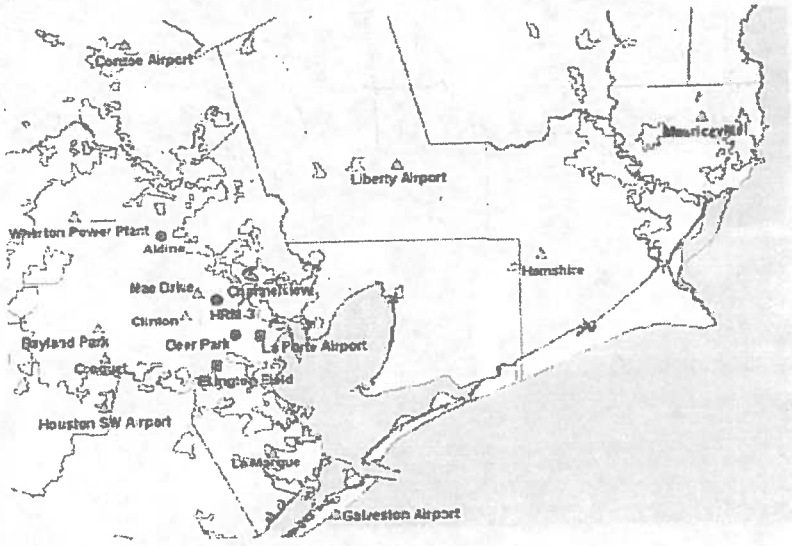




H_2CO Detection in Ambient Air at 3.53 μm



Map of the Greater Houston Area



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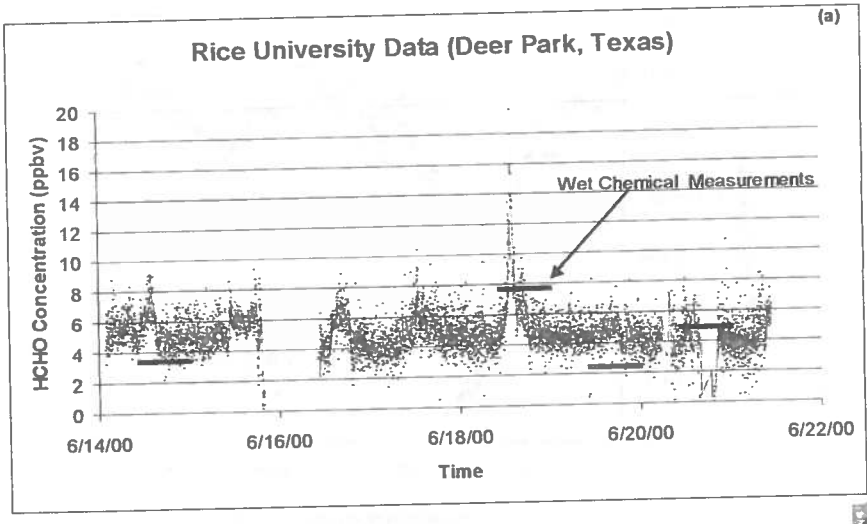
Nine Days of Continuous HCHO Data



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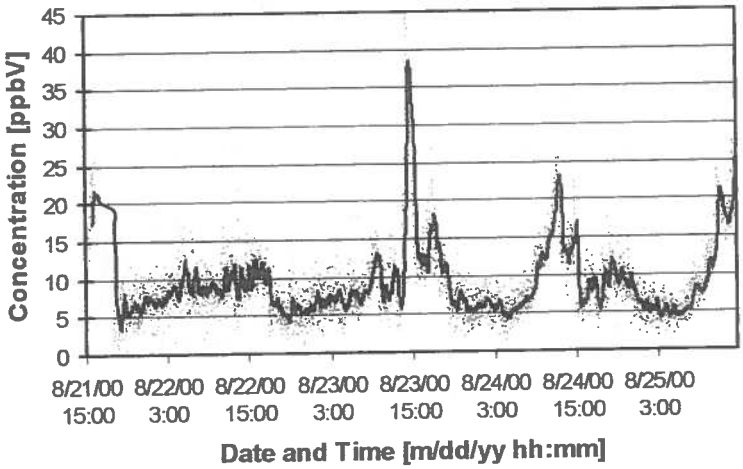
Five Days of Continuous HCHO Data at Channel View,TX



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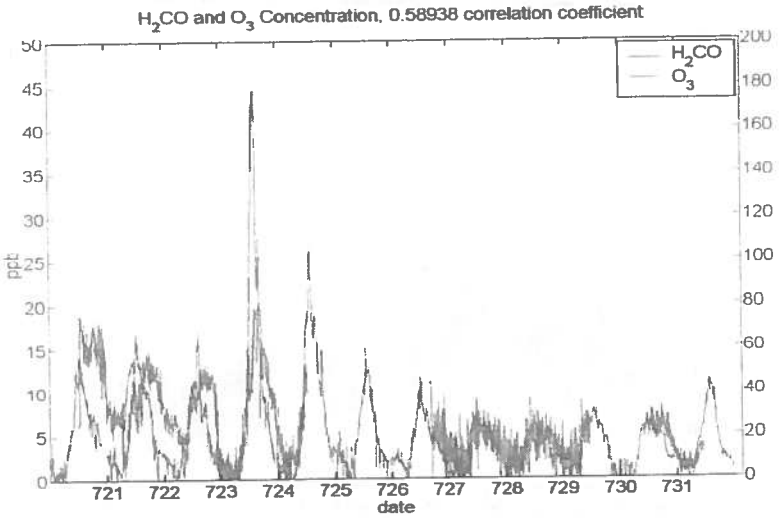
HCHO and O_3 Concentrations at Deer Park, TX for July 20-31, 2002



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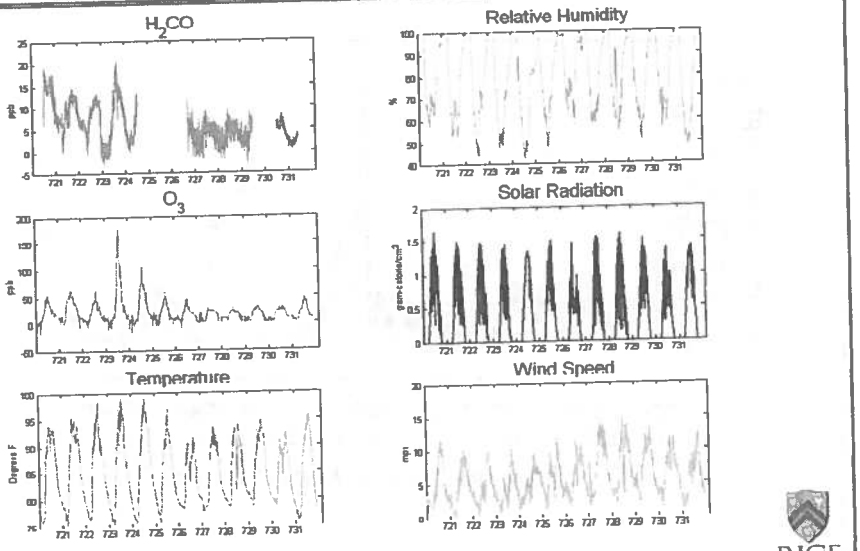
Environmental data at Deer Park, TX for July 20-31, 2002



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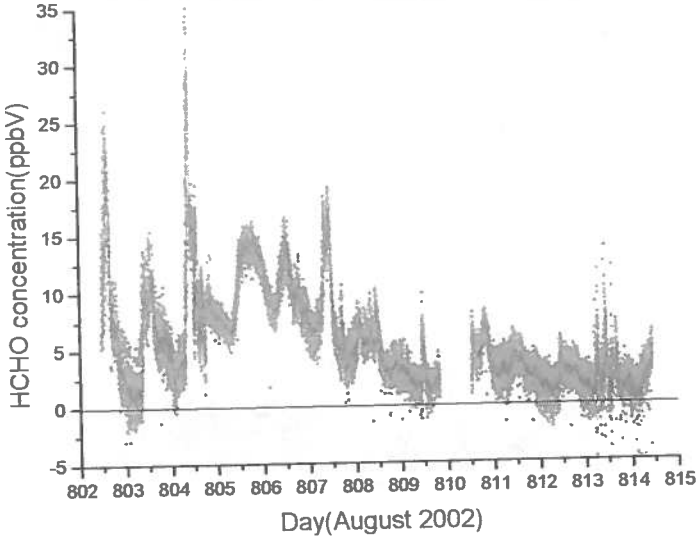
HCHO Concentrations at Deer Park, TX for August 2-14, 2002



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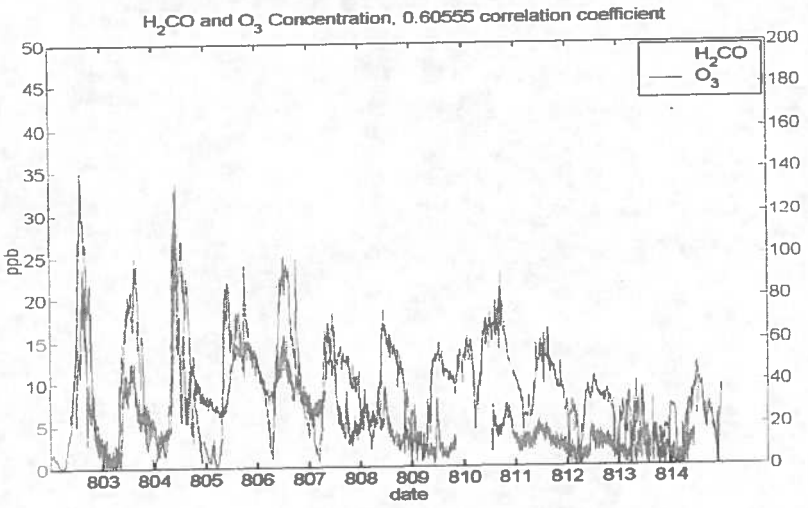
HCHO and O_3 Concentrations at Deer Park, TX for August 2-14, 2002



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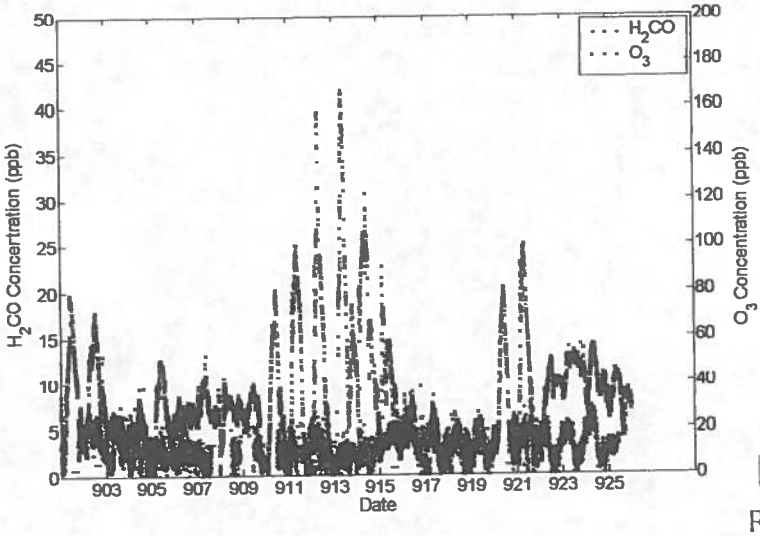
HCHO and O_3 Concentrations at Deer Park, TX for September 2-25, 2002



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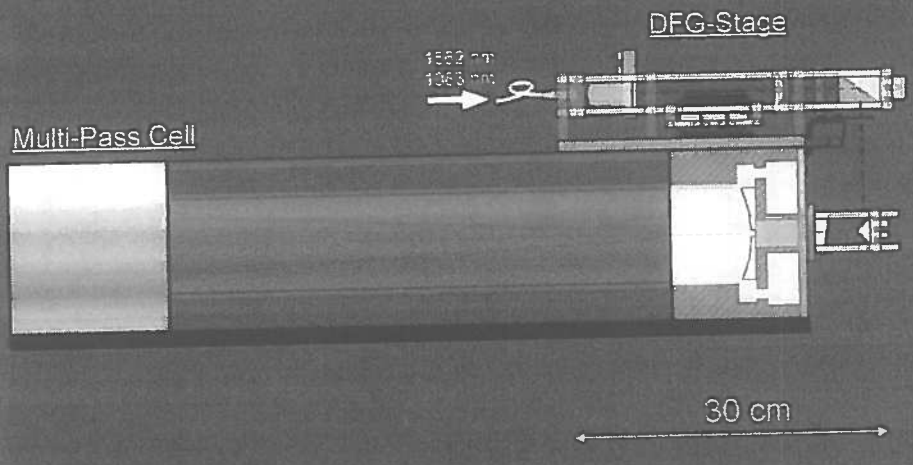
Current Development Highlights: "Plug-and-Pray" to "Plug-and-Play"

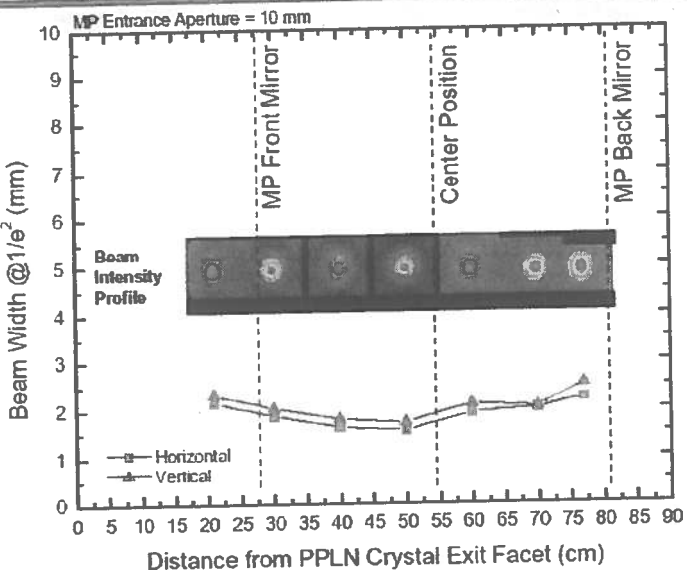
- Fiber Laser Seed Source
  - **60 ppb** (16 MHz) absolute frequency stability over 24 hours
  - No pump diode laser dependency ($\Delta\nu_c \gg \Delta f$)
  - <100 kHz linewidth (free-running)
- DFB Diode Laser Seed Source
  - **173 ppb** (33 MHz) absolute frequency stability over 24 hours
  - **100 Hz** frequency tuning accuracy (over 12 GHz | 0.4 cm^{-1})
  - <2 MHz linewidth (free-running)
- DFG Module
  - Rugged, close-coupling design
  - Clean, predictable near Gaussian spatial mid-IR beam
  - ~0.0003% / h power stability (~1/1000 of Fiber Amplifier Stability)
  - Self-compensating temperature induced drift (Residual<5.6 MHz/h)

Airborne High-Power DFG Based Trace Gas Sensor



DFG Spatial Beam Propagation

NCAR



Summary

- Diode Laser Based Trace Gas Sensors
  - Compact, tunable, robust (alignment insensitive),fieldable
  - High sensitivity (<$2 \cdot 10^{-4}$ to 10^{-5}) and selectivity (10–300 MHz)
  - Fast data acquisition and analysis
  - Detected trace gases: **H_2CO, NH_3 ,CH_4,, NO_2, N_2O, H_2O, CO_2,**
  - **CO, NO, HCl, SO_2, C_2H_5OH, isotopic species of $^{12,13}C$, $^{16,17,18}O$, $^{35,37}Cl$**
- Applications in Trace Gas Detection
  - Environmental monitoring: **H_2CO**, CO, CH_4 (EPA, NASA, NCAR, NOAA,)
  - Industrial process control and chemical analysis
  - Medical diagnostics (NO, CO, CO_2, NH_3)
- Future Directions
  - Fiber lasers and amplifiers
  - Longer mid-IR wavelengths with orientation patterned GaAs and QC lasers, detection of complex molecules

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