In-situ multi-component trace gas measurements with a fiber coupled, mid-IR difference-frequency mixed laser sensor

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- Merits and Advantages of DFG
- Wavelength tuning and quasi-phase matching
- Applications
- Summary and Future Directions

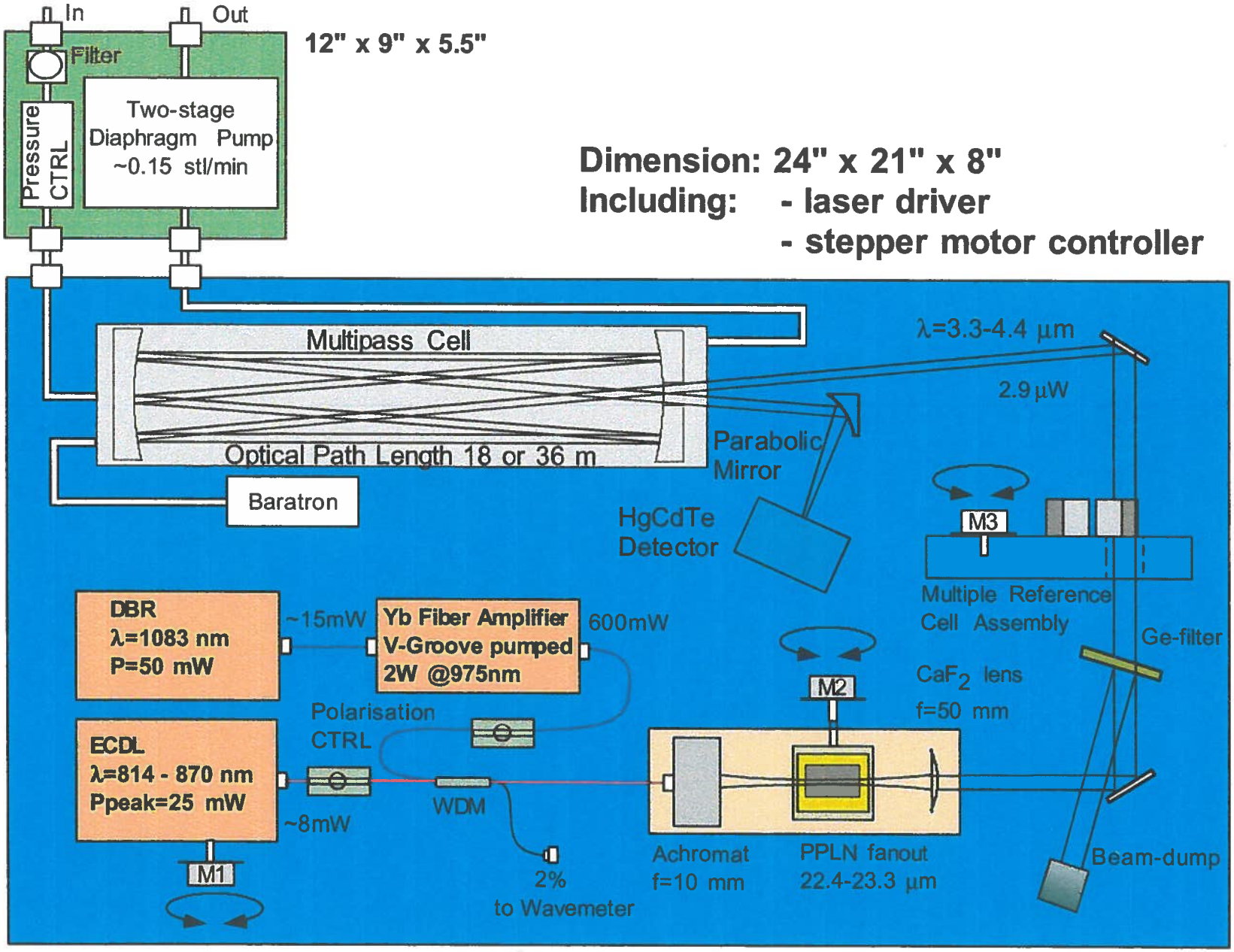
Applications of Trace Gas Detection

- Urban Emission Measurements
  - Industrial Plants
  - Combustion Sources
  - Automobile
  - Waste Dumps
- Rural Emission Measurements
  - Agriculture
  - Forest Fires
- Environmental Monitoring
  - Atmospheric Chemistry
  - Volcanic Emissions
- Spacecraft and Planetary Surface Monitoring
  - Crew Health Maintenance & Life Support
- Chemical Analysis and Process Control
  - Semiconductor Industry
- Medical Applications
- Aircraft Identification

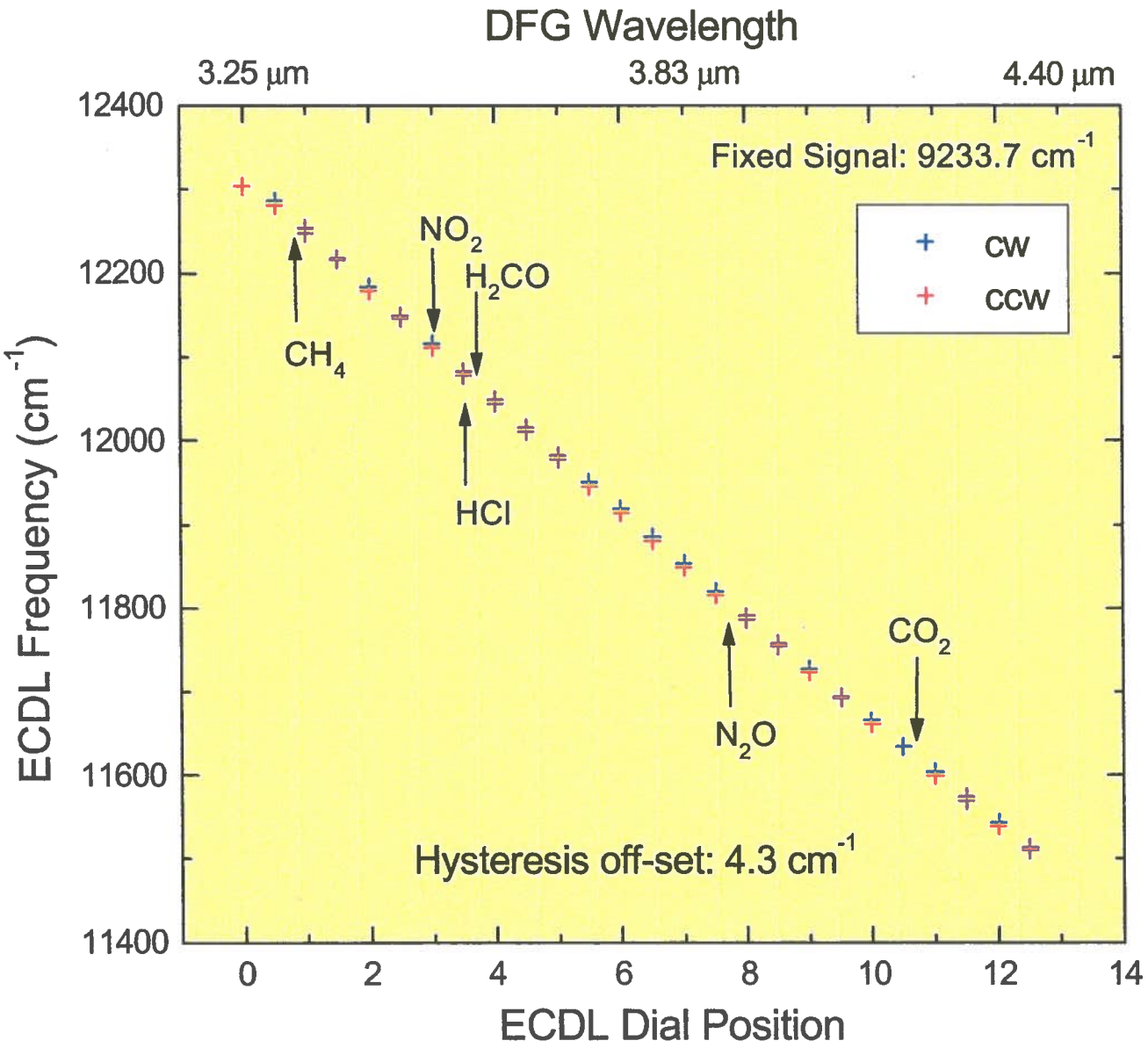
Mid-IR DFG Trace Gas Detection: Merits and Advantages

- Finger print region: Stronger line intensities (x20 to 200) compared to overtone absorptions
- Hence: Direct absorption spectroscopy can be used
  - > absolute measurement technique
  - > High sensitivity: 2×10^{-4}
- Wide, mode-hop free tunablility: 3.25 μm to 4.4 μm
  - > detection of 8+ gas species:
    CH_4, H_2CO, CO_2, N_2O, NO_2, HCl, CH_3OH, H_2O
- Selective: ~40 MHz DFG linewidth
- Near real time concentration measurements (1-10 s)
- Robust: Alignment and maintenance free operation using fiber coupled diode laser pump sources
- Automated: Stepper motor controlled tuning and quasi-phase matching

Schematic of DFG based gas sensor



ECDL Tuning Characteristics



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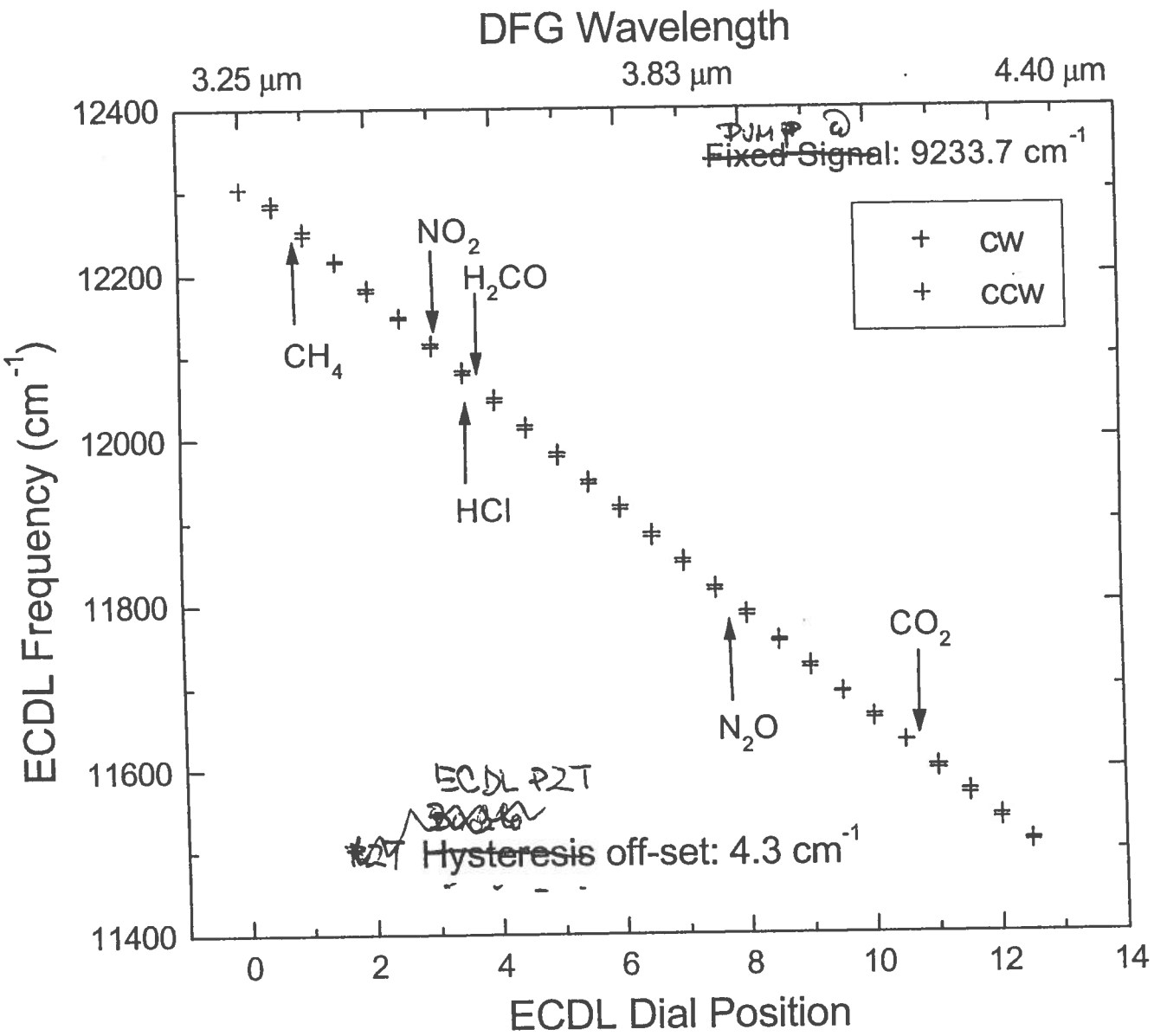
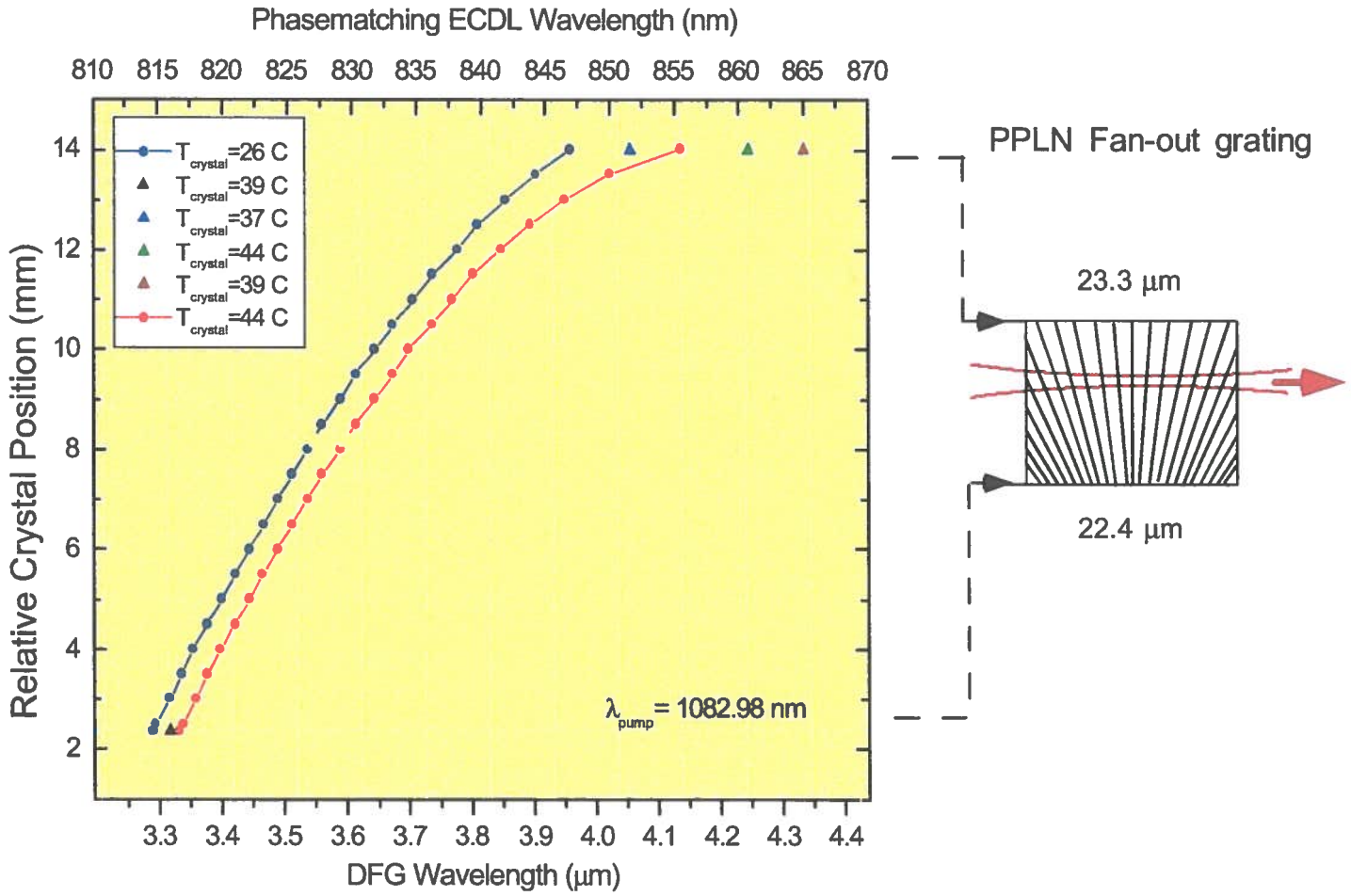
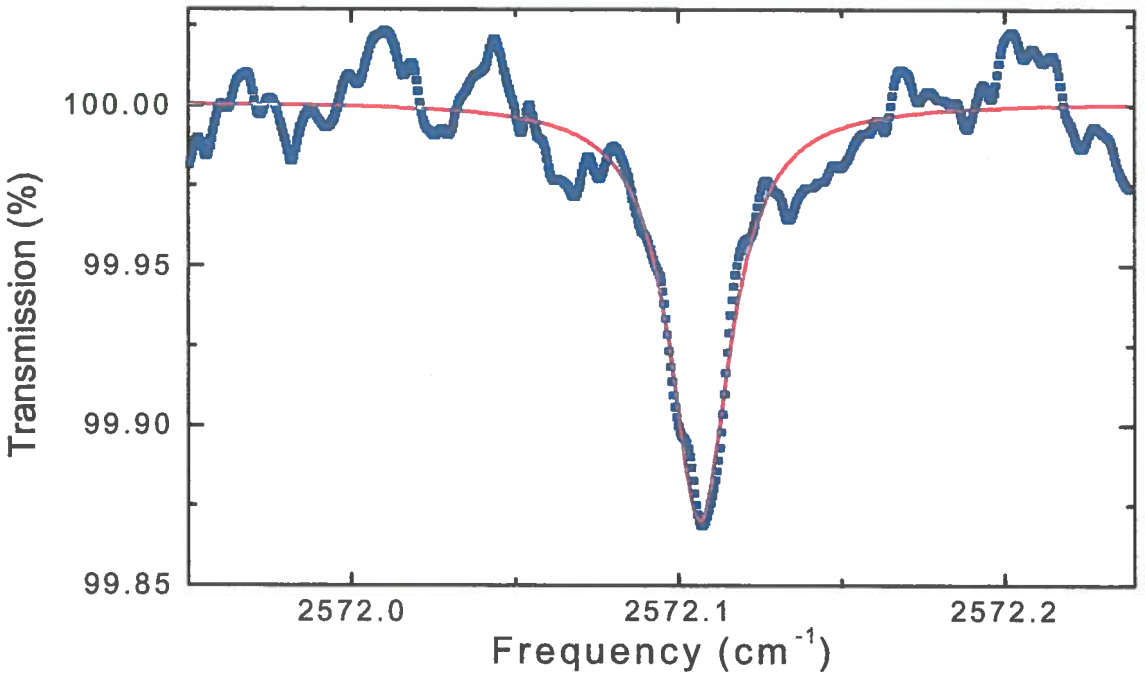


Continuous quasi-phase matching using a fan-out PPLN crystal

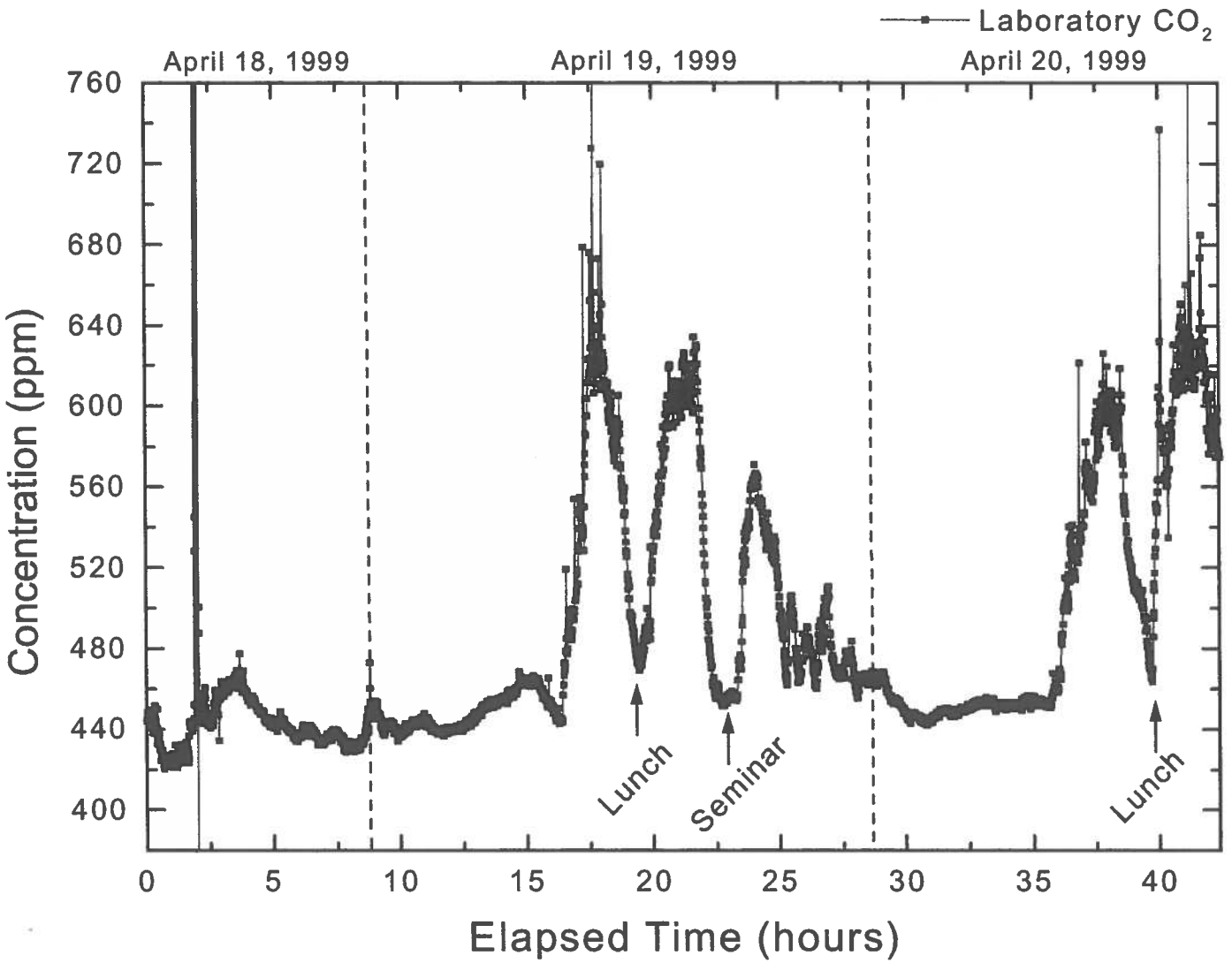


SPECTROSCOPIC PERFORMANCE

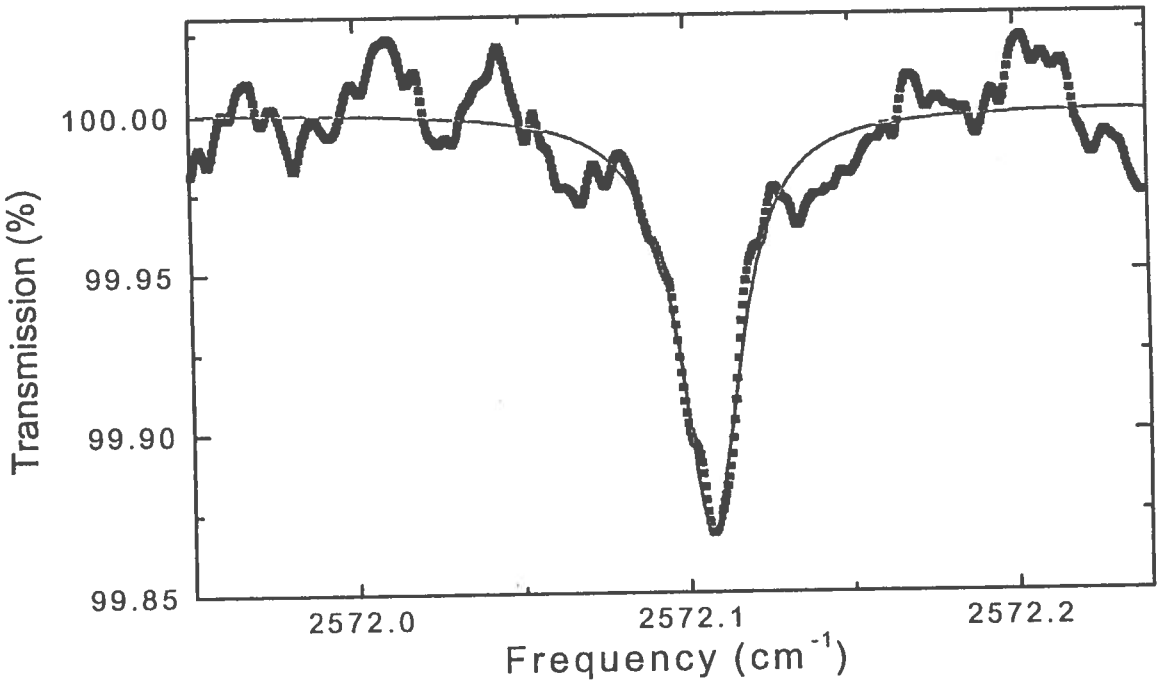


- Ambient N_2O (c=315 ppb)
- Sampling pressure: 88 Torr
- Optical path length: 18 m
- Averaging time: 2 s
- Sensitivity: 2×10^{-4}

Ambient CO_2 Laboratory Sampling over 42 hours



SPECTROSCOPIC PERFORMANCE: N_2O @ 2572 cm^{-1}



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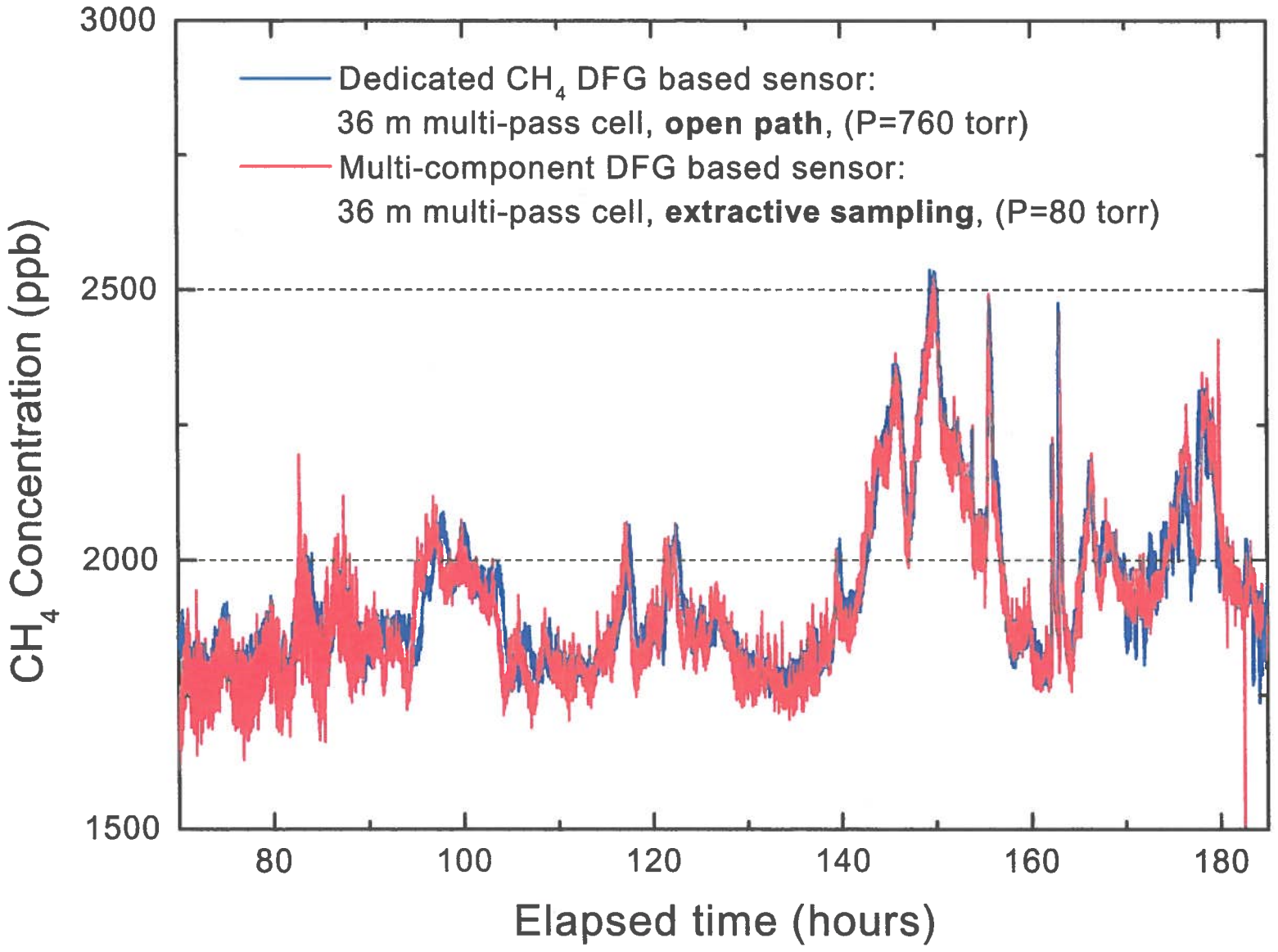
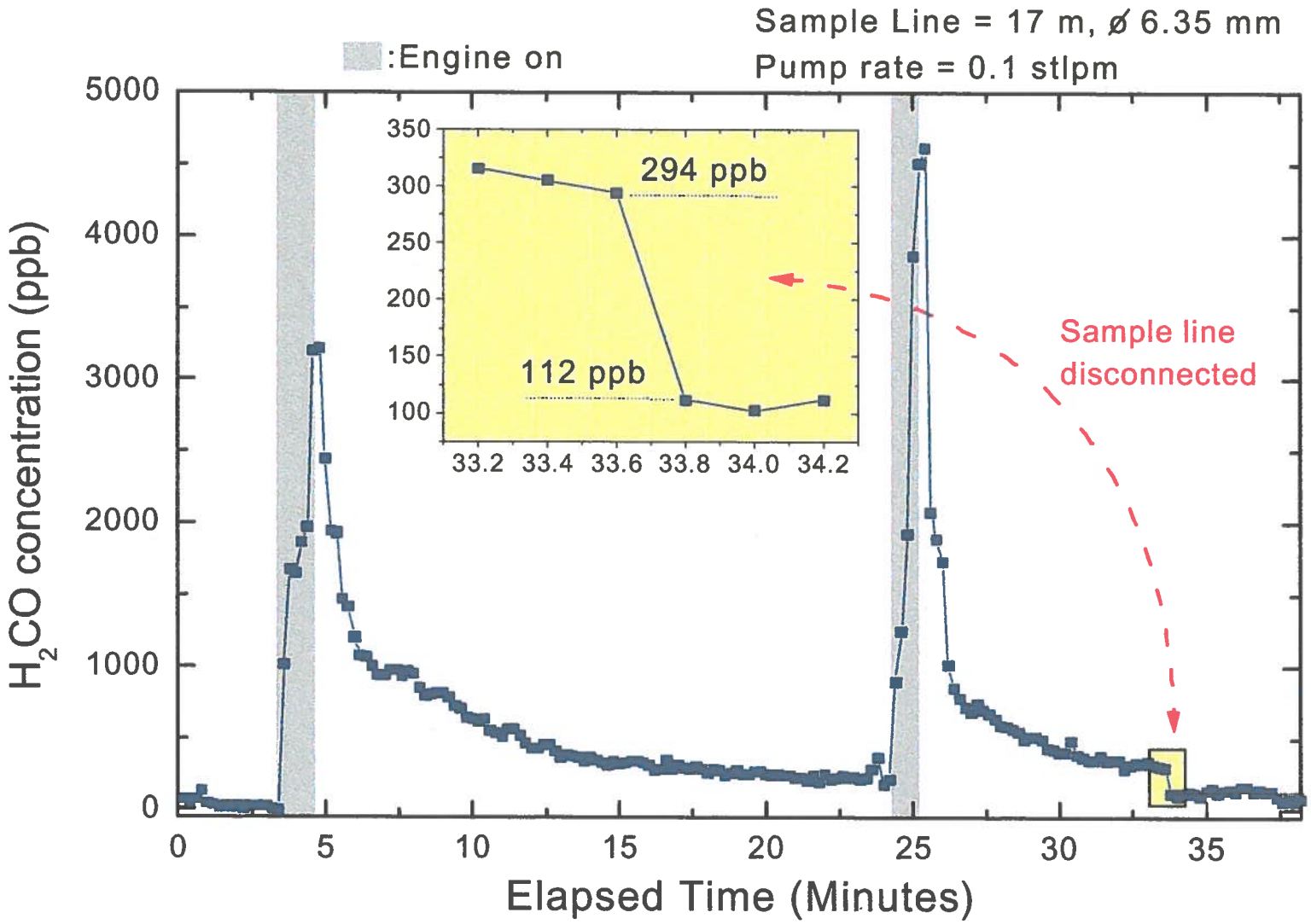
Cross Comparison: CH_4 Long Term Detection of Two Independent DFG Based Gas Sensors

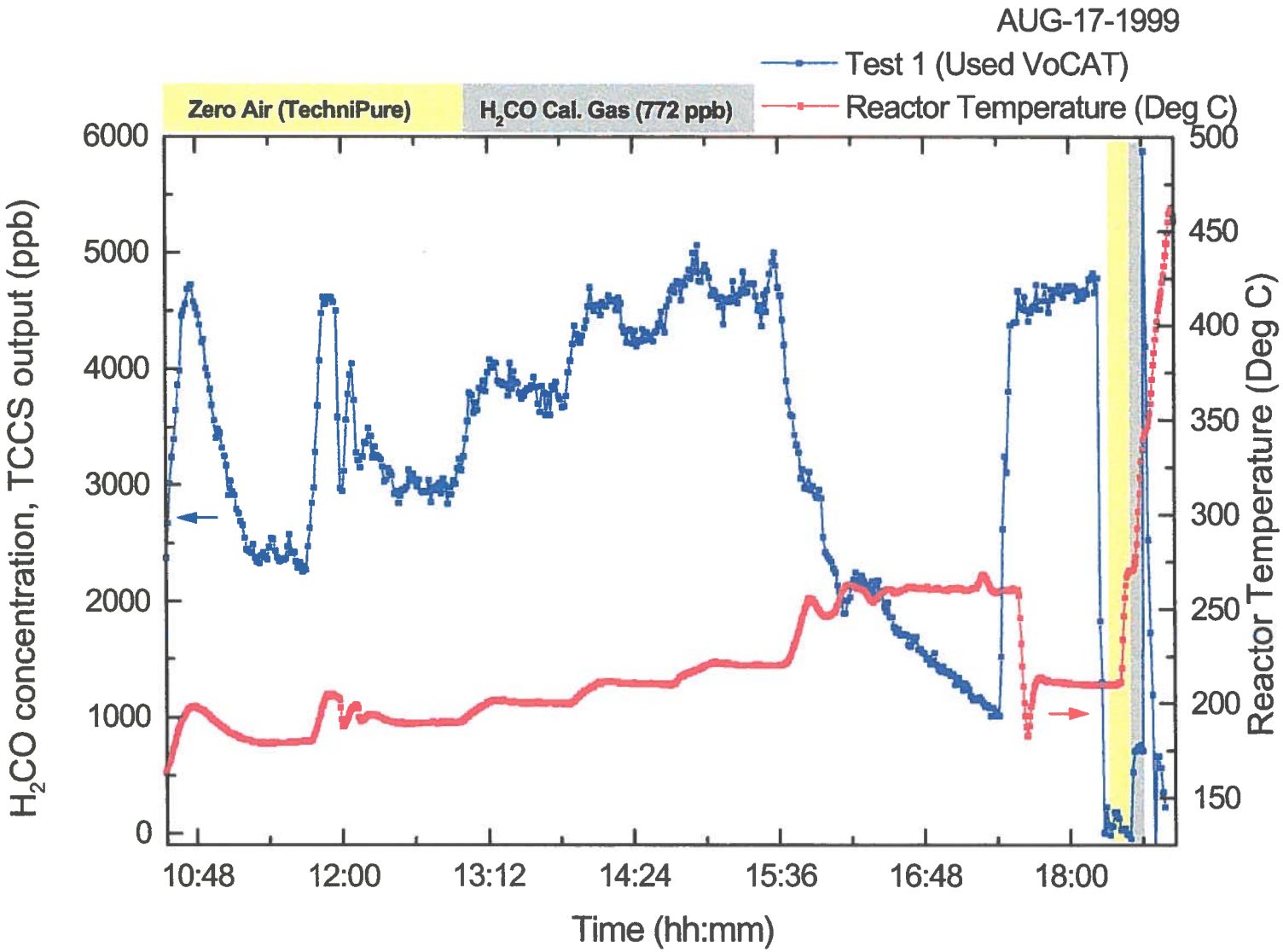


Formaldehyde Measurements from a Car Exhaust

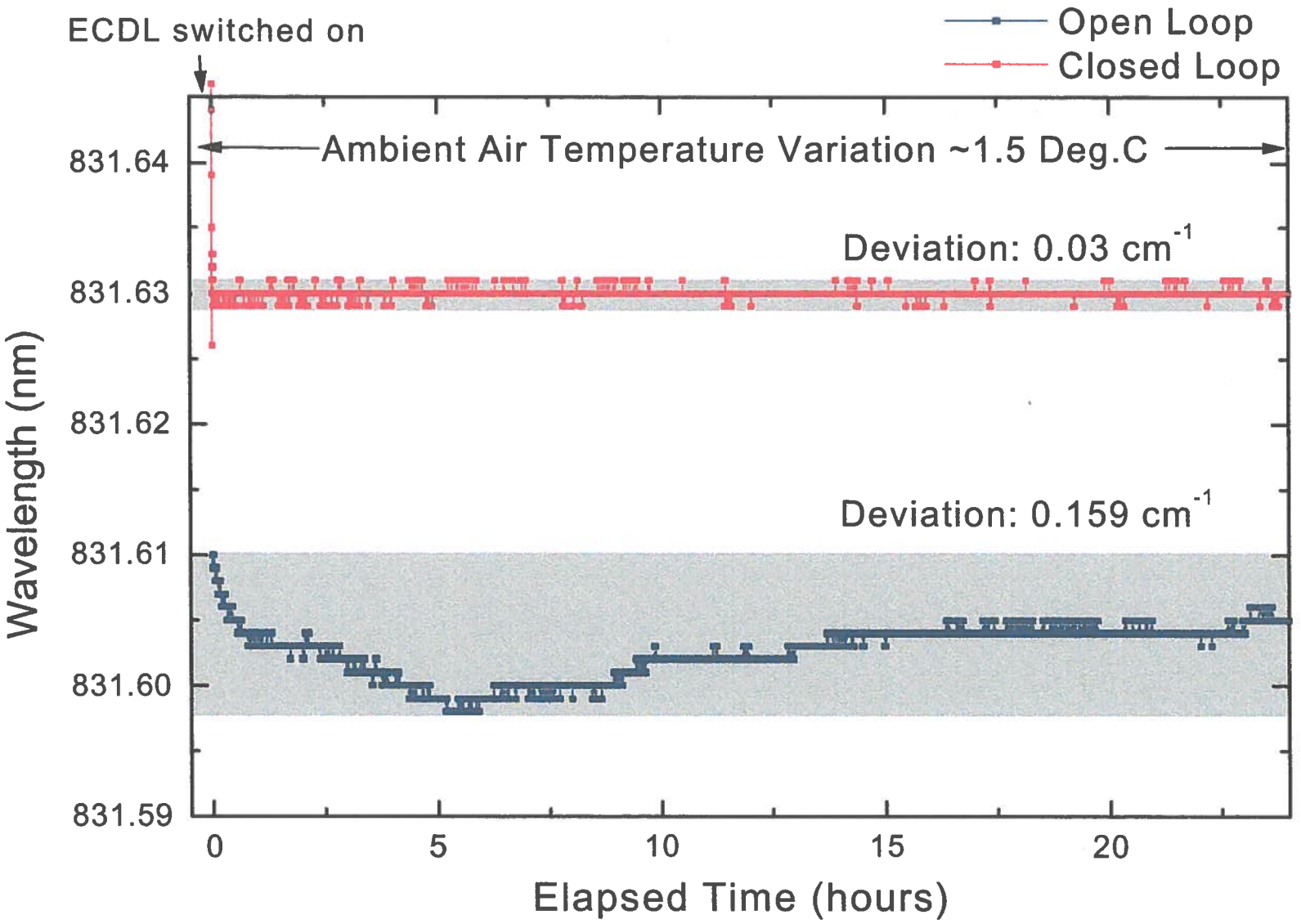


VoCAT analysis: Generation of H_2CO

VoCAT: Volatile Organic CATalyst



ECDL Operation: Open and Closed Loop



Summary and Future Directions

- Reliable, longterm operation (7 days)
- Robust and compact
- Autonomus operation using stepper motor controlled ECDL tuning and quasi-phase matching

- Continuous multi-component detection
- Higher power version using Yb and Er/Yb fiber amplified 1 µm ECDL and 1.5 µm DFG pump sources
- Dual beam spectrosocopy (~2×10^{-5})
- QPM GaAs to extend wavelength coverage (6 to 16 µm)

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