Mid-Infrared Laser Sensor for Multicomponent Trace Gas Detection

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Outline

* Motivation, Design, and Technology Issues
* Performance Characteristics of Compact IR Sensor
* Detection of Trace Gas Species
* Future Prospects

Current Issues of Trace Gas Detection

* Urban Emission Measurements
  - Industrial Plants
  - Combustion Sites
  - Automobile
  - Waste Dumps
* Rural Emission Measurements
  - Agriculture
  - Forest Fires
* Environmental Monitoring
  - Atmospheric Chemistry
  - Volcanic Emissions
* Spacecraft and Spacestation Monitoring
  - Crew Health Maintenance
  - Regenerative Life Support
* Chemical Analysis and Process Control
* Aircraft Identification
* Medical Applications

Tunable CW IR Laser Sources

* **Color Center Lasers**
  Tunable (1-4 μm)
  Low temperature needed

* **Lead Salt Diode Lasers**
  Tunable (3-30 μm)
  Each diode ~100 cm^{-1}
  Undesirable discontinuities
  Low temperature needed

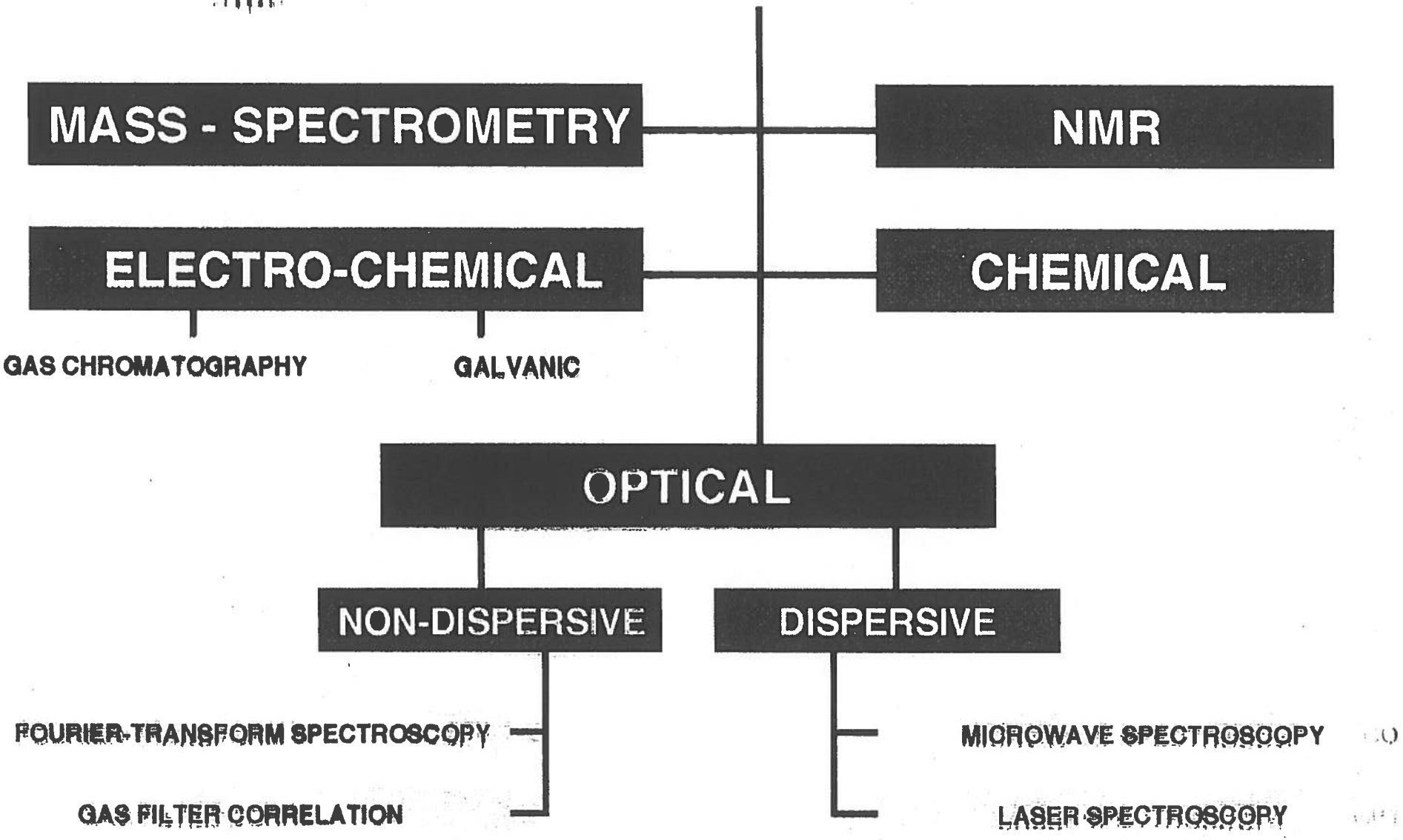
* **CO and CO_2 Sideband Lasers**

* **Optical Parametric Oscillators (OPO)**
  Tunable 2-14 μm ($LiNbO_3$, KTP, BBO, $AgGaS_2$, $AgGaSe_2$, $ZnGeP_2$) CW and Pulsed

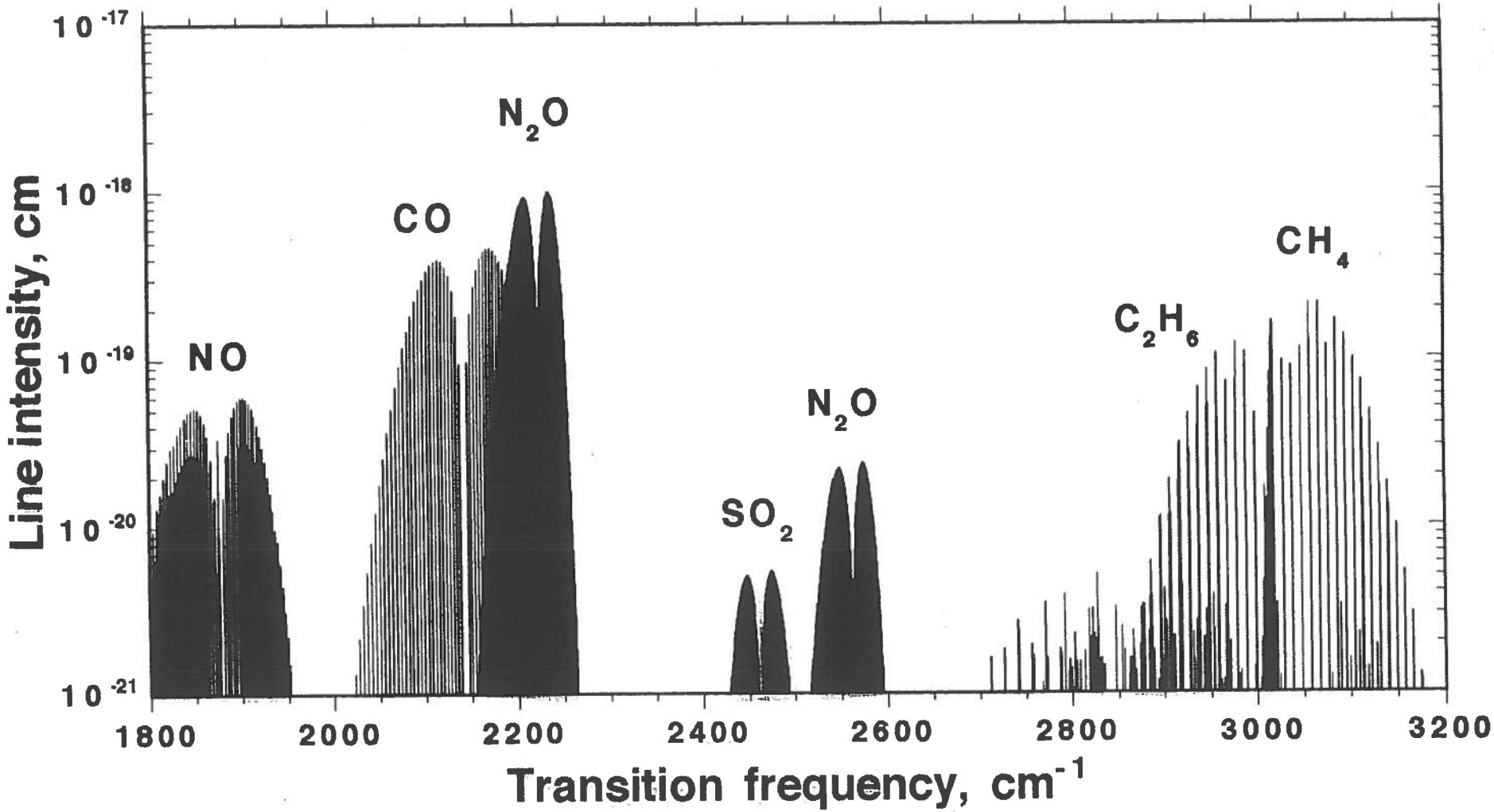
* **Tunable III-V Semiconductor Diode Lasers**
  Single frequency, 0.63-2 μm

* **Difference Frequency Generation (DFG)**
  Tunable: 2-5.3 μm (QPM-$LiNbO_3$), 3-9 μm ($AgGaS_2$), > 8 μm ($AgGaSe_2$), 7-18 μm (GaSe), Room Temperature

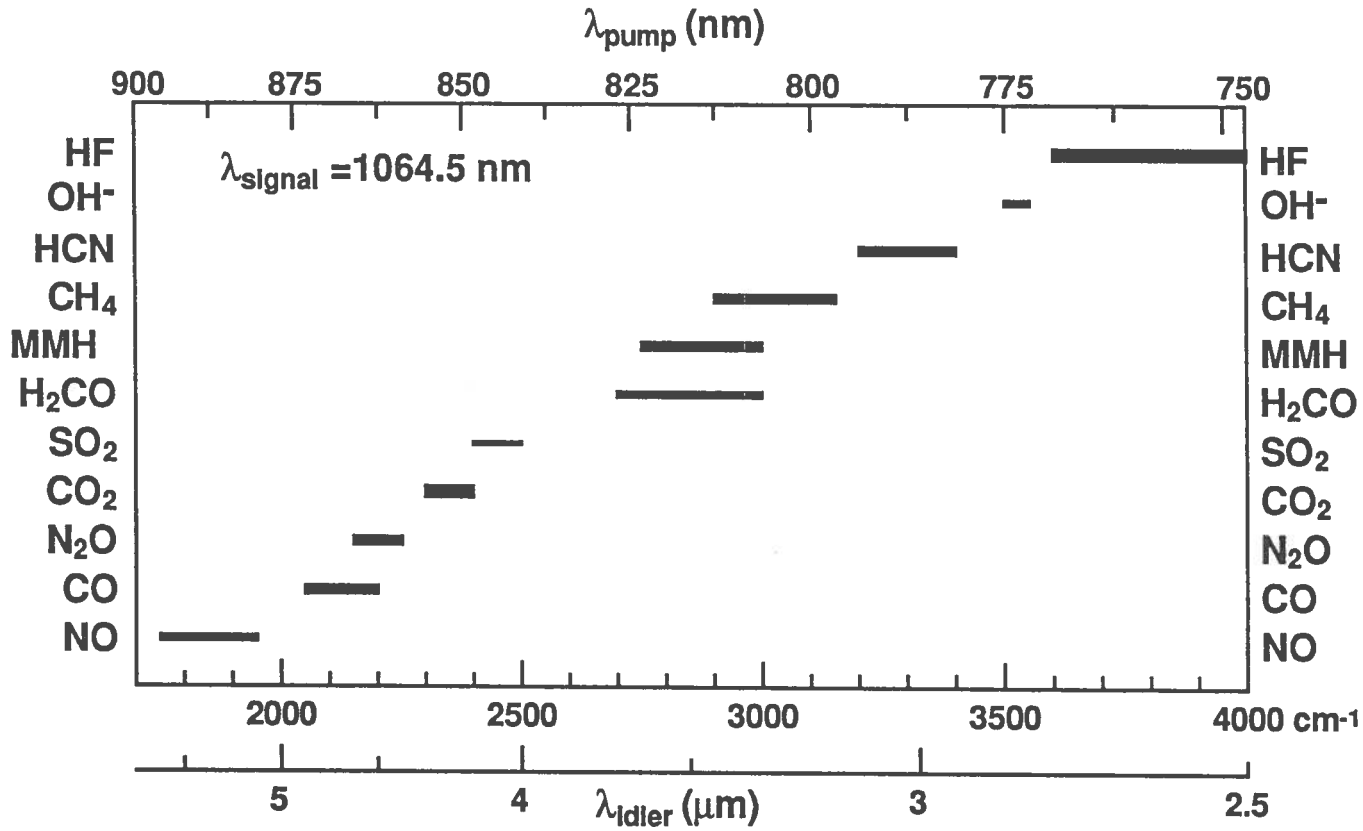
EXISTING METHODS FOR TRACE GAS DETECTION



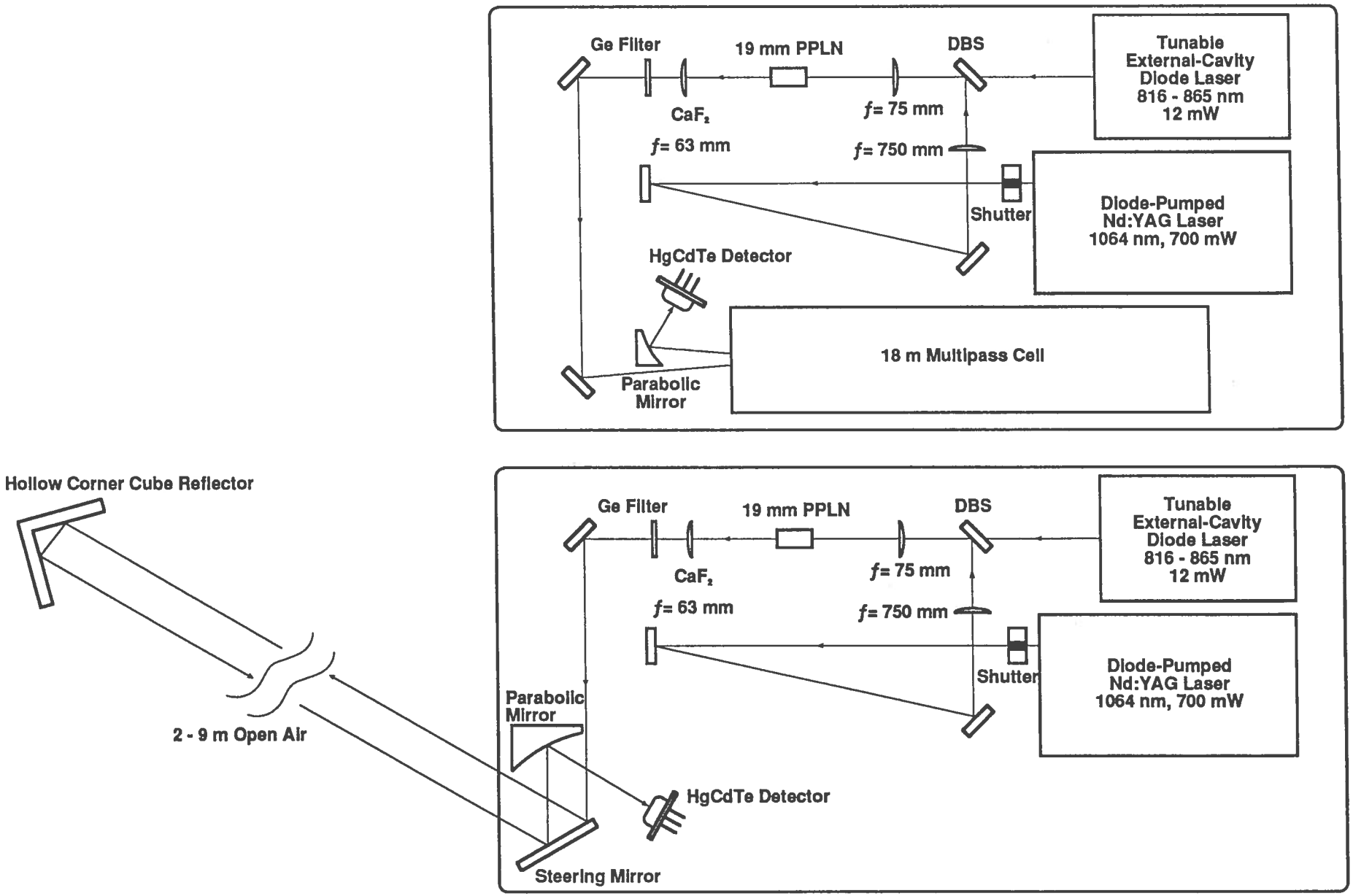
SURVEY ABSORPTION SPECTRA OF SOME ATMOSPHERIC TRACE GASES



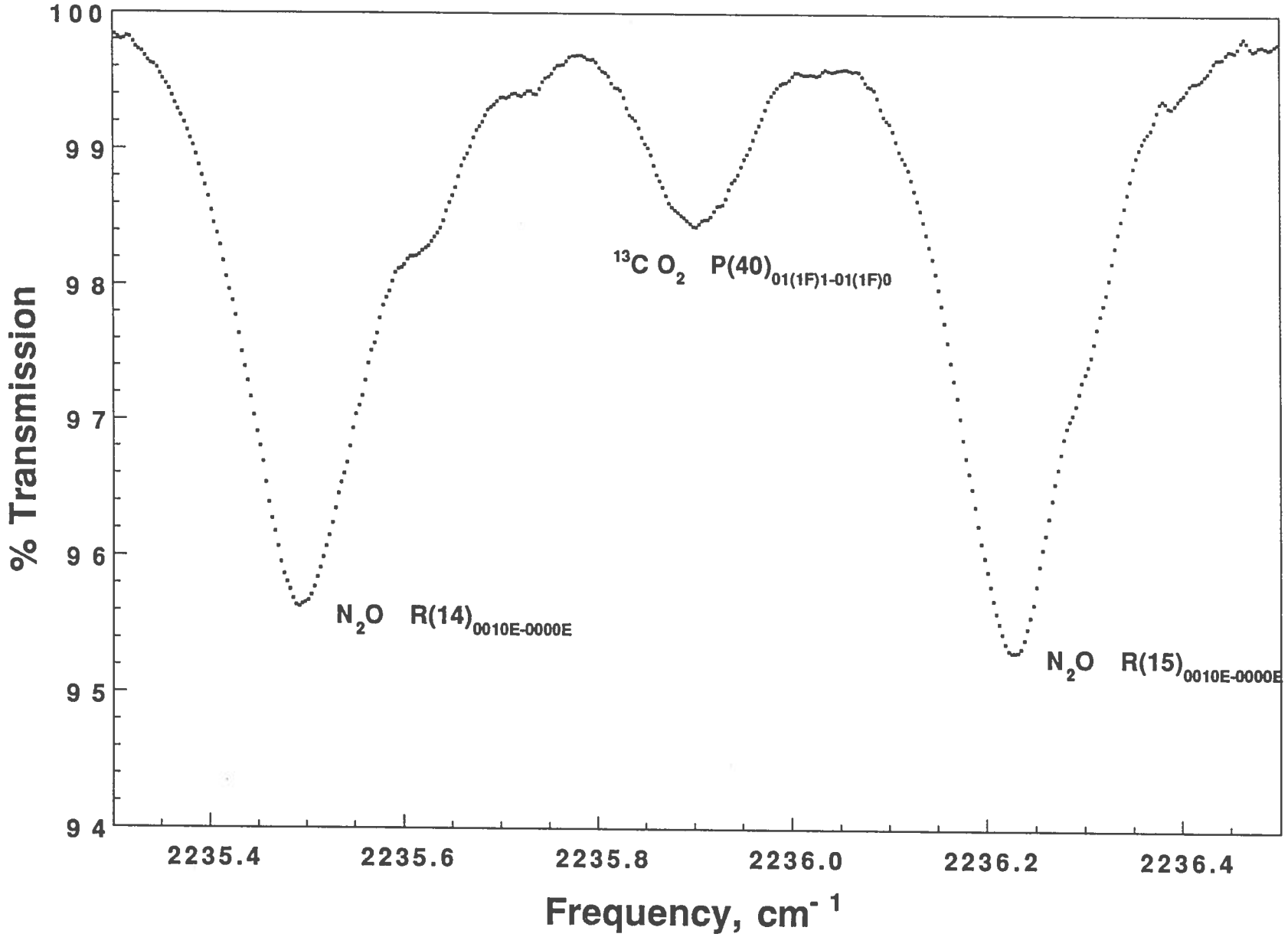
MID-INFRARED WAVELENGTH COVERAGE BY DIFFERENCE-FREQUENCY MIXING IN PPLN



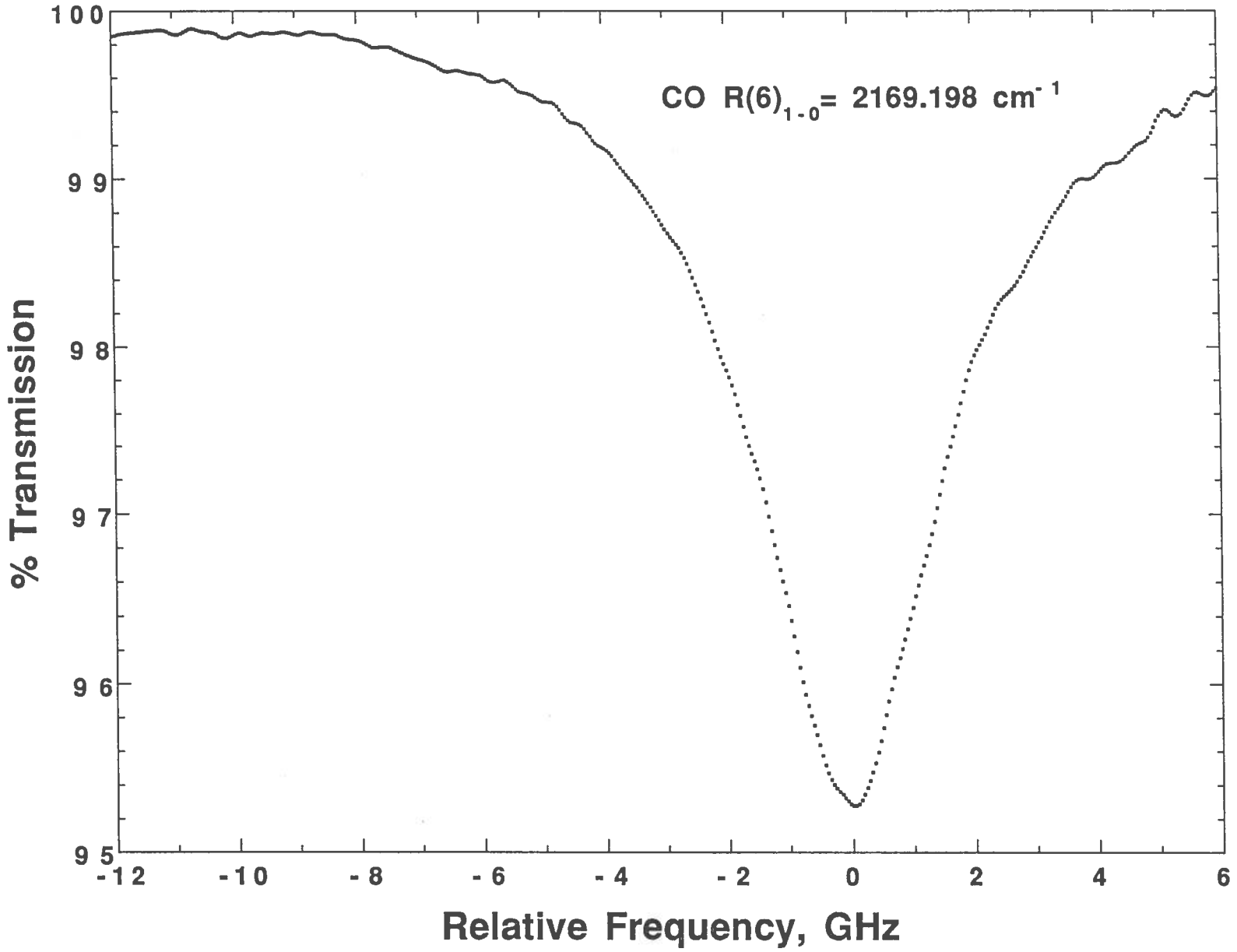
DFG-BASED GAS SENSOR



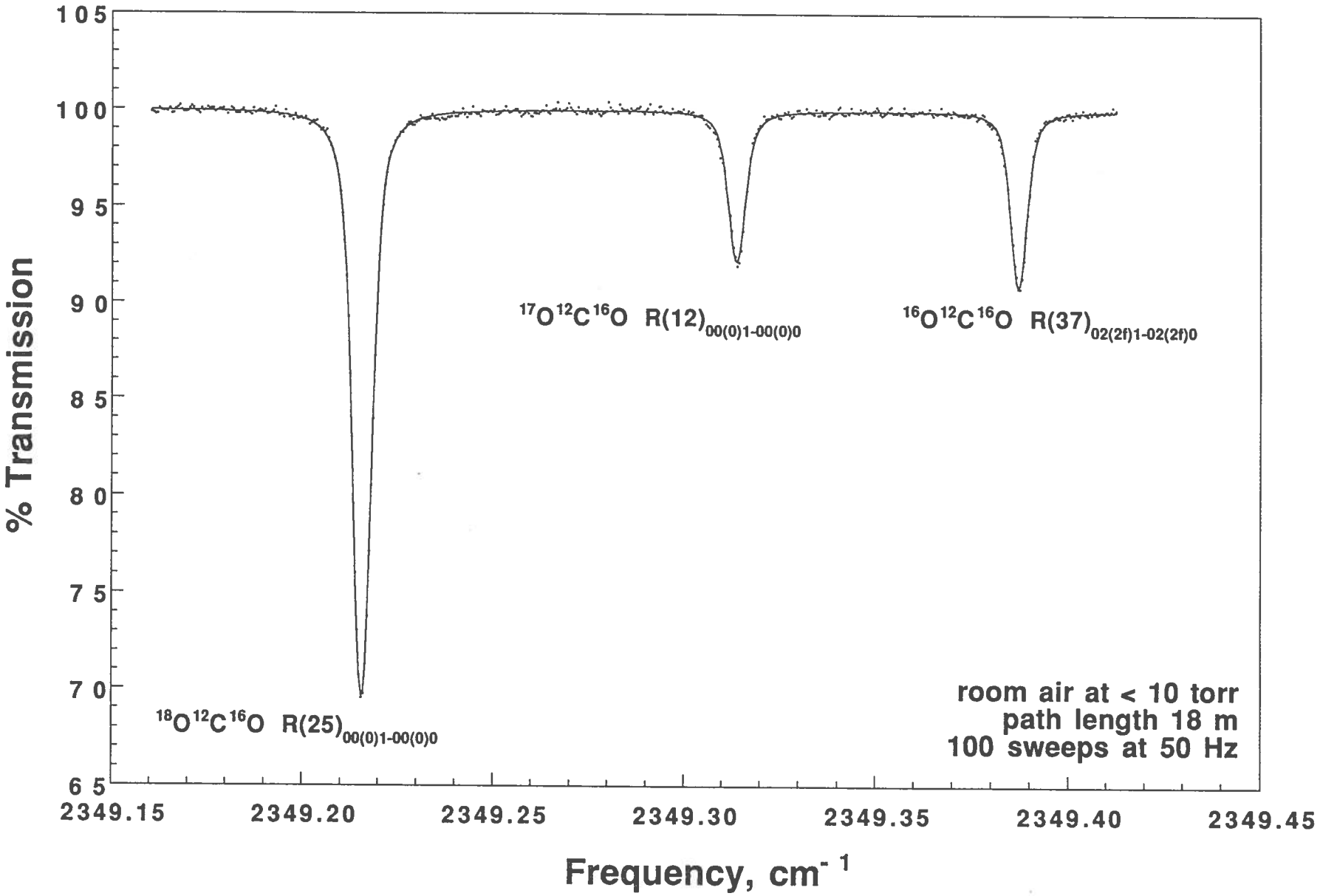
SPECTRUM OF N_2O AND $^{13}C\ O_2$ IN AMBIENT AIR



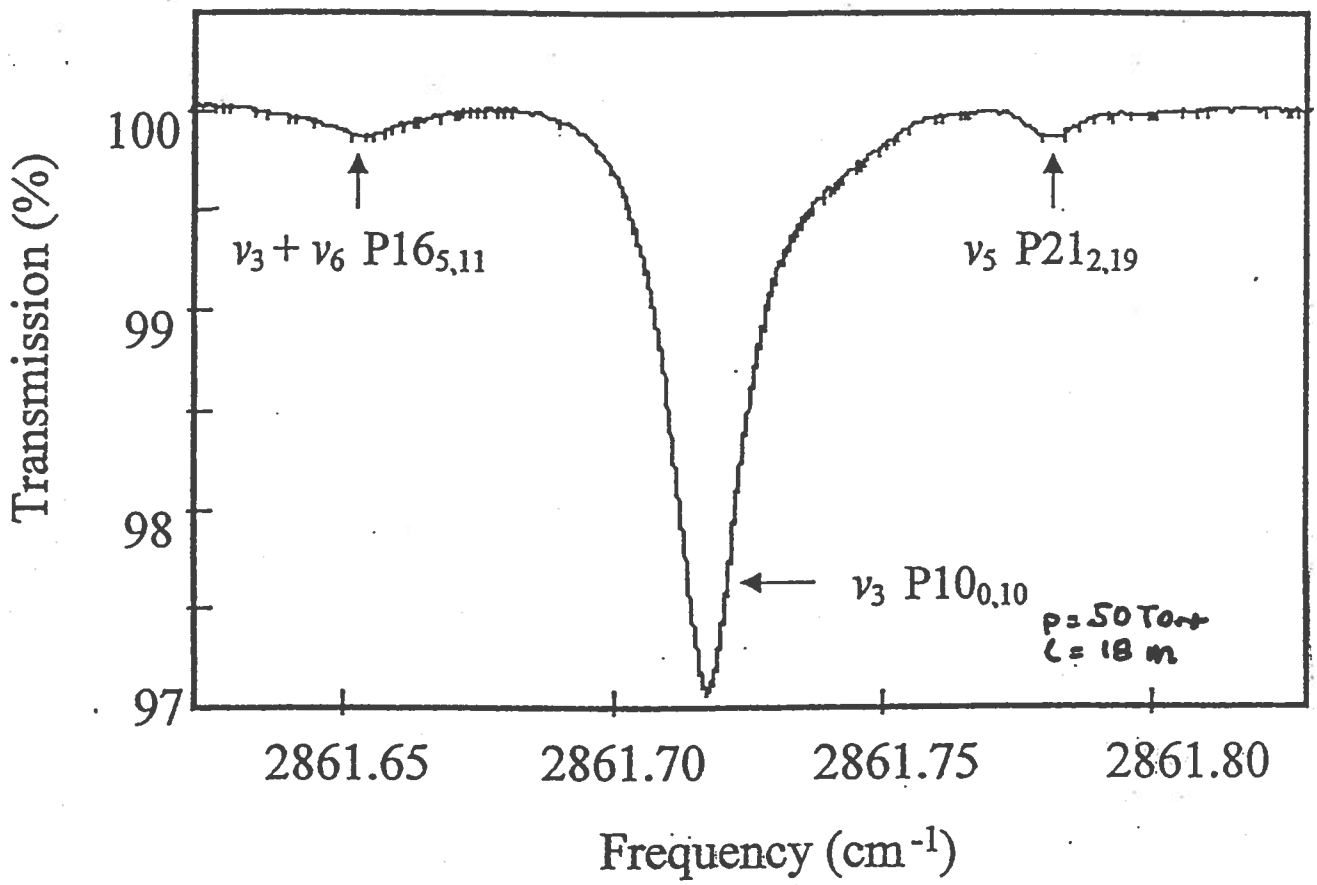
SPECTRUM OF CARBON MONOXIDE IN AMBIENT AIR

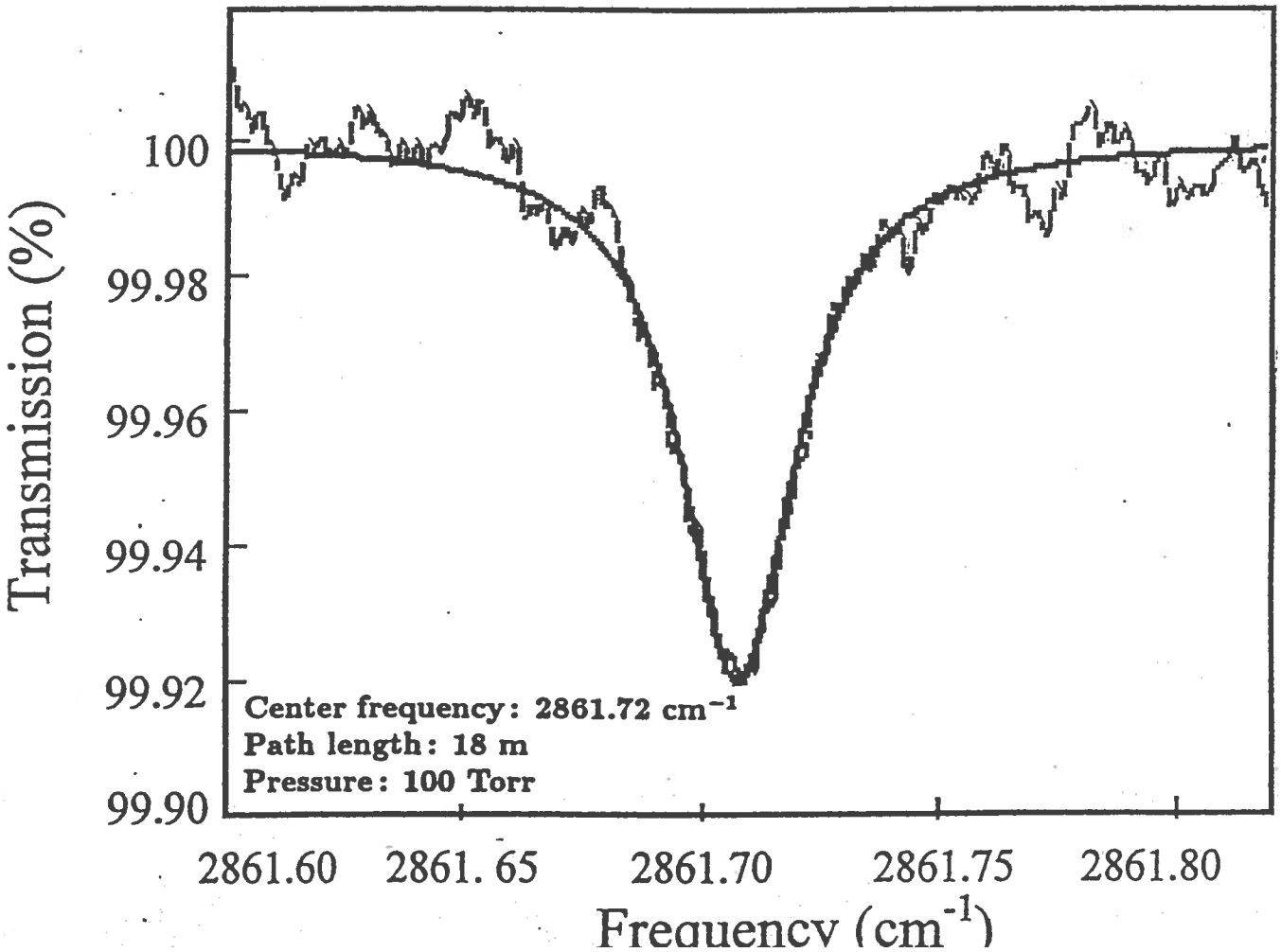


Measurements of the ^{16}O :^{17}O :^{18}O isotopic ratio in atmospheric CO_2



Spectrum of H_2CO in Nitrogen





Summary

* Multi-component trace gas detection is feasible with all-solid-state DFG sensors.

* Detector-limited sensitivity of 1 ppb.m/$\sqrt{Hz}$ for many trace gases can be achieved.

* Characteristics of a PPLN based DFG sensor:
  - Wavelength: 3 - 5.3 μm
  - DFG Power: 1 - 10 μW
  - Linewidth: 0.5 - 50 MHz
  - Detectors: InAs, HgCdTe
  - Environment: Multipass cell, open air
  - Species Detected: CH_4, H_2CO, SO_2, CO_2, N_2O, CO, NO, H_2O
  - Pump Power: 50 mW + 500 mW
  - Power Consumption: 50 W
  - Lifetime: 10,000 hrs.
  - Size: 2 cu. ft.

Desired Improvements

* More IR DFG Power
* Less Optical Pump Power
* Fiber Coupled Pump Sources
* More Wavelength Coverage
* Faster Data Processing
* Smaller Size
* Lower Cost

Acknowledgments

E. Dlugokencky (NOAA)
L. Goldberg (NRL)
M. Fejer (Stanford)
R. Putnam (Aerodyne)
L. Hollberg (NIST)
D. Lancaster
J. Graf (NASA)
D. Richter

National Aeronautics and Space Administration (NASA)

Texas Advanced Technology Program

Welch Foundation