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LACEA 2000 Santa Fe, NM

Trace gas detection in ambient air using a 7.9 μm QC-DFB laser

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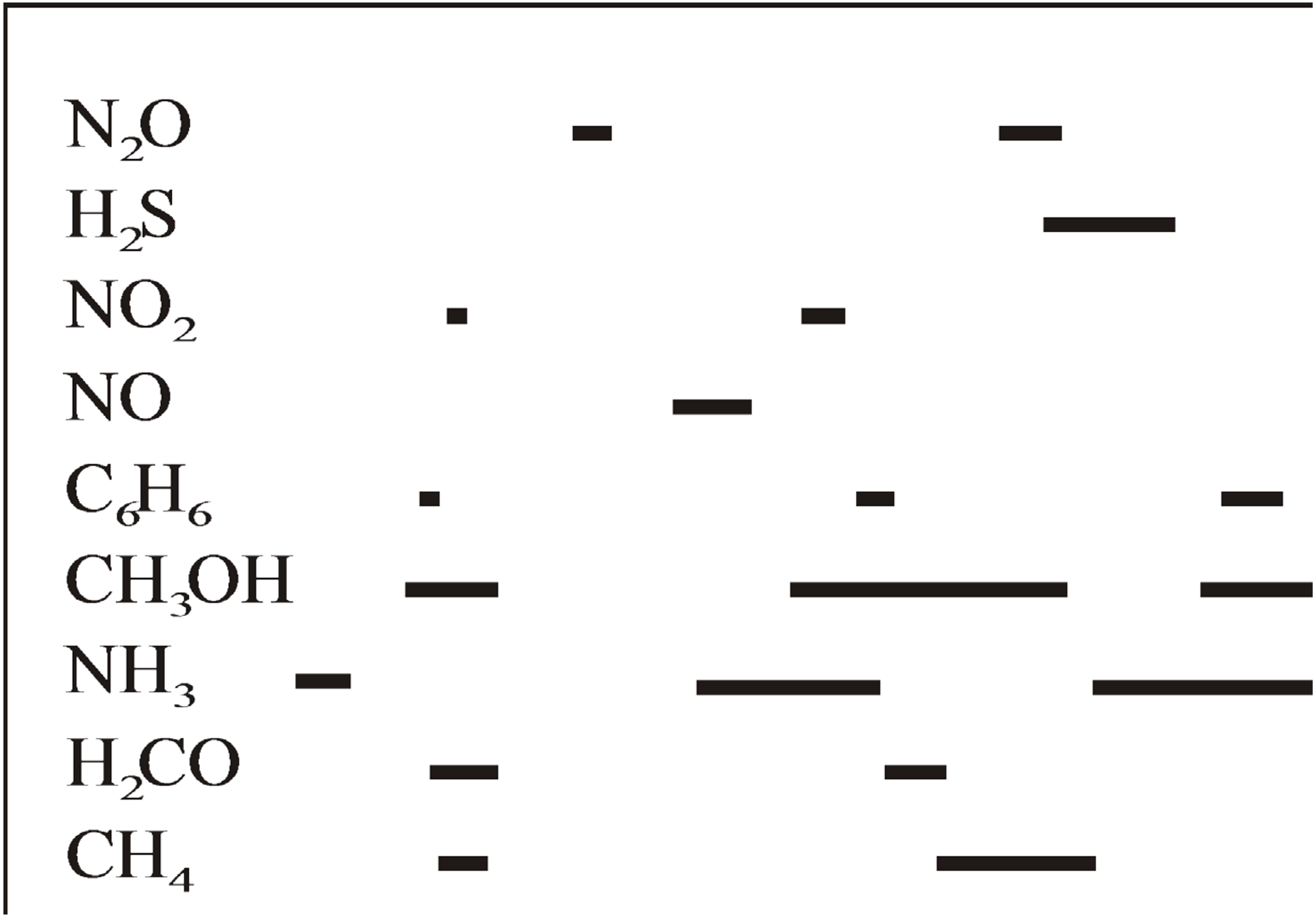
OUTLINE

- Background and Motivation
- Detection of simple molecules in air, cw laser operation
- Detection of ethanol and linear regression data analysis
- Pulsed operation based laser spectrometer
- Summary and future outlook

Spectral Coverage by Diode/QC Lasers



Motivation for CH_4 and N_2O Detection

- Contribution to global warming
- Important in tropospheric and stratospheric chemistry
- Emitted by agricultural sources
- CH_4 leaks from gas pipelines

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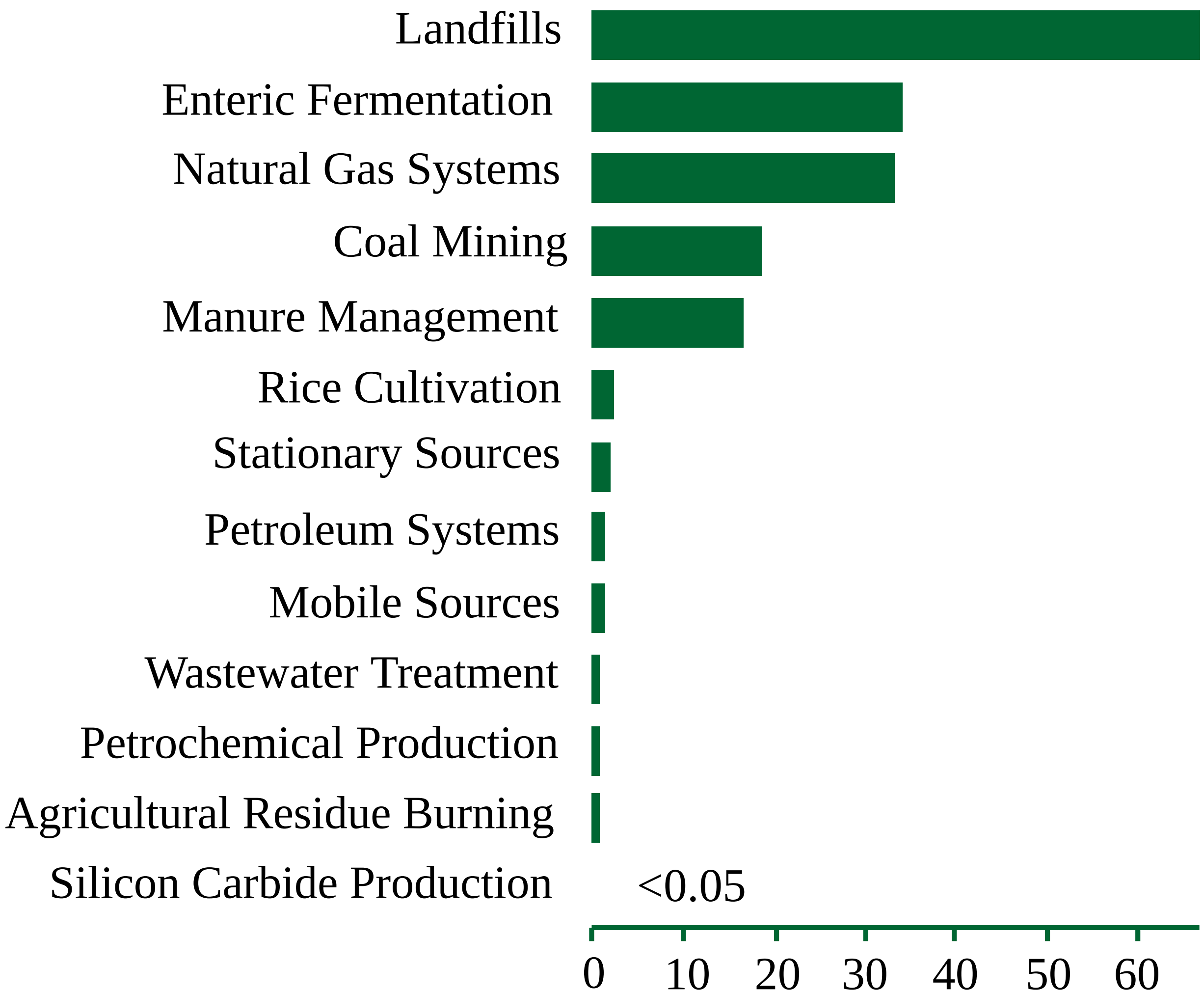
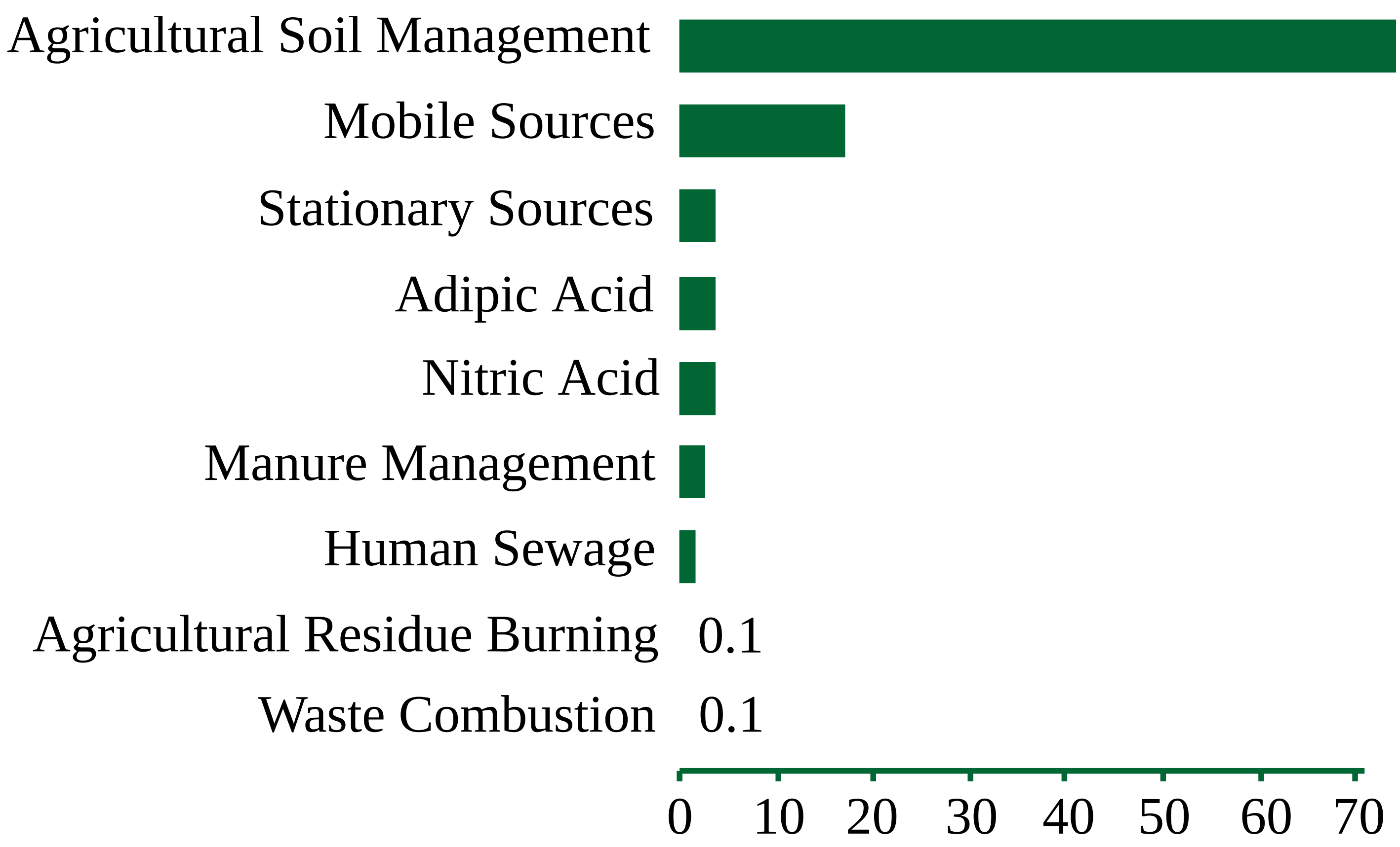
Sources of atmospheric CH_4



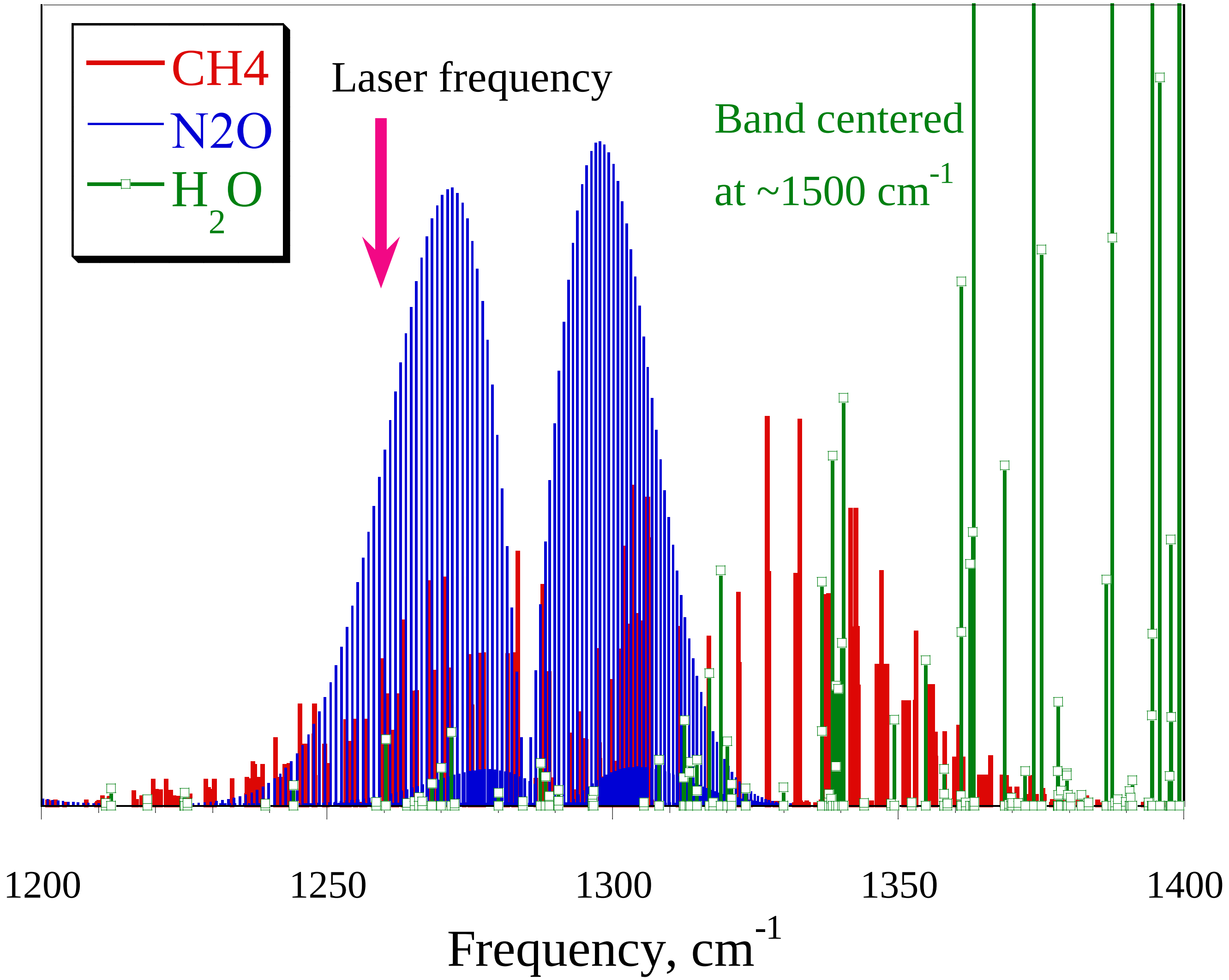
http://www.epa.gov

Sources of atmospheric N_2O

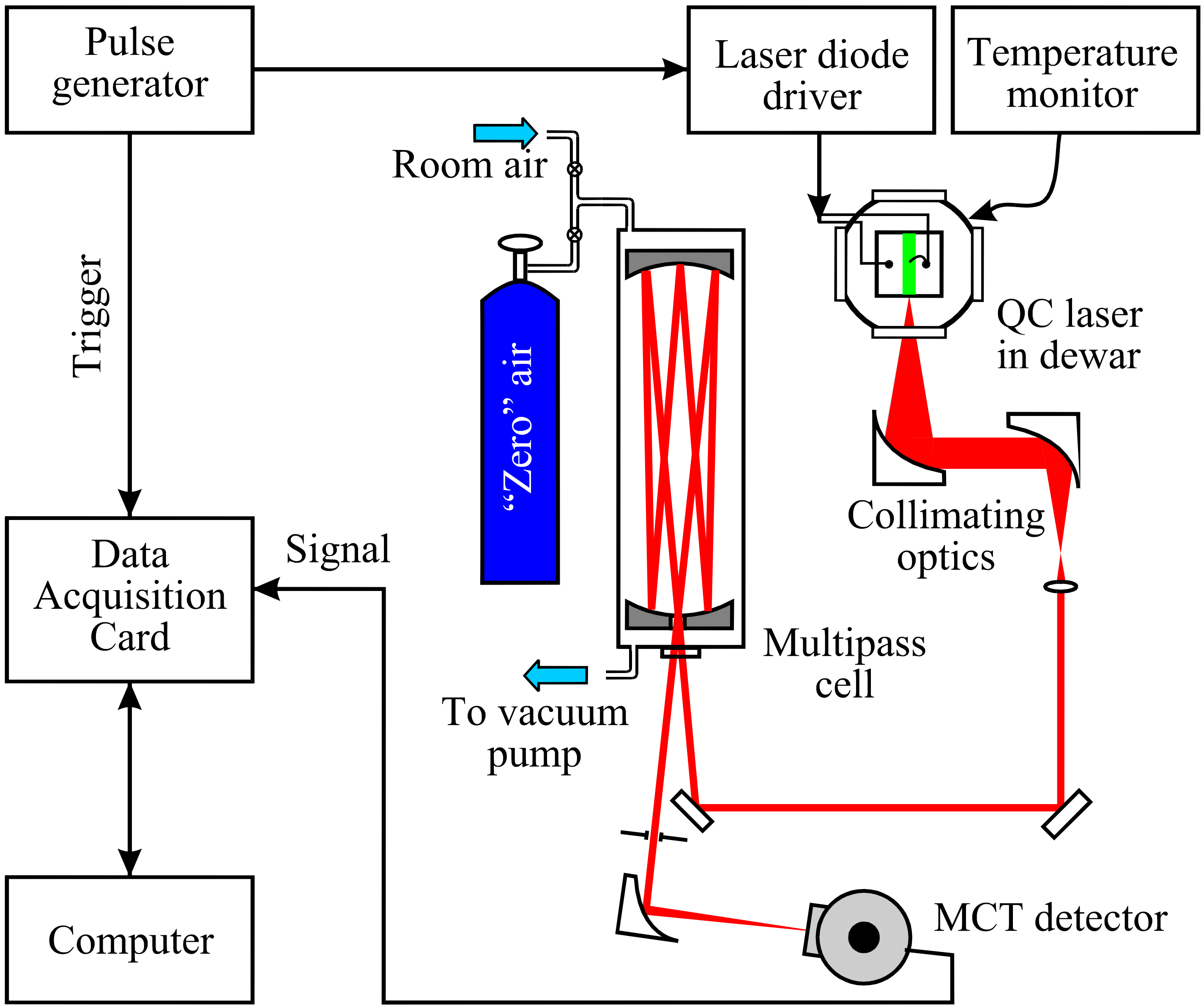


http://www.epa.gov

CH_4, H_2O and N_2O Absorption Spectra



Trace Gas Detection with a Multipass Cell



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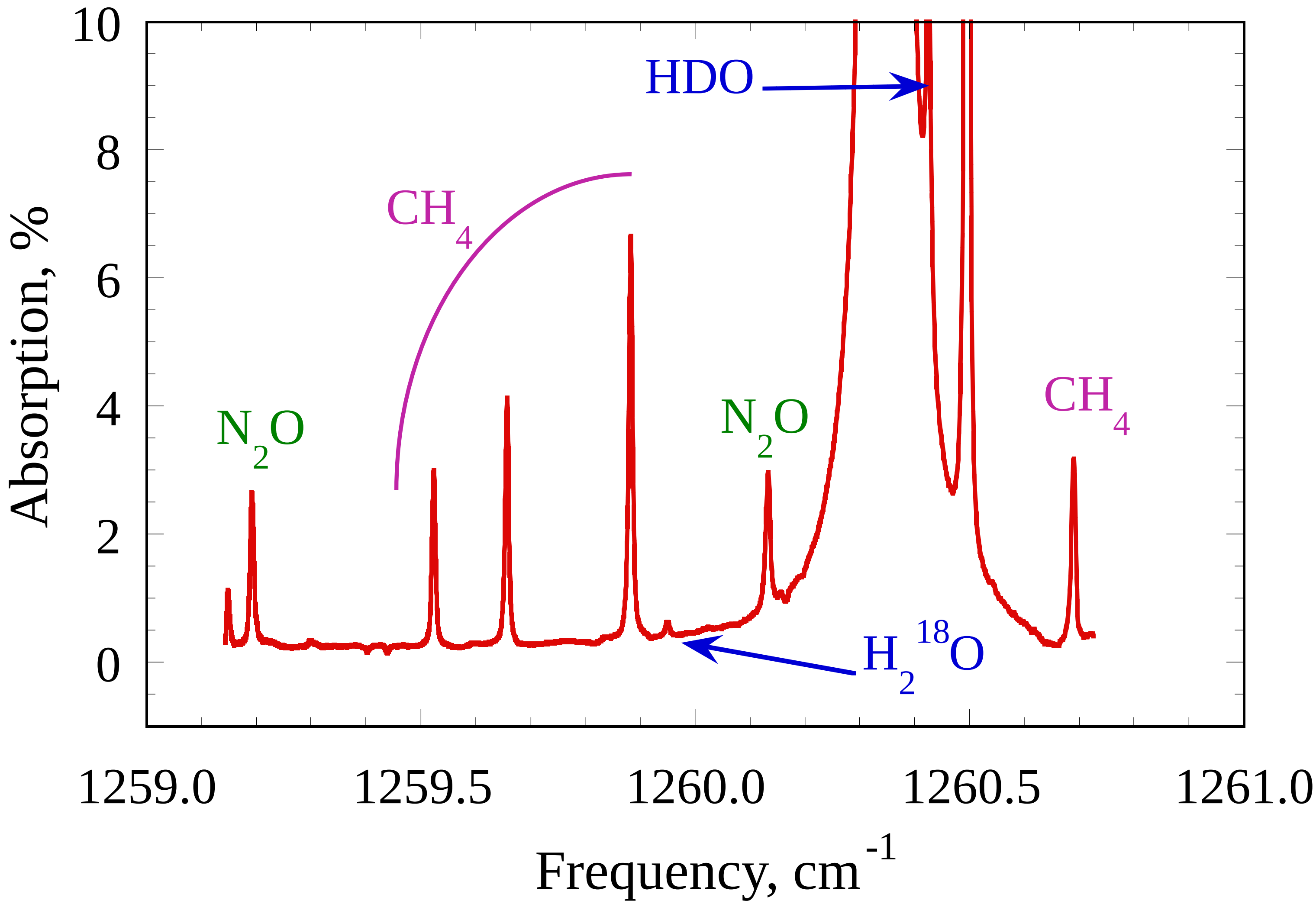
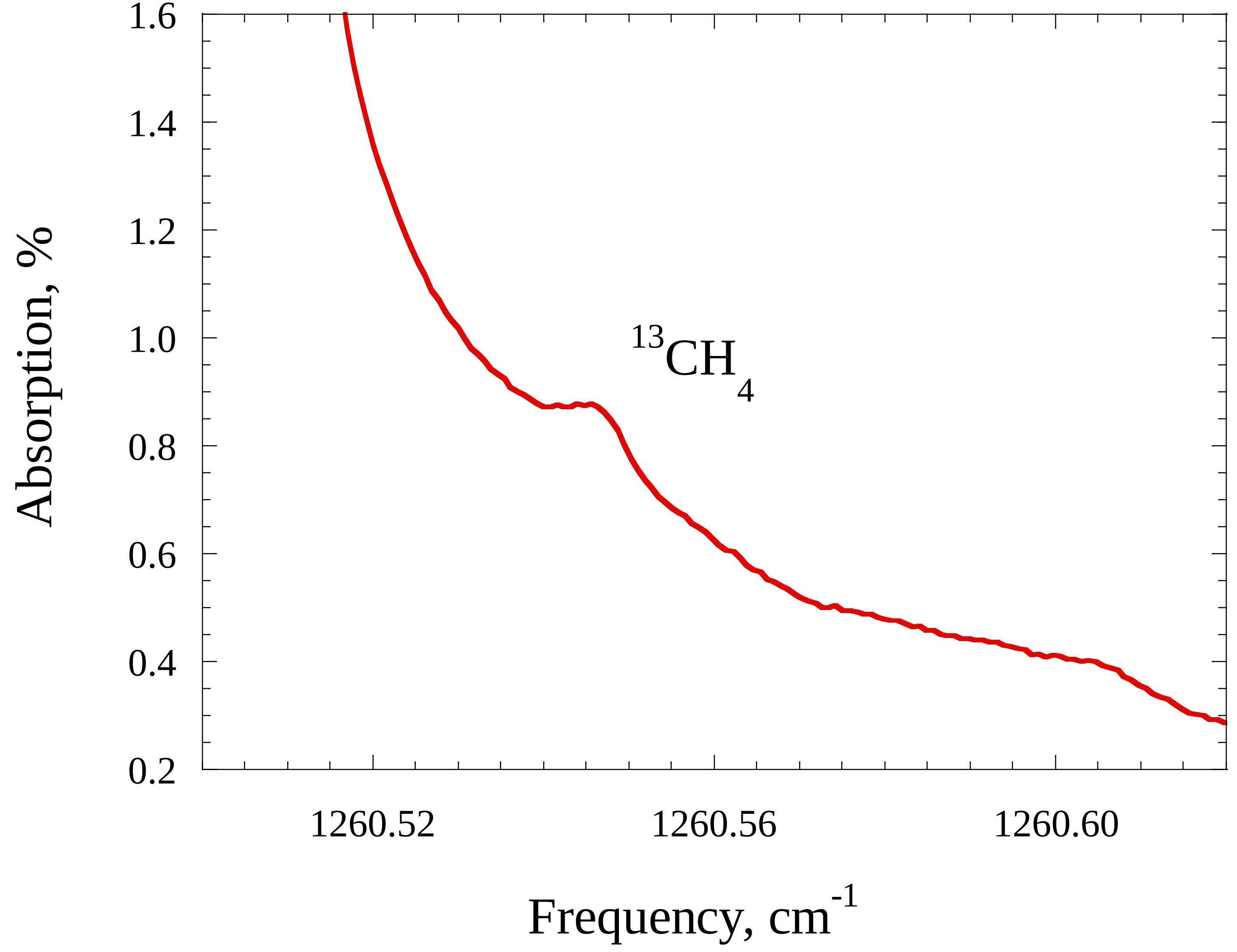
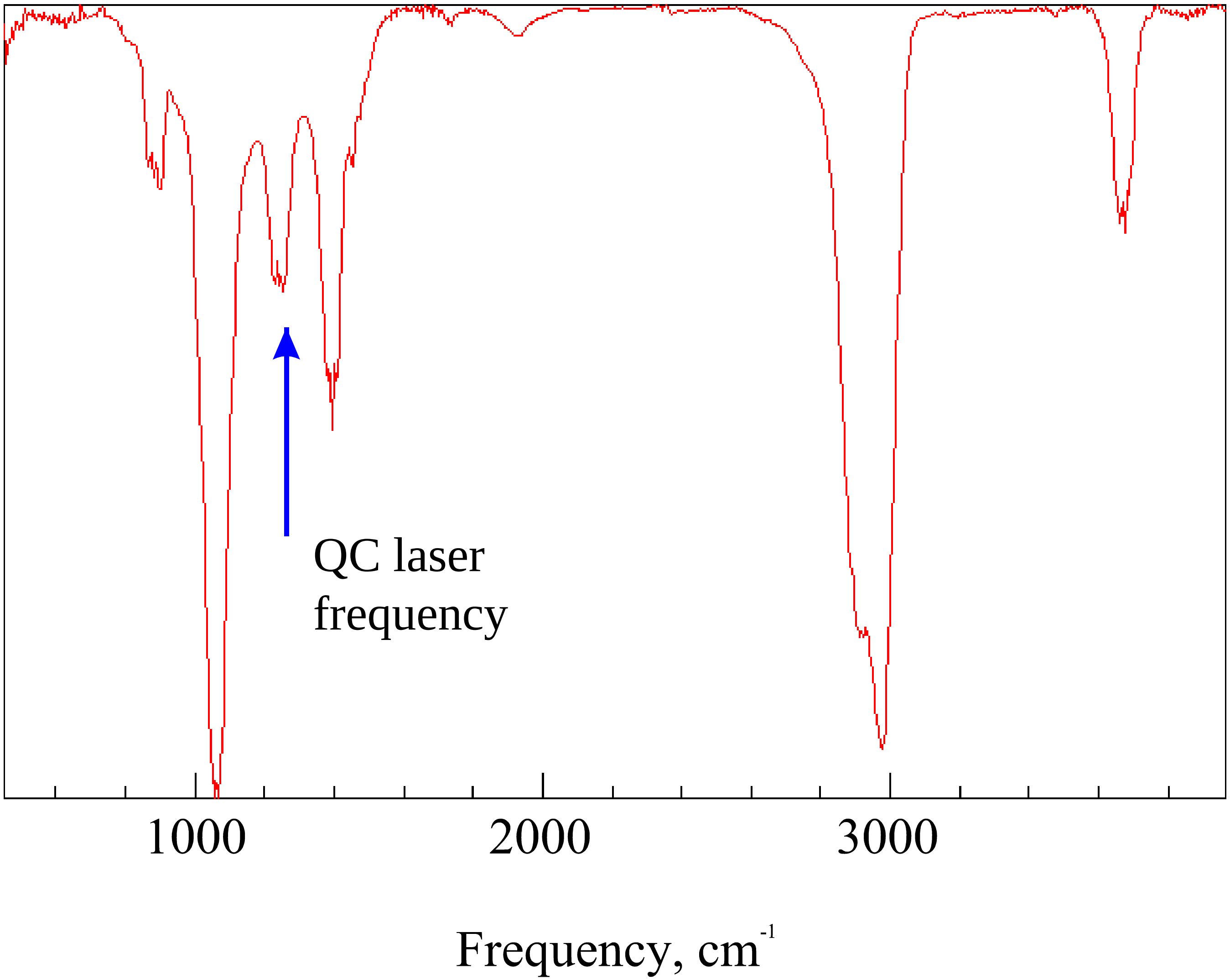
Absorption Spectrum of Room Air



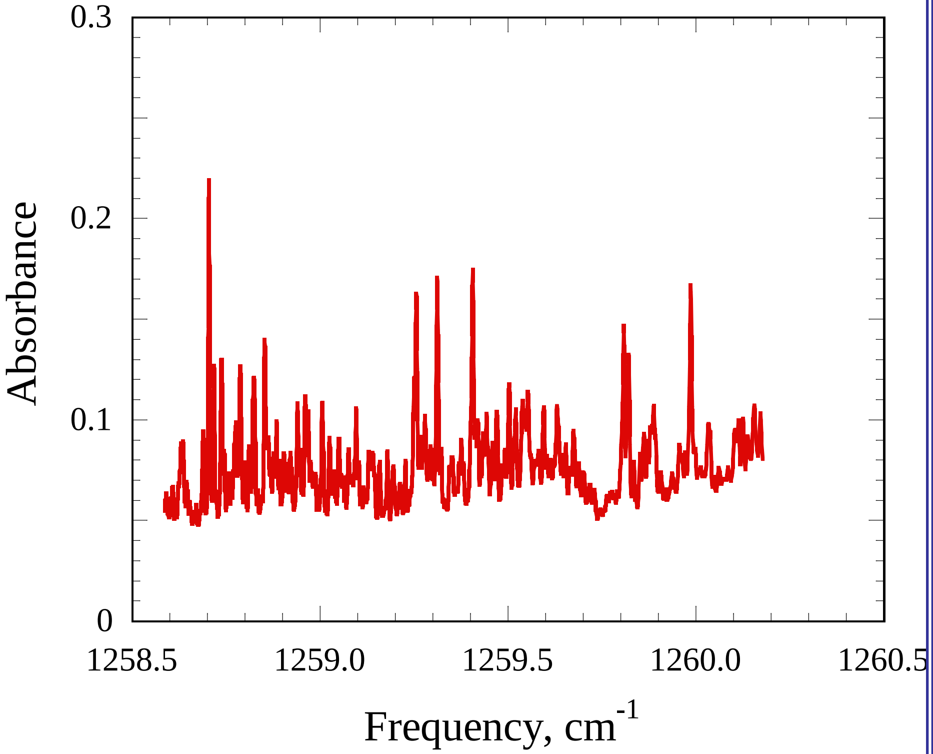
Detection of $^{13}CH_4$ in Ambient Air



IR Absorption Spectrum of Ethanol

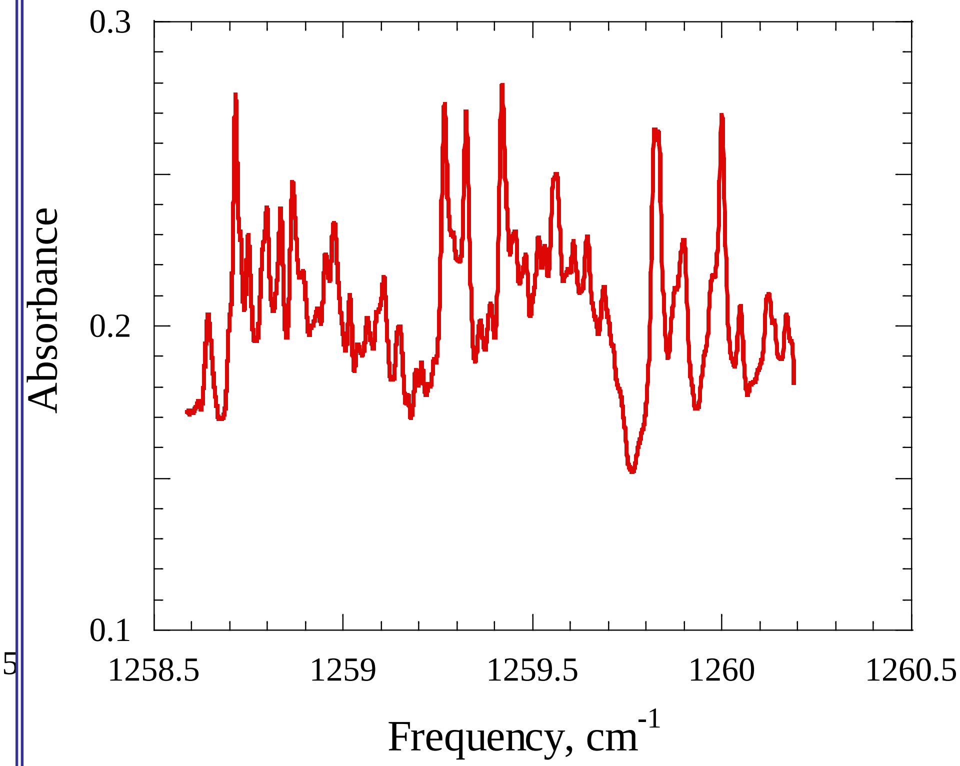


High-resolution IR Ethanol Spectrum



Pure ethanol vapor

P=1 Torr



Ethanol vapor +air

P_{eth}=1 Torr, P=36.6 Torr

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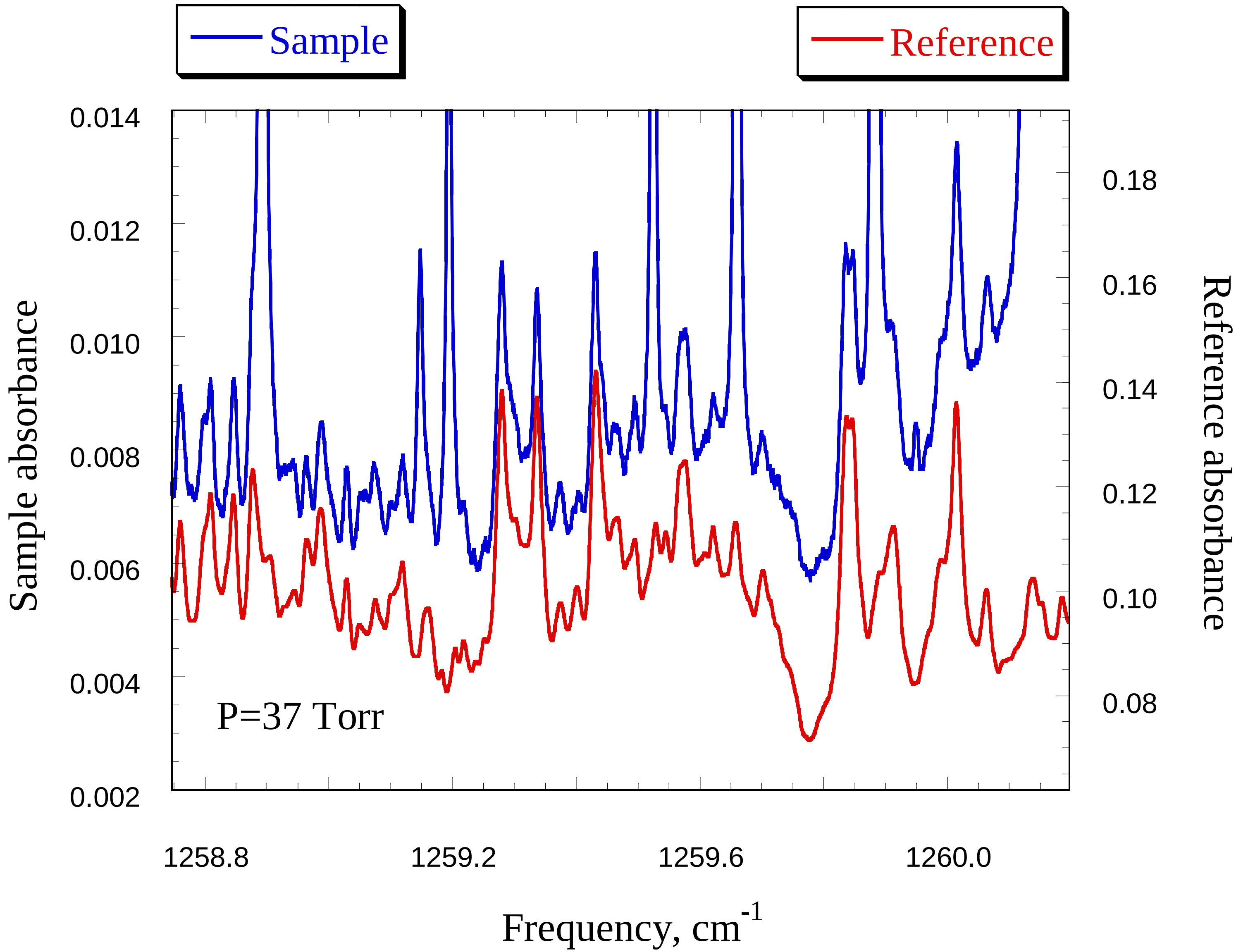
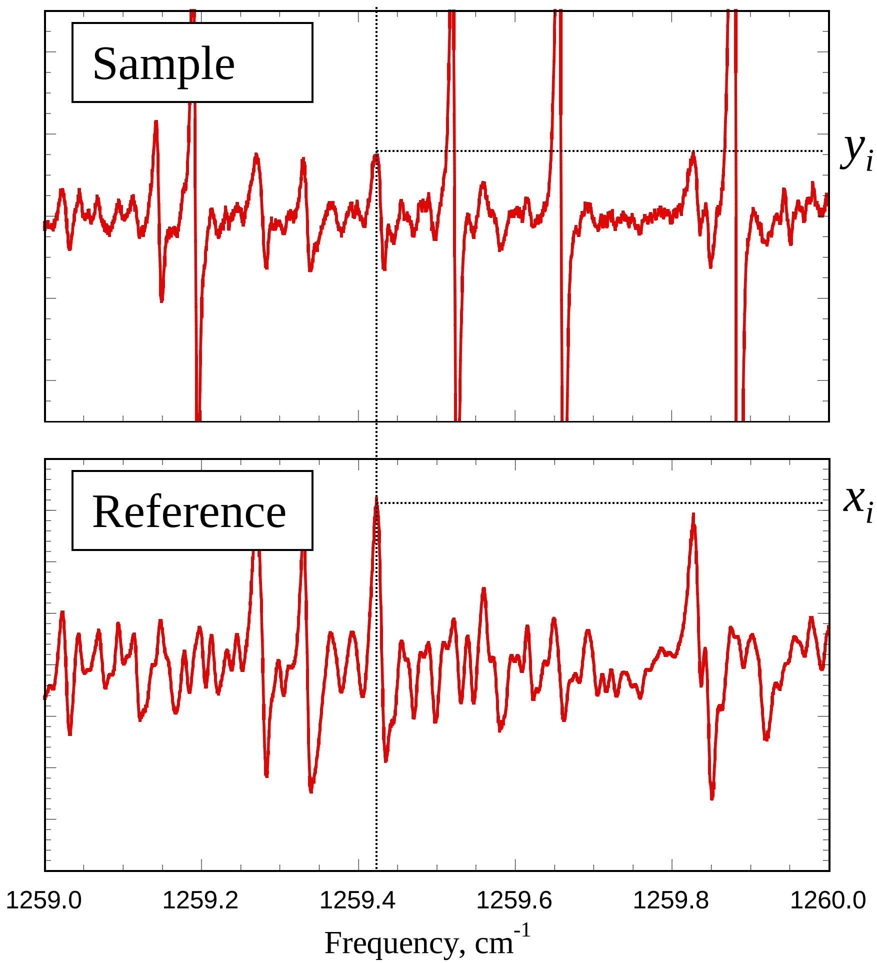
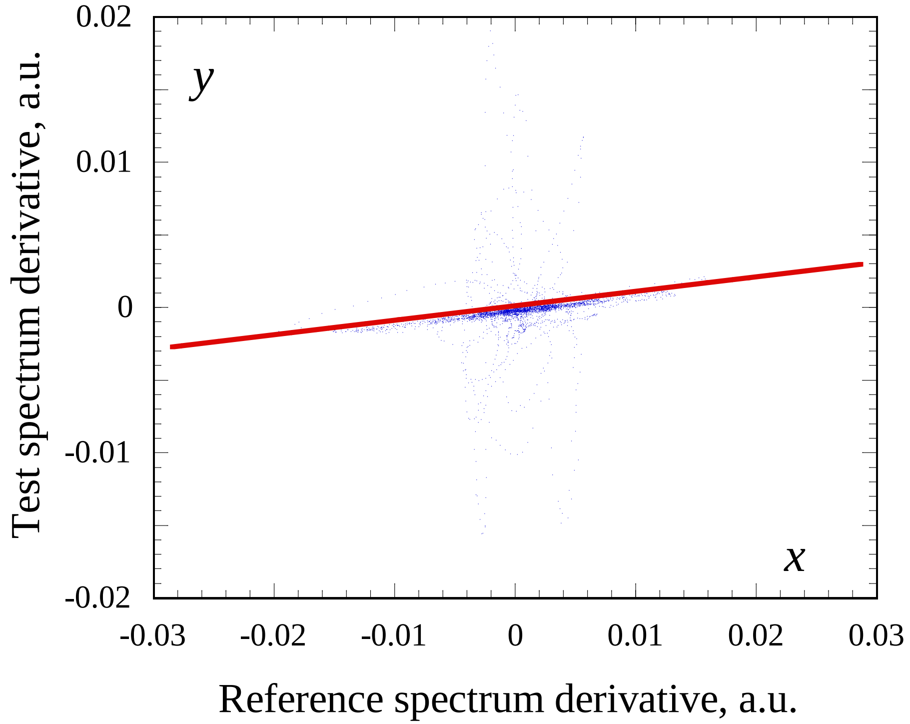
Reference and Sample Spectra of Ethanol in Air



Linear Regression Technique





$$1-\mathrm{D}: \quad y_i = a x_i$$

$$\mathrm{MLR}: \quad y_i = \sum_{k=1}^{N} a_k x_{ki}$$

Results of the Linear Regression Analysis

Species	Measured concentration – sample 1		Measured concentration - sample 2	
	MLR	1-D regression	MLR	1-D regression
C_2H_5OH	11.60×10^{-6}	12.12×10^{-6}	1.44×10^{-6}	1.41×10^{-6}
CH_4	1.72×10^{-6}	-	1.70×10^{-6}	-
N_2O	0.302×10^{-6}	-	0.301×10^{-6}	-
H_2O	1.72×10^{-3}	-	1.73×10^{-3}	-

Pulsed Operation of a QC-DFB Laser

ADVANTAGES	DISADVANTAGES
♦ Laser can be operated at near-room temperature	♦ Broader linewidth (~400 MHz)
♦ Easy temperature handling	♦ Less average power
♦ No consumables (liquid N_2)	♦ More sophisticated electronics for driving QC laser and data acquisition
♦ Compact	

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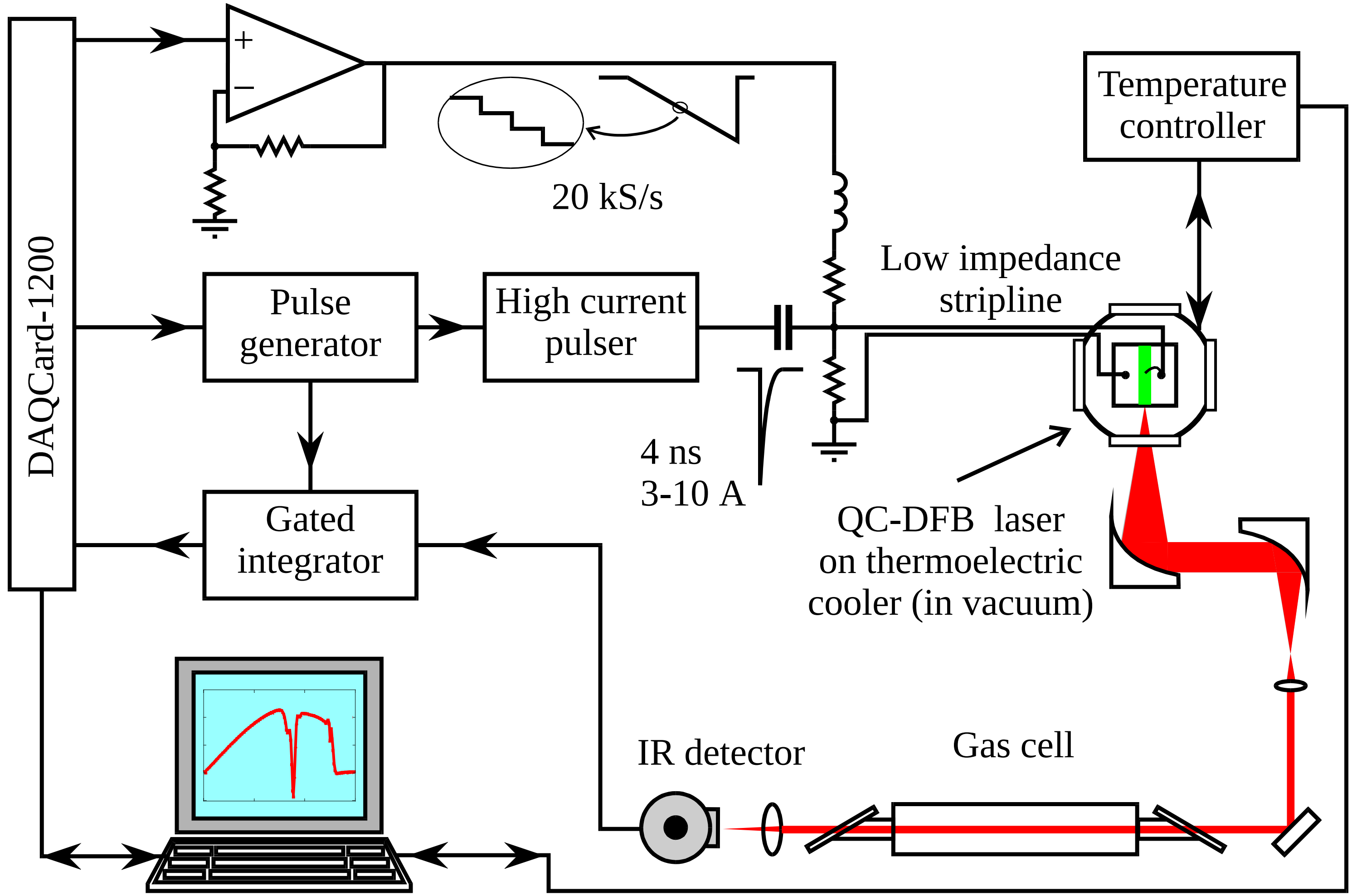
Pulsed QC-DFB Spectrometer



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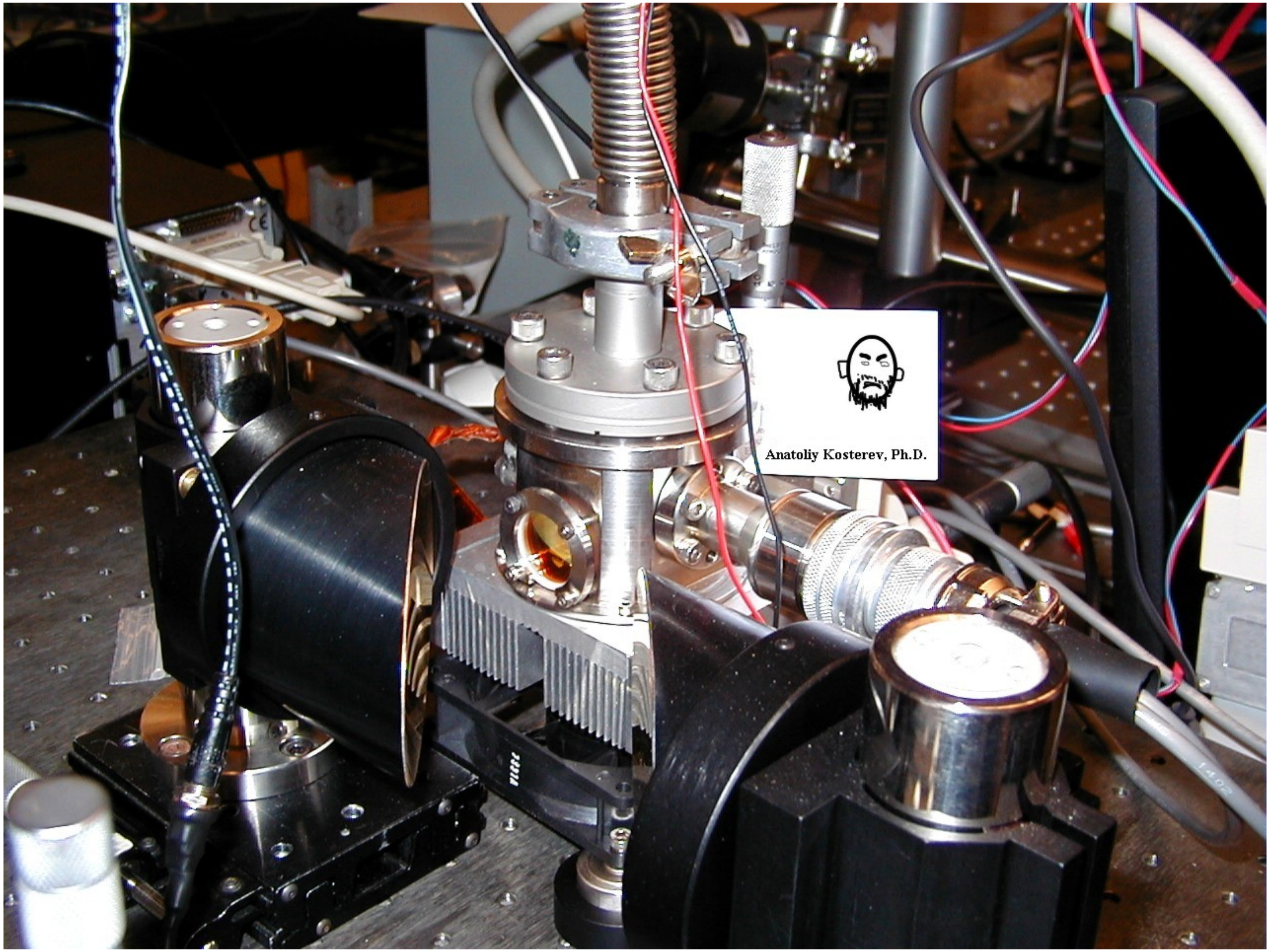
Pulsed QC Laser Housing



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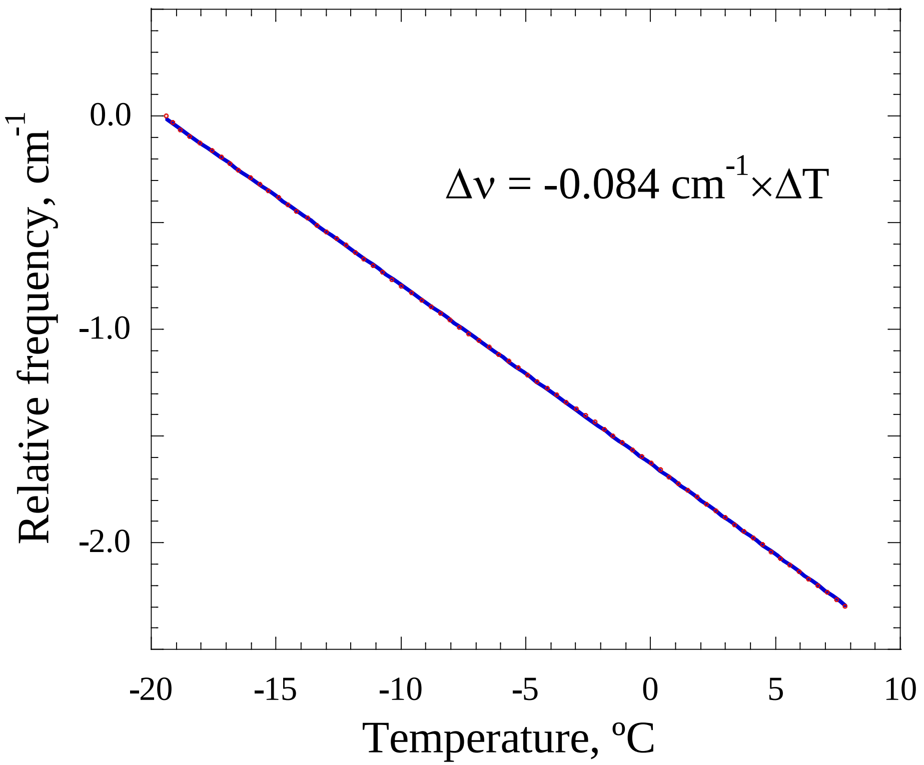
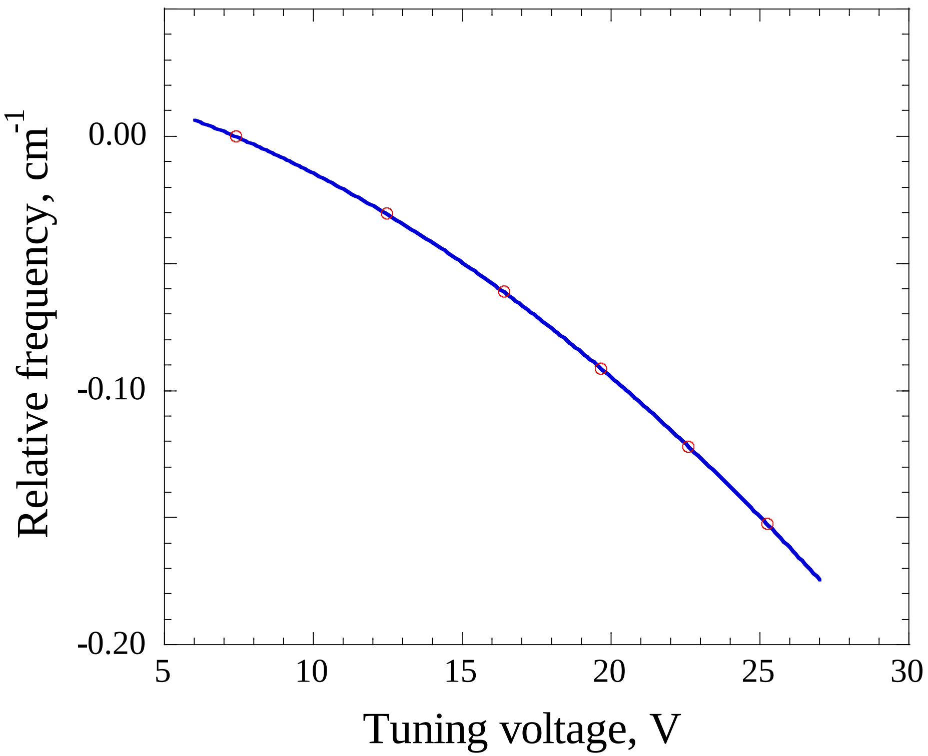
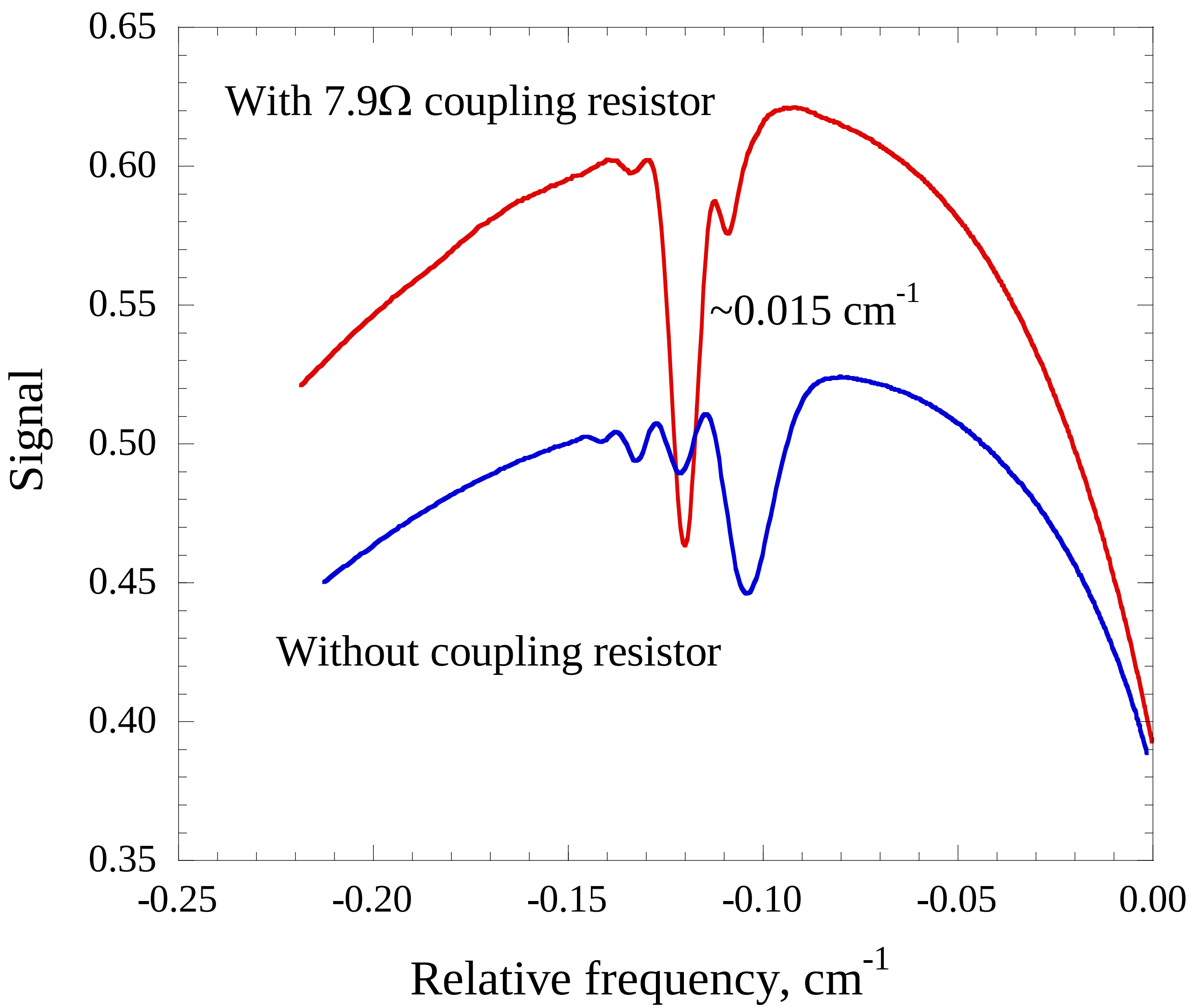
Tuning of the Pulsed QC-DFB Laser





Lineshape dependence on electric coupling



Summary and Future Outlook

- A cw QC-DFB laser based gas sensor at 7.9 μm was designed and tested for methane, nitrous oxide, water and ethanol detection in ambient air; a detection limit of 2.5 ppb for CH_4, 1.0 ppb for N_2O, 60 ppb for H_2O and 125 ppb for C_2H_5OH was achieved
- A new technique for processing congested spectra of VOC was developed and applied to ethanol detection
- A spectrometer based on the near-RT operated pulsed QC-DFB laser was designed and tested

Future development

- ♦ Medical applications - NO detection (~5μm)
- ♦ Field applications
- ♦ Development of cavity-enhanced detection methods

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