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OUTLINE

Compact automated gas sensors based on pulsed QC-DFB lasers

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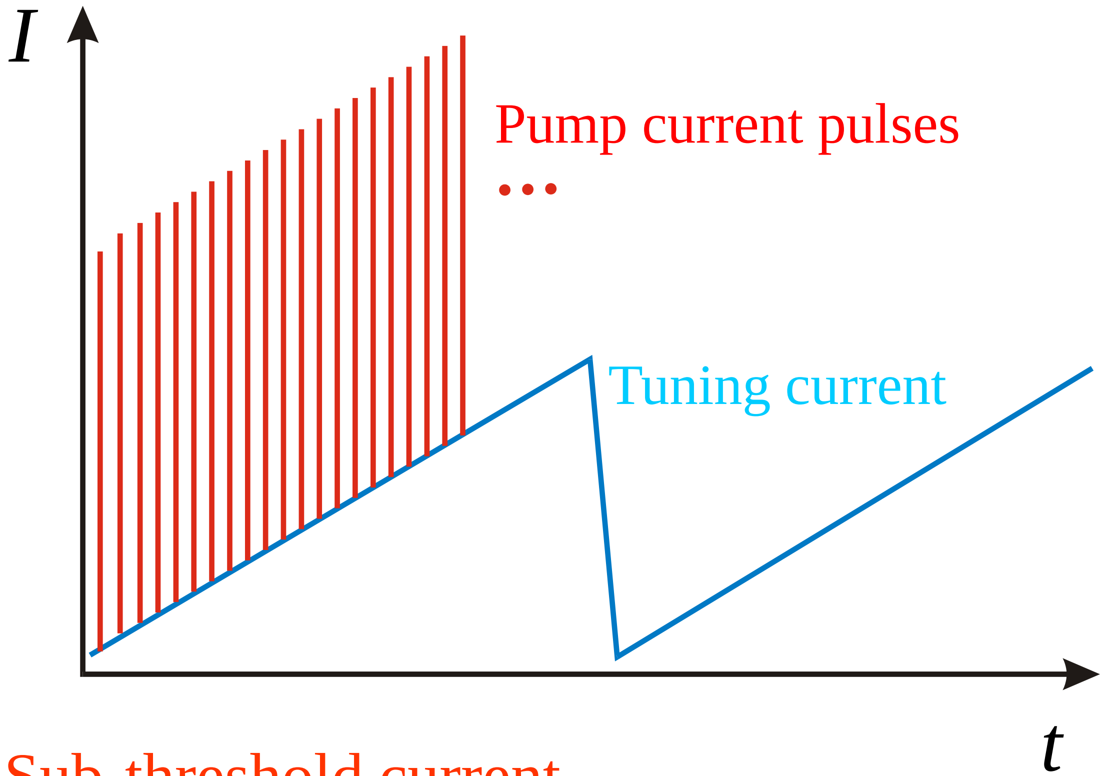
- Pulsed QC lasers: problems and solutions
- Data acquisition and analysis
- Conclusions and future development

QC-DFB Laser: Pulsed vs. CW

ADVANTAGES	SPECIFIC ISSUES
♦ Laser can be operated at near-room temperature (TE cooling)	♦ Broad asymmetric linewidth (~300 MHz FWHM) related to heating during the pulse
♦ Facilitates temperature control	♦ How to tune the frequency
♦ No consumables (liquid N_2)	♦ Reduced average power
♦ Compact	♦ More sophisticated electronics for driving QC laser and data acquisition are required

Pulsed QC Laser Wavelength Scanning



Solution: Sub-threshold current

K. Namjou, S. Cai, E.A. Whittaker, J. Faist, C. Gmachl, F. Capasso, D.L. Sivco, and A.Y. Cho, “Sensitive absorption spectroscopy with a room-temperature distributed-feedback quantum-cascade laser”, *Opt. Lett.* **23**, 219-221 (1998)

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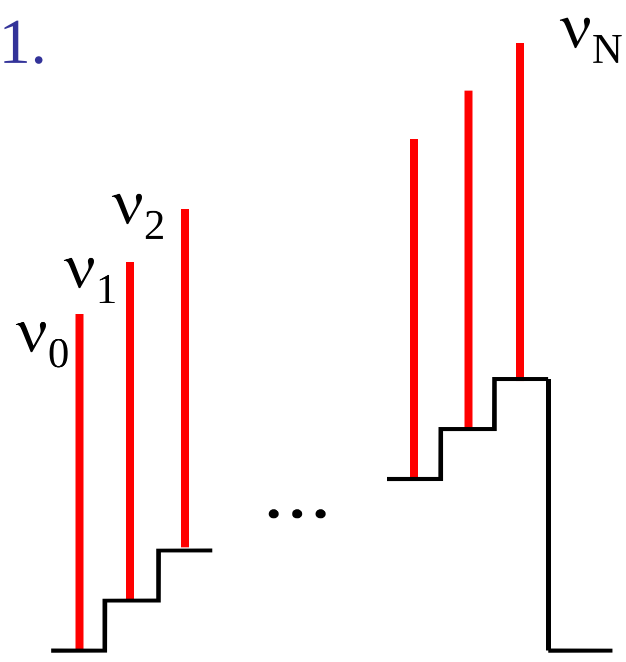
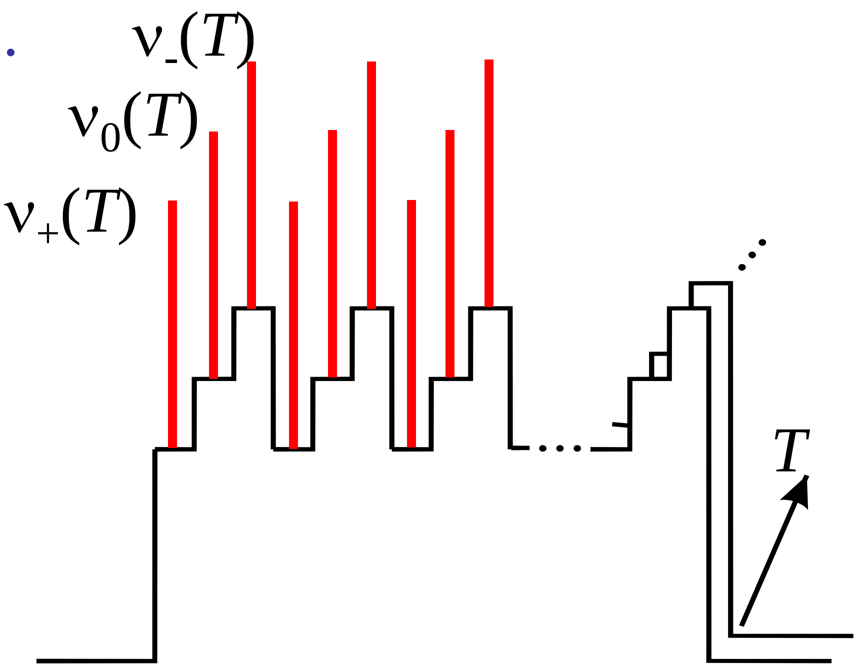
Synchronous Frequency Manipulation

1.



Synchronous digitally synthesized steps of tuning current (enables linearization of scan)

2.



Fast cycling of the laser frequency with a subthreshold current and slow scanning with temperature (wavelength modulation)

A. A. Kosterev, F. K. Tittel, C. Gmachl, F. Capasso, D. L. Sivco, J. N. Baillargeon, A. L. Hutchinson, and A. Y. Cho, "Trace-gas detection in ambient air with a thermoelectrically cooled, pulsed quantum-cascade distributed feedback laser", *Appl. Opt.* **39**, 6866-6872 (2000)

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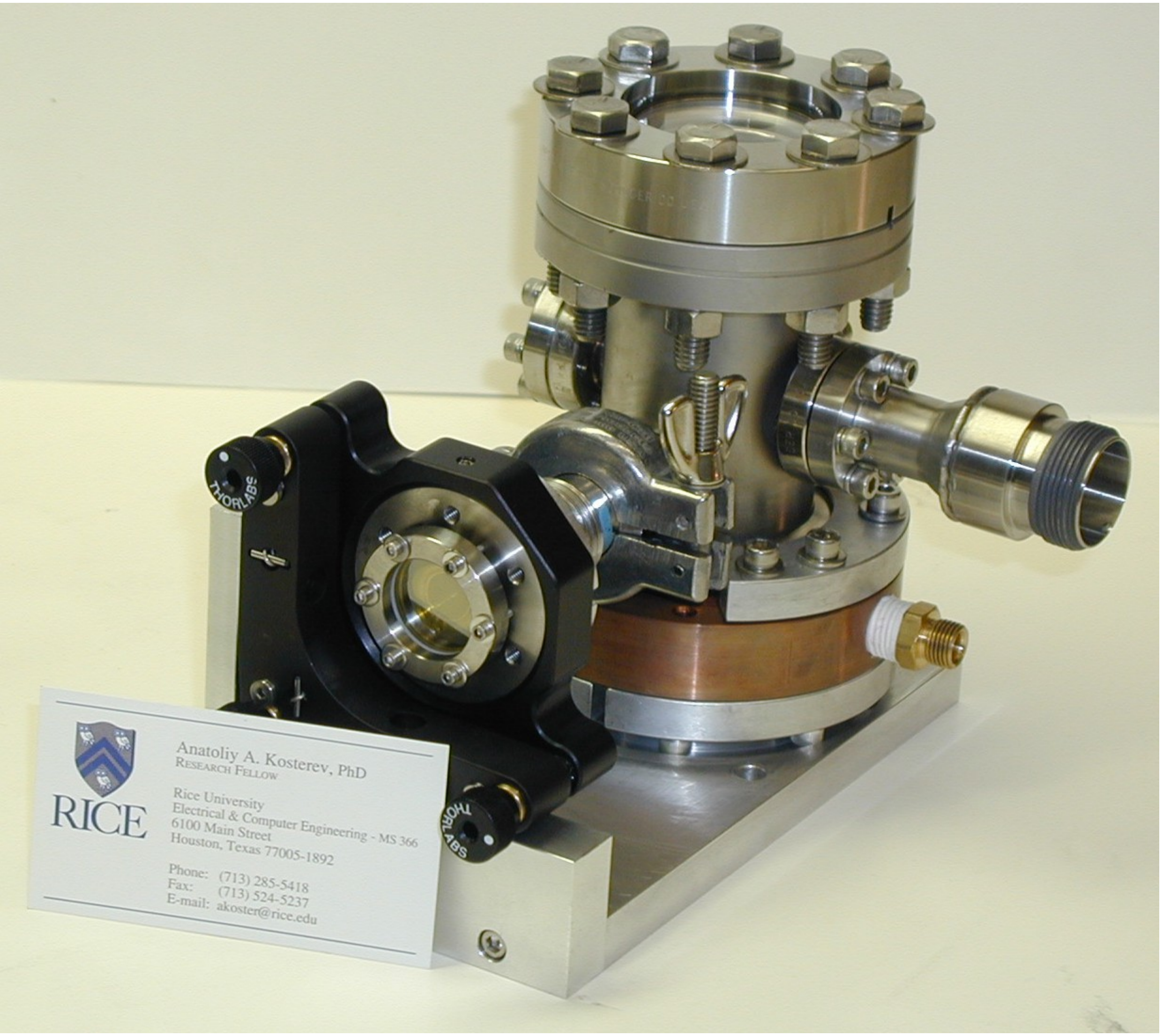
Pulsed QC-DFB Laser Housing



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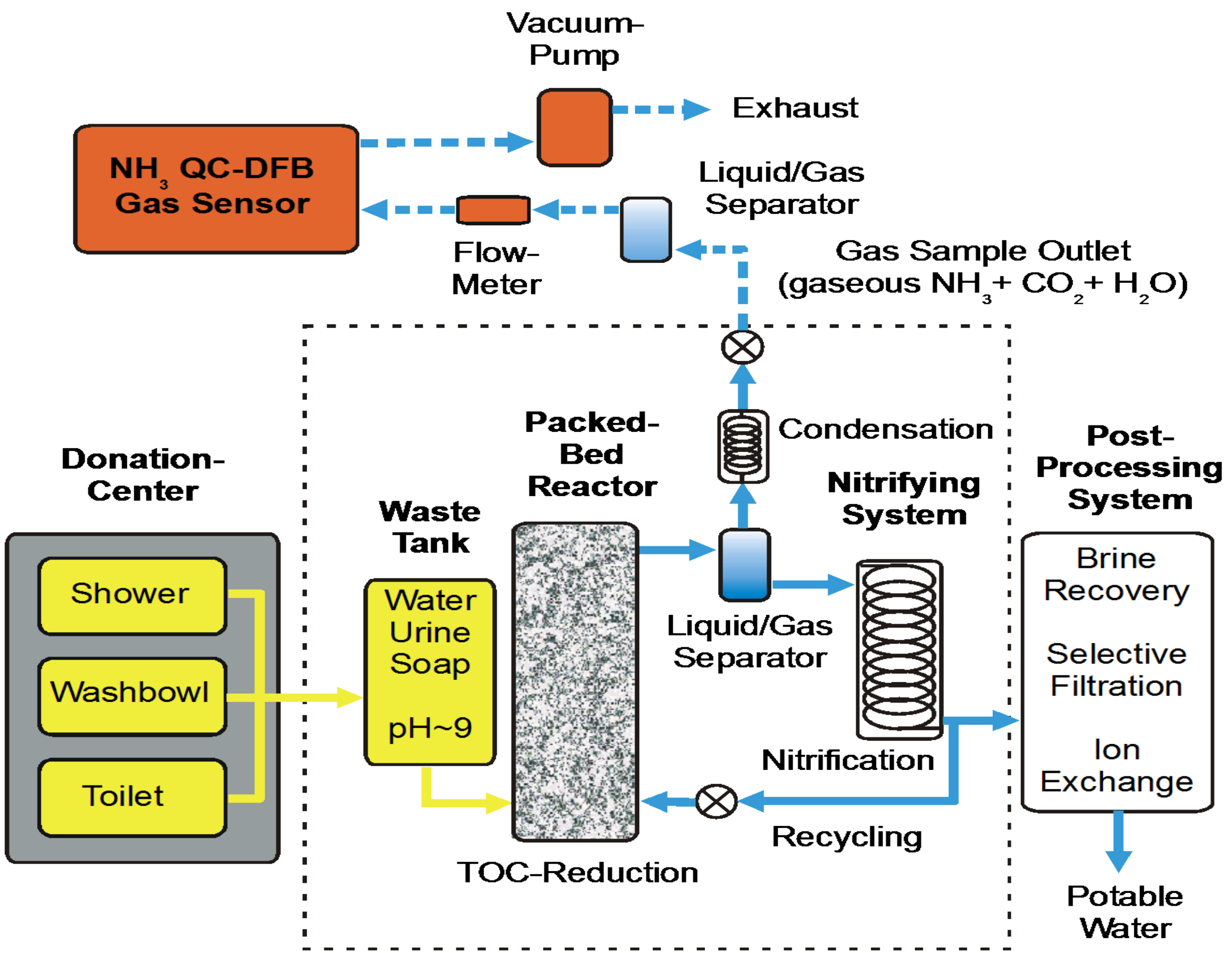
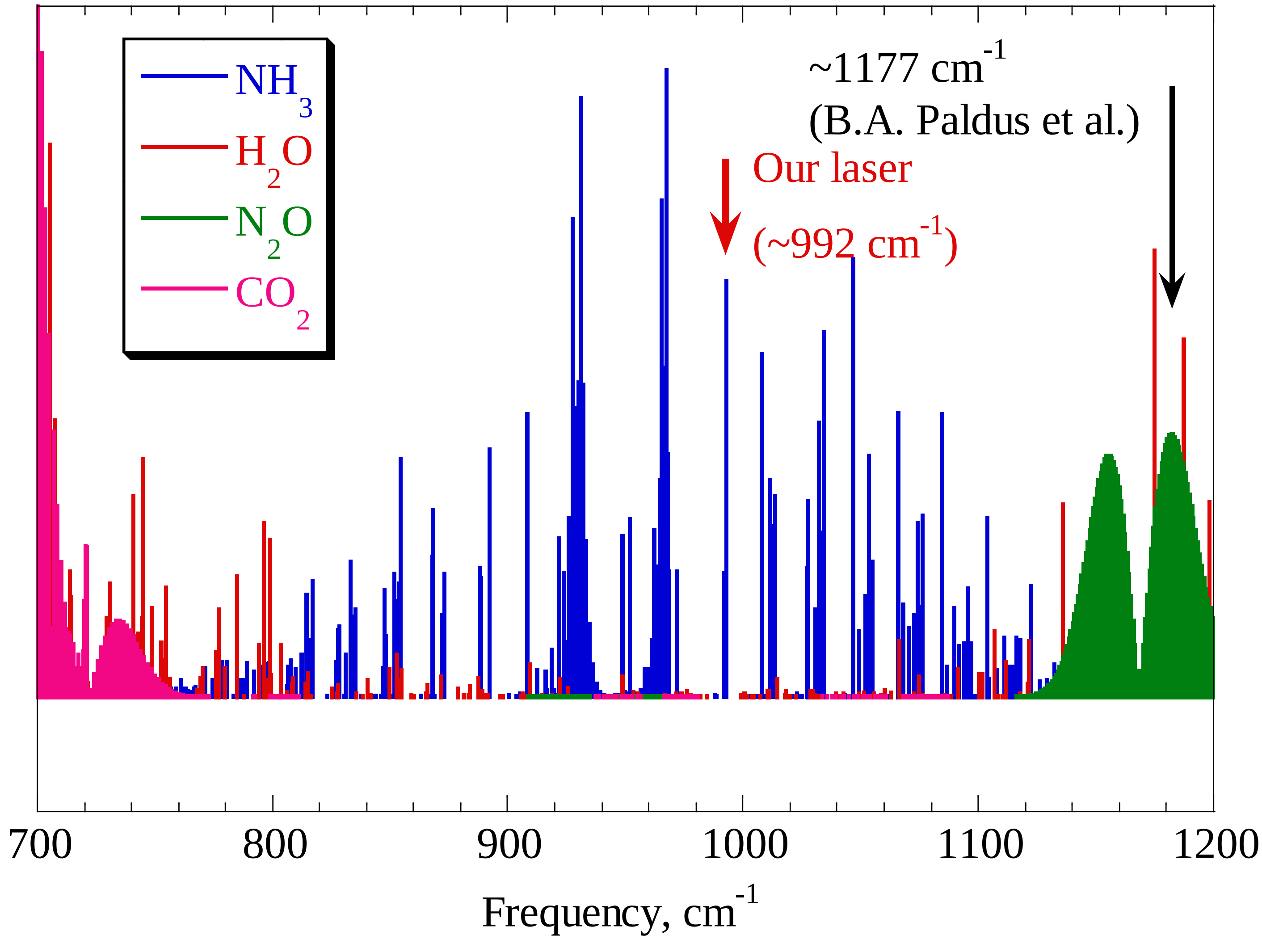
Motivation for NH_3 Detection

- Monitoring NH_3 concentration after De-NO_x process in exhaust pipes in electric power stations
- Pollutant gas monitoring
- Atmospheric chemistry
- Semiconductor Processing
- Medical diagnostics (kidney & liver malfunction)
- **Space craft related gas monitoring**

NASA Water Recovery System



Ammonia Absorption Spectrum



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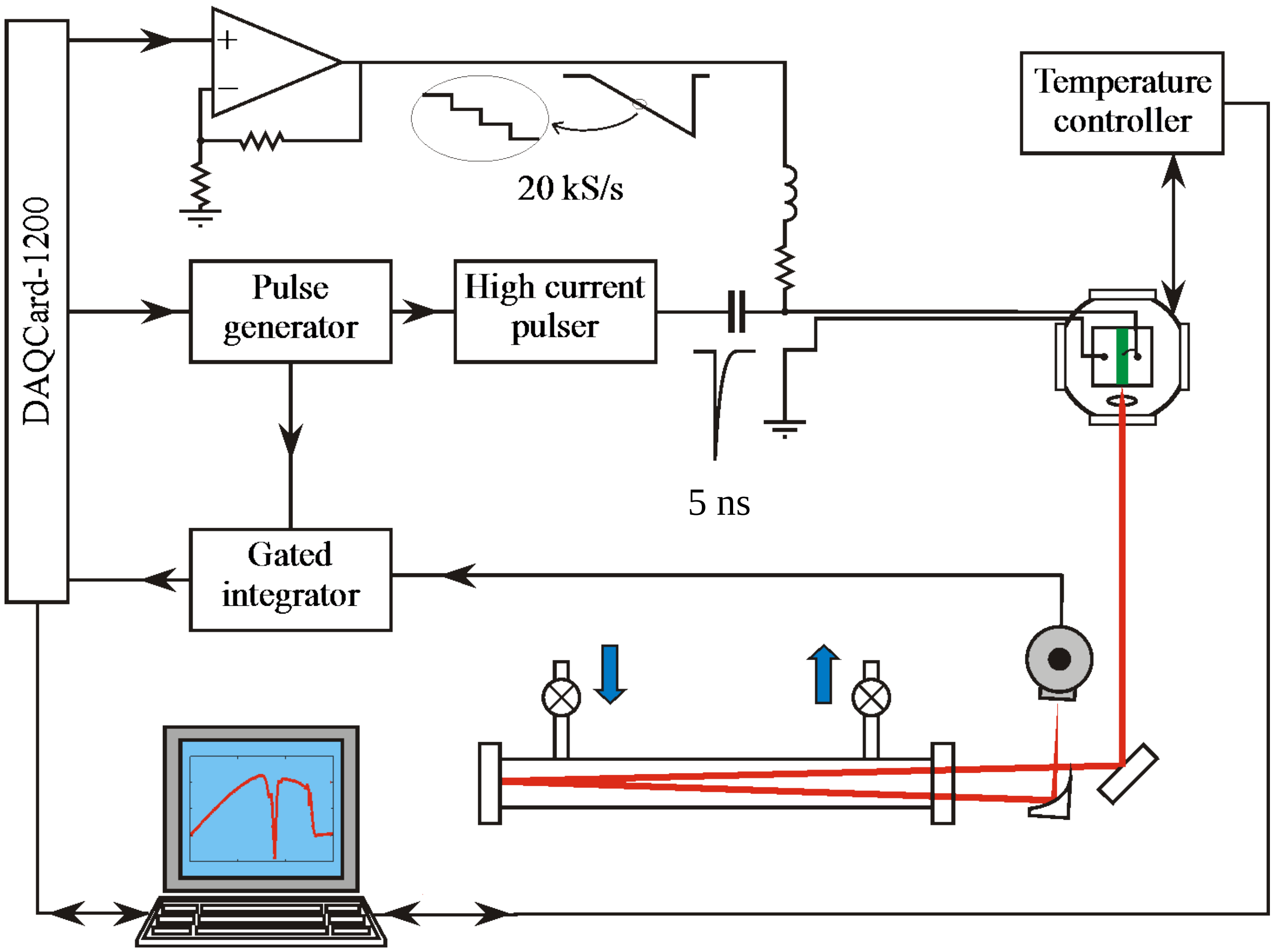
Pulsed QC Laser Based Gas Sensor Schematic



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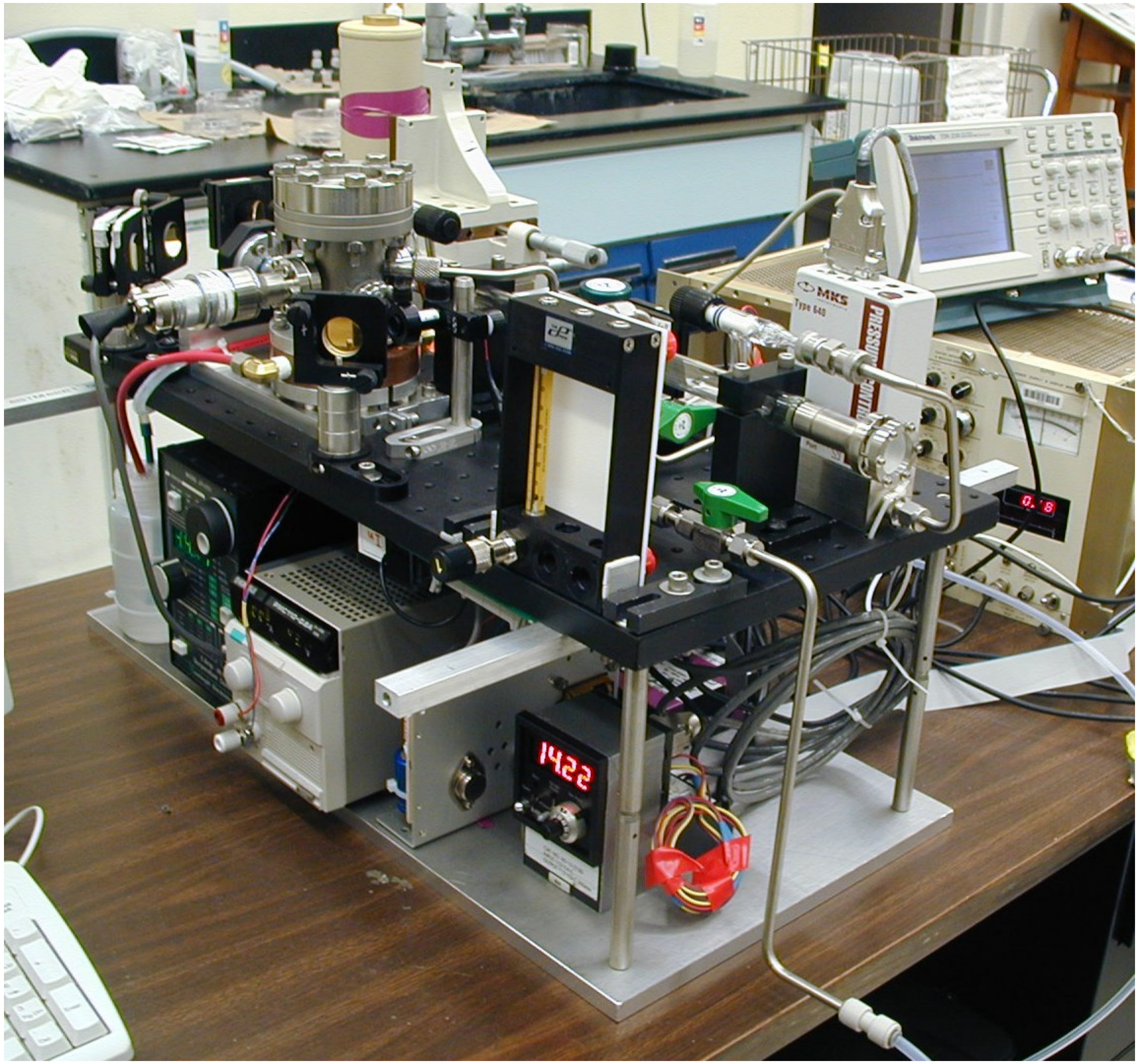
NH_3 Sensor Based on Pulsed 10.05 μm laser



One IR detector

Sensitivity ~0.3 ppm

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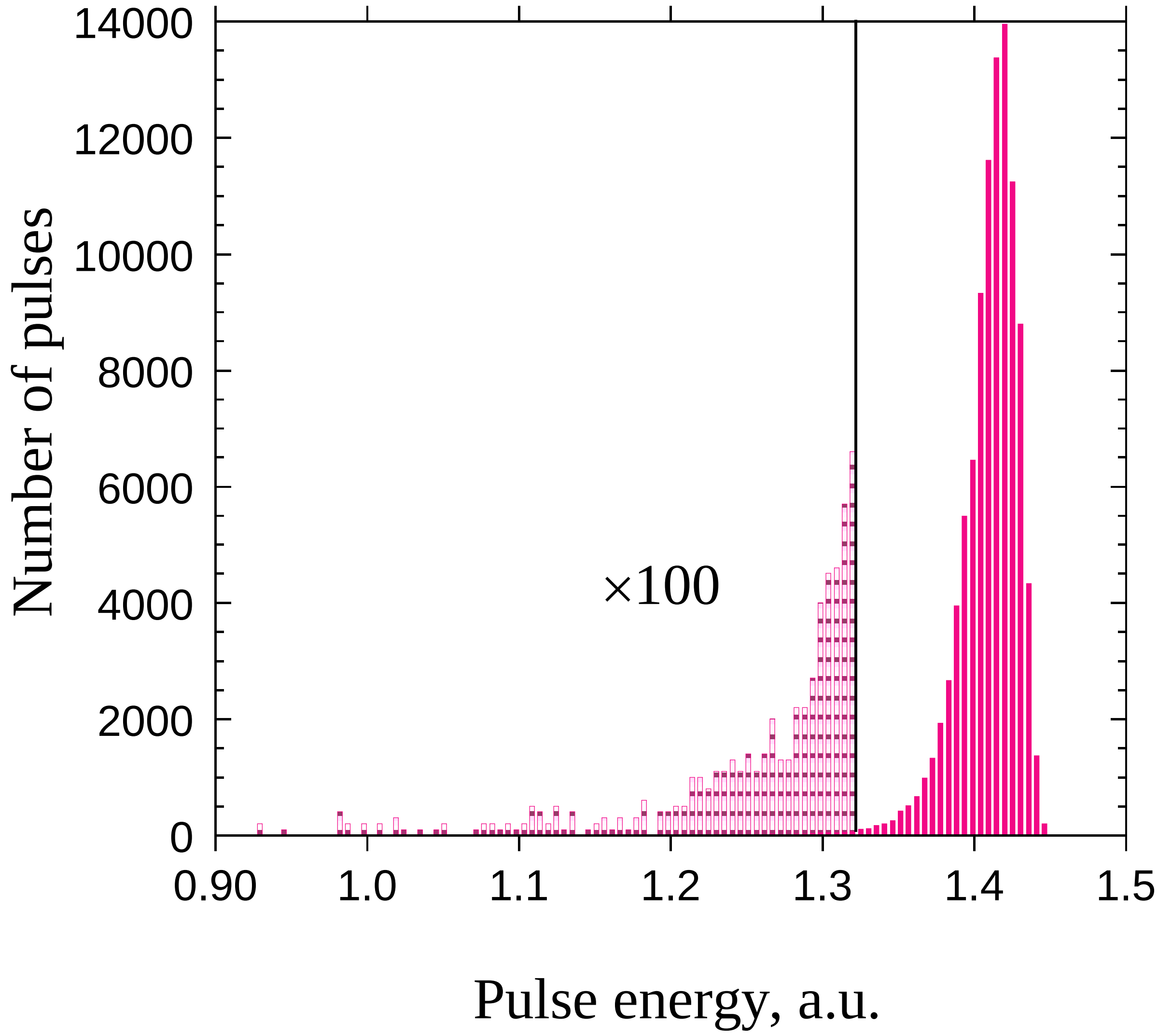
Energy Distribution of the QC Laser Pulses



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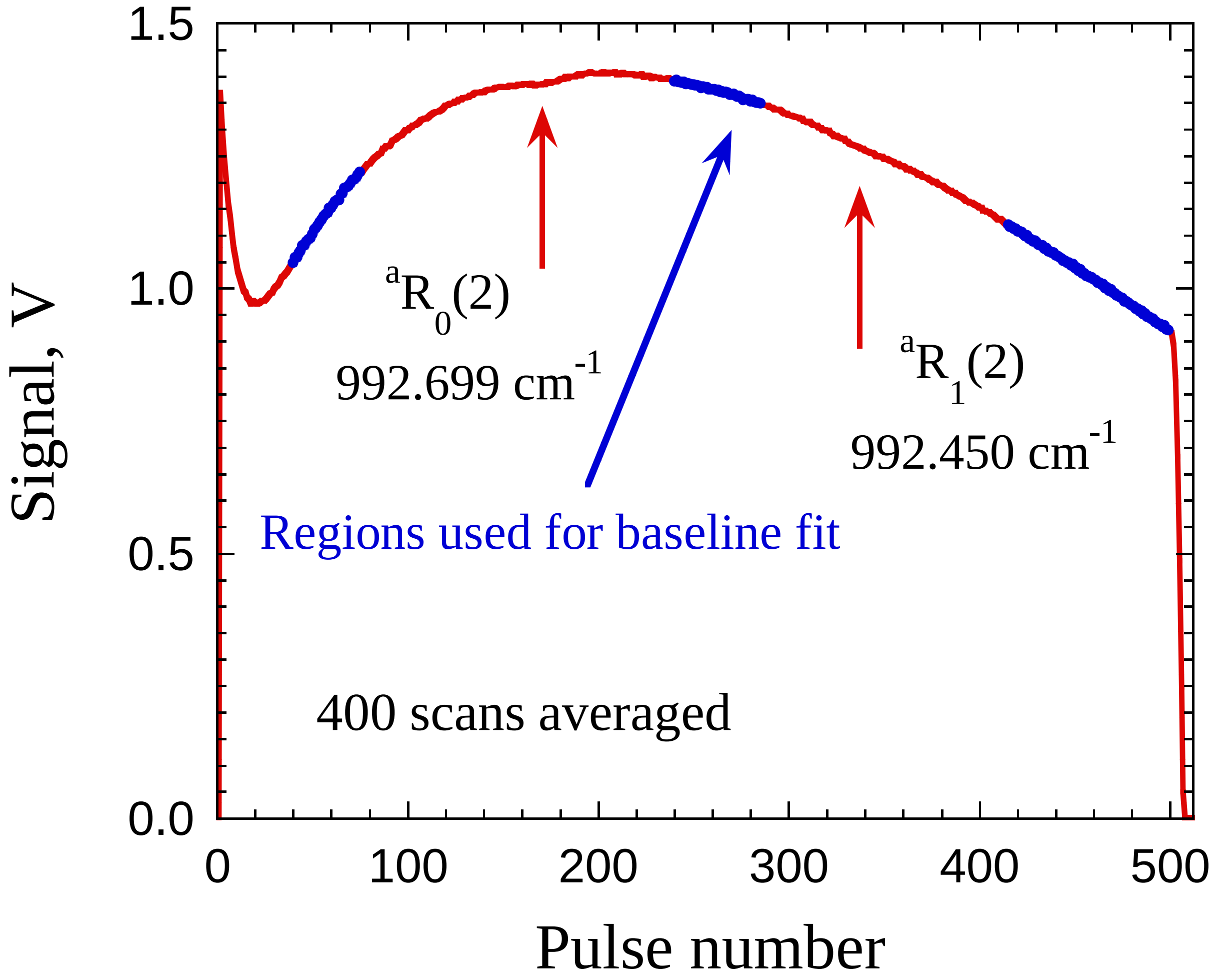
Raw Data – NH_3 Detection



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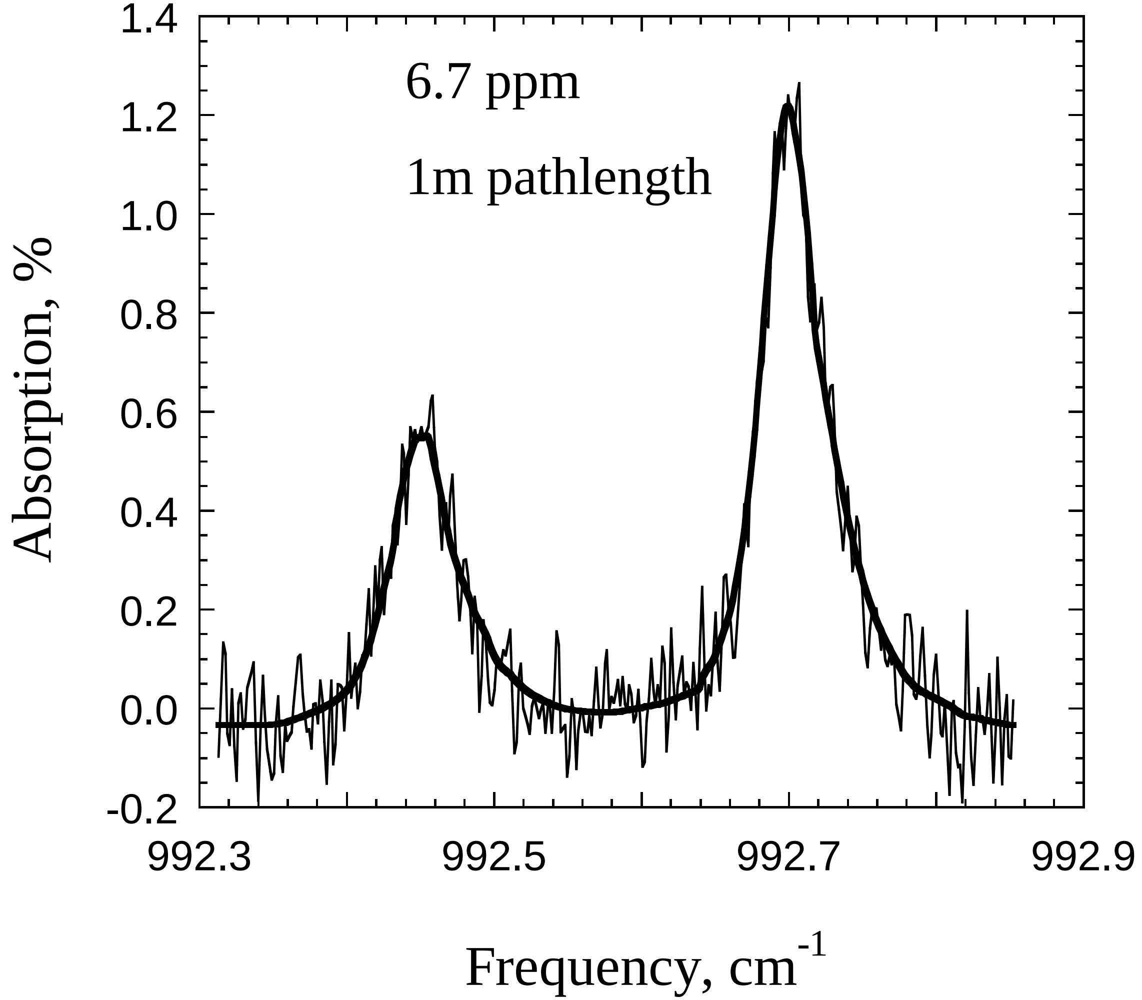
Detected Ammonia Absorption



$$y_i = Bf(i - x)$$

i – pulse number

B~[NH_3]

x – peak shift

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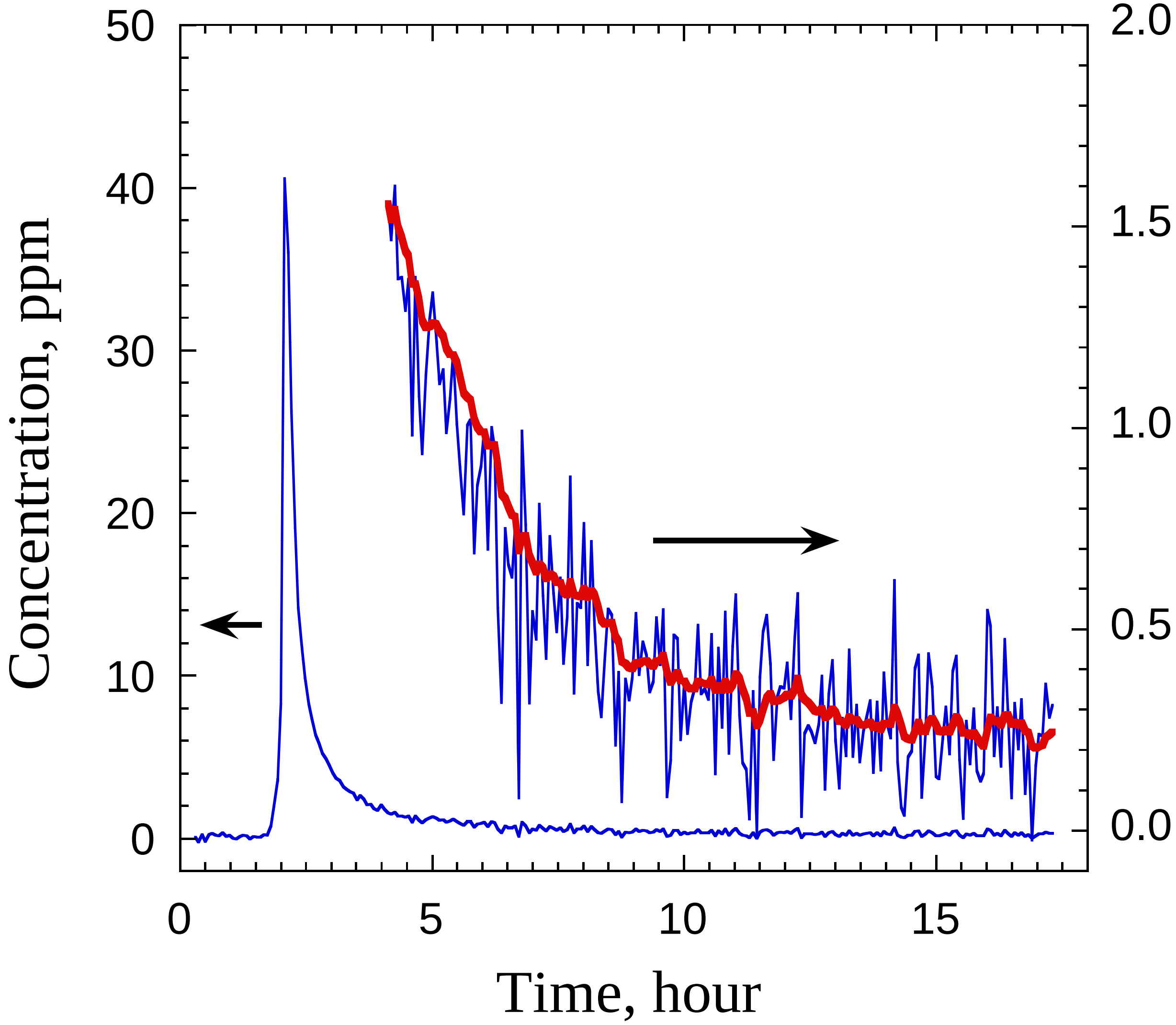
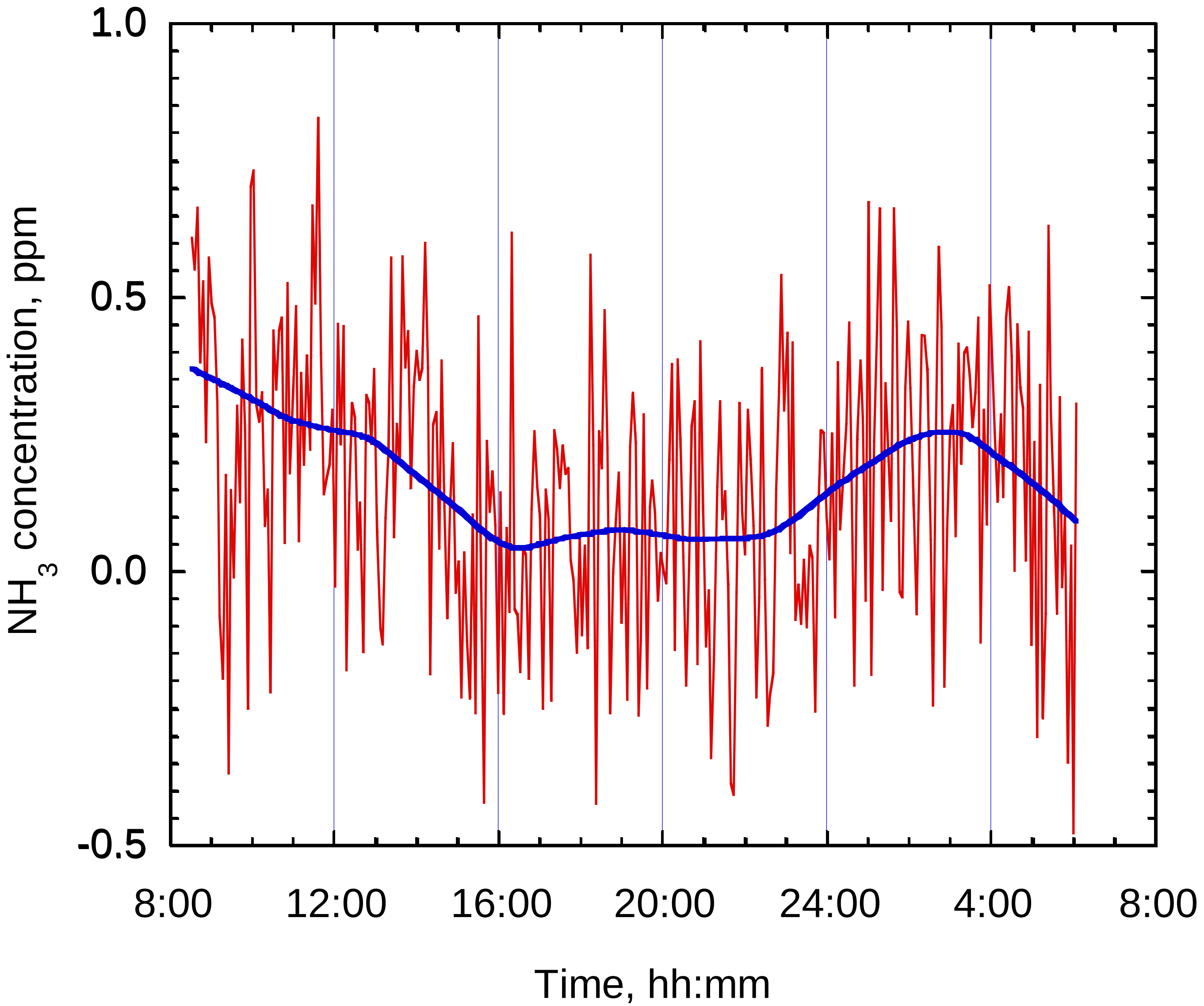
Kalman Filtering of the Data



NASA-JSC Bioreactor Vent Gases



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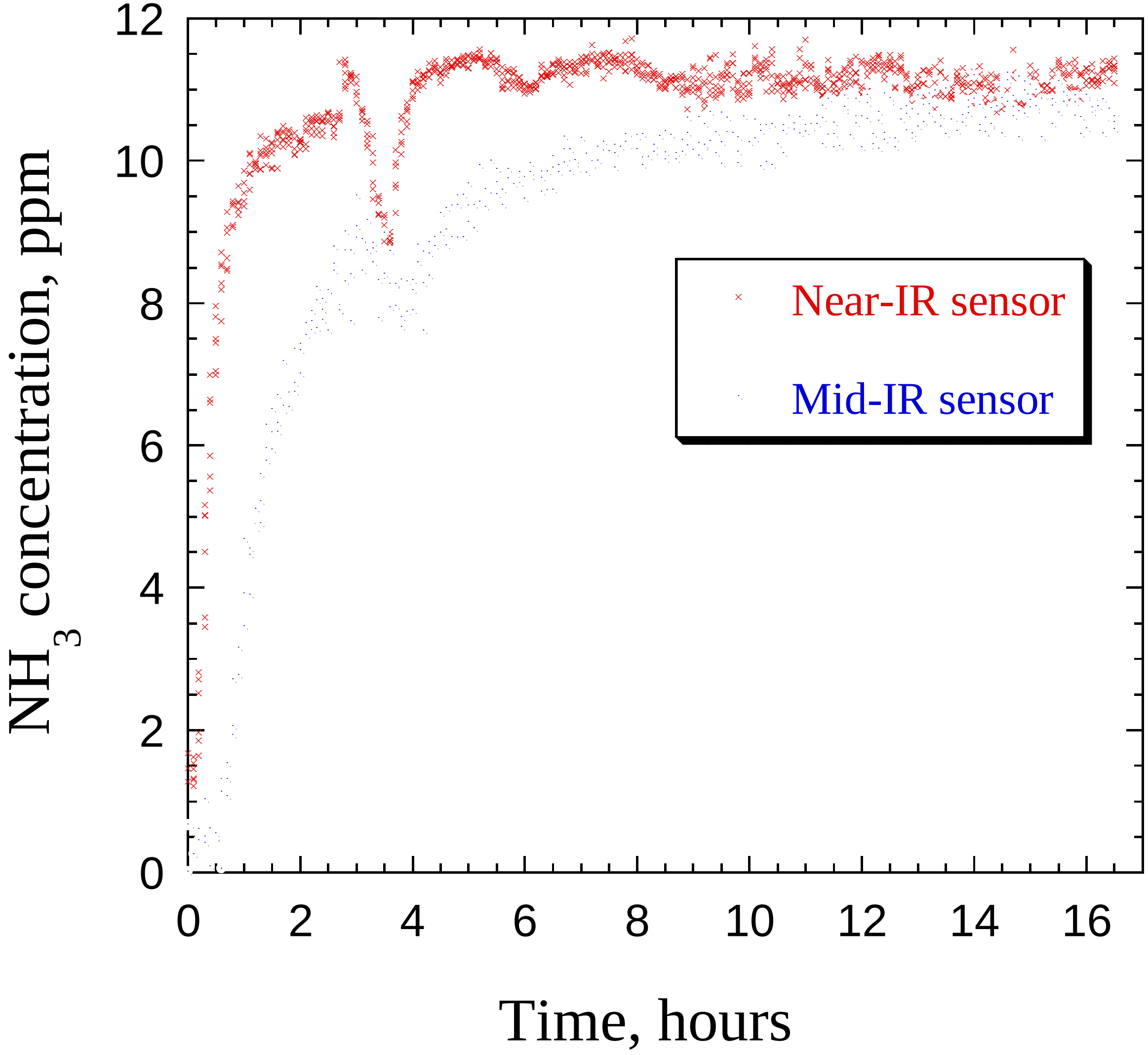
Conclusions and Future Developments

- A compact mobile gas sensor based on a thermoelectrically cooled QC-DFB laser was developed and applied to continuous monitoring of NH_3 concentration levels.
- The sensor can be readily modified to detect other species by replacing the QC-DFB laser.
- The principal error source in the reported sensor architecture is laser power fluctuations. Thus, the sencitivity can be improved if the reference channel is added (Listen to the next talk!!!).
- The data acquisition time can be reduced or the accuracy improved if the laser pulses repetition rate is increased from the present 20 kHz to 1-3 MHz.

Ammonia Absorption Spectrum



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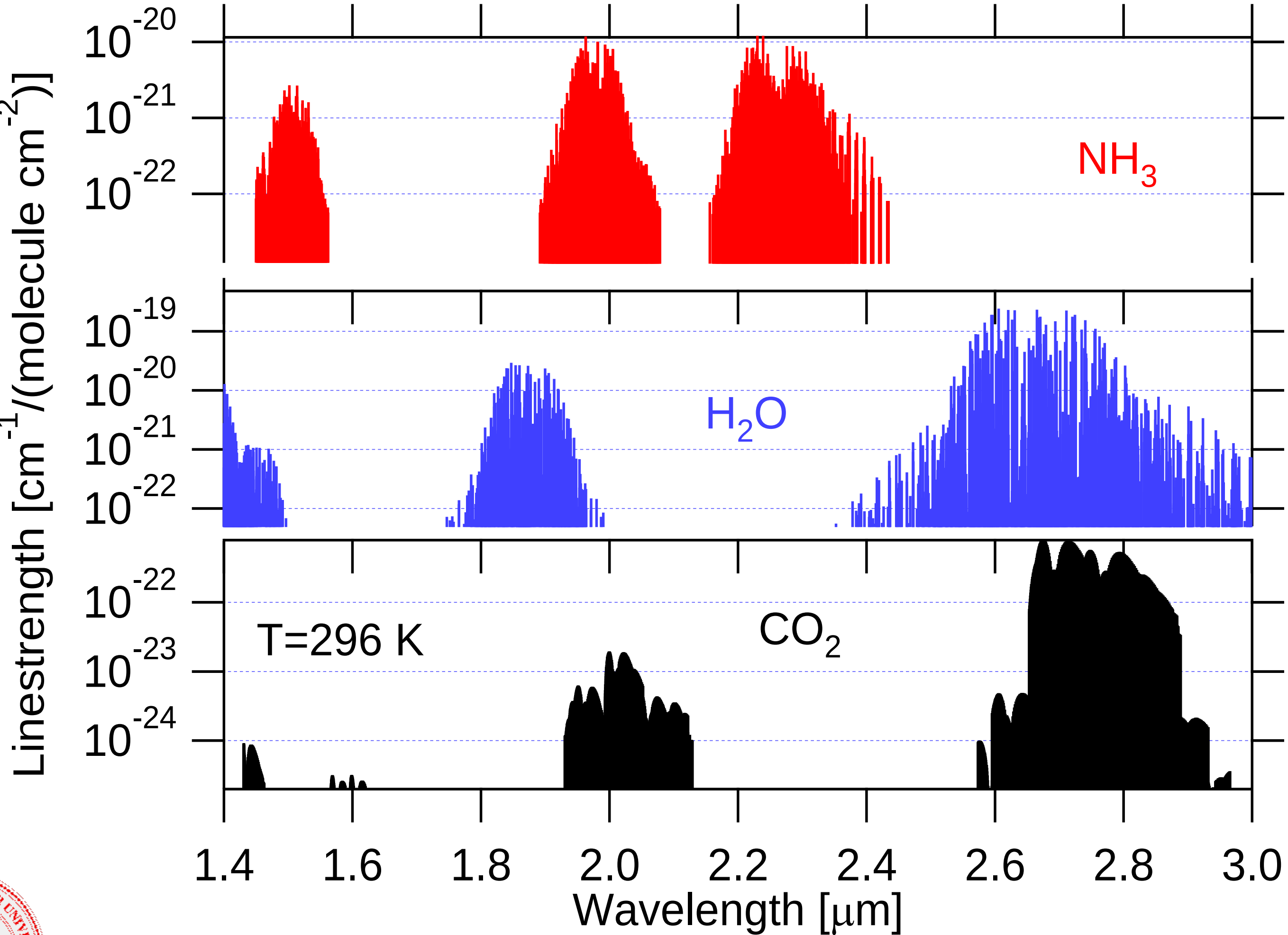
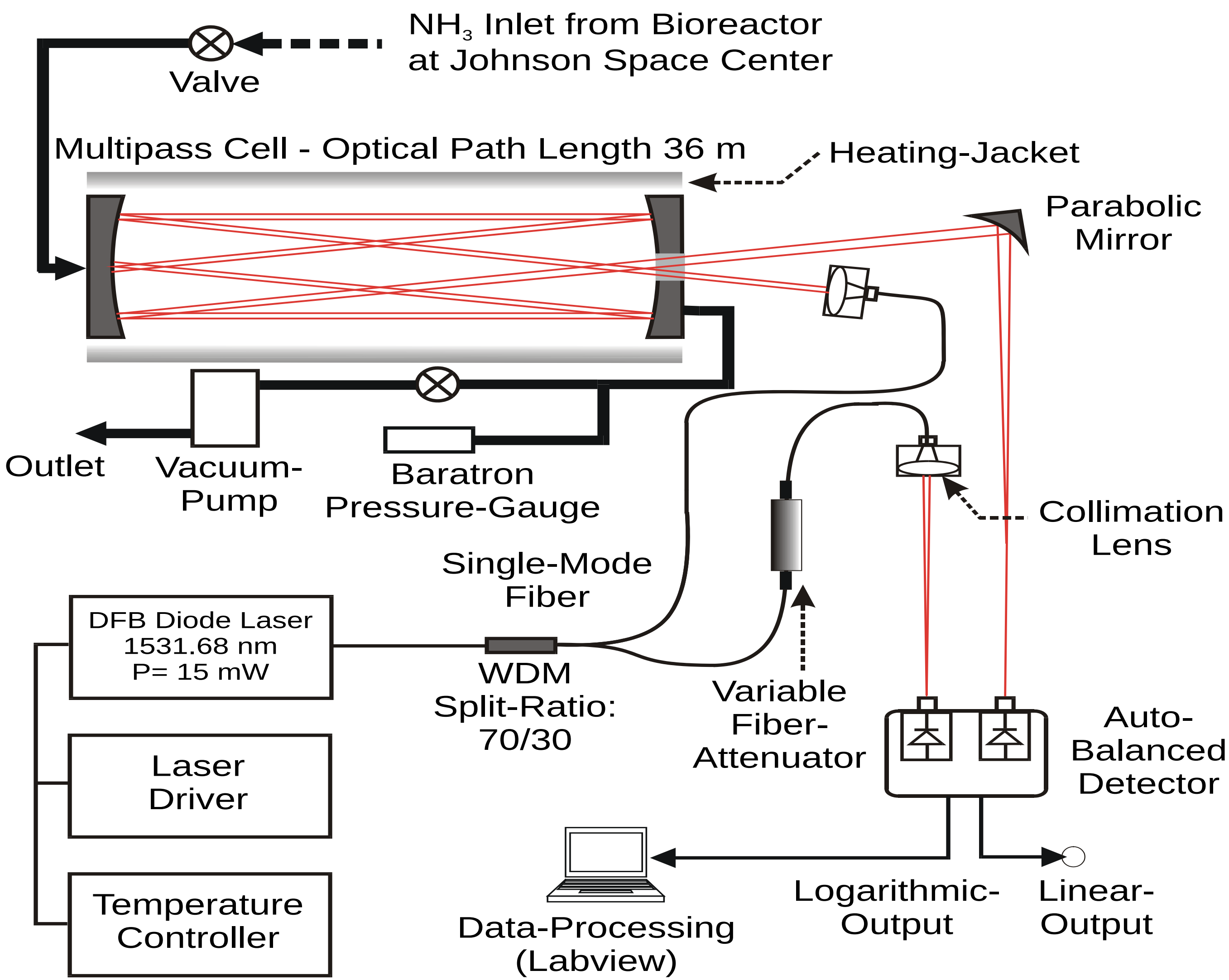
NIR Spectra of NH_3 , CO_2 and H_20



M.E. Webber, et al.
Applied Optics August 2001

NH_3 Diode Laser Based Sensor



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