

## **CAMS – Compact Atmospheric Multispecies Spectrometer**

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The CAMS instrument's core design and operation is similar to the DFGAS (Difference Frequency Generation Absorption Spectrometer) instrument, which has been successfully deployed for fast, accurate, and sensitive airborne measurements of the important trace gas formaldehyde ( $\text{CH}_2\text{O}$ ). CAMS like DFGAS is based on tunable mid-IR ( $3.53\text{-}\mu\text{m}$ ) absorption spectroscopy utilizing advanced fiber optically pumped difference-frequency generation (DFG) laser sources. A comprehensive discussion of the measurement principle and performance of the DFGAS instrument is found in Weibring et al. [2006, 2007], and only a brief discussion is presented here.

Mid-Infrared light at  $2831.6\text{-cm}^{-1}$  ( $3.53\ \mu\text{m}$ ) is generated by mixing two near-IR room temperature lasers (one at 1562 nm and the other at 1083 nm) in a non-linear crystal (periodically poled lithium niobate). The DFG laser output is directed through a multipass Herriott absorption cell (90-m pathlength in  $\sim 1.7$  liter volume) where the laser light is selectively absorbed by a moderately strong and isolated vibrational-rotational absorption feature of  $\text{CH}_2\text{O}$ . The transmitted light from the cell is directed onto an IR detector employing a number of optical elements. A portion of the IR beam is split off by a special beam splitter (BS) before the multipass cell and focused onto an Amplitude Modulation Detector (AMD) to capture and remove optical noise from various components in the difference frequency generation process. A third detection channel from light emanating out the back of the beam splitter is directed through a low pressure  $\text{CH}_2\text{O}$  reference cell and onto a reference detector (RD) for locking the center of the wavelength scan to the absorption line center. The mid-IR DFG output is simultaneously scanned and modulated over the  $\text{CH}_2\text{O}$  absorption feature, and the second harmonic signals at twice the modulation frequency from the 3 detectors are processed using a computer lock-in amplifier [Weibring et al., 2006].

In the CAMS instrument, ambient air will be continuously drawn through a heated HIML inlet at flow rates around 5 standard liters per minute (slm), through a pressure controller, and through the multipass Herriott cell maintained at a constant pressure around 50-Torr. Ambient measurements will be acquired in 1-second increments for time periods as long as 60 to 120-seconds, and this will be followed by 15-seconds of background zero air acquisition, using an onboard  $\text{CH}_2\text{O}$  scrubbing unit. The zero air will be added back to the inlet a few centimeters from the tip at flow rates  $\sim 2$  to 3 slm higher than the cell flow. This frequent zeroing procedure very effectively captures and removes optical noise as well as residual outgassing from inlet line and cell contaminants. This is accomplished by averaging the background spectra before and after each ambient sampling period, and the resultant spectrum is then subtracted point-by-point from each 1-second ambient spectrum. Retrieved  $\text{CH}_2\text{O}$  mixing ratios are determined for each 1-second ambient spectrum by fitting to a reference spectrum, obtained by introducing high concentration calibration standards ( $\sim 5$  to 10-ppbv) from an onboard permeation calibration system

into the inlet approximately every hour. The calibration output is determined before and after the field campaign using multiple means, including direct absorption employing the Beer-Lambert Law relationship. The 1-second ambient CH<sub>2</sub>O results can be further averaged into longer time intervals for improved precision. However, in all cases the 1-second results are retained. This flexibility allows one to further study pollution plumes with high temporal resolution, and at the same time study more temporally constant background CH<sub>2</sub>O levels in the upper troposphere using longer integration times.

As CAMS incorporates a number of major improvements over the DFGAS instrument in many areas, we anticipate improvements in the limits of detection (LOD) for CH<sub>2</sub>O. For reference, our latest DFGAS flights during the 2011 NASA Venture Class studies produced 1-second actual in-flight CH<sub>2</sub>O LODs (1 $\sigma$  level) in the 50 – 100 pptv range with an estimated measurement accuracy (1 $\sigma$  level) of 4%. Unfortunately, cell problems encountered during GV test flights in May of 2011 prevented us from obtaining comparable CAMS in-flight LODs. Figures 1 & 2 below show the CAMS instrument on the GV aircraft during the test flights.



***Figure 1: Petter Weibring operating the CAMS instrument on the GV. The optical system, including the lasers, detectors, multipass cell and other components are mounted in the Aluminum covered enclosure near the top.***



**Figure 2: Front of CAMS instrument on the GV.**

## References

Weibring, P., D. Richter, A. Fried, J.G. Walega, and C. Dyroff, *Ultra-High-Precision Mid-IR Spectrometer II: System Description and Spectroscopic Performance*, Appl. Phys. **B**, doi: 10.1007/s00340-006-2300-4, 2006.

Weibring, P., D. Richter, J.G. Walega, and A. Fried, *First Demonstration of a High Performance Difference Frequency Spectrometer on Airborne Platforms*, Optics Express, **15** (21), 13476 - 13495, 2007.