THE JPL CARBON DIOXIDE LASER ABSORPTION SPECTROMETER

Gary D. Spiers(1), Sven Geier(2), Mark W. Phillips(3), Robert T. Menzies(4)

(1) Jet Propulsion Laboratory, M/S 306-366, 4800 Oak Grove Dr., Pasadena, CA 91109-8099, gary.d.spiers@jpl.nasa.gov
(2) Jet Propulsion Laboratory, M/S 306-366, 4800 Oak Grove Dr., Pasadena, CA 91109-8099, sven.geier@jpl.nasa.gov
(3) Lockheed Martin Coherent Technologies, 135 South Taylor Avenue, Lafayette CO 80027-302, mark.w.phillips@lmco.com
(4) Jet Propulsion Laboratory, M/S 168-214, 4800 Oak Grove Dr., Pasadena, CA 91109-8099, robert.t.menzies@jpl.nasa.gov

ABSTRACT

We provide an overview of the current state of progress on the development of an integrated path differential absorption laser absorption spectrometer operating at 2 microns for the detection of carbon dioxide sink and source locations.

I. INTRODUCTION

Observations of carbon dioxide mixing ratios from Earth orbit, primarily in the lower and middle troposphere with measurement precision equivalent to a few ppmv, are desired to define spatial gradients of carbon dioxide, from which sources and sinks can be derived and quantified and separated from the seasonal fluctuation component. There is currently no available remote sensing instrumentation that is capable of providing the high-accuracy carbon dioxide mixing ratio measurements with the vertical and horizontal spatial resolution required by the carbon cycle research program. We have been developing an aircraft based integrated path differential absorption instrument known as the laser absorption spectrometer (LAS) operating in the 2-µm spectral region that has the potential to achieve the required precision and it will have its first flight in early June of 2006.

2. LAS INSTRUMENT DESCRIPTION

Figure 1 shows the vacuum wavenumbers for each of the three lasers used in the LAS together with representative plots of atmospheric absorption in the region of 2051nm for a horizontal path in the PBL.

The LAS transceiver uses separate transmit/receive channels for the on-line and off-line components of the measurement. Each channel has a dedicated heterodyne detector, telescope, and a cw laser which acts both as the transmitter and as the local oscillator for heterodyne detection of the return signal. A third laser acts as an optical reference frequency source and is locked to line center using phase-modulation spectroscopy of a sealed carbon dioxide reference cell. The online transmitter frequency is offset locked from the reference laser frequency using a wide-band heterodyne detector that monitors the beat frequency between the outputs of the two lasers. The offline transmitter is similarly frequency offset-locked to the reference laser frequency, however since this laser is detuned significantly from the reference laser, it is convenient to impose frequency modulation sidebands on the reference laser and to lock the offline laser to one of these sidebands thereby reducing the detection bandwidth requirements needed for the offset-locking function to a few GHz.

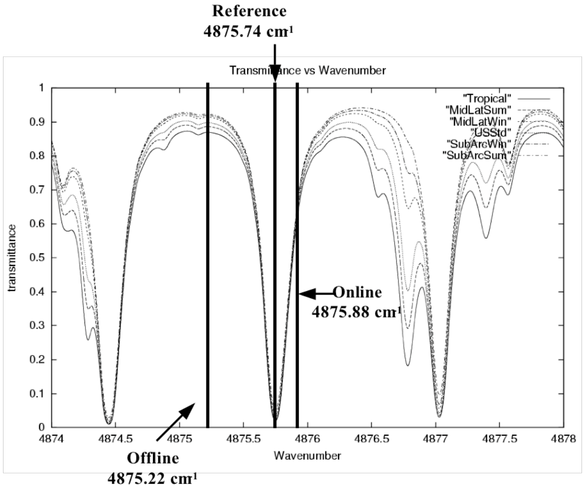

Fig. 1. Vacuum wavenumbers used in the LAS transceiver.

The components of the transceiver head (Fig.2) are mounted on both sides of a water-cooled aluminum optical bench. Most of the beam paths and components for optical mixing and frequency locking are located on one side of the optical bench, while the beam-expanding telescopes and the three laser sources are located on the other surface. The output beams from the lasers are fiber-coupled and routed to the main surface of the optical bench, while the transceiver beams are routed to and from the telescopes using through-the-bench periscope assemblies.

A frequency shift in each channel between the outgoing signal and the return signal is accomplished by pointing the transmit beams slightly away from nadir below the aircraft. The off-nadir angle is selected to set the center frequency shift and variation based on the aircraft flight speed and attitude control. A polarization transmit/receive architecture is implemented to route signals to and from the transceiver, with circularly polarized light being transmitted through the atmosphere.

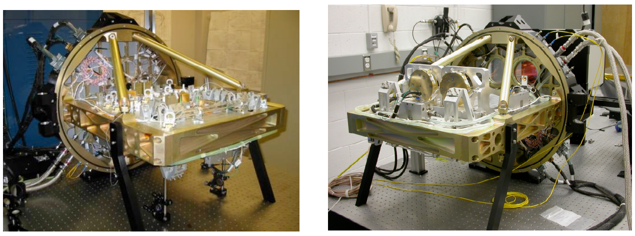

Fig. 2 Photographs showing both sides of the instrument optical bench.

The output powers of all three lasers are monitored; the output power values for the online and offline lasers are used in the determination of the on-line and off-line absorption as part of the LAS measurement; the output power value for the reference laser is used primarily as a laser health status to check on the integrity of the CO_2 line center lock.

The two frequency offset-lock (FOL) beat detectors require detection of signals at several GHz frequency. To avoid signal attenuation and noise pick-up at these high frequencies, the optically mixed light is coupled into single mode fibers and routed to detectors remotely located in the frequency offset-locking electronics unit. The heterodyne detectors used for the on-line and off-line LAS measurements require detection of signals of just a few tens of MHz and are located on the optical bench. All lasers and RF detectors (with the exception of the CO_2 servo lock detector) are fiber-coupled to the optical bench with an intervening fiber-to-fiber connector in each fiber lead. This permits component replacement in the field, allows BPLO (back-propagating local oscillator) alignment of the receive path to the transmit path for each LAS channel, and allows laser source switching for relative alignment of the two transmit/receive telescopes to ensure monitoring of the same volume of atmosphere and ground surface return.

During operation there are real time diagnostics of the environment within the instrument, the status of the lasers and the tracking of the ground Doppler frequency as well as a capability to do quick look processing on a subset of the signal data. The instrument generates ~300 MB of raw data every minute that is stored for post processing and at the present time we have ~4TB of data storage available for the instrument.

3. INSTRUMENT CHARACTERIZATION

We have been characterizing the instrument performance in a laboratory environment using a large diameter gas cell that we can fill with carbon dioxide in a controlled manner.

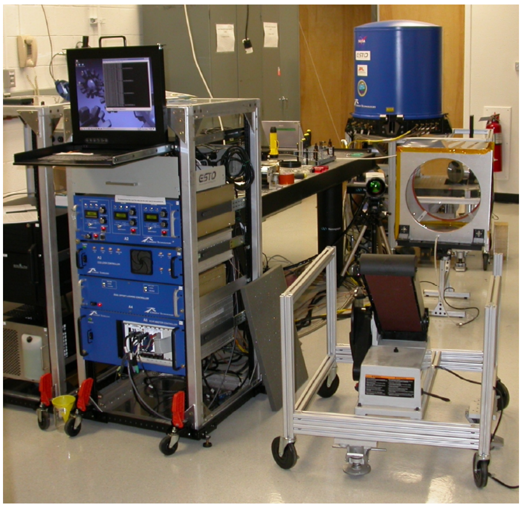

Fig.3 LAS instrument laboratory testing.

Fig. 3 shows the LAS instrument with protective cover (blue cylinder) undergoing laboratory testing. The optical beams are directed by external mirrors under the instrument through the gas cell onto a belt sander target that simulates the moving ground beneath the aircraft. The instrument electronics in the flight racks to be used on the aircraft can be seen on the left of the picture. In lab testing we have demonstrated the ability of the instrument to measure changes in the carbon dioxide concentration in the cell. These ongoing laboratory tests are in preparation for the first flight test of the instrument on a Twin Otter aircraft in early June 2006. Experience with the instrument to date has shown it to be stable and reliable and it is now several months since we have had to remove the cover from the instrument.

The meeting presentation will discuss the laboratory testing results and present the initial findings from the aircraft flight test.

4. ACKNOWLEDGMENTS

This work is being carried out by the Jet Propulsion Laboratory, California Institute of Technology under a contract with the National Aeronautics and Space Administration. Funding for the instrument development was provided by NASA's Earth Science Technology Office Instrument Incubator Program and the initial flight tests are being funded by JPL's Research and Technology Development Program.