Imaging Configuration

Aligning M1 and M3 by Use of Negative DOE

Aligning M1 and M3 by Use of Positive DOE

Three Mirrors Would Be Aligned with a DOE and, hence, with each other, in a sequence of interferometric procedures that would involve no more than six degrees of freedom of adjustment at one time.

alignment with the DOE and, hence, with each other.

With M1 and M3 thus fixed, one could align M2 by performing similar adjustments on M2 while observing the interferogram of the entire optical system in double pass, as is standard practice. For this purpose, it is necessary to generate an object beam with sufficient accuracy. For an infinitely distant object, it would suffice to remove the DOE and rotate the assembly of M1, M2, and M3 by a prescribed amount that can be easily calculated. The collimated beam from the interferometer would then act as object beam. For an object at a finite distance, one would place a focusing lens in front of the interferometer to generate a spherical wavefront, which could then be made to pass through a pinhole that could be fabricated at an otherwise unoccupied area of the DOE. The position of the pinhole could be known with high accuracy, inasmuch as it would be controlled during fabrication of the DOE.

By virtue of the precisely known geometric relationships between (1) the position of the pinhole and the rest of the DOE and (2) the DOE and the mirrors, the geometric relationship between the position of the pinhole and the object would thus also be known. The whole assembly could then be translated to the required coordinates, making it possible to use the interferometer beam as the object beam for final testing and alignment.

This work was done by Pantazis Mouroulis and Daniel Wilson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* **free on-line at www.nasatech.com**.
NPO-30279

passing through the rest of the area of the optical flat. Light rays reflected from M1 and M3 would retrace their paths through the DOE and would propagate leftward to the interferometer.

One would adjust the position and orientation of each of M1 and M3 in an effort to minimize the number of fringes in its portion of the interferogram. Such adjustments are commonplace in interferometry and can be performed easily. Once these adjustments were complete, M1 and M3 would be in

---

Calibrating Laser Gas Measurements by Use of Natural CO$_2$

Every spectral scan includes a calibration line.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved method of calibration has been devised for instruments that utilize tunable lasers to measure the absorption spectra of atmospheric gases in order to determine the relative abundances of the gases. In this method, CO$_2$ in the atmosphere is used as a natural calibration standard. Unlike in one prior calibration method, it is not necessary to perform calibration measurements in advance of use of the instrument and to risk deterioration of accuracy with time during use. Unlike in another prior calibration method, it is not necessary

to include a calibration gas standard (and the attendant additional hardware) in the instrument and to interrupt the acquisition of atmospheric data to perform calibration measurements.

In the operation of an instrument of this type, the beam from a tunable diode laser or a tunable quantum-cascade laser is directed along a path through the atmosphere, the laser is made to scan in wavelength over an infrared spectral region that contains one or two absorption spectral lines of a gas of interest, and the transmis-

sion (and, thereby, the absorption) of the beam is measured. The concentration of the gas of interest can then be calculated from the observed depth of the absorption line(s), given the temperature, pressure, and path length.

CO$_2$ is nearly ideal as a natural calibration gas for the following reasons: CO$_2$ has numerous rotation/vibration infrared spectral lines, many of which are near absorption lines of other gases. The concentration of CO$_2$ relative to the concentrations of the major constituents of the atmosphere is well
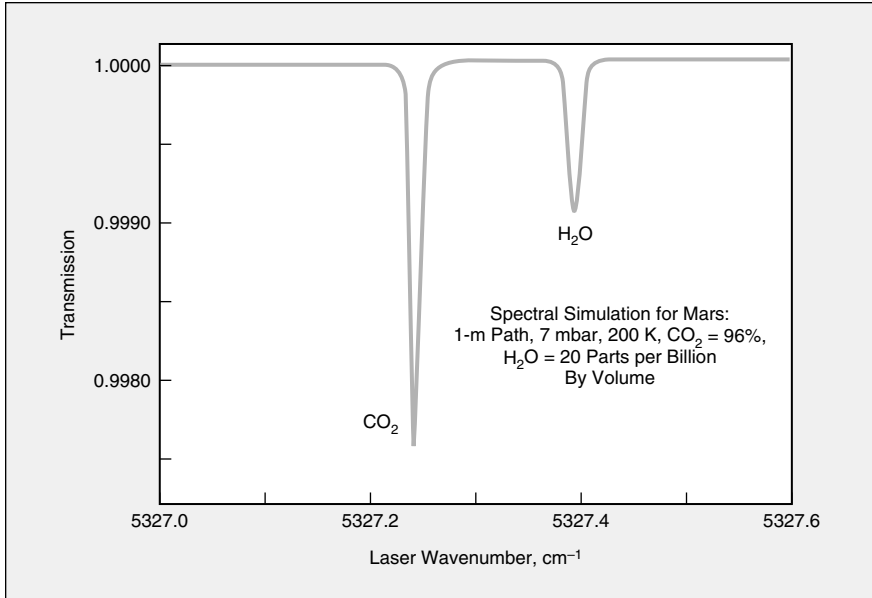
Figure 1. These **Simulated Spectral Transmission Measurements** illustrate the present method as applied to a wave-number range that contains absorption lines of N_2O and CO_2.
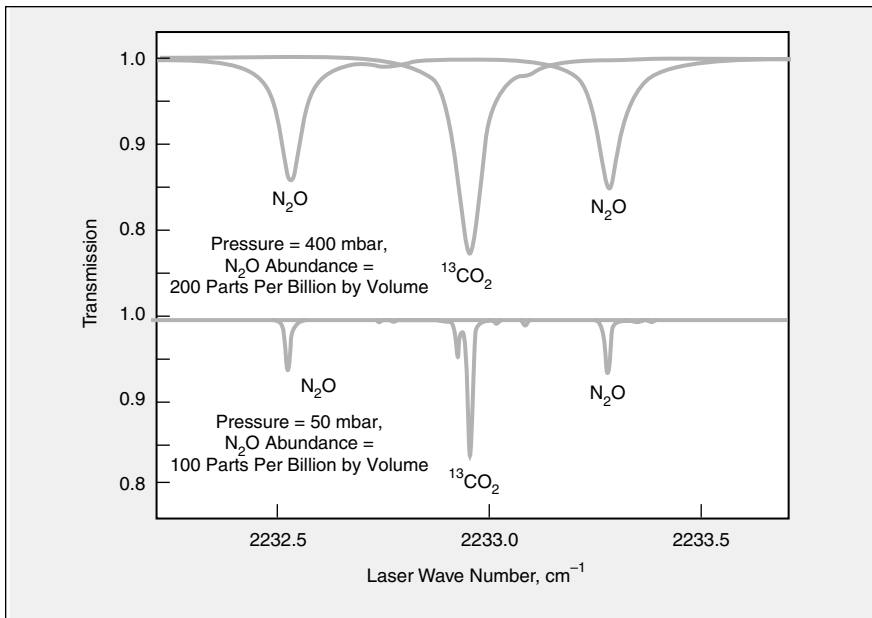

Figure 2. The **Spectral Region Near 1.88 μm** would be appropriate for measurements of water on both Mars and the Earth where suitable near-infrared laser devices would exist.

known and varies slowly and by a small enough amount to be considered constant for calibration in the present context.

Hence, absorption-spectral measurements of the concentrations of gases of interest can be normalized to the con-

centrations of CO_2. Because at least one CO_2 calibration line is present in every spectral scan of the laser during absorption measurements, the atmospheric CO_2 serves continuously as a calibration standard for every measurement point.

Figure 1 depicts simulated spectral transmission measurements in a wave-number range that contains two absorption lines of N_2O and one of CO_2. The simulations were performed for two different upper-atmospheric pressures for an airborne instrument that has a path length of 80 m. The relative abundance of CO_2 in air was assumed to be 360 parts per million by volume (approximately its natural level in terrestrial air). In applying the present method to measurements like these, one could average the signals from the two N_2O absorption lines and normalize their magnitudes to that of the CO_2 absorption line. Other gases with which this calibration method can be used include H_2O, CH_4, CO, NO, NO_2, HOCl, C_2H_2, NH_3, O_3, and HCN.

One can also take advantage of this method to eliminate an atmospheric-pressure gauge and thereby reduce the mass of the instrument: The atmospheric pressure can be calculated from the temperature, the known relative abundance of CO_2, and the concentration of CO_2 as measured by spectral absorption.

Natural CO_2 levels on Mars provide an ideal calibration standard. Figure 2 shows a second example of the application of this method to Mars atmospheric gas measurements. For sticky gases like H_2O, the method is particularly powerful, since water is notoriously difficult to handle at low concentrations in pre-flight calibration procedures.

Laser Ranging Simulation Program

Laser Ranging Simulation Program (LRSP) is a computer program that predicts selected aspects of the performances of a laser altimeter or other laser ranging or remote-sensing systems and is especially applicable to a laser-based system used to map terrain from a distance of several kilometers. Designed to run in a more recent version (5 or higher) of the MATLAB programming language, LRSP exploits the numerical and graphical capabilities of MATLAB. LRSP generates a graphical user interface that includes a pop-up menu that prompts the user for the input of data that determine the performance of a laser ranging system. Examples of input data include duration and energy of the laser pulse, the laser wavelength, the width of the laser