REMOTE INFRARED SPECTROSCOPY OF THE EARTH

by

C. R. Steinmann

Deutsche Forschungs- und Versuchsanstalt
für Luft- und Raumfahrt e.V.
P.O. Box 90 60 58
D-5000 KÖLN 90
GERMANY

ABSTRACT

Increasing interest in the mineralogical application of infrared spectroscopy has recently been shown by geologists, petrologists, and pedologists to use this method as a tool for mineral identification. Several laboratories have conducted studies of the infrared absorption characteristics of minerals and rocks.

Mineralogists are still in the preliminary stage of compiling a library of reference curves that are prerequisit for the correlation of spectral characteristics, molecular lattice-structures and for the identification of unknown minerals and mixtures.

Very little interest has been shown for the infrared reflexion-spectra which correlates to the absorption spectra.

In this investigation the infrared reflexion-spectra of minerals and rocks are used for remote sensing of the targets.

The reflexion-spectra of silicate rocks vary quite significantly from mineral to mineral in the wave length region from 8 to 12 um. The rock forming minerals like quartz, feldspar, mica and the clay minerals show very different spectral shapes and positions of their maximum of the spectral reflexion.

The presence of a good atmospherical window in that spectral region makes the method of differential-reflexion measurement feasible, for remote sensing application.

As transmitter for infrared radiation we used a tunable CO_2-Laser working with sufficient power and stability in the spectral band between 9.1 µm and 11.6 µm at more than 100 emission-lines.

Laboratory tests showed the feasibility of the method under different simulated environmental conditions. Because of the very narrow bandwidth of the Laser-emission lines we could obtain reflexion-spectra with extremely high spectral resolution when tuning the Laser stepwise from line to line covering the spectrum between 9.1 and 11.6 µm.

Next the method was tested using a light twin-engined aircraft. As IR-transmitter a 3 Watts tunable CW-CO_2-Laser was used.

The reflected Laser-energy was detected with the heterodyne method using the natural Doppler-shift which occurs when the Laser-beam looks some degrees forward in flight direction, as local oscillator.

The signal to noise ratio was still 25 at an altitude of 4.000 ft. The discrimination of different surface materials was already possible

Development of the airborne Laser-system and more fundamental laboratory investigations are in progress.

1.) Introduction

There are many techniques for remote sensing of the earth operating in different portions of the electromagnetic spectrum ranging from the ultraviolet to the microwave region. These techniques have been implemented by systems that are either passive or active. All these systems can detect surface features suited to each individual technique. However, it is still difficult to discriminate different types of rocks and soils. Because of this need an active airborne remote sensing system is developed based on infrared Laser-spectroscopy in the spectral region of the crystal-lattice resonant frequencies (residual rays) of the rock forming minerals.

2.) Laboratory Investigations and Results

To investigate the feasibility of the method and to identify the different parameters of noise, a Laser-spectroscopy facility has been installed.

The system consists of a tunable CO_2-Laser, power supply, Laser-gas-supply, vacuum pump, cooling system, beam forming module, pyroelectric detector, chopper and lock-in-amplifier, radiometer and stripchart-recorder.

The Laser was developed by the Battelle-Institut in Frankfurt, Germany, and is tunable between 9.1 µm and 11.6 µm on abt. 100 emission lines with an average power of 10 W.

The Laser-beam was directed onto the rock-sample. The reflected energy, detected and divided by the total output energy. The Laser was then tuned stepwise from emission-line to emission-line.

The reflected radiation enables to draw curves of the spectral reflectivity with very high spectral resolution.

Ten representative samples were investigated. The influence of surface-structure, temperature and moisture on the spectral shape was investigated too.

It could be shown that the influence of temperature and moisture is very little. The influence of the surface varied the height of the reflexion peaks, but not their spectral position.

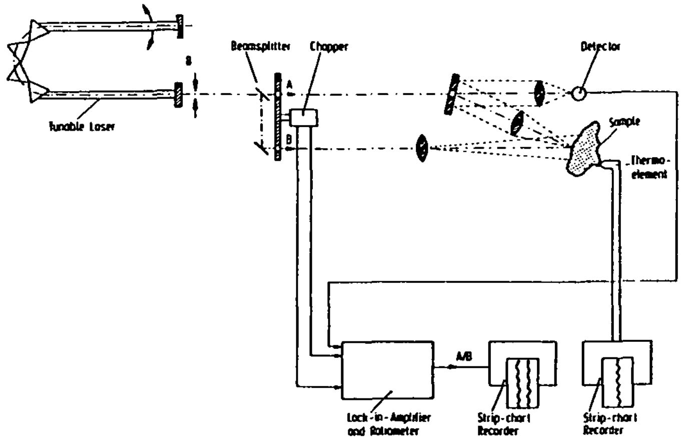

FIGURE 1. SCHEMATIC OF THE LABORATORY MODEL OF THE CO_2 LASER REMOTE SPECTROMETER

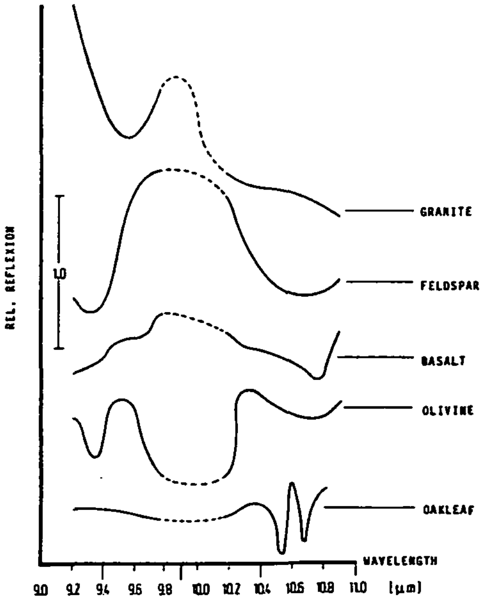

FIGURE 2. RELATIVE REFLEXION VERSUS WAVELENGTH

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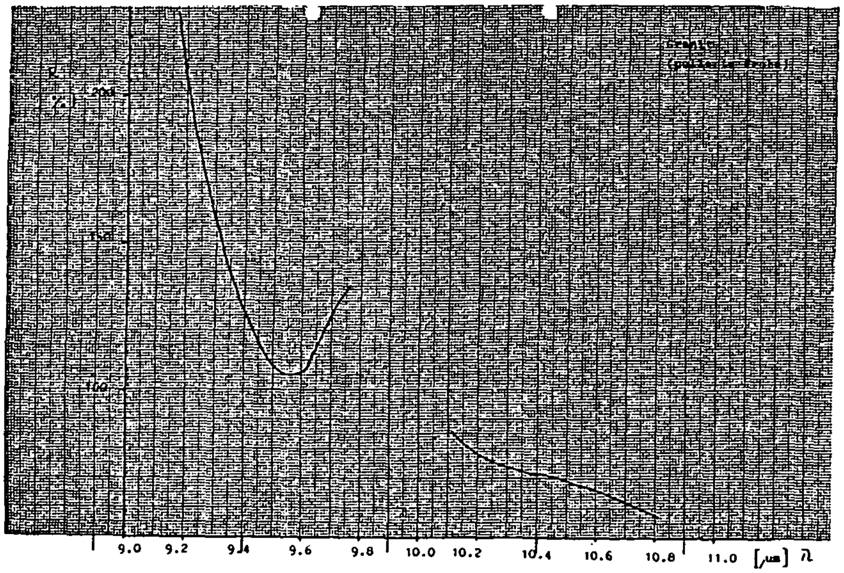

FIGURE 3. RELATIVE REFLEXION OF A POLISHED SAMPLE OF GRANITE VERSUS WAVELENGTH

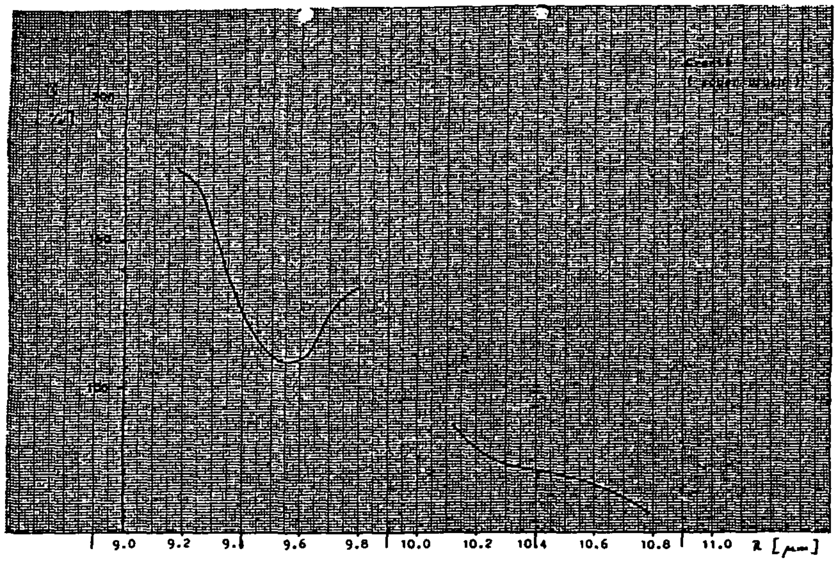

FIGURE 4. RELATIVE REFLEXION OF A ROUGH NATURAL SURFACE SAMPLE OF GRANITE VERSUS WAVELENGTH

3.) Airborne System development

Commissioned by the West German Federal Ministry for Research and Technology an aircraft-borne measuring system is being developed which is to be used for spectroscopic investgations of the earth's surface and quantitative analysis of air pollutants and natural atmospheric trace gases.

Using tunable CW-IR-molecular Lasers, the method of differential absorption or reflection measurements is applied. The Laser-radiation scattered back from the earth's surface is detected in the aircraft by means of the heterodyne technique.

The measuring system has a weight of 285 kg, a volume of 1.7 m^3 and a power input of 1.2 kW. It consists of the optomechanical subsystem, which comprises the Laser head, all optical components (including telescope), the detector system and the instruments for inflight calibration and adjustment, a 19" rack containing the measurement electronics, the data recording system and the Laser supply equipment.

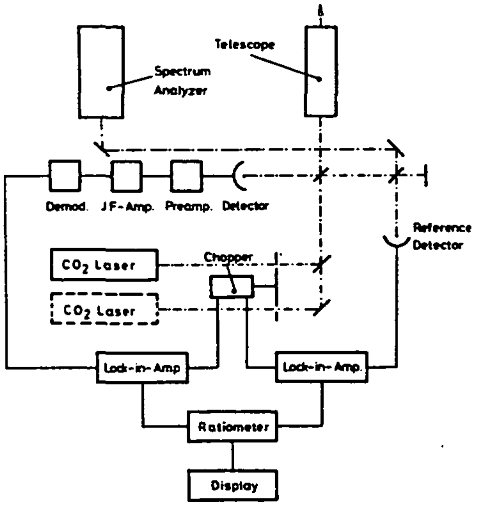

FIGURE 5. SCHEMATIC OF THE AIRBORNE LASER SPECTROMETER

4.) System Installation and Test

The flight tests of the system were carried out in the Dornier 28 Skyservant of the "Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (DFVLR)" at altitudes between 500 and 4000 ft. The signal to noise-ratio of about 25 , that has been achieved proves the feasibility and superiority of the selected detection method (heterodyne detection using the natural Doppler effect).

Differential measurements have not yet been performed because the functional model for these preliminary flight test was equipped with one Laser only.

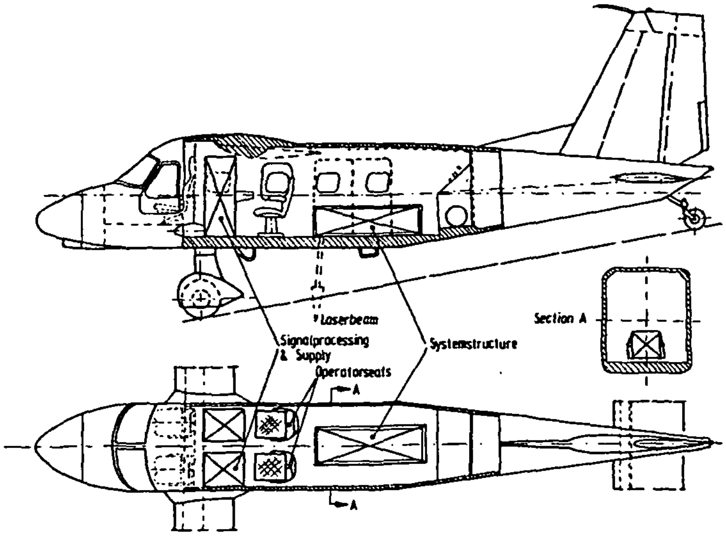

FIGURE 6. CONFIGURATION OF THE AIRBORNE IR LASER SPECTROMETER IN THE AIRCRAFT

Results

The first series of tests of the CO_2 airborne Laser-spectrometer were conducted in September 1976 totalling 7 hours of flight and tests.

First taxiing tests showed good results. The high acoustic and electromagnetic fields of the engines and radio didn't interfere with the Laser detector.

The program consisted of the following items:

- Calibration of telescope focus for altitudes between 500 and 4000 ft.
- Calibration of the deflection angle to produce a constant Doppler-shift.
- Demonstration of the independence from topography to Doppler-shift.
- Documentation of the reflectivity of different surface materials.
- Measurement of Signal to Noise Ratio at different altitudes.

For documentation of the different reflectivity of the surface, photographs were taken. Fig. 7 shows reflexion signal of a forest with signatures of a highway and a clearing.

In later missions in June 1977 two Laser frequencies will be used, making feasible a differential spectroscopic investigation by applying the ratio of the different spectral reflections.

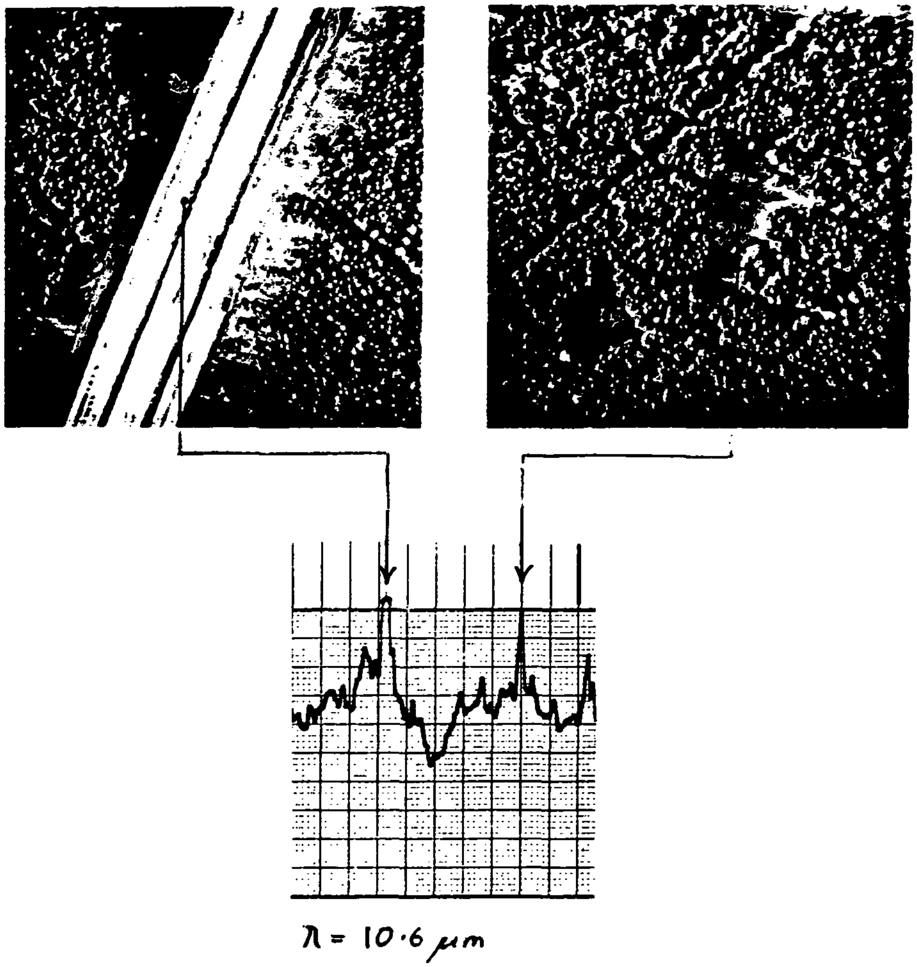

FIGURE 7. DETECTED HETERODYNE SIGNAL
FOREST WITH CROSSING HIGHWAY AND CLEARING

Flight 4	Sept. 13, 1976
Altitude	1500 ft
Speed	50 m/sec
y-axis	10 mV maximum
x-axis	3 inch/min
Integration time	0.25 sec
Length of profile	2 km

Conclusions

An experimental airborne Laser-Infrared-Spectrometer-System based on the interaction of Laser-radiation with the crystal lattice frequencies of the surface minerals is in development.

Laboratory investigations have shown the feasibility of the method.
First test flights have shown the feasibility of the heterodyne-detection method of the re-emitted Laser-radiation.

Based on the laboratory and airborne data the following can be concluded:

- Detection of most of the rock forming minerals and clay-minerals with Laser differential measurements is feasible.
- With a two frequency system many geological questions e.g. basic-acid ratio of igneous rocks can be discriminated.
- The geometrical resolution is about 10 m at 10.000 ft altitude.
- The Laser-Spectroscopic System operated reliable in the light aircraft.

Acknowledgements

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The opto-mechanical portion of the experimental airborne Infrared-Laser-Spectrometer was designed and fabricated by the Battelle-Institut, Frankfurt, Germany.

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FIGURE 8. OPTO-MECHANICAL FACILITY TO PERFORM LASER-SPECTROSCOPIC INVESTIGATIONS OF ROCKS

FIGURE 9. IN HOUSE LABORATORY TEST FACILITY. TUNABLE CO_2-LASER IN FRONT

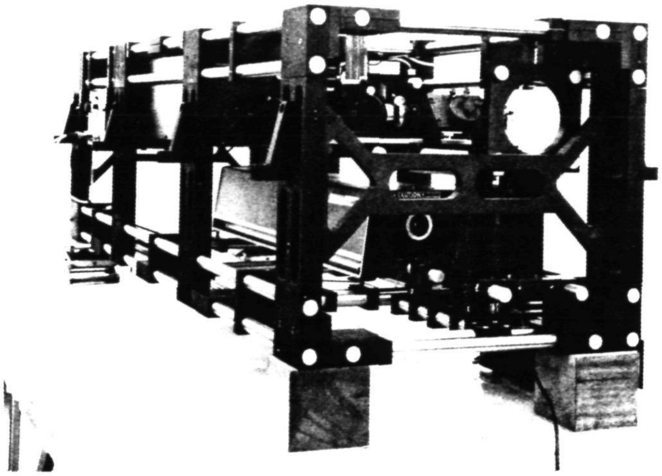

FIGURE 10. MEASURING SYSTEM WITHOUT SHOCK-MOUNTS. THE VACANT SPACE NEXT TO THE LASER IS RESERVED FOR THE SECOND CO_2-LASER

FIGURE 11. A VIEW OF THE CO_2-LASER-IR-SPECTROMETER MOUNTED IN THE AIRCRAFT