ACTRIS TNA Activity Report

FITR-MAIDO-3

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Introduction and Motivation

The present activity had two objectives. First we wanted to optimize the alignment and the performance of our Fourier Transformation Infrared (FTIR) spectrometer at Maïdo, which carries out measurements of various atmospheric trace gases within the framework of the Network for the Detection of Atmospheric Composition Change (NDACC). During previous missions to Maïdo, we often did not have the time to fully optimise the optical performance of the FTIR spectrometer, which is a very delicate and time consuming procedure. The intent of this mission was to specifically dedicate enough time to carry out the optical alignment more properly, using the latest technique recommended in the community, and to implement some other improvements for which until now there was never enough time.
The second objective of the mission was to be present during the installation of the Picarro G2401 GHG analyser owned by BIRA-IASB. An expert from the LSCE would carry out the installation, and we would be present to learn from this installation, since BIRA-IASB has no previous experience with these instruments. The Picarro GHG at Maïdo will be integrated in the Integrated Carbon Observing System (ICOS), and will measure the in-situ concentrations of CO2, CO and CH4 at surface level. These surface-level values may prove useful in the retrieval of the vertical profiles of these gases from the FTIR measurements.

Scientific Objectives

The optical alignment is a critical factor of the FTIR spectrometer. Especially the correct alignment of the entrance optics, which determine the field of view of the instrument, and of the interferometer arm are important for optimal performance of the instrument, and have an influence on the instrument line shape (ILS) of the spectrometer. By optimising the alignment of the spectrometer, we aim to approach as much as possible the ideal ILS of an interferometer, since exact knowledge of the lineshape is important for the retrievals of the trace gases. The vertical mixing ratio profile of an atmospheric trace gas can be retrieved from the line shape observed in the FTIR absorption spectra because of the height-dependent pressure broadening. Thus, the shape of an absorption line reveals information about the vertical distribution of a target gas. When analysing the shape of these absorption lines, it is important to correctly take into account the actual line shape of the spectrometer, since for various reasons (optical alignment, mechanical imperfections, etc.) this true line shape may differ from the theoretical line shape. Failing to take into account the actual line shape of the instrument may introduce a substantial systematic error in the retrieved vertical profiles (Hase et al., Applied Optics Vol, 38, 1999).

Reasons for choosing the Maido station

The Belgian Institute for Space Aeronomy (BIRA-IASB) has a long history of solar-observing infrared measurements on Reunion Island. The first campaign on the island dates back to 2002; during this, and later campaigns, which typically lasted a few weeks, the infrared spectrometer was installed on the Maïdo. Since 2009, continuous measurements are performed from the University of Reunion at St. Denis near sea-level. Initially these measurements were carried out within the framework of the NDACC, but since September 2011 also in the framework of the Total Carbon Column Observing Network (TCCON). The principal benefit of the Maïdo station is its high-altitude location (2200 m). This puts the station above most of the water-vapour content in the troposphere. This results in much less intense water absorption lines in the infrared solar absorption spectra, allowing the analysis of weak absorption lines of other gases that would otherwise suffer interferences from the strong water vapour lines. An additional benefit of the high-altitude station is that it is located close to the free troposphere, which limits the effects of local pollution. Yet because of its location the station is well situated to study the transport of biomass burning plumes from Africa and Madagascar, which affect the free troposphere.

Method and Experimental Set-up

The alignment of the FTIR spectrometer was optimized according to the recommended technique in the NDACC Infrared Working Group (IRWG) community, with the help of a telescope. For the alignment of the entrance collimator, the telescope is focused to infinity and brought into the arm of the interferometer. The entrance aperture is observed via a camera connected to the telescope, and the position of the off-axis mirror and the plane mirror in front of it are optimised so that the image of the entrance aperture appears sharp, with the telescope focus at infinity.

Subsequently, the telescope is placed outside of the spectrometer, and using an extra mirror the beam exiting the interferometer is observed with the telescope. A monochromatic light source is coupled into the spectrometer. In practice, the diffused light of a strongly attenuated compact solid-state laser is used. The laser is positioned in the source compartment of the instrument and several layers of tracing paper are used as an attenuator and diffuser. When this monochromatic light is observed after it has passed through the interferometer, a ring-shaped interference pattern (Haidinger fringes) can be observed on the image of the camera connected to the telescope. The entrance optics are adjusted so that the centre of these fringes remains centred for all positions of the interferometer mirror along the entire length of the interferometer arm. Finally the alignment of the reference laser is checked and adjusted so that the intensity registered by the two laser detectors varies minimal between zero- and maximum path difference of the interferometer.

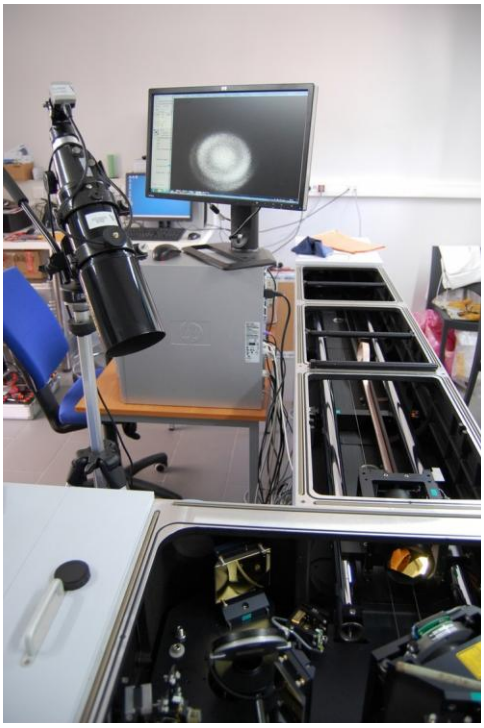


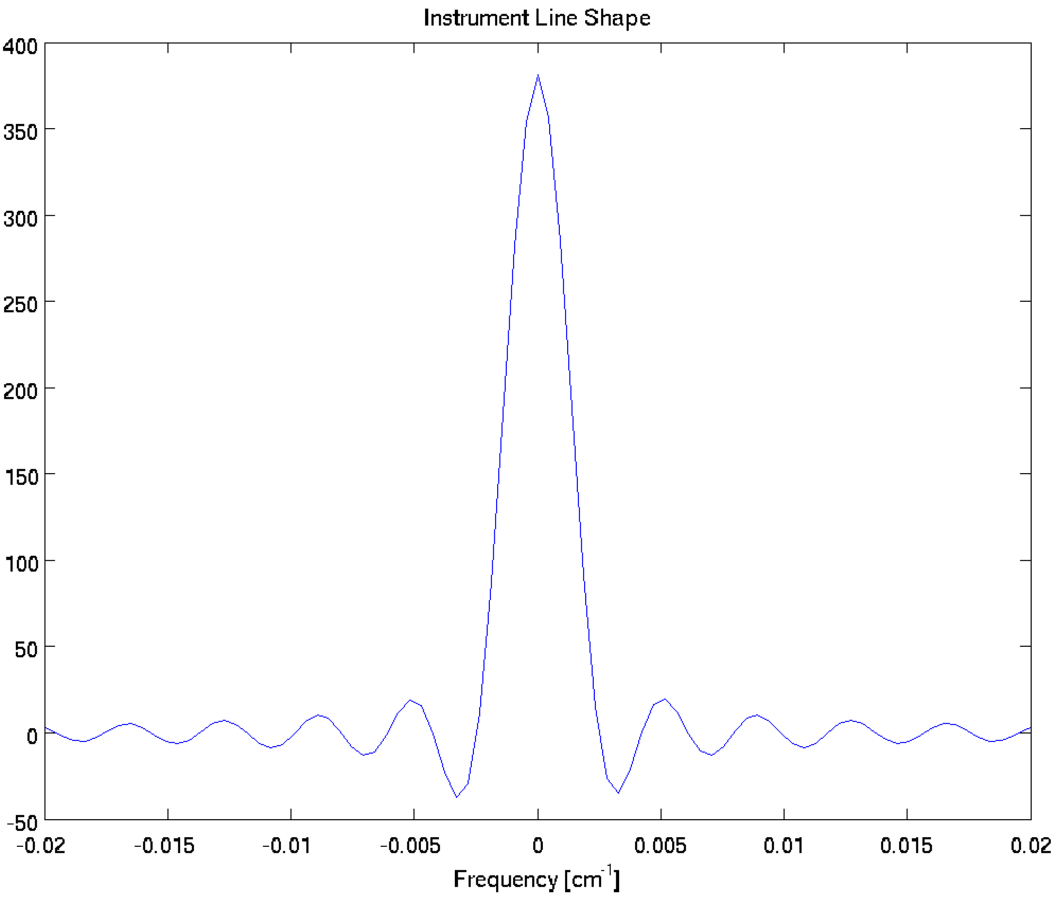
Illustration 1: A telescope is mounted on a tripod outside the FTIR spectrometer, such as to observe monochromatic light (laser light that has passed through a diffuser) after it has passed the interferometer, giving rise to Haidinger fringes that are visible on the computer image.

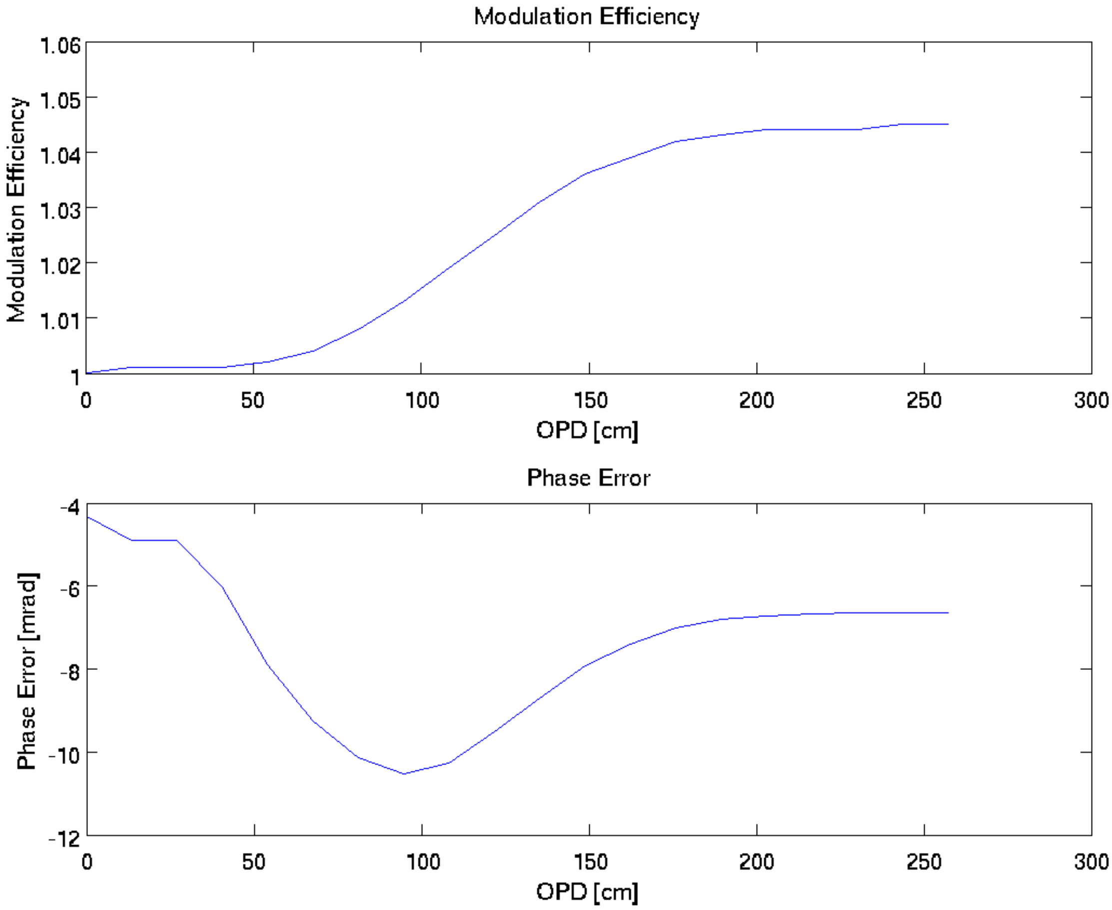
Apart from the optical alignment, some maintenance was carried out on the spectrometer and the auxiliary equipment. A serial server in the meteorological station was replaced, and a blockage in the water-cooling system for the lamps of the FTIR spectrometer was fixed.

Preliminary Results and Conclusions

The alignment of the instrument can be verified by means of a measurement of a cell containing a gas at a known pressure. To determine the instrument lineshape, the NDACC uses a cell filled with HBr gas. This cell is placed inside the sample compartment of the FTIR spectrometer, and using a globar as light source, an absorption spectrum of the HBr gas in the cell is measured. This spectrum is then analysed with the Linefit software (version 12) developed by Frank Hase *et al.* (Hase et al., Applied Optics Vol, 38, 1999).

The figures below show the instrument lineshape, and the modulation efficiency and the phase error of the interferometer as a function of the optical path difference (OPD), after the alignment procedure.





Outcome and Further Studies

A problem was identified with the gold-plated mirrors of the solar tracker on the roof of the FTIR laboratory. The protective coating of these mirrors shows signs of degradation due to salt depositions. Salt crystals are formed which penetrate microscopic imperfections in the coating and thus damage the protective layer. The damage is much less severe than the damage which we observed at the FTIR observatory in St. Denis near sea-level. In the near future we will replace the elevation mirrors of the tracker (which are the most exposed to the environmental conditions) with spare mirrors which are available at BIRA-IASB. For a more long-term solution, we will explore other options for the mirror material or the coatings (including special seawater-resistant stainless steel).

Due to a late delivery of some critical equipment for this mission, we were unable to travel to Reunion Island at the time when the expert of LSCE was there to install the Picarro GHG analyser. Jean-Marc Metzger who was present during the installation, and who is responsible for the Picarro instruments at Maïdo and St. Denis explained the installation, and the functioning of the valve system with the various ICOS calibration gases, and demonstrated the software.

References

Hase et al., Applied Optics Vol, 38, 1999