ILS Characterization procedure for COCCON

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Document version: 141202

Abstract: this document describes an ILS (instrumental line shape) characterization scheme for the EM 27 SUN. The proposed approach uses an open-path observation of a few meters of lab air to avoid the need for a gas cell, only an external source is required. The ILS is derived from strong H_2O lines. First the setup of the external source is described. Next, the recording of spectra is described. Finally the analysis of the recorded spectra in the 7000 – 7400 cm^{-1} region with LINEFIT is outlined.

Figure 1 shows a picture of our lamp system. We employ a Osram Halogen Display/Optic lamp 64602 50 W 12 V G 6.35 NAED 54607 as radiation source, together with a fast aspherical collimation lens of 2 inches diameter, as used in projection collimators. In order to avoid channeling we tilted the light bulb with respect to the optical axis, and for assuring a uniform illumination the glass surface of the bulb is roughened towards the lens (one can simply use a piece of sandpaper for this purpose). The system is mounted on a stable photographic tripod because this makes the fine adjustment (achieving a uniform light beam on the tracker mirror and a uniform image of the source on the field stop) much easier. Due to the modification of the bulb a voltage lower than the nominal voltage should be applied for operation. A stabilized digital laboratory DC power supply is used, we apply 11 V voltage.

Figure 1: Setup lamp system

Two hours prior to the actual measurements the instrument should be powered up to guarantee that the unstabilized reference laser operates at a constant wavelength. As the water column inside the spectrometer cannot be neglected, we recommend to vent the instrument by opening the two apertures indicated in figure 2, in order to ensure that the mixing ratio of water vapor is about the same inside and outside the spectrometer (the apertures are opened when the instrument is switched on and closed after recording of the spectra). Also note that the distance between instrument and lamp should not be chosen too small, because otherwise the heat of the lamp will affect a non-negligible section of the open path, thus introducing a systematic error. Furthermore

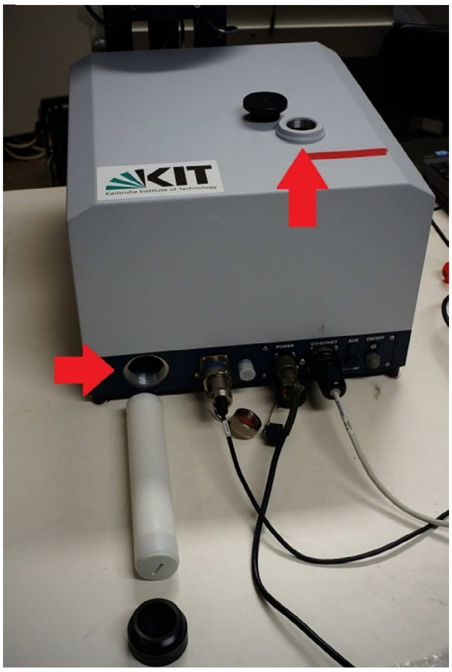

Figure 2: Open at these positions for air exchange

care should be taken that the free aperture of the tracker is fully illuminated and that the image of the lamp on the fieldstop is evenly illuminated and exceeds the diameter of the fieldstop. This can be achieved by shifting and tilting the source and by rotating the mirrors of the tracker using the CamTracker software. The resulting illumination on the field stop aperture can comfortably be judged using the CamTracker camera (you have to set gain and exposure to maximum in the CamTracker software). As we depend on stable thermal conditions and because we temporarily violate the sealed spectrometer closure, we recommend to apply this procedure only in a reasonably clean, controlled environment. **Never open the spectrometer apertures if the instrument is colder than the surrounding (risk of condensation) or if the humidity in the room is too high.**

For the measurement itself we propose to record 30 times 10 scans (double-sided scans at full resolution). The settings in the measurement file are the same as for solar measurements except that we change the pregain setting from B to Ref. We obtain the final spectrum used in the subsequent analysis by taking the averaged IFG and performing a DC correction + FFT by hand (copy IFG in OPUS, repeatedly average data points of the IFG until only the smoothly variable DC offset remains, ratio the original IFG over the DC part of IFG, apply an FFT, normalize the resulting spectrum to around unity in the 7000 to 7400 cm^{-1} region. For the FFT, apply a Norton-Beer apodization function (as for a solar measurement) and a zero filling of 8).

In order to predict the correct width of the observed H_2O lines (and so correctly retrieve the correct ILS width), the distance between instrument (measured from first / elevation tracking mirror) and lamp needs to be measured as well as air temperature and pressure at the time of measurement. The optical path length between first tracking mirror and the longpass filter is fixed (38 cm) as well as the path length inside the spectrometer housing (58 cm). These contributions have to be added to the aforementioned measured distance. A preliminary LINEFIT analysis run on the measured spectrum is performed in order to determine the H_2O column. From this H_2O column value, the total path length, and the temperature, the partial pressure of H_2O is calculated. This value is afterwards used for the final LINEFIT run, which provides the ILS parameters. Because we expect that the ILS of the EM27sun is very near to the nominal performance, we use the simple 2 parameter ILS fitting option of LINEFIT. Note that the analysis is based on the HITRAN 2009 water linelist with some minor ad-hoc adjustments.

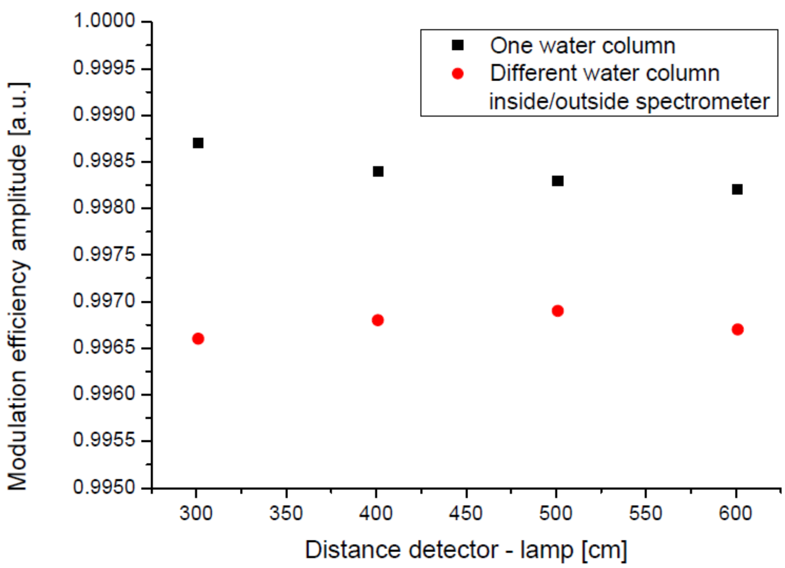

Figure 3: ILS results obtained with LINEFIT

For providing a demonstration of the level of reliability of the procedure, we determined ILS parameters from spectra recorded at several different distances. The results are depicted in Figure 3, applying two different ways of performing the analysis. The simple analysis assumes a uniform path between lamp and detector. The more refined approach divides the observed absorption into two contributions, one from inside and one from outside the spectrometer. We assume that due to the venting, the mixing ratio of H_2O inside the spectrometer is the same as outside, but we respect that the air inside the spectrometer is slightly warmer due to the power dissipation of the spectrometer (a T value recorded by a sensor inside the spectrometer is provided in the housekeeping data of each OPUS file). As indicated by Fig. 3, both results are in agreement within 0.15%. We recommend to follow the refined procedure which is probably more accurate. Note that the deduced ILS parameters are also quite consistent as function of distance between source and spectrometer.

Parts required:

- Stable photographic tripod with head (we use the standard ¼ inch photo thread for mounting the cage cube)
- 60 mm Cage Cube: https://www.thorlabs.com/thorproduct.cfm?partnumber=LC6WR
- Cover plate for 60 mm Cage Cube (available with metric or Inch tap): https://www.thorlabs.com/thorproduct.cfm?partnumber=LB1C
- Adjustable lens tube: https://www.thorlabs.com/thorproduct.cfm?partnumber=SM2V10
- Aspheric condensor lens : https://www.thorlabs.com/thorproduct.cfm?partnumber=ACL5040U
- Halogen light bulb : https://www.osram.de/ecat/Halogen%20(%3C%2075%20V)%20Single%20End-Halogen%20(%3C%2075%20V)-Medical%20&%20Scientific-Entertainment%20&%20Industry/de/de/GPS01_265590/ZMP_1006727/
- Lamp socket : https://www.reichelt.com/de/en/shop/product/lamp_socket_g4_gu4_gu5_3_gy6_35_ceramic_white-278374