

EUMETRISPEC Newsletter 3

Advanced determination and control of gas absorption cell properties – optical path length and gas temperature

The Beer-Lambert law for optical absorption, $I/I_0 = e^{-\alpha(\nu) \times L}$, is of fundamental importance in spectroscopy. The optical path length L , i.e. the interaction length between molecules and optical radiation, is directly governing the amount of absorption as it is represented in the Beer-Lambert equation. Accurate knowledge of the optical path length when using an absorption gas cell for spectrometers is obviously important in order to achieve accurate measurement results. In recent work EUMETRISPEC has taken steps in advancing the accuracy of the absorption cell's optical path length determination.

The optical path lengths of various absorption cells, including those of the central FTIR facility, have been successfully calibrated by means of a joint measurement campaign of DFM and PTB. Both expert groups combined their knowledge to arrive at an updated absolute path length calibration approach based on phase modulation laser distance meters. This approach was in particular used to calibrate the optical path lengths of two variable length White-type and two Herriott-type multi-pass cells. Combined measurement uncertainties have been estimated on the central facility's 42-m multi-pass cell to be ± 4 mm corresponding to a relative uncertainty of 0.01 %.

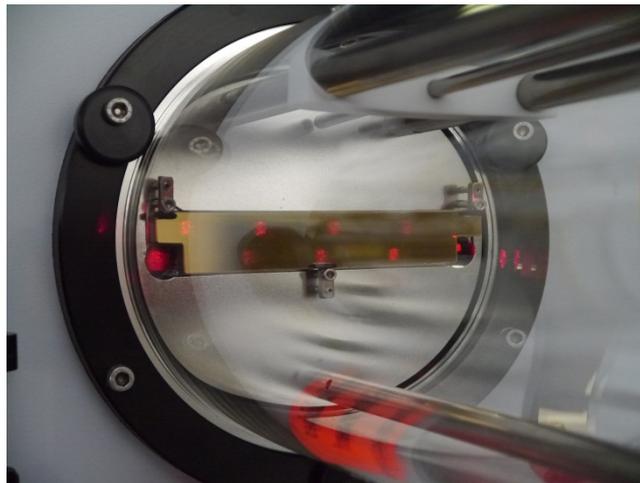


Figure 1: Spot pattern of reflections on the gold mirror of the White-cell within the path length calibration procedure by means of the laser distance meter approach.

As important as optical path length is accurate control of the pressure and temperature of a gas sample confined in a gas cell in order to model the spectroscopic measurement. At the central FTIR facility the development of absorption cells has reached the next stage by introducing a new cell design, which enables the spectrometric measurement of spectral line data as a function of both, pressure and gas temperature. This new cell generation allows for FTIR spectroscopy of gas samples at pressures between 0.1 mbar up to 1000 mbar at stabilized gas temperatures in the range of 220 K to 300 K.

Based on the new cell design pressure broadening coefficients are currently being measured for the four different molecular species, i.e., N_2O , CH_4 , CO_2 , and CO . Accordingly, progress on N_2O broadening coefficients has recently been presented at the colloquium on High Resolution Molecular Spectroscopy (HRMS) 2013 in Budapest (see list of publications below).

Accurate determination of line centres

In the previous newsletter we presented the successful measurements on absolute line centre frequencies performed by MIKES using comb-assisted cavity ring down saturation spectroscopy. These measurements have now been supplemented by direct saturation spectroscopy performed by LNE-CNAM.

The absolute frequencies of the 4 components of the P(7) line of the ν_3 band of CH_4 near 88 THz were determined using a 1m long cell to measure the Lamb dip with a 2% contrast. An error signal is generated corresponding to the 3f lock-in amplifier demodulated absorption signal of the lamb dip, probed by the idler beam from an OPO. The OPO signal beam is offset-phase-locked to a tooth of an Optical Frequency Comb (OFC: octave wavelength spanning Er-doped mode-locked fiber laser). This is phase-locked to the 10 MHz signal of a quartz oscillator of a Rb microwave clock, disciplined via GPS to the Temps Atomique International for traceability of the absolute frequency measurements to the time/frequency standard. The error signal is then used to lock the pump laser frequency (at 1064 nm) to the MIR saturation dip.

LNE is now working on the experiments for the line-by-line measurements of pressure-induced shifts of line positions and line broadening (two deliverables of EUMETRISPEC).

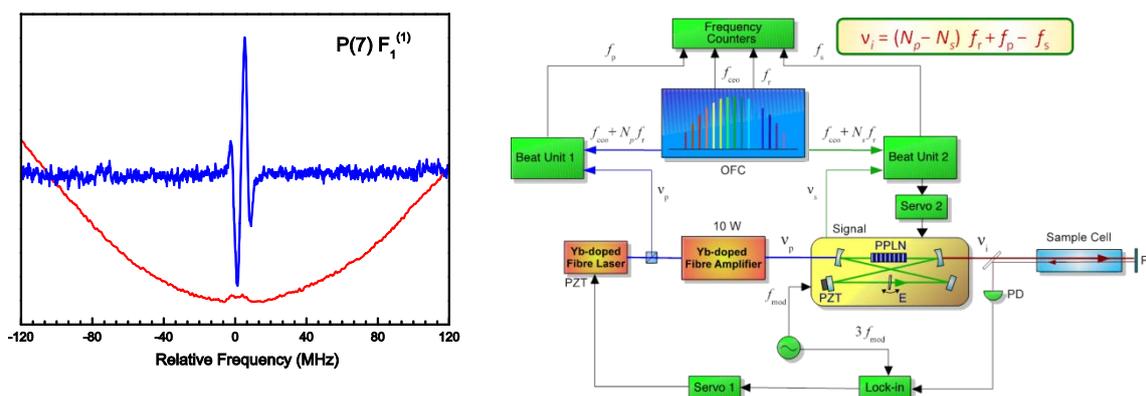


Figure 2 Left: Saturated absorption spectrum (red curve) and the respective 3f spectrum of the P(7) F1(1) component of the ν_3 band of CH_4 . The MIR frequency of the OPO is locked to the zero crossing of the 3f signal for absolute-frequency measurement of the absorption line center. Right: Experimental setup.

Recent Activities

Reflecting on the JRP's design, its aims, and on first results, EUMETRISPEC was introduced to a national German standardization body (Normenausschuss KRdL im VDI und DIN, NA 134-04-02-16 UA) that facilitates guideline production and recommendation release on ground-based remote sensing by means of FTIR spectroscopy. PTB was asked and agreed to provide input to the production of a new guideline. Further on, PTB succeeded to place a presentation to the SPIE Remote Sensing conference Europe which highlighted the stakeholder alignment of the JRP and described the basic ideas of implementation as well as first results based on the central FTIR facility at PTB.

Recently the EUMETRISPEC consortium submitted a proposal to the European Metrology Research Programme (EMRP) 2013 Environment call for follow-up funding. Notwithstanding the outcome of this proposal, its authors and the partners of the current EUMETRISPEC project agreed recently, that the established infrastructure and capabilities will be maintained and further developed without further funding by the EMRP framework.

New Consortium Publications with relevance to Eumetrispec

I. Ricciardi, S. Mosca, V. Di Sarno, P. Maddaloni, M. Parisi, L. Santamaria, M. De Rosa, J.-J. Zondy, P. De Natale: "Absolute frequency measurements of CH₃I and CH₄ rovibrational transitions by a frequency-comb-referenced optical parametric oscillator". in 24th Colloquium on High Resolution Molecular Spectroscopy (HRMS), Budapest, Hungary, August 25-30, 2013.

J. Courtois, R. Bouchendira, M. Cadoret, I. Ricciardi, S. Mosca, M. De Rosa, P. De Natale and J.-J. Zondy, "High-speed, multi-THz-range, mode-hop-free tunable MIR OPO spectrometer". Poster Presentation at ASSL-MICS, Paris, 2013.

J. Peltola, M. Vainio, T. Fordell, M. Merimaa, and L. Halonen, "High-Accuracy Molecular Spectroscopy with Frequency Comb-Linked Mid-Infrared Continuous-Wave Optical Parametric Oscillator," in Mid-Infrared Coherent Sources (MICS), Paris, France, October 27 - November 01, 2013 (Talk).

J. Peltola, M. Vainio, T. Fordell, M. Merimaa, and L. Halonen, "High-Accuracy Molecular Spectroscopy with Frequency Comb-Linked Mid-Infrared Continuous-Wave Optical Parametric Oscillator," in High Resolution Molecular Spectroscopy (HRMS) 2013, Budapest, Hungary, August 25-30, 2013 (Poster).

A. Pogány, O. Ott, O. Werhahn, V. Ebert, "Towards traceability in CO₂ line strength measurements by TDLAS at 2.7 μm", J. Quant. Spectrosc. Rad. Transf. Volume 130, November 2013, Pages 147–157, HITRAN2012 special issue, doi: 10.1016/j.jqsrt.2013.07.011.

V. Werwein, J. Brunzendorf, A. Rausch, A. Serdyukov, O. Werhahn, V. Ebert, „First measurements of N₂O-self-broadening coefficients in the 0001-0000- and 0002-0000-bands", Colloquium on High Resolution Molecular Spectroscopy (HRMS), Budapest, Hungary, August 25-30, 2013 (Poster).

O. Werhahn, A. Pogány, J. Nwaboh, V. Werwein, V. Ebert, „Spectral reference data of molecules relevant to Earth's atmosphere: Impact of European Metrology Research on atmospheric remote sensing", Proceeding of SPIE – Remote Sensing of Clouds and the Atmosphere XVIII; and Optics in Atmospheric Propagation and Adaptive Systems XVI, vol. 8890 (2013), pp 889007-1 889007-16, doi: 10.1117/12.2028761.

Meet us

In the coming period you can meet us at the following events:

Conference	Date	Location
DPG spring meeting	Mar. 17 – 21, 2014	Berlin
FLAIR 2014	Mai 05 – 09, 2014	Florence
HITRAN	Jun. 22 – 25, 2014	Boston
EUCMOS	Aug. 24 – 28, 2014	Düsseldorf
HRMS 2014	Sep. 02 – 07, 2014	Bologna

Contact and further information

This is a newsletter about on-going work and development of the EUMETRISPEC project, which is carried out by the following partners / institutions:

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Additional information on EUMETRISPEC and the partners can be found on the project homepage www.EUMETRISPEC.org, where our contact details and a registration access are available to get access to the stakeholder area where additional information will be made available.

Please forward this newsletter to your colleagues. They can send an email to any of the project's representatives with subject 'register EUMETRISPEC newsletter' to register for this 6-monthly newsletter.