NEWSLETTER N°3
OCTOBER 2020

Welcome to the newsletter n°3 from the LEMON project

The overall objective of LEMON is to provide a new Differential Absorption Lidar (DIAL) sensor concept for greenhouse gases and water vapour measurements from space, based on a versatile transmitter.

Word of the Coordinator

Despite the difficulties we are all facing, LEMON partners' motivation is still intact. Over the last months, having access again to the laboratories allowed us to go on performing several validation tests at different levels. An important fact to highlight is that we achieved completion of our instrument mechanical readiness review and launched the fabrication for several sub-systems. In this newsletter, we will thus disclose some information about the DIAL instrument design. Also, since the European Space Research Establishments (ESRE) published its white paper in January this year, we took the opportunity of analysing its proposed roadmap to assess that LEMON is in line with its propositions for earth observation. Following our goal to provide Europe with new instruments and methods for earth observation, in this newsletter we will also present you a preliminary campaign, where in-situ water vapour isotopes sensing instruments as well as a Raman lidar for water vapour sensing were used. Finally we try to go on opening our range of application towards other topics than space. Enjoy reading us!

Dr. Myriam Raybaut
Research engineer
ONERA – France

NEWS & EVENTS

The LEMON consortium has conducted the radiation tests for the most critical devices used within the lidar system.
>> More information here

Have a look at the upcoming conferences that the LEMON partners will attend.
>> More information here

LEMON presentation leaflet is downloadable:
>> Download the pdf

LEMON presentation poster is downloadable:
>> Download the pdf

CONTACT US

E-mail: contact@lemon-dial-project.eu

Project website: www.lemon-project.eu

Follow LEMON on LinkedIn: *LEMON-DIAL*

Project Coordinator & Co-Coordinator:
Myriam Raybaut (ONERA)
Cyrille Flamant (CNRS/LATMOS)

Dissemination Manager:
Sofia Santi (L-UP)

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement N° 821868.

MECHANICAL DESIGN REVIEW

Focus on the Outcomes of the Mechanical Readiness Review for the DIAL instrument (performed during March-September 2020).

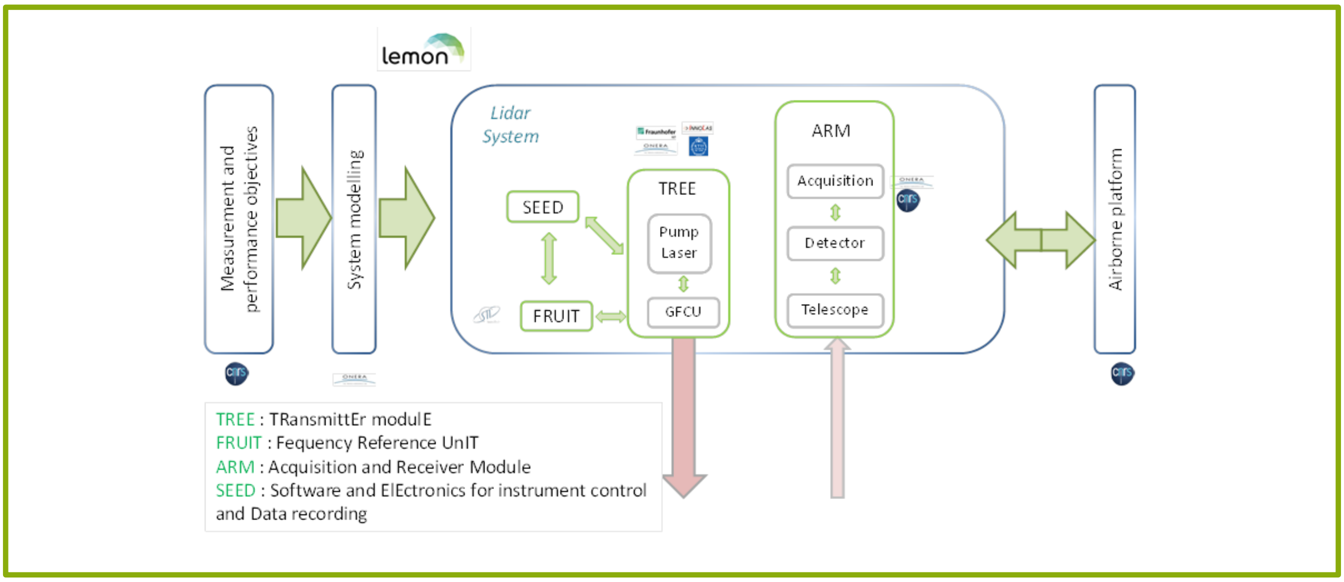

Figure 1: LEMON DIAL sub-systems

Over the last months, lots of work have been performed on the mechanical design, to be able to get the desired performances for the Differential Absorption Lidar (DIAL) instrument, especially for the operation within the aircraft.

We recall the instrument sub-systems in Figure 1. One of the main building-blocks of the instrument is the emitter, which will be composed of two optical housings: a first one including the pump laser and optical parametric oscillators, to generate the wavelengths in line with our objectives, and a second housing to amplify these radiations to the required level of energy. The mechnaical design of these two housings are depicted in Figure 2.

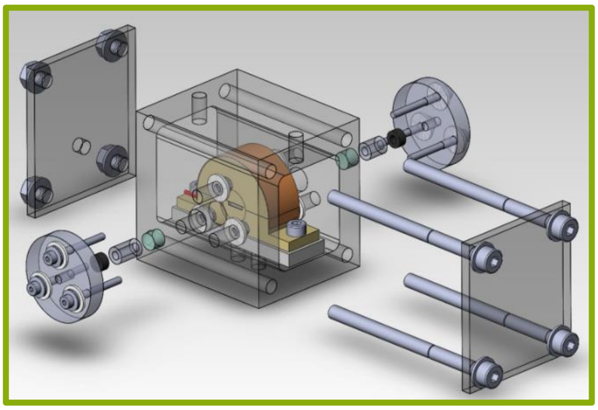

Figure 2: OPO thermo-mechanical design

During the optical design phase, our main goal was versatility in terms of targetted gas species.

Concerning this mechanical design, our main goal was thus versatility in terms of possible operability: from the aircraft or from the ground.

One important point about this instrument, that we wish versatile, is that it was designed not only to be able to perform integrated measurements from an aircraft, but also to be used from the ground, for range resolved measurements, to have access to high spatial resolution and more regular measurement campaigns. This induced of course compromises: a range resolved measurement from the ground requires a bigger receiver sub-system than for airborne integrated path measurements. Moreover, special care was taken on the OPOs thermo-mechanical design, so that preliminary environmental testing for space operation is envisionned.

Work is now ongoing with partner CNRS Safire, to ensure the integration within the aircraft.

By Marine Dalin, Vincent Lebat, Jean-Baptiste Dherbecourt, Myriam Raybaut (ONERA)

lemon

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement No 821868

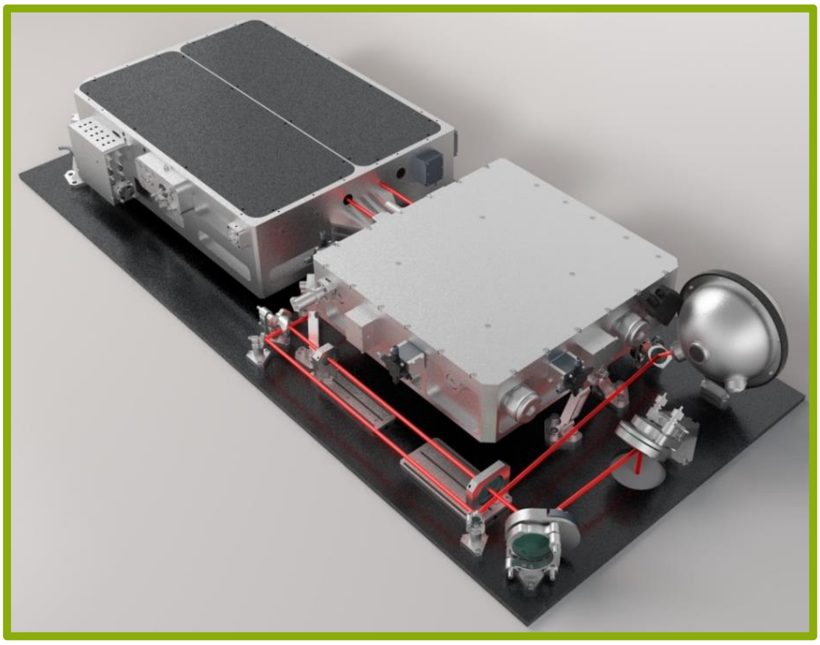

Figure 3: Emitter mechanical design

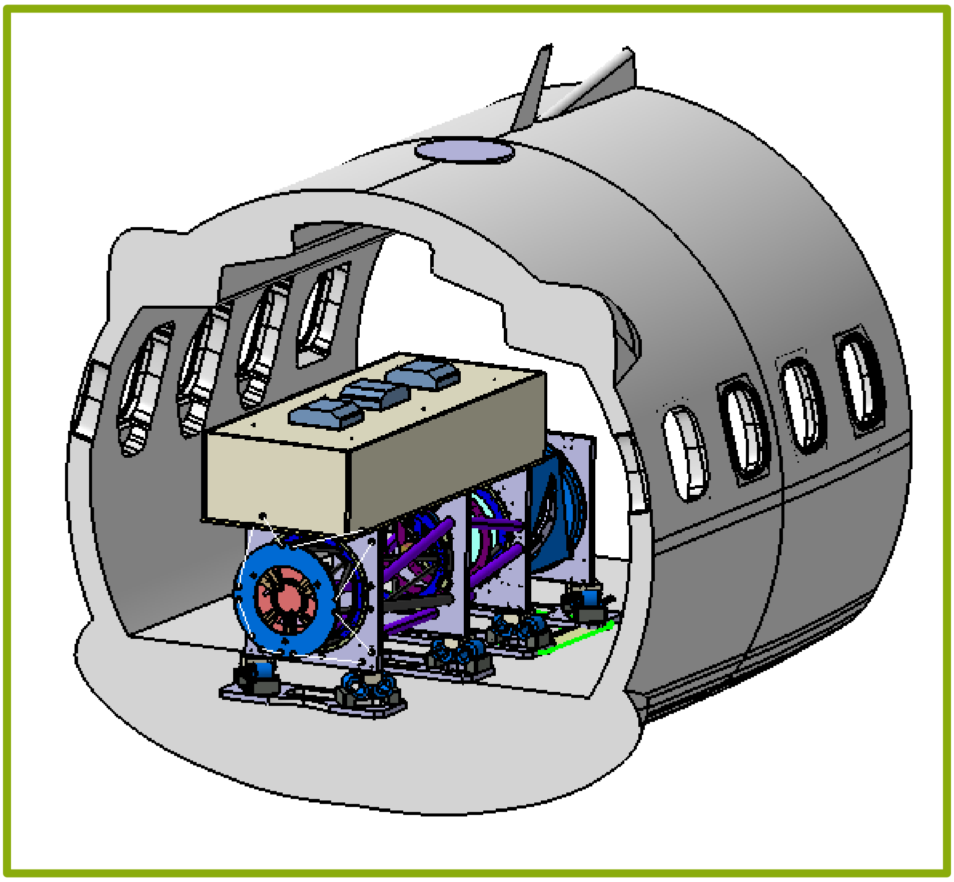

Figure 4: Preliminary CAD of the implantation of the instrument within the aircraft

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement No 821868

Lidar: a Space Technology Expected to Shape the Next Decade

In 2020, the Association of European Space Research Establishments (ESRE) updated its White Paper first published in November 2017 in order to provide a further contribution to the Space Strategy implementation process for the decade to come.

In the new issue of the White Paper, ESRE defined the major trends in the Space sector and its main fields of activity. Earth observation is quoted among them, and particular relevance is given to "the possibility to monitor Greenhouse Gases (GHG) from space, through active lidar sensors".

Figure 5: Active Lidar sensors to monitor Greenhouse Gases (GHG) from space. ©ESA

These lidar sensor technologies are expected to represent a major breakthrough in environmental monitoring applications, to provide reliable measures from space where ground-based or airborne technologies are still limited. The ESRE White Paper even advocates for prioritising such technologies in the Copernicus roadmap.

The environmental monitoring market is currently driven by national and international organisations, although it is foreseen to be spread out in the coming years, mainly by the provision of high-resolution optical and radar imagery, with short revisit times that are suitable for local scale analyses. According to Technavio, "the satellite-based earth observation (EO) market size has the potential to grow by $ 4.51 billion during 2020-2024"[1].

The ESRE White Paper also mentions that an "enhanced combined use of space-based data with locally measured data is a potential that also has to be better exploited in the context of the Copernicus programme and is expected to be a key driver for the development of the space Earth observation market in the next years".

The versatility of the LEMON technology is in line with this need since the Differential Absorption Lidar (DIAL) sensor concept will be able to either measure CO_2, CH_4 or water vapour stable isotopes. The final design will fit in a rugged and compact architecture that would be compatible, after specific maturation for space, with satellite missions size requirements, but it may also be integrated in airborne or ground-based monitoring missions, as explained in the article "applications targeted with LEMON systems or sub-systems, LEMON LIDAR for the global sea level rise challenge" published in the LEMON Newsletter N°2.

In addition, within the LEMON project, the requirements for LEMON instruments were defined with available roadmaps such as the Copernicus report "Towards European operational observing system monitor fossil CO_2 emissions".

Beside, the LEMON project will build-up a roadmap towards a space-borne instrument, based on LEMON GFCU, and propose a new Earth observation space mission based on this versatile instrument and on the analysis of existing roadmaps and ongoing technological actions. This analyse will also include roadmaps generated in the framework of actions for the development of Key Enabling Technologies supported by the European Union, to take into account ongoing complementary developments in terms of 1µm pump lasers for space or specific detectors for space Lidar developments.

This shows that the LEMON project is in line with one of the main ESRE White Paper recommandations, e.g. "make a stronger use of commonly agreed technology roadmaps, in particular in the context of the EU's upcoming Horizon Europe research programme, in order to guarantee the timely availability of technologies needed for competitiveness and for tackling global challenges".

By Magali Mares (L-UP) and Myriam Raybaut (ONERA)

[1] Technavio, Jan2020, "Satellite-based Earth observation Market by Type, Application, and Geography - Forecast and Analysis 2020-2024"

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement No 821868

L-WAIVE: A WATER CYCLE CLOSURE EXPERIMENT IN THE ANNECY LAKE REGION

Focus on the L-WAIVE campaign that took place in the region of the Lac d'Annecy in June 2019 and relevance for the preparation of LEMON ground-based validation campaign

CNRS and UiB have conducted a preliminary analysis of the best location for the implementation of the ground-based campaign based on analysis the open questions on the topic of water vapor stable isotopes. The project was funded by a sister project WaVIL (Water Vapor and Isotope Lidar) funded by the French ANR (Agence Nationale de la Recherche).

The region of the Lac d'Annecy (Haute-Savoie, France) was selected as a potential site for performing such a preparatory campaign in the framework of LEMON.

A 2-week campaign, L-WAIVE (Lacustrine Water vApor Isotope inVentory Experiment), was conducted from the 10th to the 24th June 2019 to assess the variability of the main H_2O stable isotopes above the lake of Annecy and assess the contribution of advection versus evaporation processes, as well as the processing by clouds at the top of the boundary layer. The equipment deployed during the campaign consisted of:

- Two Ultra-Light Aircrafts (ULA): one being equipped with a H_2O/HDO Picarro cavity ring-down spectrometer (CRDS) and an in-cloud liquid water collector specifically developed for this experiment, the other ULA being equipped with a backscatter lidar among other instruments (fluxmeters, FIDAS optical counter, …);
- The instrumented truck from the Laboratory of Climate and Environmental Sciences at CEA (LSCE) equipped with a zenith pointing Weather Atmospheric LIdar WALI, as well as a wind lidar with the free scientific contribution of Université du Littoral Côte d'Opale (ULCO);
- A ship to make air isotopic measurements close to the surface, temperature profiles as well as liquid water samples at the interface and close 2 m depth.

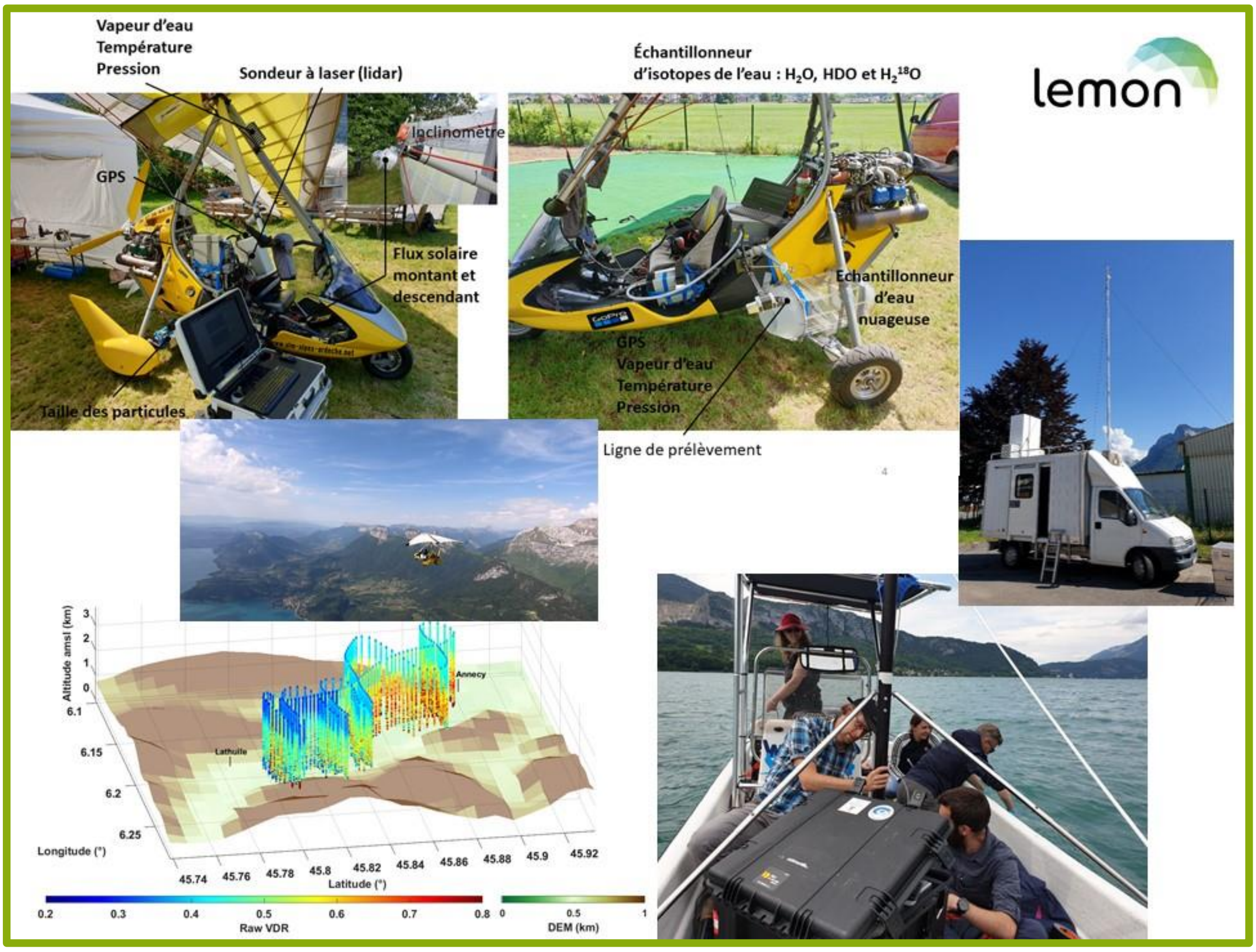

Figure 6: Overview of facilities involved in L-WAIVE

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement No 821868

The field experiment was implemented to design and test an experimental strategy to validate the LEMON instrument. For the first time, a cavity ring-down spectrometer dedicated to the measurement of H_2O/HDO (CRDS, Picarro™) and a cloud water collector were flown on an ULA (Figure 7).

All instruments were reported to have functioned nominally. Overall, the ULA embarking the CRDS conducted 16 flights, while the ground-based H_2O lidar WALI operated continuously (24h a day) between the 12th and 22nd June producing over 260 h of H_2O and temperature profiles up to 8 km agl during the night and up to 2 km agl during the day, as well as aerosols up to 10 km agl. In addition, UiB analysed the isotopic composition of nearly 60 bottled liquid water samples of precipitation (~20 samples), cloud water (~10 samples) and lake water (~30 samples).

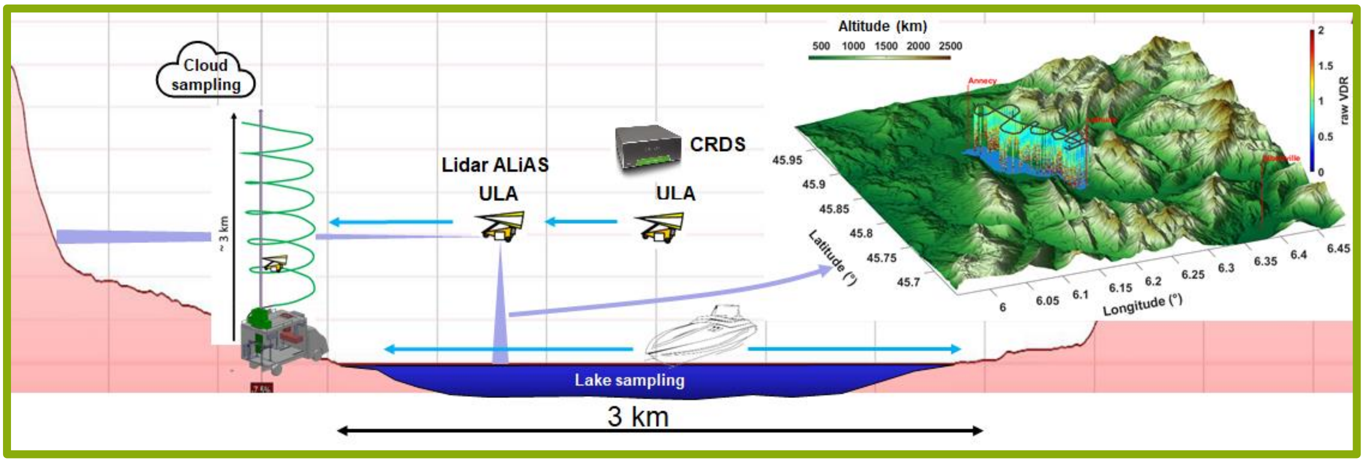

Figure 7: Illustration of the sampling strategy involving the ULA-borne H_2O/HDO CDRS and cloud water sampler around the ground-based WALI lidar and across the lake in the vicinity of a boat equipped with water sampling (probes and bottles)

Figure 8 illustrates the variability of δD measurements acquired over the Lac d'Annecy during the L-WAIVE campaign on 14th June 2019. In this day, the Annecy region was under impacted by long-range transport of Saharan dust. The ULA equipped with the CRDS conducted isotope measurements in the lower part of the dust plume present over the lac d'Annecy (above ~2 km amsl).

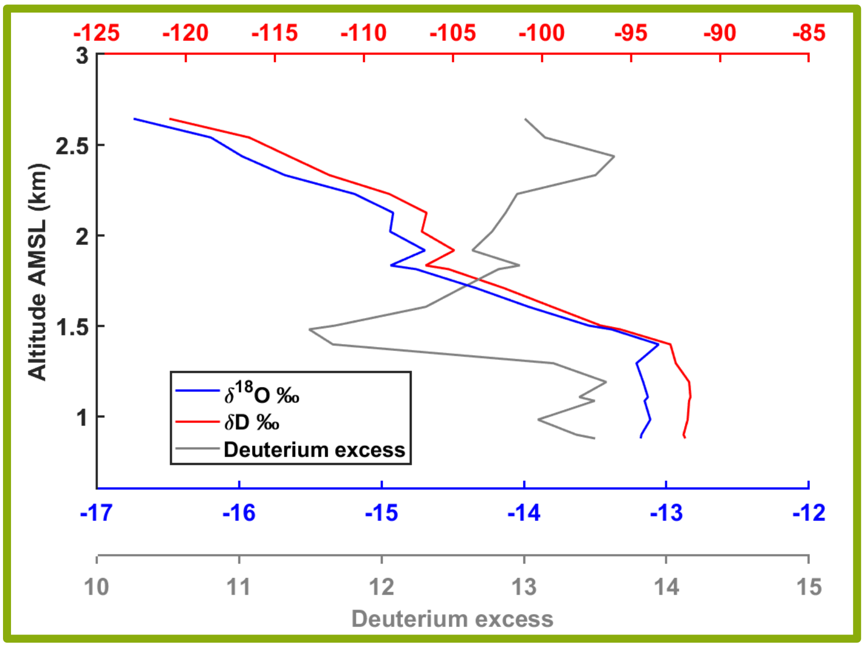

Figure 8: Vertical profiles of $\delta^{18}O$, δD and d-excess data acquired from the dedicated ULA during L-WAIVE on 14 June 2019

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement No 821868

The main results so far are:

- Characterisation of the water vapour isotopologues variability above and around the Lac d'Annecy. Closure analysis of water vapour H_2O/HDO over the Lac d'Annecy in the boundary layer, including surface forcing and process in the clouds at the top of the boundary layer;
- Implementation of strategies to optimize the inter-comparison of ground-based lidar H_2O profiles with airborne CRDS measurements;
- Calibration procedure of CRDS airborne measurements tested an ULA to be used as a test-bed for the preparation of the measurements on the ATR 42 aircraft;
- Qualification of the comprehensive H_2O/HDO dataset acquired during the L-WAIVE campaign over the Lac d'Annecy, organisation of the L-WAIVE wash-up meeting and roadmap for publication of the related dataset;
- Verification of the strategies to optimize the intercomparison of ground-based lidar H_2O profiles with airborne Picarro measurements,
- Validation of the calibration procedure of CRDS airborne measurements tested one of the ULA flown during L-WAIVE, to be used as a test-bed for the preparation of the measurements on the ATR 42 aircraft as well as other preparatory ground-based field campaign involving the UiB ULA-borne CRDS;
- Preparation of the LEMON end-to-end simulator for H_2O/HDO retrievals.

A publication providing an overview of the campaign as well as first highlights of L-WAIVE is currently being prepared by P. Chazette et al., and will be submitted at the end of 2020 to Atmospheric Environment.

A calibration procedure has been tested by UiB for CRDS measurements made on an ULA during the L-WAIVE campaign, using ground-based calibration before and after flights, and a long-term calibration from repeated injections of standard waters with a standard delivery module. A method has been tested for preparing standard vapour in 300 ml vessels, that are flushed with dry air, and then have a small amount of water added. Calibration tests with the vessel showed very stable calibration periods of 10 min, which will enable precise control of the instrument state also during flight. Future work will include building a setup that allows to switch between ambient vapour measurements and measurements from the gas vessel.

Overall, these calibration experiments indicate that prepared gas vessels can provide a robust calibration option on the ATR 42 aircraft in preparation of the airborne demonstration, but also for future ground-based campaigns involving the UiB CRDS instruments on ULA.

By C. Flamant (CNRS), P. Chazette (CNRS), H. Sodemann (UiB), Hans-Christian Steen-Larsen (UiB), Julien Totems (CNRS), Andrew Seidl (UiB), Daniele Zannoni (UiB).

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement No 821868

APPLICATIONS OF LEMON TECHNOLOGY IN MEDICAL IMAGING

Focus on potential LEMON application in other fields than space: LEMON sub-instrument can be used in photoacoustic imaging.

Photoacoustic imaging is a technic allowing to obtain images of biological tissues based on the photoacoustic effect. The photoacoustic effect is the formation of sound waves following light absorption in a material sample. The light delivers energy to the tissue which absorbes it causing an expansion that generates ultrasound waves.

Photoacoustic imaging allows to map the optical absorption coefficient of tissue, by pairing a pulsed light source with an acoustic detector. Various types of lasers and ultrasound receivers can be integrated into a photoacoustic system depending on the imaging application.

Photoacoustic is an emerging biomedical imaging with an immense potential for clinical application since it allows high resolution, sufficient imaging depth, with diverse endogenous and exogenous contrast, and is free from ionizing radiation. With the development of this technologies, the potential applications are increasing rapidly from brain functional imaging to breast cancer screening and much more including diagnosis of psoriasis and skin lesions, biopsy and surgery guidance, the guidance of tumor therapies at the reproductive and urological systems, as well as imaging tumor metastases at the sentinel lymph nodes.

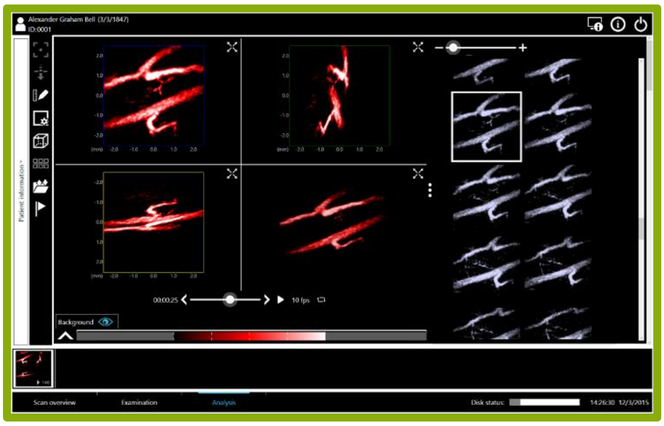

Figure 9: Photoacoustic (PA) imaging example

The advantage of photoacoustic imaging compared to traditional ultrasounds, lays in the fact that it is possible to generate a 3D topographical image with chemical specificity. Because of the wavelength dependence of absorption in tissue, the 3D topographical image is obtained by using a tunable laser.

Tunability also allows a deeper penetration by minimizing absorption by intervening tissues while targeting a specific tissue type. The advantage of photoacoustic imaging compared to other optical techniques is, therefore, the limitation of light scattering in the tissues, allowing high resolution, while being non invasive.

Thanks to the use of Optical Parametric Oscillators (OPO), many photoacoustic imaging systems allow wavelength tunability, so a single device can serve multiple applications.

The LEMON partner INNOLAS developped an OPO allowing to get a deeper view thanks to the high speed tunability.

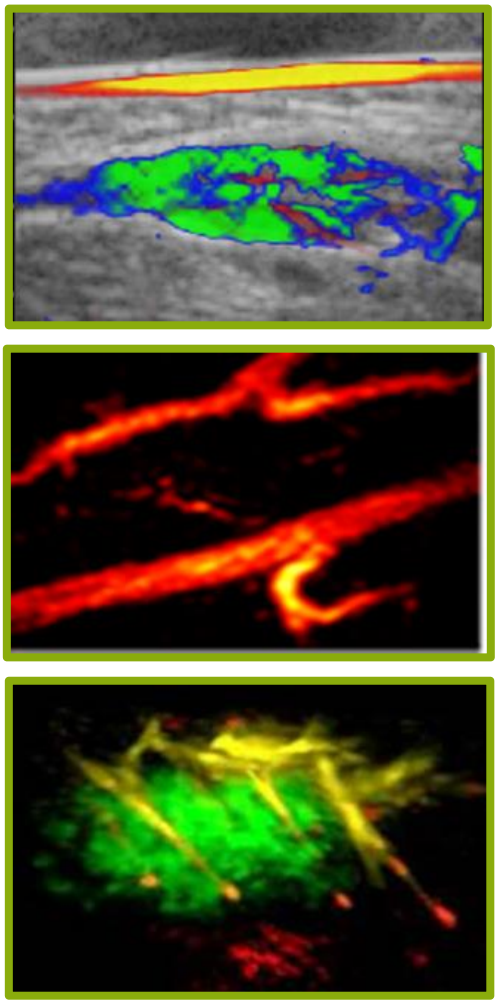

Figure 10: from top to down, PA tomography, PA microscopy, PA endoscopy

During the LEMON project, significant improvements will be brought to the emitters and OPOs in term of output energy and wavelength tunability, which could highly benefit to the medical imaging field in the future.

By Magali Mares (L-UP), Stephan Rapp (Innolas).

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement No 821868

GET TOGETHER LIST

19TH INTERNATIONAL CONFERENCE LASER OPTICS - ICLO 2020, ST.PETERSBURG, RUSSIA, 2-6 NOVEMBER 2020

The International Conference Laser Optics takes place biennially in Saint Petersburg, Russia. This is a traditional scientific event in the field of laser physics, optics, and photonics, which attracts more than 1000 attendees from all over the world.

Due to the COVID-19 crisis, the 19th International Conference Laser Optics, initially planned in June 2020, has been postponed and will take place between the 2nd and the 6th November 2020.

LEMON consortium partner Valdas Pasiskevicius from KTH is the organiser of the Green Photonics session, including LIDAR technologies, during which invited talks from LEMON will take place.

ONERA representatives, Myriam Raybaut and Jean-Michel Melkonian, will give a talk on LEMON during this event.

Source: https://www.laseroptics.ru/

INTERNATIONAL CONFERENCE ON SPACE OPTICS - ICSO 2020, ANTIBES JUAN-LES-PINS, FRANCE, 29 MARCH-2 APRIL 2021

The International Conference on Space Optics - ICSO 2020, initially planned between the 19th and the 23rd October 2020, was postponed and will take place from the 29th March to 2nd April 2021 in Antibes Juan-les-Pins, France.

ICSO 2020 is the 13th edition of the largest meeting worldwide of experts working in all disciplines of Optical, Optoelectronic and Photonic Technologies for Space Applications. The purpose of ICSO is to bring together the Space Optics Community and exchange information and ideas on the Research, Development, Qualification and Flight Experience of using optical technologies for space missions.

During this event, SpaceTech will give a presentation on the LEMON Fequency Reference UnIT (FRUIT), whereas ONERA will give a talk about the LEMON Instrument design.

Source: https://icso2020.com/

20TH COHERENT LASER RADAR CONFERENCE - CLRC 2020, GARMISCH PARTENKIRCHEN, GERMANY, 8-13 NOVEMBER 2020

The 20th COHERENT LASER RADAR CONFERENCE, initially scheduled between the 8th and the 13th November 2020, was unfortunately cancelled. LEMON partners hope to attend the next edition of the event.

Source: https://clrc2020.besl-eventservice.de/front/index.php

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement No 821868

Interview

The ONERA team members involved in the LEMON project are listed as follows: C. Blanchard, M. Dalin, S. Duzellier, J.B. Dherbecourt, A.Godard, V. Lebat, J.M. Melkonian, Ph. Nicolas, R.Santagata, N.Tanguy, R. Chhun, M. Raybaut.

In this edition of the LEMON Newsletter n°3, we propose an interview with some representatives of the ONERA team: Myriam Raybaut (LEMON coordinator), Jean-Baptiste Dherbecourt (WP2 Leader), Marine Dalin, Rosa Santagata and Sophie Duzellier.

These tags will lead you into the interview: **Space System design, Optical Instruments, Lasers, Non-Linear Optics, Space Environment, gender equity.**

THE ONERA TEAM: MYRIAM RAYBAUT, JEAN-BAPTISTE DHERBECOURT, MARINE DALIN, ROSA SANTAGATA AND SOPHIE DUZELLIER

Question 1 (Myriam): ONERA is one of the most important research centers in Europe in the field of aeronautic and space. Can you present shortly the different ONERA units involved in the project?

Three different units from the space department (Physics, Space, Environment) are involved in LEMON. This allows to benefit from the know-how and knowledge of scientists working in the optics domain, mechanics domain, and space environment domain. The people involved in LEMON over these units are working hand in hand, and this complementarity is necessary to achieve the goal of realization of a multi-disciplinary instrument. Moreover, we also benefit from the support of colleagues to help us for the purchases, the financial management aspects, as well as quality aspects.

Question 2: Myriam, as LEMON Project Coordinator, you endorse many responsabilities and tasks: can you summarise your main activities in the project?

As coordinator, I have to monitor all technical workpackages advancements, be able to analyze and measure the effect of a delay on one task on all the others, keep a vigilant eye on the risks and on intellectual property rights issues. This would not be possible without the help of the workpackage leaders, who are doing a tremendous job. I also have to deal with the management and dissemination aspects, for which L-UP is of great support. I am a scientist and I am still strongly involved in the technical developments, especially concerning the non-linear optics developments, as well as the Lidar conception and testing. With my colleagues, I am involved on a day-to-day basis in experimental characterisations and tests.

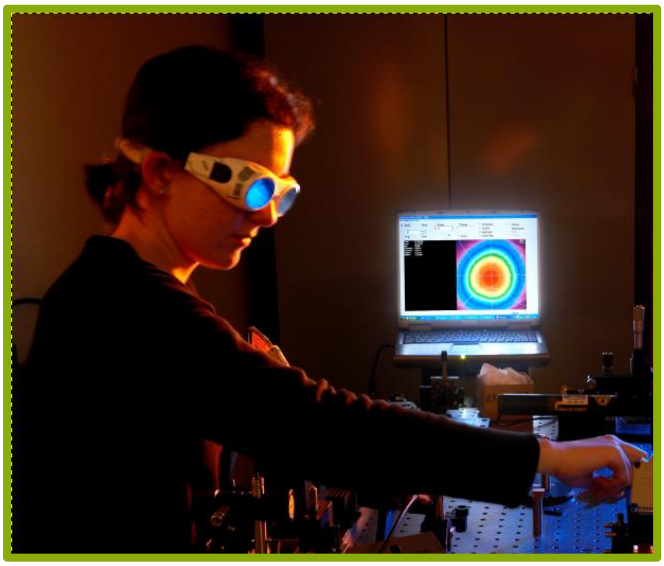

Figure 11: Myriam Raybaut the LEMON coordinator.

Question 3 (Jean-Baptiste): As presented in the first article of the present newsletter, the LEMON system Mechanical Readiness Review has been achieved. What were the main challenges leading to this milestone?

The main challenges were to be able to keep the versatility of the instrument: on the one hand multi-species capability, and on the other hand operation from the groung in range-resolved DIAL mode as well as airborne operation. This leads to technical compromises.

The airborne environment operation is also a challenge, for which we did our best to be successful, with the help of our mechanical engineers colleagues at Onera, Marine Dalin and Vincent Lebat, as well as with the help of our partners at Fraunhoffer ILT, Innolas, KTH, and SpaceTech.

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement No 821868

When you design a high energy laser, you also have to keep an eye on the laser induced damage threshold issues. To assess the optical design, laboratory testbeds are necessary. We were lucky to have the French ANR project WAVIL for which we had already developed a laboratory testbed allowing to test some Lemon sub-systems.

Over the next weeks and months we will go on pursuing test experiments, including with the FRUIT or on the receiver aspects.

The interfaces are also something we are dealing with carefully, both for the mechanical aspects as also the optical and electronical aspects.

Question 4 (Myriam and Jean-Baptiste): As the technology design is frozen now, what are the next main steps towards the achievement of the LEMON Differential Absorption Lidar (DIAL) sensor concept able to measure CO_2, CH_4 and water vapour stable isotopes (H_2O and HDO) with a single laser emitter?

In the next months, in continuity with the Mechanical Readiness Review, we will work hand in hand with our partner CNRS/Safire to refine some points to move towards the certification for airborne operation.

The next monthes will also be dedicated to the realization and assembly of the emitter. This will be a key point to assess the future instrument multi-species capability. The main idea is not to perform simultaneous measurements on all the targetted species, but on some key couples such as water vapour and its isotope HDO, or CO_2 and water vapour. For all species including methane, the idea is to demonstrate that the emitter can adress those species, to show that future develeopment of an emitter based on such technology would only need a single maturation phase towards space (which is costly) for different future space missions.

Question 5 (Myriam): How do you plan to link the developments within LEMON and the market?

As a laboratory, over the last few years our developments in terms of parametric sources led to two technology transfers. This is also the case for several partners, such as KTH. Keeping in mind the potential of our technolgies for other fields of application or for potential technolgy transfers is part of our job. Before beeing able to think about technology transferts of LEMON developments, we have to assess performances of the instrument, of some sub-systems or of some more preliminary and promising concepts we are testing in parrallel. I know that our industrial partners are constantly analysing the market opportunities.

Question 6 (Myriam): How did you handle the COVID-19 crisis and which measures were taken to mitigate its impact on the LEMON project?

In fact, working within a European project gave us before hand means and methods to keep an efficient workflow from different locations. In the framework of, for instance, DIAL development, for which several partners are involved in several sub-systems, we are used to have frequent audio and visioconferences between the involved partners and teams to ensure the workpackages advancement. As lock-down measures were declared in several countries, access to the laboratories was limited and moreover some of our suppliers were also impacted. We estimate that this induced a 6-month delay on the overall project.

Question 7 (Myriam, Marine, Rosa and Sophie): Several women are part of the ONERA team, including the Project Coordinator, which is – unfortunately - still quite unusual in this research field. Does ONERA apply any specific gender policies? Within the LEMON project, are there any measures to enhance gender equity?

Onera does not apply specific gender policies. However, fair carreer consideration between genders is applied during recruitment. In this project, indeed, several women are involved, which is great not because they are women, but first hand because they are great at their jobs!

This project has received funding from European Union’s Horizon 2020 research and innovation programme under grant agreement No 821868