NEWSLETTER °2
APRIL 2020

Welcome to the Newsletter n°2 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.

Dear Reader,

We hope this Newsletter finds you and your families well and healthy in these uncertain times.

We are happy to release the LEMON Newsletter n°2, which will provide interesting insights about the project latest progress and news throughout these much-needed restrictions stemming from the COVID-19 pandemic.

We remain available for any questions or feedback on the LEMON project on a permanent basis.

Let us all stay safe and informed!

Word of the Coordinator

Times of crisis, like we are facing now, naturally make us question ourselves, our work, our purpose. They also make us see more clearly our responsibilities as citizens, colleagues, neighbours, parents. During these times, working towards achieving LEMON project goals is our humble way to serve our fellow European citizens. Although many of us are working from home, although adaptations in the way we interact had to be done, although some delay might arise from the situation, we are all still dedicated to this project, as you will discover by reading our second newsletter.

Dr. Myriam Raybaut
Research engineer
ONERA – France

NEWS & EVENTS

LEMON presentation leaflet is now downloadable:
>> Downlaod the pdf

LEMON presentation poster is now downloadable:
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CONTACT US

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

Project website: www.lemon-dial-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.

THE LEMON INSTRUMENT DESIGN

Over the last year, the overall consortium has been implicated in the requirements definition for our water vapour, HDO isotope, and other greenhouse gases (CO_2 especially) differential absorption Lidar (DIAL). Such observation platform development is in line with the latest European Space Research Establishments Association (ESRE) white paper.

Our methodology was based on frequent interactions to ensure a proper work flow. After more than twenty specific technical meetings, mostly by audio or visio-conference, including four in-flesh meetings at partners sites, several achievements were realised:

- The refined instrument and sub-system specifications, resulting in two project deliverables.
- The instrument and its sub-systems design, resulting also in two project deliverables.

An optical critical design review (Optical CDR) took place at T0+9 months (September 2019).

The overall instrument critical design review (CDR) was performed at M12 during the review meeting in January 2020, in Palaiseau, France. There are still a few remaining open points concerning the mechanical design, which we continue to refine in order to ensure a proper mechanical stability with respect to the airborne environment.

Figure 1 shows the LEMON instrument block-diagramme.

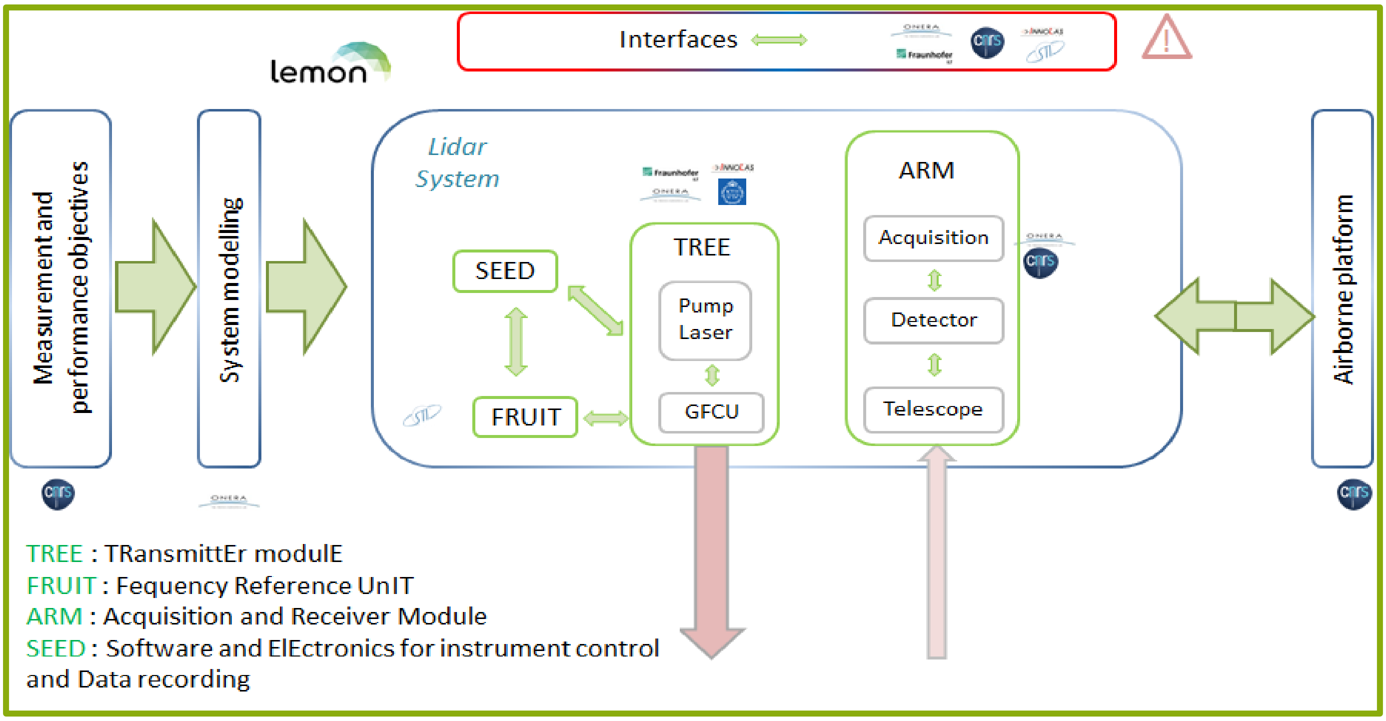

Figure 1: *LEMON DIAL architecture.*

Our mechanical approach is based on a “generic” receiver platform, which will enclose an achromatic receiver unit, on which the transmitter (TREE) can be plugged. Control units and Frequency Reference unit (FRUit) will be placed in adjacent electronics bays. We offer you hereafter (Figure 2) a first glimpse at this receiver platform.

After the last mechanical design refinement, we hope to move towards fabrication in the next weeks!

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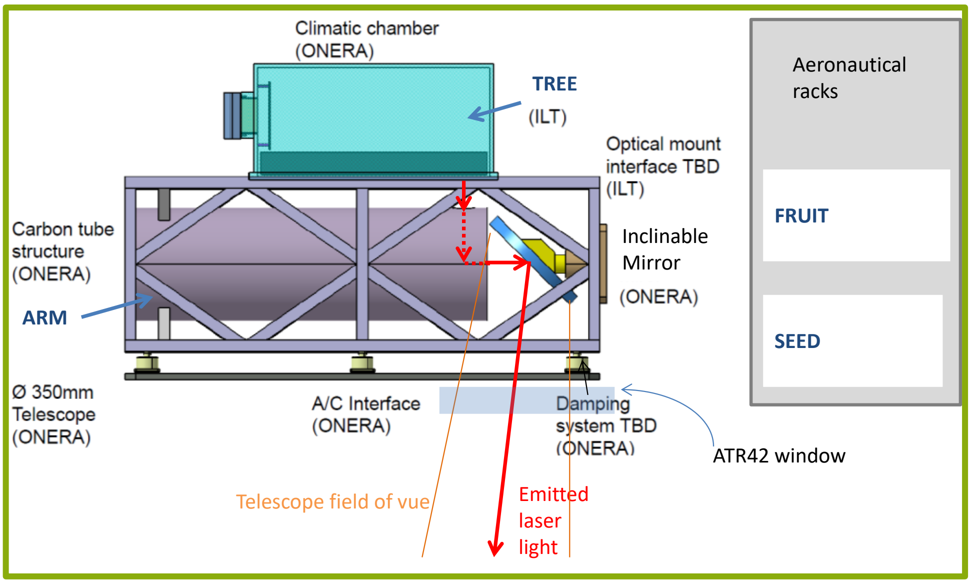

Figure 2: *LEMON DIAL instrument preliminary assembly.*

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

EXISTING LIDAR APPLICATIONS IN THE SPACE SECTOR

The first spaceborne LIDARS

The first spaceborne lidar system **LITE (Lidar In-space Technology Experiment**, NASA) was flown onboard the US Space Shuttle Discovery in September 1994 during 11 days. The lidar was pointing towards the Earth from the open cargo bay from an altitude of 240 km. The system has been designed to observe clouds, tropospheric and stratospheric aerosols, characteristics of the planetary boundary layer, and stratospheric density and temperature perturbations with much greater resolution than available from current orbiting sensors. Measurements in the atmosphere were made at 1064 nm, 532 nm and 355 nm.

The **Geoscience Laser Altimeter System (GLAS)** was the first lidar instrument to be flown on a spacecraft (ICESAT) 600 km above the Earth, for continuous global observations of Earth from January 2003 to June 2005. ICESAT's primary objectives were to determine the mass balance of the polar ice sheets and their contributions to global sea level change, and to obtain essential data for prediction of future changes in ice volume and sea level. Secondary objectives were to measure cloud heights and the vertical structure of clouds and aerosols in the atmosphere, to map the topography of land surfaces, and to measure roughness, reflectivity, vegetation heights, snow-cover, and sea-ice surface characteristics. Measurements were made at 1064 nm and 532 nm.

CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) is a two-wavelength polarisation-sensitive lidar that provides high-resolution vertical profiles of aerosols and clouds since April 2006.

Figure 3*: Lidar LITE system installed in the cargo bay of the space Shuttle Discovery.*

CALIOP utilises three receiver channels: one measuring the 1064 nm backscatter intensity and two channels measuring orthogonally polarised components of the 532 nm backscattered signal. CALIOP flies on the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite in order to provide new insight into the role that clouds and atmospheric aerosols play in regulating Earth's weather, climate and air quality. CALIOP has now gathered nearly 14 years of data from a

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nominal orbital altitude of 705 km and is still operating.

The latest addition to the series of spaceborne laser remote sensing systems dedicated to the study of the atmosphere is the **Doppler wind lidar ALADIN** which was launched in August 2018 onboard the spacecraft Aeolus. It is the first satellite mission to acquire profiles of Earth's wind on a global scale to improve the accuracy of numerical weather and climate prediction and advance our understanding of tropical dynamics and processes relevant to climate variability. In addition, ALADIN will provide information on cloud top heights, vertical distribution of cloud and aerosol properties. ALADIN is operating 355 nm, from an altitude of approximately 320 km.

By Cyrille Flamant (CNRS)

LIDAR technology for space operation at Fraunhofer ILT

Besides carbon dioxide, the long-lived molecule methane (CH_4) contributes effectively to the greenhouse effect and global warming. The methane concentration in the atmosphere has been increasing for many years. For efficient climate protection, it is now necessary to identify the methane sources and to reduce emissions as far as possible in the future. Against this background, the German-French climate research mission MERLIN (Methane Remote Sensing LIDAR mission) was initiated in 2010. The small satellite MERLIN is scheduled to be launched in 2024 and will map the methane in the Earth's atmosphere.

Figure 4*: Artist's rendition of the deployed MERLIN spacecraft (image credit: CNES, DLR).*

Core of the satellite is a LIDAR system, which sends light pulses in the atmosphere and from the back-scattered light from the ground determines the methane concentration with high precision and unprecedented accuracy on a global scale. With national and international partners like ESA, DLR, Airbus Defence and Space, Safran-REOSC, TESAT Spacecom, von Hörner & Sulger and SpaceTech, Fraunhofer ILT has been developing for many years technologies for space-qualified laser. A special task lies in the development of the laser system for the MERLIN mission.

Fraunhofer ILT, together with Airbus Defence and Space, on behalf of European Space Agency (ESA) and with the support of the DLR Space Administration, developed the "Future Laser System" (FULAS), a technology platform for the design and construction of individual laser systems. Through manufacturing processes, such as special soldering, components are made suitable for space operation.

Figure 5: *Optical parametric oscillator realised by soldering ©Fraunhofer ILT, Aachen, Germany.*

An appropriately developed assembly technology allows precise, safe and efficient assembly. As part of the MERLIN mission, a LIDAR system is built based on the FULAS platform. The requirements to the system, that has to operate reliably and maintenance-free for at least 3 years in space, are extremely demanding. It must be able to withstand vibrations up to 25 grms and thermal cycles from -25°C to +50°C. Organic materials, such as adhesives, should be avoided as these outgas and high-purity mirror surfaces can be contaminated.

The LIDAR laser is composed of a laser oscillator with active length control, an INNOSLAB amplifier and a length-controlled OPO as frequency converter. The generated radiation must be limited in bandwidth and switchable in wavelength, the efficiency as high as possible and at low load on the optical components. The system generates 9 mJ double pulses at two close wavelengths around 1645 nm, one of which stabilised on a characteristic methane absorption line.

Currently, Fraunhofer ILT is in phase C/D and, after close-out of the Critical Design Review (CDR), Fraunhofer ILT will start to build one Engineering Qualification Model (EQM) and one Flight Model (FM) of the final laser system.

More information can be found at: https://directory.eoportal.org/web/eoportal/satellite-missions/m/merlin. The MERLIN project (FKZ: 50EP1601) is funded by the Federal Ministry for Economic Affairs und Energy BMWi and managed by the DLR Space Administration.

By Bastian Gronloh, Hans-Dieter Hoffmann and Michael Strotkamp (Fraunhofer ILT)

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

FIRST RESULTS OF THE FRUIT MANUFACTURING

In order to obtain accurate column-integrated greenhouse gas concentrations from DIAL measurements, the knowledge of the emitted laser wavelengths is important. For the LEMON instrument, the task of measuring the laser pulses sent out by the transmitter module is delegated to the so-called Frequency Reference UnIT (FRUIT). The key task of the FRUIT is to provide a reliable and traceable frequency standard across a large spectral range (1.98 to 2.3 µm). The ruler which the FRUIT employs to measure the frequencies is based on a frequency comb. A frequency comb-based solution suggests itself when considering the broad spectral range required by the LEMON instrument and the universal approach for the generic frequency conversion unit (GFCU) developed for generating the LIDAR pulses. Wavelength conversion or expansion is intrinsically required for the stabilisation of a frequency comb and straightforward to implement. Due to ultra-short pulse durations and high peak powers associated with the mode-locked laser producing the frequency comb, nonlinear wavelength conversion in bulk and more efficiently in fiber or waveguides is possible. The frequency comb acts as a transfer oscillator to transfer the stability and accuracy of a GPS disciplined oscillator into the optical domain.

In the early phase of the LEMON project, before starting with the procurement, first tests were required in order to settle the baseline concept and to minimise the development risks associated with the approach. In close cooperation with Menhir Photonics, a 1 GHz laser was successfully evaluated. By now, a laser with a specific repetition rate and repetition rate tunability has been procured, matched to the expected operation condition in the airplane,. Together with an amplifier and suitable dispersion compensation, the nonlinear spectral broadening stage has been implemented and the required spectral coverage has been reached. Using the octave spanning spectrum, a first implementation of measuring and stabilisation of the offset frequency has been successfully implemented. Together with measurement and stabilisation of the repetition rate, this gives full control of the degrees of freedom of the frequency comb and absolute knowledge of the frequency of the frequency comb modes.

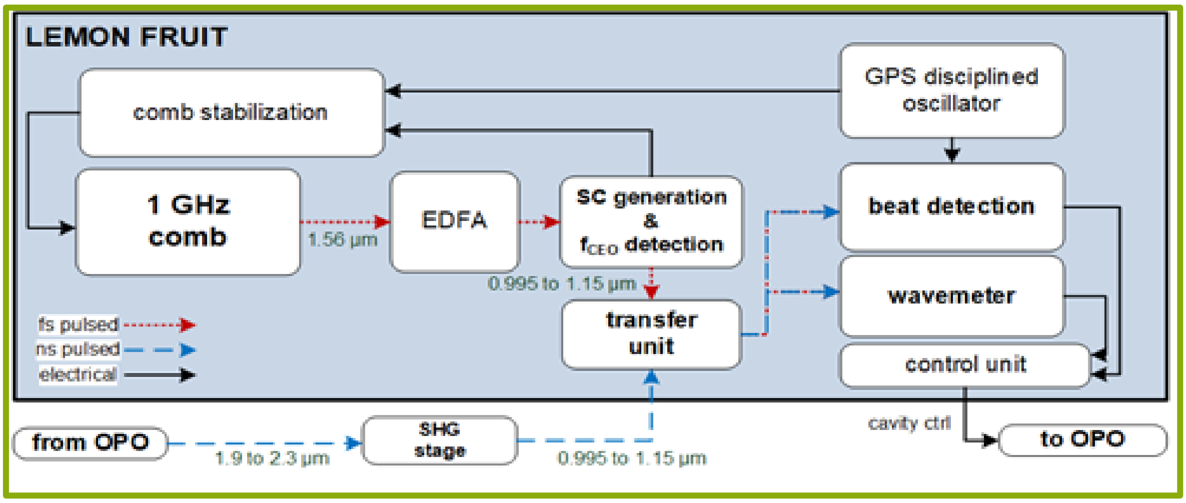

Figure 6: *Schematic of the FRUIT: The output of the laser is amplified in an erbium-doped fiber amplifier (EDFA). After dispersion compensation, a supercontinuum (SC) is generated spanning an octave and covering the LIDAR spectral range. One part of the supercontinuum is split off for detecting of the carrier envelope offset frequency of the comb. The second part of the supercontinuum is filtered and overlapped with the light from the optical parameter oscillator (OPO). The OPO pulses are frequency doubled (SHG: second harmonic generation) to shift the detection to 1 µm, which allows to use standard silicon detectors. With a fast analog-to-digital converter, the heterodyne beat signal between comb mode and OPO pulses is sampled. Together with a wavemeter measurement, the control unit can determine the absolute frequency of the OPO pulse. This value is used for data analysis, but also for providing a cavity control signal for stabilisation of the OPO.*

Besides the development of the FRUIT for the LEMON airborne instrument, the current activities also cover the development of a space compatible design of the FRUIT. This involves in particular the identification of components which are critical with respect to the space environment, an assessment on their suitability, and if required, to provide alternative solutions. In addition, a route towards a higher integration level is paved. Environmental testing will be performed with respect to compatibility of components and subsystems,. This includes thermal-vacuum, vibration and shock testing of components and subunits as well as radiation testing of components like crystals and fibres. A step towards the development of a spaceborne system is the investigation of waveguide devices for nonlinear frequency conversion instead of using fibre and bulk material.

For an in-depth review on the LEMON FRUIT please refer to our White Paper published on the LEMON website.

By Hanjo Schäfer and Dirk Heinecke (SPACETECH)

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

APPLICATIONS TARGETED WITH LEMON SYSTEMS OR SUB-SYSTEMS

LEMON LIDAR for the global sea level rise challenge

The Mass Balance of the Greenland Ice Sheet – have we missed an important factor?

What is the influence of water vapor deposition and sublimation on the total mass balance of the Greenland Ice Sheet?

Due to its impact on global sea level rise, the mass balance of the Greenland Ice Sheet has been studied extensively over the last several decades. However, this research has primarily focused on the processes responsible for melting at the margins and calving of icebergs into the ocean. Surprisingly, the net amount of mass accumulated in the interior of Greenland either through deposition or condensation directly on the surface, or lost due to sublimation, *is essentially unconstrained*.

The lowest part of the atmosphere, known as the planetary boundary layer, is the media through which the surface of the Earth is interacting with the atmosphere. The layer is governed by turbulent mixing and has a thickness of 100 to 1000 meters above the ice sheet. The turbulent mixing transports water vapor from the surface to the free troposphere during sublimation and evaporation and in opposite direction during condensation.

At the interface between the planetary boundary layer and the free troposphere, water vapor is exchanged through a process called entrainment exchange. However, the questions are: how much water vapor in the boundary layer above the ice sheet is exchanged with the free troposphere? Does the entrainment exchange between the planetary boundary layer and the free troposphere result in a significant mass loss or a mass gain? The answers to these questions are critical for projections of future global sea level rise. But how do we measure and quantify the processes in the extreme conditions experienced on top of the Greenland Ice Sheet?

Measuring water vapor content across the interface of the planetary boundary layer and free troposphere does not allow quantification of the entrainment exchange as this represents an underdetermined problem. Using the water vapor isotopologues ($^{1}H_2{}^{18}O$ and $^{1}H^{2}H^{16}O$) of the moisture in the free troposphere and boundary layer as independent measurable quantities we can constrain this problem. These isotopologue quantities are conserved during mixing, which will allow us to solve the system of equations coupled to the entrainment exchange processes. The challenge is to measure the water vapor isotopologues with sufficient precision across the interface of the boundary layer and free troposphere.

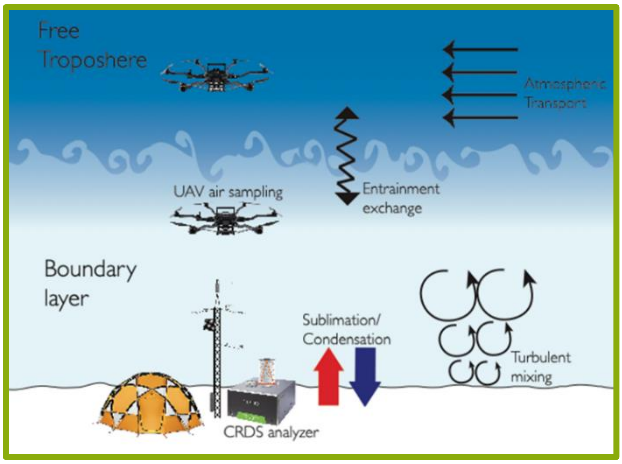

***Figure 7**: Infography from the the joint project between University of Colorado and University of Bergen, aiming at measuring the water vapor isotopologues across the interface of the boundary layer and free troposphere by using UAVs above the Greenland Ice sheet.*

A joint project led by Bruce Vaughn, University of Colorado, and Hans Christian Steen-Larsen, University of Bergen, with support from US NSF, has started to tackle these big questions and measurement challenged by using UAVs above the Greenland Ice sheet. The UAV brings air samples from up to thousand meters above the ground down for analysis using field-deployable cavity-ring-down-spectrometer (CRDS) analysers.

However, with the LEMON LIDAR it will in the future be possible to measure the vertical distribution of water vapor isotopologues. This will not only simplify the very cumbersome measurements that is currently being done with UAVs, but it would also significantly expand the details with which we can map and quantify the processes controlling the exchange between the boundary layer and the free troposphere. This opens up a complete new series of research questions that can be addressed.

By Hans Christian Steen-Larsen (UiB)

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

Methane-LIDAR for pipeline inspection

Detecting leaks in gas pipelines previously required walking along the pipeline with hand-held gas detection devices. This laborious process is now a thing of the past, since the company Open Grid Europe (OGE) operates CHARM®. It is a laser-based system integrated into a helicopter that flies along the pipeline while the system scans the pipeline corridor and identifies even the tiniest gas leaks. The name stands for "CH_4 Airborne Remote Monitoring", i.e. the LIDAR based remote detection of methane from the air.

For several years, OGE has been operating this first generation CHARM® to detect leaks in gas pipelines. Now, using the INNOSLAB concept, Fraunhofer ILT has designed and built a more powerful beam source with a ten-time higher pulse repetition rate and other advantageous properties – such as a double pulse mode adjustable over a wide range. The use of a helicopter requires not only a compact, weight-saving construction, but also high robustness, both in operation as well as during transport and storage. Several measurement campaigns served to prove that these properties are feasible.

After the specified laser features were checked, a load-free continuous test was first carried out in the laboratory environment in which relevant temporal, spatial and energy parameters were monitored. Subsequently vibration and shock tests in all spatial axes were conducted with the beam source. Operational and non-operational stress scenarios (e.g. excitation frequencies and bandwidths, shocks) were simulated and relevant laser parameters measured after or during the trial.

The beam source has successfully passed all tests and shows no relevant changes in beam characteristics. Thus, the tests have demonstrated fundamental suitability for the intended use. After temperature tests have been conducted, the client has supplemented the beam source with a frequency converter for methane detection and subsequently incorporated it into the second generation CHARM LIDAR system.

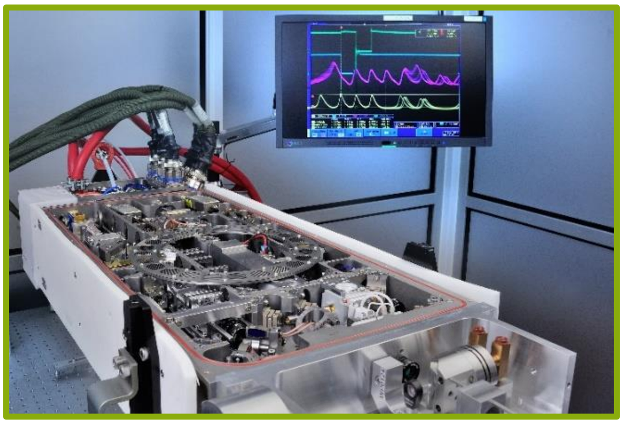

Figure 8*: ©Fraunhofer ILT. Laser for the next generation of the CHARM LIDAR system.*

These kind of beam sources and the construction technology used can be deployed for numerous LIDAR measurement tasks, for example, wind speed measurements, detection of water vapor, methane, CO_2 and emissions measurements from industrial plants and traffic. Generally, these applications require a mobile application, thereby causing the associated loads upon the beam source. The results are also relevant for the development of other lasers for use in industry and medical technology.

By Michael Strotkamp, Marco Höfer, Benjamin Erben (Fraunhofer ILT)

Figure 9: *BO 105 helicopter on which Open Grid Europe currently operates the CHARM Lidar System for Pipeline Monitoring.*

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

GET TOGETHER LIST

Important note: unfortunately, due to the COVID-19 pandemic outbreak, and in light of travel and health concerns, the organisation of the events listed below might be affected. Please refer to the related websites for more information.

EGU2020: SHARING GEOSCIENCE ONLINE, 4-8 MAY 2020

The annual EGU General Assembly is Europe's largest and most prominent geosciences event. It attracts more than 16 000 scientists, more than half of which are early career, from all over the world.

Due to the COVID-19 crisis, the European Geosciences Union (EGU) General Assembly 2020 has been converted into *EGU2020: Sharing Geoscience Online,* which will take place from 4 to 8 May. The online programme for the week focusses on inter- and transdisciplinary sessions, disciplinary sessions, Union symposia and debates. Short courses and other events will take place in different formats. The meeting's sessions cover all disciplines in the Earth, planetary and space sciences.

LEMON partner CNRS will be present at the event with an online lecture.

Source: https://www.egu2020.eu/

19TH INTERNATIONAL CONFERENCE LASER OPTICS - ICLO 2020, ST.PETERSBURG, RUSSIA, 8-12 JUNE 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.

LEMON 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, held by e.g. ONERA representatives.

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

INTERNATIONAL CONFERENCE ON SPACE OPTICS - ICSO 2020, ANTIBES JUAN-LES-PINS, FRANCE, 19-23 OCTOBER 2020

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.

Several LEMON partners have submitted abstracts to hold extended speeches on different aspects of the LEMON project. SPACETECH will present the Frequency Reference UnIT (FRUIT); ONERA will focus its lecture on the LEMON Istrument design.

Source: https://icso2020.com/

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

The CLRC 2020, initially planned from 28 June to 03 July 2020, will be postponed due to COVID-19 crisis and will take place from 08 to 13 November 2020 in Garmisch-Partenkirchen, Germany.

Scientists, researchers, engineers, manufacturers, and decision makers from all over the world will be gathered at CLRC 2020. All presentations held will cover the areas of coherent and direct detection wind lidars and related topics.

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

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Interview

In this edition of the LEMON Newsletter n°2, we propose an interview with two representatives of the SPACETECH team: Dr. Hanjo Schaefer, Project Manager and LEMON WP5 Leader, and Dr. Dirk Heinecke, Optical Engineer at the System Engineering Department at SPACETECH.

These tags will lead you into the interview: **space system - space flight hardware - spaceborne LIDAR - optical instrument - frequency reference unit - greenhouse gas - satellite constellation – COVID-19.**

THE SPACETECH TEAM: HANJO SCHAEFER, PROJECT MANAGER, AND DIRK HEINECKE, OPTICAL ENGINEER

Question 1 (Q1): SPACETECH is a German SME active in the field of space system development. How was SPACETECH involved in the LEMON consortium?

Answer 1 (A1)/Hanjo: At the International conference on Space Optics (ICSO) in 2016, we presented our first design and results on the frequency reference unit for the MERLIN mission. The MERLIN instrument is a similar type of instrument as LEMON but operates only at the single wavelength of 1645 nm for measuring methane. After our speech, Myriam [Raybaut, today's LEMON Project Coordinator from ONERA, *editor's note*] approached us and asked if we could envision getting involved in the LEMON project. From there on we started the discussions on how to extend the MERLIN design to meet the requirements for the multi-species system for LEMON and to contribute to the proposal.

Q2: What are the strengths of SPACETECH within the LEMON consortium?

A2/Dirk: Our experience in the design, manufacturing and testing of space-qualified flight hardware allows us to provide a reliable instrument subunit for the airborne campaign as well as to support the overall development towards a spaceborne LIDAR system. In terms of optical instrument design, we are used to start working from scratch with only a requirement preset. SPACETECH open-minded development approach allows us to identify the best suited solutions in terms of performance and budget. Developing a new system which has not been realised so far is a challenge we gladly accept. We further offer a lot of test and manufacturing capabilities in house, which speeds up the design iterations usually necessary for such new and complex systems.

"I like the design phase, when you iterate through the options you have to pin down the final solution. But I also enjoy putting the hardware together and it feels great when things start to come to life".

Q3: Within LEMON project, SPACETECH is WP5 leader and leader of several tasks (2.6, 3.6, 5.1, 5.4). Hanjo and Dirk, how much of your working time do you dedicate to the LEMON project? What is the part of your work on the LEMON project which is most exciting for you?

Figure 10: *Hanjo Schaefer (left) and Dirk Heinecke (right), respectively Project Manager and Optical Engineer at SPACETECH.*

A3/Dirk: On average, I spend about 50% of my working time on the LEMON project, although in the first couple of months, when the initial design phase happened, it was close to 100%. I like the design phase, when you iterate through the options you have to pin down the final solution. But I also enjoy putting the hardware together and it feels great when things start to come to life.

Hanjo: For me it's also about 50%. When it comes to reviews and other milestones this can increase due to the management efforts needed in order to prepare such events. I am also glad that even having the project management task on my side, I am able to spend a larger amount of time in the practical area of assembly and testing.

Q4: Task 2.6 "Frequency reference unit", led by SPACETECH, has just come to an end. Was the work achieved in line with the expectations? Have you encountered any particular difficulties?

A4/Dirk: In the first step, when we started to settle the requirements for the frequency reference unit

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together with Myriam and Jean-Baptiste from ONERA, it turned out that the design foreseen in the proposal would not be able to deliver the required performance. Therefore we had to find a way to modify the design but at the same time to keep the same budget. I think we have found a good solution which keeps up to the other parts of the instrument and does not compromise the overall system performance.

Q5: Could you explain in what extent WP5 "Components space qualification and sub-systems TRL improvement" plays a key role in view of the project outcomes? Why is SPACETECH the best placed partner to lead this WP?

A5/Hanjo: Global monitoring of GHGs requires spaceborne instruments. A well-judged TRL assessment is very important to pave the way for a spaceborne LIDAR instrument. Improving the TRL helps to reduce the risks on schedule and cost significantly. Therefore the results of WP5 will be key for future developments. SPACETECH has successfully designed, manufactured and delivered space flight hardware, from mechanical and electrical components up to instrument level units. This gives us a good understanding of the whole development process starting from the design phase up to the final integration. We want to incorporate this experience in the project as much as possible, so that the next developments can build on a strong groundwork. We believe that the LEMON project can show the way for the next generation of GHG LIDAR systems.

> *"With the advance of satellite constellations there might also be a growing demand for LIDAR systems to sample greenhouse gas concentrations with a higher temporal density. The developments within LEMON are an important setup to improve the versatility of the instruments. Consequently, the next steps beyond the project end will need to focus on compactness and simplicity."*

Q6: How does the work within LEMON correlate to contemporary trends in industry? How does SPACETECH plan to bridge the gap from the lab to the market?

A6/Dirk: The demand for LIDAR and more generally laser systems in space is growing. Many systems are used on scientific missions, and as such, single piece developments are required. On the other hand, a mass market already exists in the field of laser communications. With the advance of satellite constellations there might also be a growing demand for LIDAR systems to sample greenhouse gas concentrations with a higher temporal density. The developments within LEMON are an important setup to improve the versatility of the instruments. Consequently, the next steps beyond de project end will need to focus on compactness and simplicity.

Q7 : The recent COVID-19 outbreak is causing severe situations worldwide, and several countries have taken isolation measures to counter the pandemic. Which are the most significant impacts of this situation on SPACETECH's activities within the LEMON project?

A7/Hanjo: Our executive board made the decision to check whether SPACETECH has any possibility to support the health care system. Within this framework, we are in strong exchange with a medical team of the University of Marburg & Gießen to investigate the possibility to provide respirators for COVID-19 patients, in case all conventional respirators won't suffice. We built a first demonstrator and are now in the run to provide a prototype for a first clinical test at Geißen Universtity. We are both strongly involved in this process, which may cause some delays in the development schedule of the FRUIT.

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