Photonics sensing platform for process optimisation in the oil industry

Reporting

Project Information

Hydroptics

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Coordinated by
ALPES LASERS SA
Switzerland

Periodic Reporting for period 2 - Hydroptics (Photonics sensing platform for process optimisation in the oil industry)

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Summary of the context and overall objectives of the project

The EU is the second largest producer of petroleum products in the world after the United States, with a crude refining capacity of about 15 million barrels per day, representing 16% of the total global capacity. Technology for oil production needs to be constantly refined and improved for competitive oil production in Europe as well as by European companies overseas. In both up- and downstream processing, water is of crucial importance. Often, it is the process water quality in terms of residual oil and particle load as well as other trace contaminants such as corrosion inhibitors, that has a decisive effect on the overall process efficiencies. Therefore, having a reliable, cost-effective, and high-accuracy monitoring of process water quality and ways to use this information for process optimization is of utmost importance for the oil industry.

Hydroptics has aimed at:
1. Advancing photonic sensor technology in the vis-IR range.
2. Developing a high-accuracy analyzer for automated, on-line measurement of residual oil and particle content in process water of the oil industry.
3. Combining on-line data with process simulations for process optimization.

With regards to these goals, significant steps towards increased sensitivity and selectivity, as well as miniaturization, were made. A modular sensing platform was developed and tested on the field. These tests were crucial to validate individual modules and pave the way for future optimizations. Digital twins were developed, and new machine learning approaches implemented, allowing process optimization.

Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

The coordinator ensured proper coordination between Partners to reach the project's goals and smooth communication with the European Commission, making sure that all reports were prepared and submitted on time.

Results of the project were disseminated through press releases, social media posts, online workshops, presentations in technical conferences and fairs, and scientific articles. Key exploitation results (KERs) were identified, and associated exploitation plans built. An individual business plan was built for every partner. Some technologies developed in HYDROPTICS were patented or led to new products.

Regulatory and standardization aspects during the project's lifetime were addressed. The Conformité Européenne (CE) marking was identified as crucial to bring a product to the market in any European country and Turkey. Relevant EU directives and harmonized standards to comply with to obtain the CE mark were identified. A standardization strategy was also built.

The technical specifications and measurement methodologies of each module were first defined, ensuring smooth integration and proper performances.

The processes taking place in oil and water separation plants were simulated by digital twinning and computational fluid dynamics (CFD) approaches. A macro-scale simulation model of the entire plant was created, allowing process optimization.

The individual modules (dual DFB-QCL spectrometer, dual frequency-comb spectrometer, particle measurement sensor, liquid handling module) were designed according to specifications, fabricated, validated through laboratory experiments, and integrated into the HYDROPTICS platform. Their performances for oil-in-water and particles content measurements were assessed in laboratory mode.

The HYDROPTICS platform was tested in two pilot field tests, giving precious indications on its performances for measuring oil-in-water and particles content in real-life conditions, and on aspects to be further optimized.

Key innovations developed during the HYDROPTICS project relate to:
- Dual-DFB spectroscopy, which performances could be improved, and for which the results obtained in HYDROPTICS were presented in several technical conferences.
- Integration of QCL sources on photonic integrated circuits (PICs), with a first demonstration of a PIC-based dual-DFB beam combiner, and for which a scientific paper has been submitted.
- A hyperspectral imaging-based particle sensor able to discriminate particles according to their size and composition, and that was presented in several technical conferences.
- Performance improvements in dual frequency-comb spectrometry, that were presented in several technical conferences and introduced in a new product.
- Liquid-liquid separation technology, with the development and patenting of a new, compact, and efficient centrifugal liquid-liquid separator, that was presented in several technical conferences and fairs.

Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)

HYDROPTICS has developed and applied advanced photonic components as key enabling technologies for optimizing most critical steps in oil production as well as to control downstream processing routines for final mineral oil product development. Advanced mid-IR laser sources and frequency combs were employed for monitoring trace contaminants such as oil in process water. Ultrasound-based particle manipulation was combined with imaging technology in the vis-NIR range for particle sensing. Computational fluid dynamic simulations have provided detailed insight in crucial unit operations and led to the development of new extraction devices. Hydroptics has also elaborated on the combination of data provided by these advanced sensors with readily available process data, and a digital twin of the process apparatus to gain in-depth process understanding. Digitalization of process data, data fusion, machine learning, and artificial intelligence have enabled a new level of process optimization yielding high and constant product quality despite fluctuating process conditions.

The developments carried out in the frame of HYDROPTICS have covered the entire value chain from laser source R&D towards a laser-based spectrometer towards online and inline subsystems for oil in water monitoring. All these modules, sub-systems and systems are exploitable separately. This has positioned partners as leaders in the supply of fast QCL frequency comb lasers and spectrometers, online and inline oil-in-water analyzers. Many online and inline water monitoring applications, for instance in pharmaceutical, as well as food and beverage industries, could benefit from technologies developed in the frame of HYDROPTICS. Furthermore, via the adoption of data-assimilation and digital twins, HYDROPTICS aims to drive the EU oil industry towards a new, more advanced, and digitized era.

Environmental impact of industrial activity remains one of the biggest structural challenges facing the EU today. A key inhibitor in further expanding oil extraction and processing in the EU, is the social pressure by citizens who oppose the construction of new oil extraction & refinery plants. Water purification can be seen as environmental water monitoring on the upstream side. Water monitoring includes all measures to avoid or early detect serious contamination of water resources. This encloses spill tracking (e.g. Deepwater Horizon, hydraulic fracturing), surface water control and monitoring of transportation-induced contamination. The current standard for checking hazardous contaminants is based on manual sampling and subsequently off-line analysis by a certified analytical laboratory. Thus, the capability by HYDROPTICS to carry out frequent online or continuous inline measurements constitutes a substantially improved sensing solution. Furthermore, the HYDROPTICS system can be part of an early-warning system for accidental or deliberate contaminations.

Project Logo

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