PHOTO-SENS: Advancing PHOTOnic BioSENSors for Aquaculture Monitoring

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In the frame of the EU PHOTO-SENS we have developed a generic system comprising of an instrument and cartridge to detect pathogens such as bacteria in aqua culture. The cartridge houses a bio-functionalized photonic chip which is mounted leak-tight in the cartridge. Liquids stored in blisters allow the operator to easily unpack a cartridge and run detection at any time.

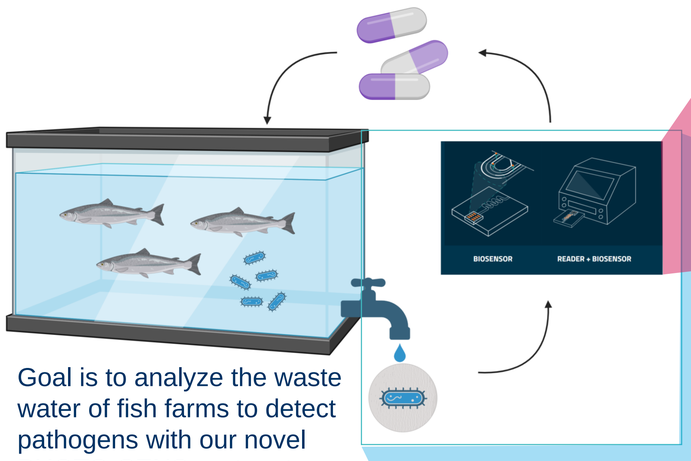
Challenge

Within the EU PHOTO-SENS consortium, CSEM are developing a cost-effective platform for detecting pathogens and identifying specific DNA biomarkers. Our use case is the detection of salmon pathogens as well as the identification of the sex of individual sturgeons.

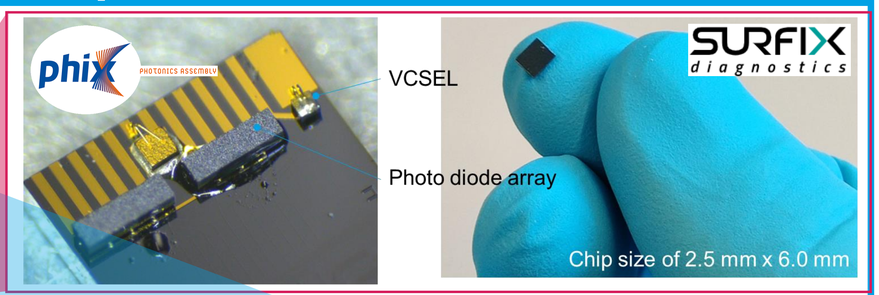
The system consists of a desktop reader coupled with disposable microfluidic cartridges that house functionalized photonic chips. These biochips are fabricated from silicon wafers through advanced cleanroom processes. To minimize costs, the team has designed and manufactured photonic chips with a smaller footprint, increasing the number of chips that can fit on a single wafer.

A major challenge lies in the packaging and integration of the photonic sensor within the microfluidic cartridge. The process required a leak-proof interface while allowing electronic access for activation and read-out. Additionally, the cartridge will feature a rapid and efficient heating meander, an antifouling coating, a degassing chamber / bubble trap, and on-chip reagent storage using blisters. Designing the microfluidic with high-throughput manufacturing (injection molding) in mind further contributes to cost reduction.

Concept & Requirements



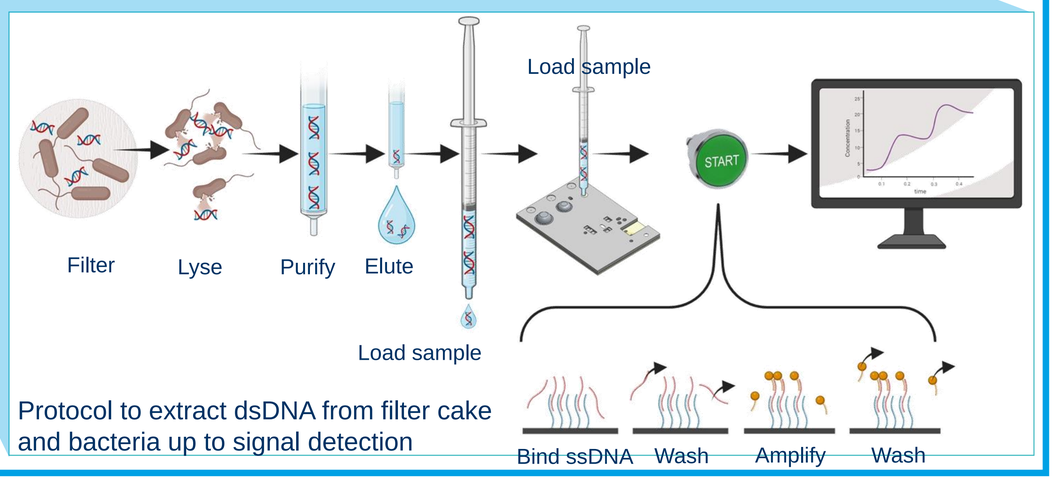
Goal is to analyze the waste water of fish farms to detect pathogens with our novel PHOTO-SENS system to later apply correct medication



Proprietary technology of Surfix is the hybrid photonic chip with VCSEL, two photodiode arrays, and NTC all assembled by Phix

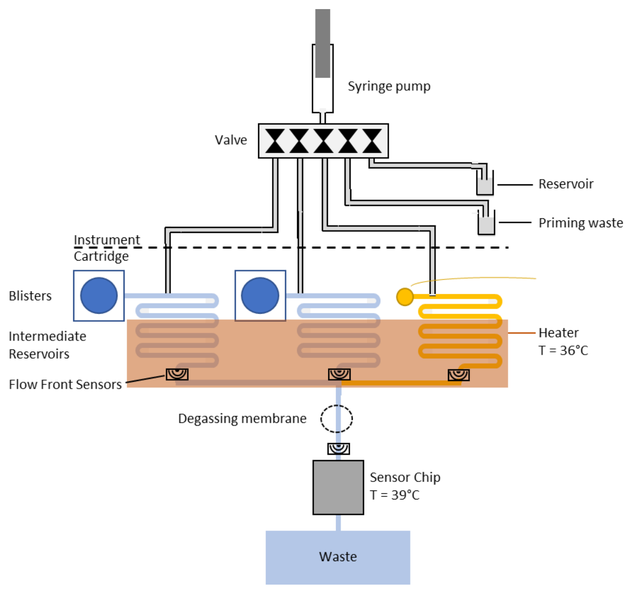
Requirements

- Non-pulsating flow
- Constant temperature
- No air bubbles
- No mechanical stress
- UV and temperature protective coating
- No contamination
- Easy to use
- Preloaded reagents
- 150 µl sample
- 15 µl/min flow rate
- Washing buffer
- Amplification buffer
- Antifouling coating



Protocol to extract dsDNA from filter cake and bacteria up to signal detection

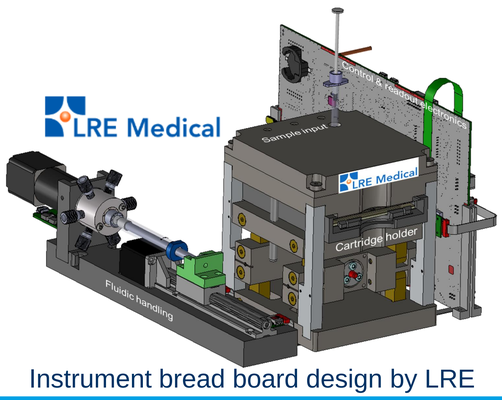
System schematics & Instrument



Schematic shows the interaction of the instrument with the cartridge.
A syringe pump and valves in the instrument are used to control the pulsation free liquid flow for all liquids.

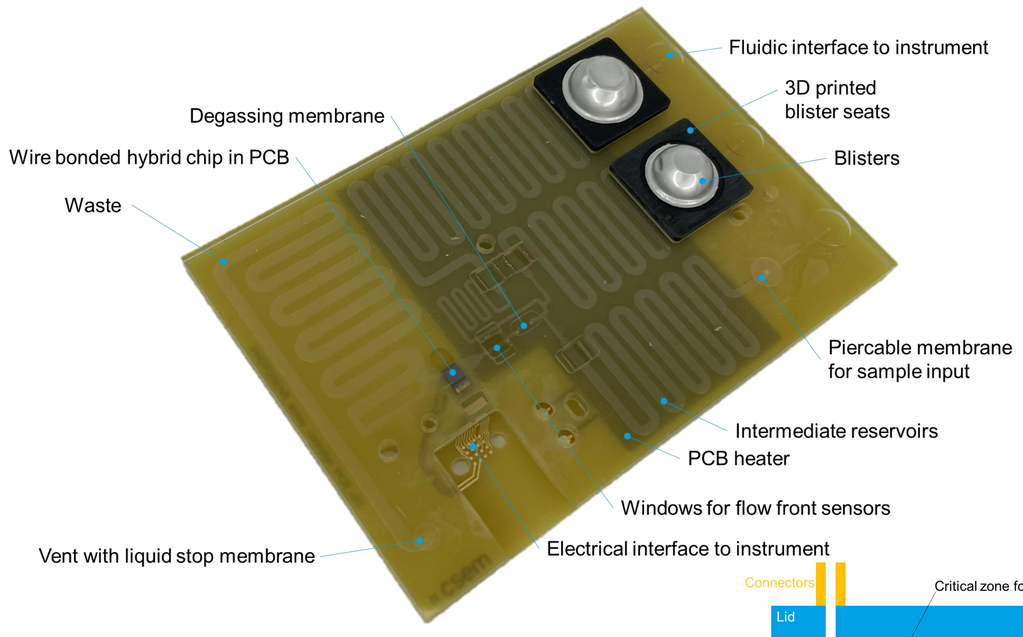
Steps by the user:

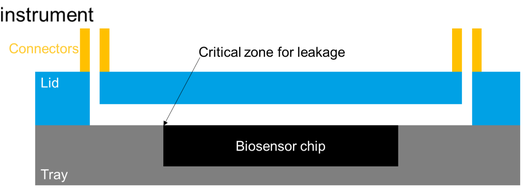
- Manual sample preparation
- Place cartridge
- Insert sample via resealing septum
- Press start
- Read result



Instrument bread board design by LRE

Cartridge





The cartridge is designed to house the bio-functionalized hybrid photonic chip mounted in a PCB. The chip is integrated in a pick-and-place procedure. On top of the cartridge, blisters are used to store the required liquids. At the time of use, the blisters are emptied into intermediate reservoirs for accurate and pulsation free fluidic transport. Inline flow front sensors allow to monitor the process while the degassing membrane ensures bubble free fluids on the chip. For bio-compatibility reasons, the liquids are preheated on the cartridge with the PCB-heater and brought to final temperature on the chip with its back-side heater. To prevent contamination of the environment, a liquid stop membrane seals once wetted.

Summary & Outlook

Within the EU PHOTO-SENS consortium, a complete system for pathogen detection in aqua culture is developed. In a first use case, this system allows to detect bacteria directly at the fish farm instead of sensing the sample for lab analysis. The system comprising an instrument and a cartridge is generically designed such that pathogen detection is only the start for this platform. The cartridge contains the bio-functionalized chip for the specific use case and was tailored to the chip's requirements such as pulsation free flow (solution: blister emptied in intermediate reservoir and pushed by syringe pump), no air bubbles on the detector (solution: in-line degassing membrane), flow control (solution: flow front sensors), minimal non-specific binding (solution: Surfix antifouling coating). For the development of the cartridge, simulations in COMSOL and prototyping methods as micro-milling, 3D printing and packaging in clean room environment are applied. All processes are compatible with high volume fabrication processes to enable a quick-to-market strategy.

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