between an OOC and the DEMO (left), alongside the four-beam profile of the QCL illuminator (right).

Contactless glucose monitoring in organ-on-a-chip systems using NIR/MIR spectroscopy

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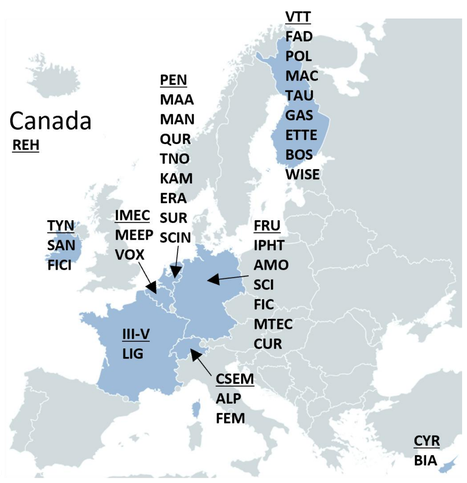
The PhotonMed consortium aims to advance photonics technologies for diagnostics, medical devices and wearables. CSEM is one among 39 consortium partner organizations in the consortium that go beyond state-of-the-art R&D to commercialize innovative photonics technologies. The application relevance and quality of the PhotonMed partner research will be validated in 16 pilot cases led by end-user companies. The research results from PhotonMed will be exploited by the end-user companies in their R&D towards the product launches.

EU Consortium PhotonMed

39 partners: Led by VTT Technical Research Center of Finland Ltd. Combination of large enterprises, SMEs, research organizations and universities to cover full development chain from concepting to industrial fabrication.

9 countries: Belgium, Cyprus, Finland, France, Germany, Ireland, Netherlands, Switzerland, Canada.



Objectives: The development of advanced photonics technologies is driven by the need for medical applications in diagnostics and personalized monitoring. Research work focuses on new components, integration technologies and new processes units for pilot line fabrication. The projects aims to:

- Introduce 10 new photonics component technologies, 11 integration technologies, and 3 new assembly units for pilot line fabrication.
- Demonstrate the significance of the research in 16 pilot cases led by the end-user companies.
- Accelerate the uptake of the advanced technologies using the pilot line operational model and ecosystem.

Pilot Case on Glucose Monitoring in OoC

Human organoid cultures in microfluidic organ-on-chip (OoC) systems can replicate human biological processes, thereby facilitating studies of organ physiology, inter-organ communication, and the pharmacological impacts of drugs on organs. These models hold significant promise for revolutionizing drug discovery by enabling efficient studies and the identification of novel drug targets, as well as testing drug interventions in physiologically relevant models. **In this pilot case we will develop an innovative glucose monitoring device for OoC applications** and demonstrate its functionality on a liver-pancreas-assay by monitoring glucose concentration in cell culture compartment of the OoC.

Objective 1: Identify and integrate near-infrared (NIR) and mid-infrared (MIR) transparent materials suitable for *in vitro* applications in OoC devices.

Objective 2: Develop a quantum cascade laser (QCL) with multiple glucose-specific wavelengths in the MIR range.

Objective 3: Design a demonstrator for glucose monitoring in NIR/MIR range.

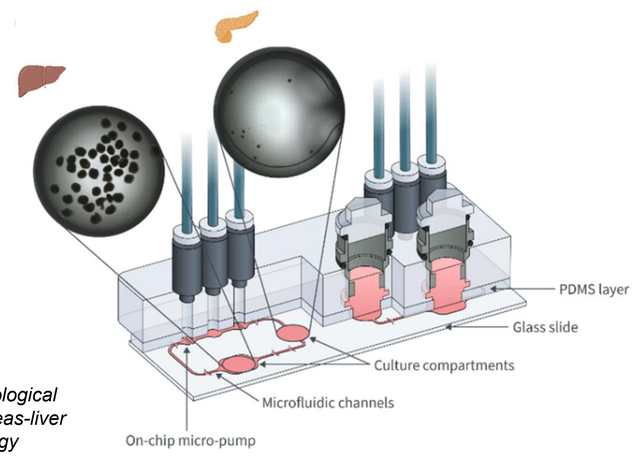


Figure source: S. Rigal, et al. Normoglycemia and physiological cortisone level maintain glucose homeostasis in a pancreas-liver microphysiological system (2024) Communications Biology

NIR Spectroscopy

Wavelength range:

- 1’000–2’500 nm or 10’000–4’000 cm^{-1}

Advantages:

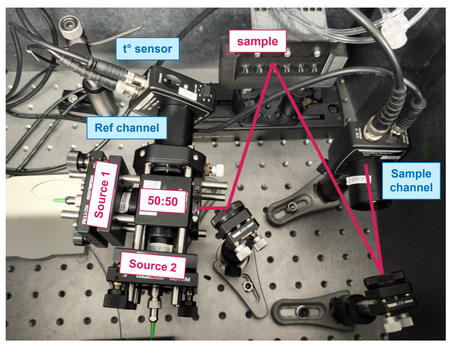
- High availability of various sources and detectors
- Relatively low instrumentation costs
- Many optical materials are transparent in NIR range
- High measurement dynamic range

Disadvantages:

- Broad overlapping absorption bands, low specificity
- Very weak absorbance
- Strong interference with water
- Strong influence of ambient temperature

Core metabolic bioanalytes:

- Glucose
- Lactate
- Glutamine



Lab setup for NIR spectroscopy developed at CSEM

MIR Spectroscopy

Wavelength range:

- 2’500–25’000 nm or 4’000–400 cm^{-1}

Advantages:

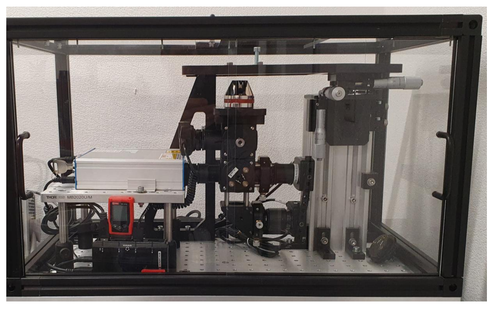
- Narrow absorption bands, higher selectivity
- Ability to analyze complex samples
- High measurement dynamic range

Disadvantages:

- Strong absorption of water
- Optical penetration depth ~ 10 μm
- Measurement in transmission is not feasible
- High instrumentation costs, expensive optical materials

Typical bio-process monitoring targets:

- Glucose
- Lactate
- Proteins



Poof-of-concept QCL-based MIR spectroscopy system developed at CSEM

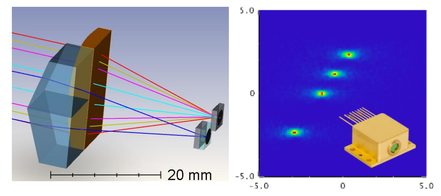
System Design, Assembly, and Validation

CSEM is developing an integrated NIR/MIR spectroscopy system for OoC applications.

In collaboration with FEMTOPRINT and ALPES Lasers, a fully integrated demonstrator will be designed and fabricated. This will include miniaturized sampling compartments integrated into an OoC device. These compartments are crucial for ensuring repeatable detection in long-term measurements.

DEMO device development:

- Optics design and performance simulations in Zemax
- Evaluation of electronic components
- Optimizing the NIR measurement concept to allow for absorbance measurement with 50 ppm precision
- System control software and real-time data processing and visualization
- Miniaturization, CAD design and system integration
- Design of the sampling compartment compatible with the optical system
- Integration of sampling compartments in OoC device



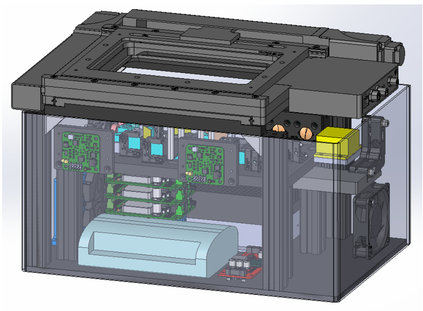
Zemax simulation of the optical interface between the OoC and the DEMO (left), alongside the four-beam profile of the QCL

NIR measurement concept validation:

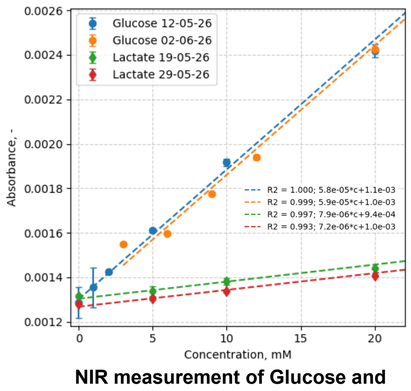
- Precision of dual-wavelength NIR system: 50 ppm absorbance (1 mM glucose)
- Interference with other bioanalytes: lactate approximately 10%
- Integration of third source to minimize interference

DEMO device validation:

The assembled device will be validated *in situ* using cell culture media solutions and *in vitro* using a liver–pancreas-assay in the next phase of the project



CAD design, component integration



NIR measurement of Glucose and Lactate in PBS in a lab setup

Schweizerische Eidgenossenschaft
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