Photonic Biosensors

Development of a photonic biosensor system for the analysis of biomolecules in liquids at the Fraunhofer Center Erfurt (FZE)

Biosensor research is advancing rapidly in clinical treatment, pharmaceuticals and healthcare. The aim of the work at the Fraunhofer Center Erfurt is to develop innovative label-free biosensors using silicon nitride (Si_3N_4) photonic integrated circuits (PICs) that can detect a wide range of biomolecules in liquids. Key applications include the detection and prevention of diseases and health monitoring. One successful medical application of these innovative photonic sensors is the detection of biomarkers indicative of neurodegenerative diseases.

On-chip integration of high-precision, low-loss, and high-density waveguide-based Si_3N_4 sensor concepts, such as those based on microring resonators (µRR), in combination with specific surface biofunctionalization and antigen molecule immobilization strategies, is expected to lead to high-performance photonic biosensor systems in terms of sensitivity, multiplexing, and miniaturization.

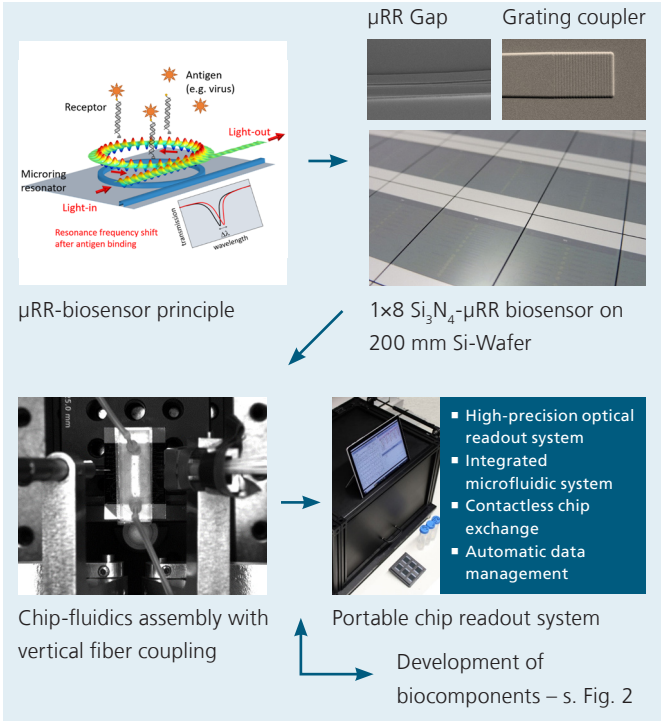

Fig. 1 Development steps for the photonic biosensor technology.

Photonic biosensor system

The development includes all basic technological modules: Photonic devices, microfluidics, surface biofunctionalization and system integration.

- Si_3N_4 waveguide platform on 200 mm Si wafers
- Multiplexed µRR-based biosensors at 1550 nm
- Microfluidic system and chip fluidic cell assembly
- Biofunctionalization of the sensor surface
- Novel capture DNA probes and biological binding assays
- System integration and proof-of-concept demonstration

Biomarker detection

The developed biosensors were evaluated for the detection of microRNA biomarkers (miRNAs). miRNAs are considered promising biomarkers for the diagnosis of cancer or NDDs such as Alzheimer's or Parkinson's disease. Since disease diagnosis based on these biomarkers is specific to each individual patient, this need for personalized diagnosis is time-consuming and expensive for technologies such as ELISA or PCR.

This is where the developed photonic sensor technology can help. The results show that the developed multiplexed µRR biosensors can rapidly detect multiple specific miRNA biomarkers in parallel.

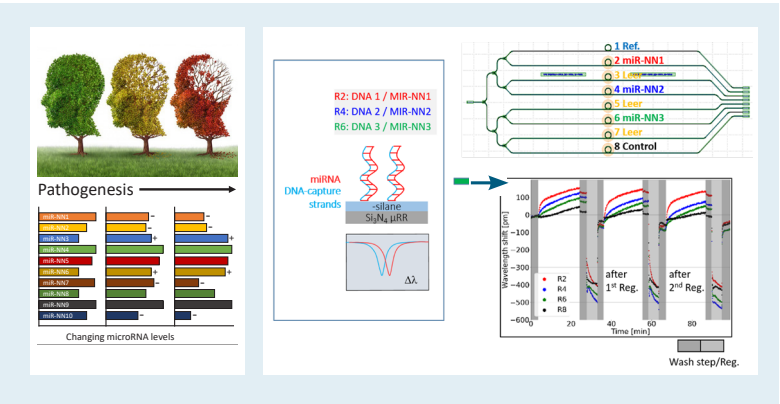

Fig 2. miRNA levels indicative of NDDs (e.g. Dementia and other Neurodegenerative Diseases https://www.ndph.ox.ac.uk/research/dementia-and-other-neurological-diseases) and their pathogenesis. Experimental data showing successful parallel detection of 3 different miRNAs using the developed µRR sensor. Successful sensor surface regeneration approach developed at FZE.

Key features

- Label-free, multiplex, fast biomolecular sensing method
- High sensitivity and specificity
- Low cost, high precision due to silicon wafer level manufacturing, high level of integration
- Sensor can be used once or multiple times
- Chip regeneration/cost reduction for the detection procedure
- Suitable for the detection of disease-indicative biomarkers (miRNA, peptides, proteins), viruses, bacteria ...

https://s.fhg.de/integrated-photonic-devices-IPMS

https://s.fhg.de/photonic-bio-sensors-IZI

Biosensors characteristics	Capabilities
Sensors	Scalable number of sensors on chip
Capture molecules	Antigen specific e.g. DNA, antibodies etc.
Antigen	miRNA, proteins, peptides, viruses, bacteria
Sensitivity	10^3 nm/RIU and higher with special designs
LOD	pM or better with special photonic designs
Regeneration cycles	To tens of times
Time to result	min

Table: Photonic biosensor performance and customisation options.

R&D offer

- **Unique selling points of photonic sensing method:** Label-free, multiplex, sensitive, fast result; scalable through wafer-level fabrication; application-specific bioprotocols; miniaturization through photonic integration
- **One-stop-shop** for silicon-based PIC sensor development for biomedical applications
- PIC sensor concepts as versatile **"plug-and-play" system** for a broad analyte spectrum, for PoC, personalized diagnostics
- **Si_3N_4-on-Si PIC technology platform** for various applications – biomedical, environmental monitoring, telecommunications, spectroscopy, quantum technology

This work has been carried out at the Fraunhofer Center Erfurt (FZE), which is a collaborative innovation center between Fraunhofer IPMS, Dresden, Fraunhofer IZI, Leipzig, and Fraunhofer IOF, Jena.

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