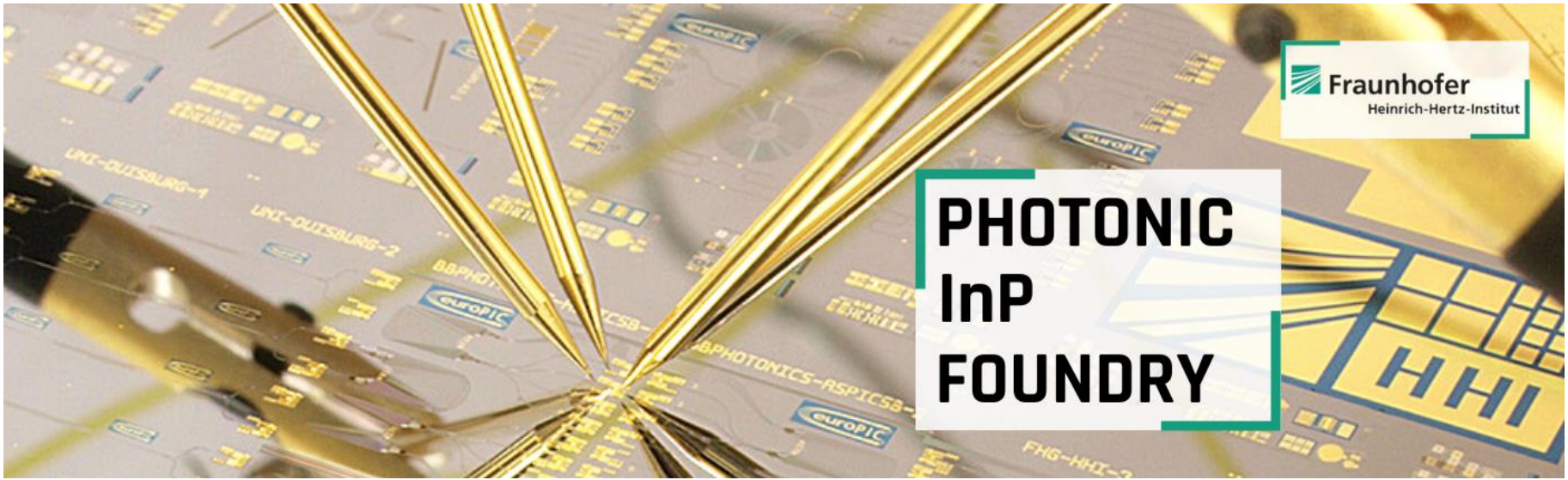
# Photonic Integrated Circuits for Biosensing

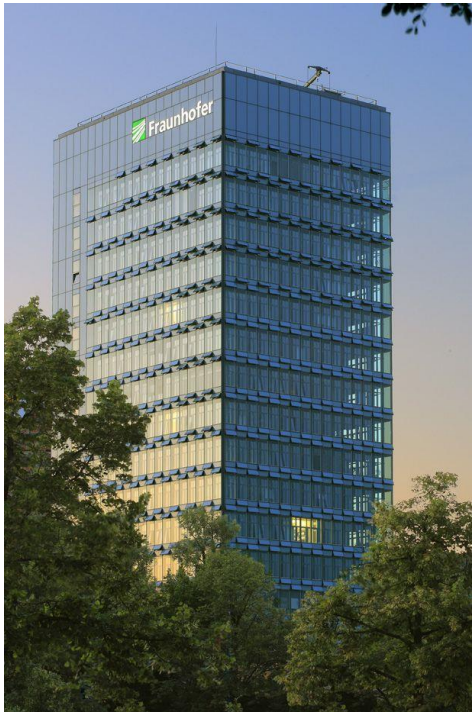
## An European PIC Ecosystem for Sensing Applications






Axel Schönau – Deputy Head of Photonic InP Foundry Group

# Fraunhofer Society




- At present, 76 institutes and research units in Germany and around the world
- 30,000 staff, mainly scientists and engineers, €3.0 billion budget
- HHI has been part of FhG since Jan. 2003

**Typical revenue structure:**

45% direct industry contracts

35% competitive research projects (e.g. BMBF, EU, regional)

20% basic financing from federal government

**HHI**

- **393 employees**
- **~ 230 students**
- **~80% third-party funding**
- **~40% industry contracts**



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# Fraunhofer HHI: Video, AI, Networks, and Photonics

## 600+ people, 80% self-financed

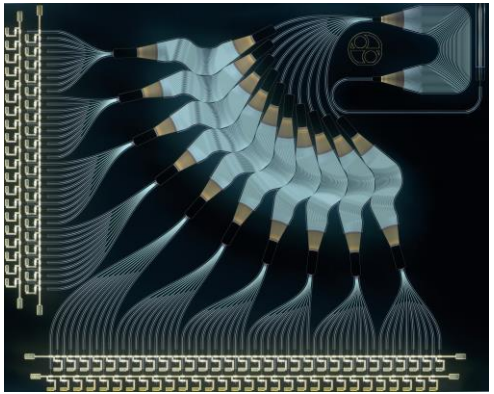
### Video Compression


- H.265 / HEVC: 4th Emmy received
- ~5B devices

### Photonic & 5/6G Networks

- LiFi for high speed data in EMI environments
- Quantum networks

### InP and Hybrid PICs



- Up to 145 GHz
- Terahertz & **biosensing**
- QKD components



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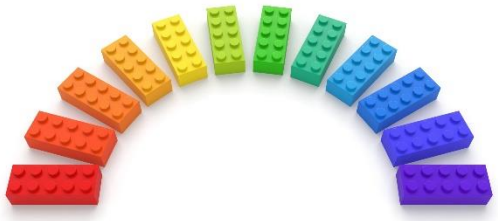
# Photonic InP Foundry

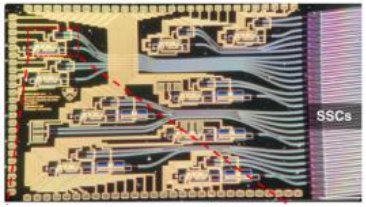
## Drag and drop photonic integration



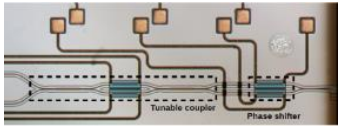
| | | |
|---|---|---|
| Bends | Tunable Gratings | Photodiodes |
| Couplers | Amplifiers, Phase Sections | Balanced Photodiodes |
| Pol. Elements | Lasers | |
| TO MZIs | EA/EO Modulators | RF tracks, crossings, … |

Stimulation, detection, analysis

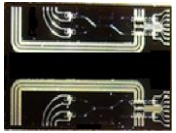
Dual-Pol EML (HHI)



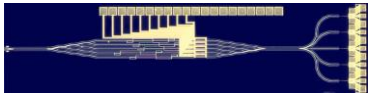

All-optical Neuron (Princeton)



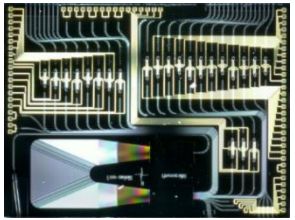

Mode Multiplexer (Uni Milano)



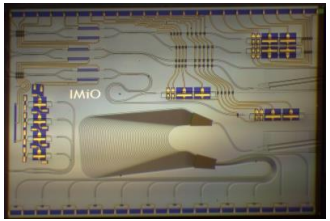
Quantum Entropy Source (Quside)



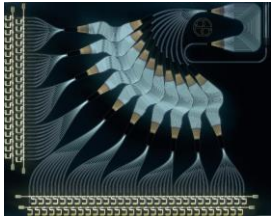
Stokes Vector Rx (HHI)



Nanosecond Wavelength Switch (Microsoft)




Fiber sensor interrogator (Uni Warsaw)



100ch WDM Rx (Bright Photonics)



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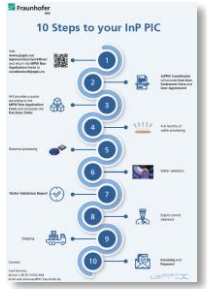
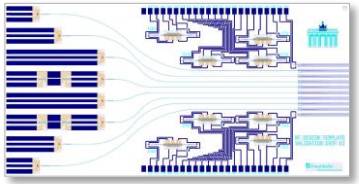
# European InP PIC Ecosystem

## PIC Design and Process Flow

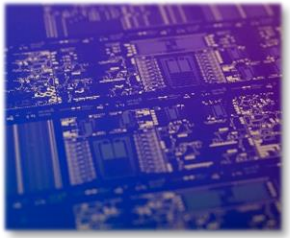
**User Agreement, Design Kit License** → **PIC design** → **Fabrication (~4 months)** → **Testing** → **Proven Prototype**



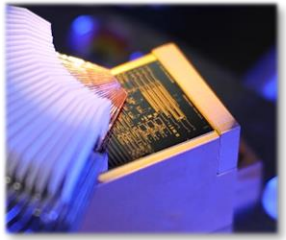

**JePPIX**



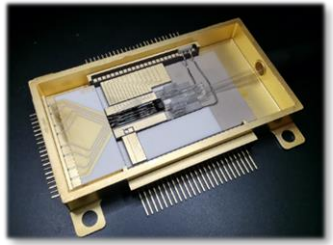
**HHI / Design House[1]**



**HHI / Wafer Fab[2]**



**HHI / other partner[3]**



**HHI / other partner[4]**

1) e.g. Bright Photonics, VLC
2) e.g. SMART (InP), Lionix (SiN)
3) e.g. VLC, JePPIX
4) e.g. PHIX, Tyndall, Cordon, Argotech





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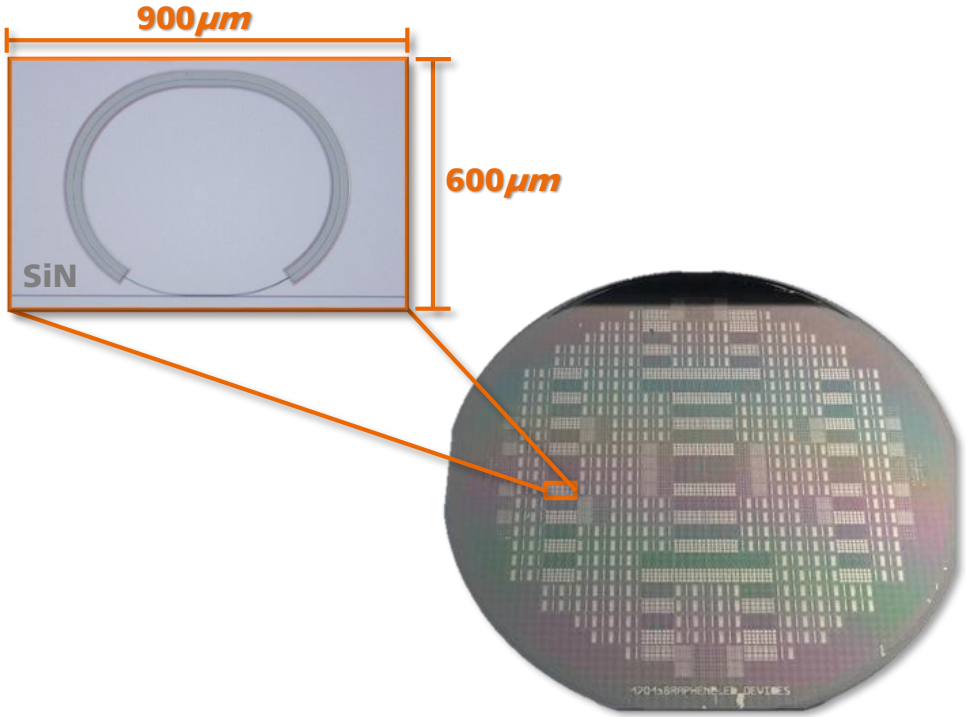
# Biosensors at Fraunhofer HHI

## Microring resonators as photonic sensor chip




- **P**hotonic **I**ntegrated **C**ircuit (**PIC**)
- CMOS compatible PIC technology
  - **SiN** platform
- Quantitative analysis by using **NIR light** & 850nm
- **Yield > 98%**

**4” Si-wafer**
(several thousand rings per wafer)



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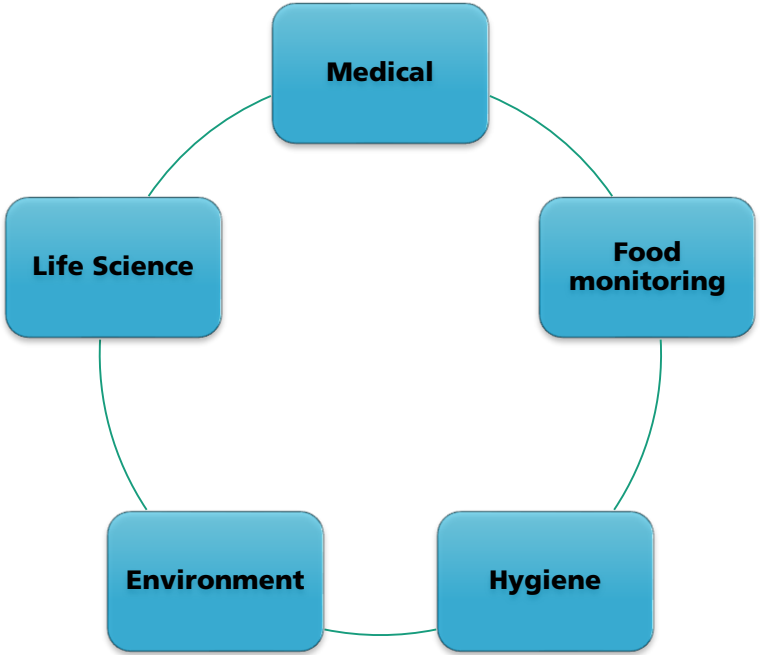
# Biosensors using Photonic Integrated Circuits (PICs)

## Opportunities




- Rapid multiparameter results
- Cost-efficient, ready for mass production
- Highly integrable, Point-of-Care
- Resource-efficient
- Digital analysis, fast data transfer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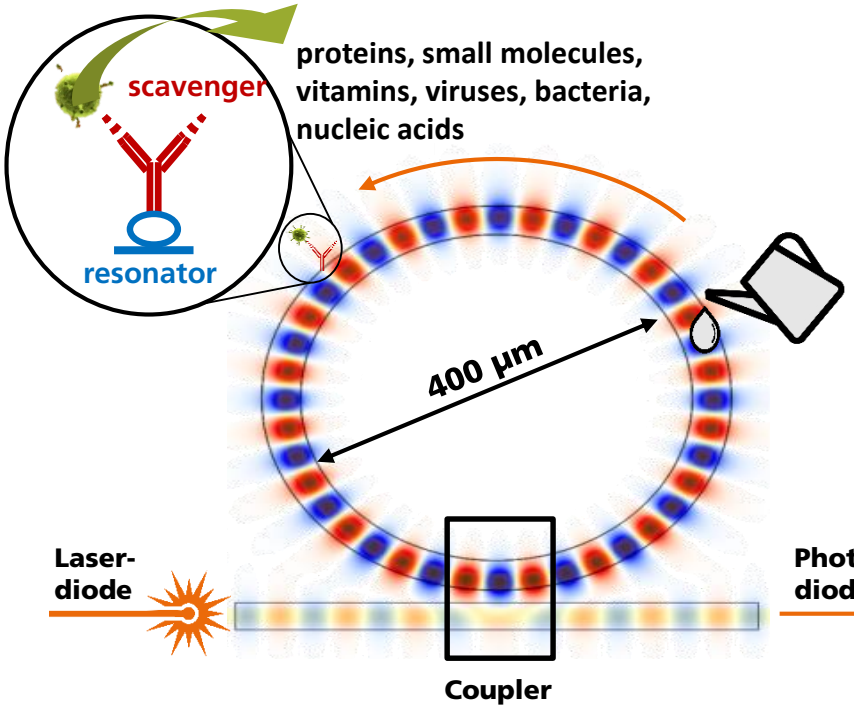
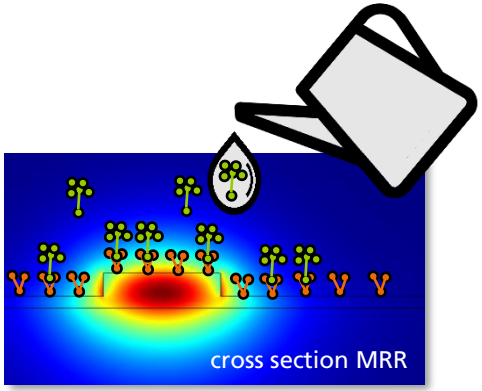
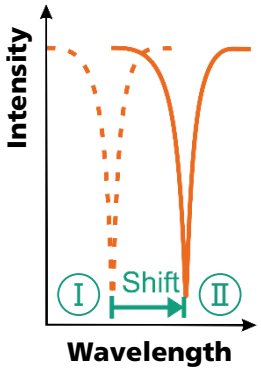
# Microring Resonator as Photonic Sensor Chip

## Selective relative measurement



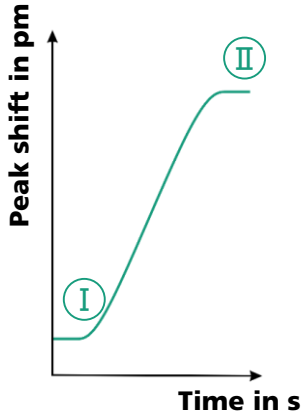

**Binding of molecules**
on MRR surface

↓

**Change of effective refractive index** ($n_{eff}$)
in waveguide

↓

**Resonance shifts**



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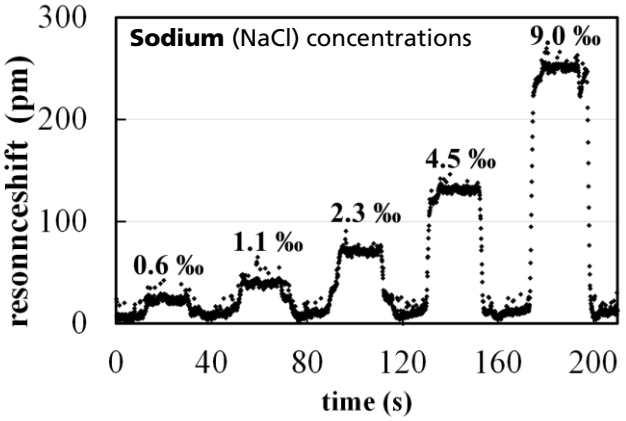
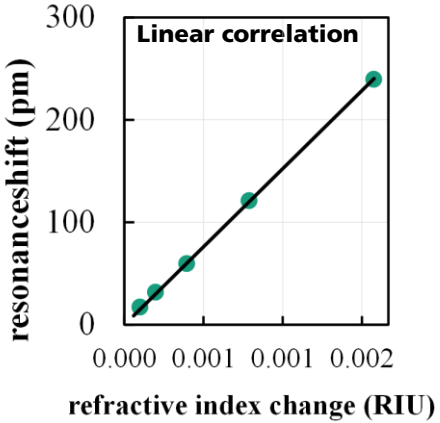
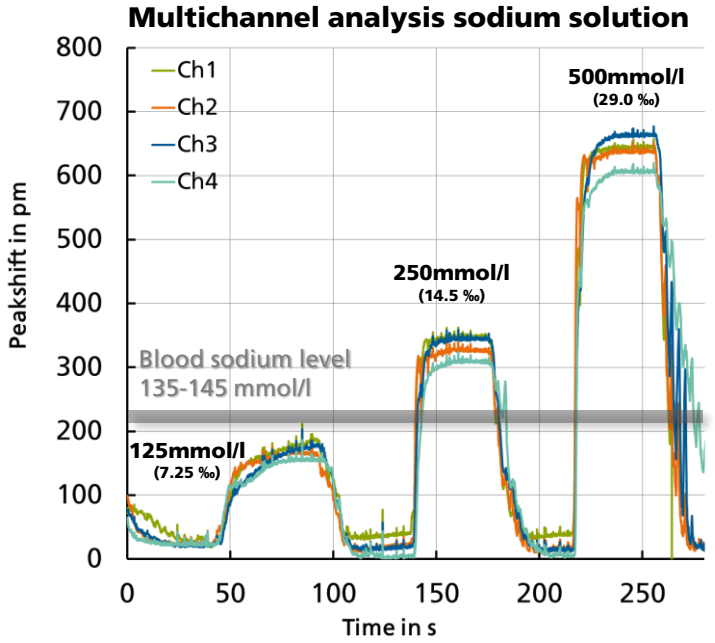
# Microring Resonator as Photonic Sensor Chip

## Technical overview

- **Fast (real-time)** → sec and msec range
- **Robust** → relative measurement
- **Precisely** → extremely high ring sensitivity
- **Reproductible** → long term stable



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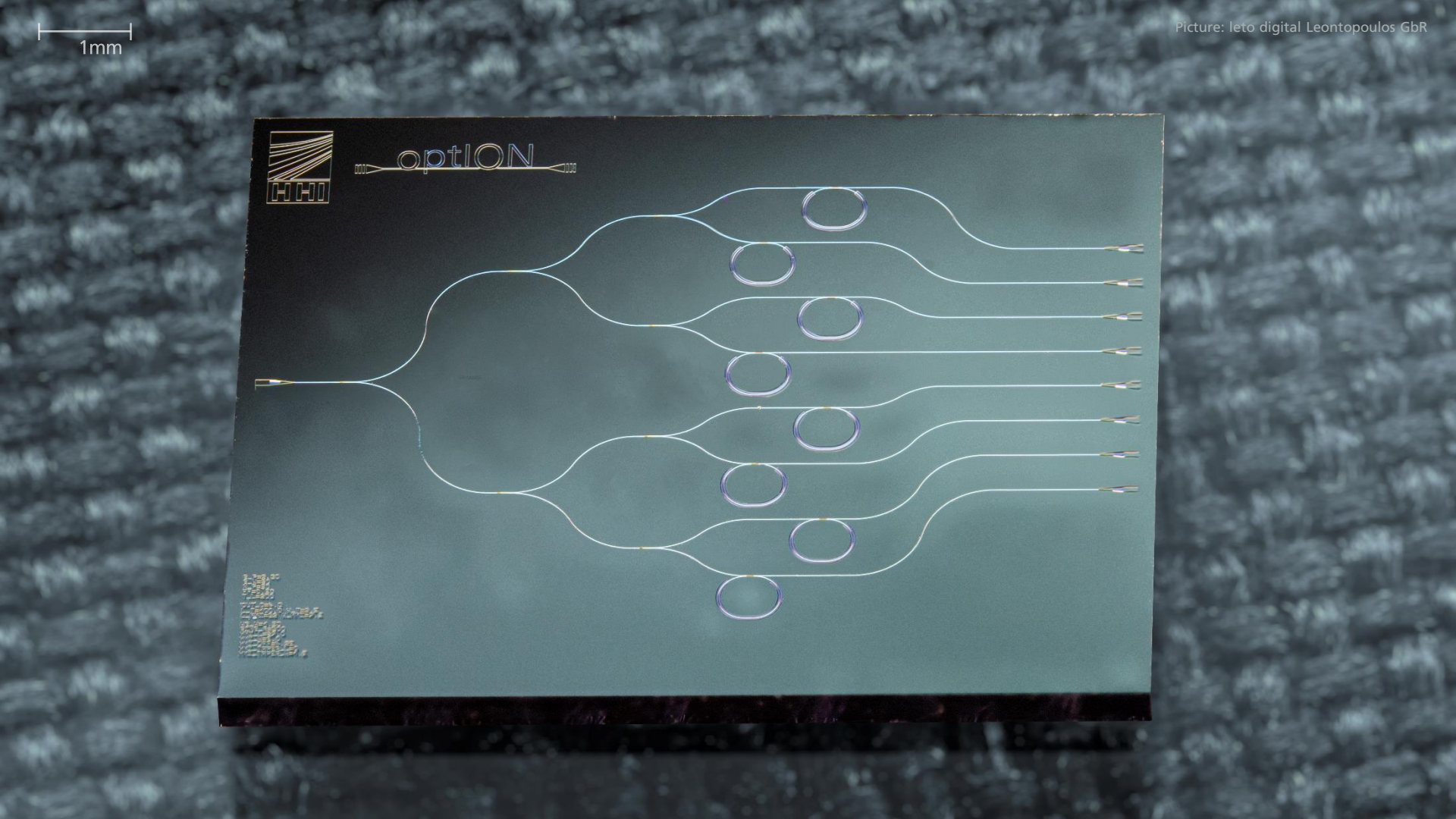
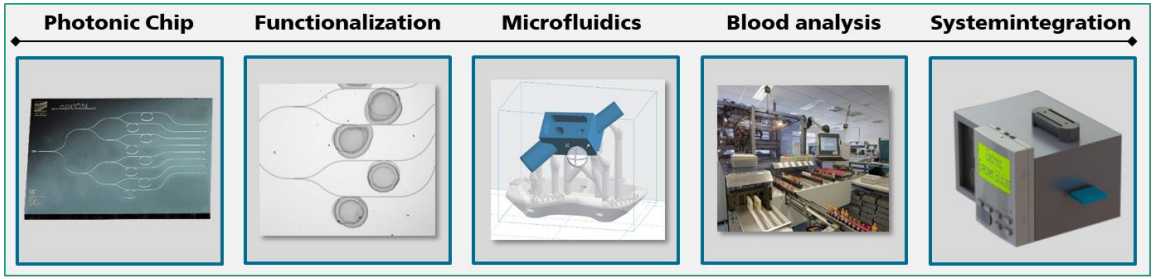

1mm
Picture: leto digital Leontopoulos GbR
HHI
optION

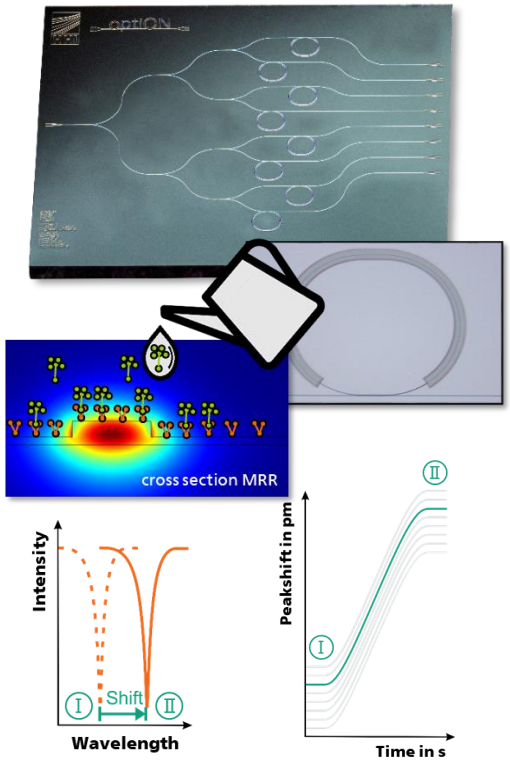
# Project optION

## Technical overview

- **Optical microring sensor for quantitative analysis of electrolytes**
  - Development of device concept that enables photonic sensor chip




Fraunhofer HHI · scienion · CHARITÉ Labor für Biofluidmechanik · CHARITÉ Institut für Laboratoriumsmedizin · ESCHWEILER automatic analysing systems




**Paper:** ***„Eight-channel SiNx microring–resonator based photonic biosensor for label-free fluid analysis in the optical C-band", Reck et al., Annu Int Conf IEEE Eng Med Biol Soc. 2023 Jul***



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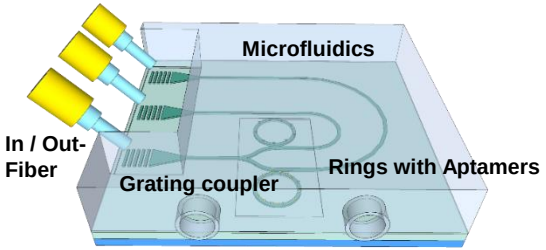
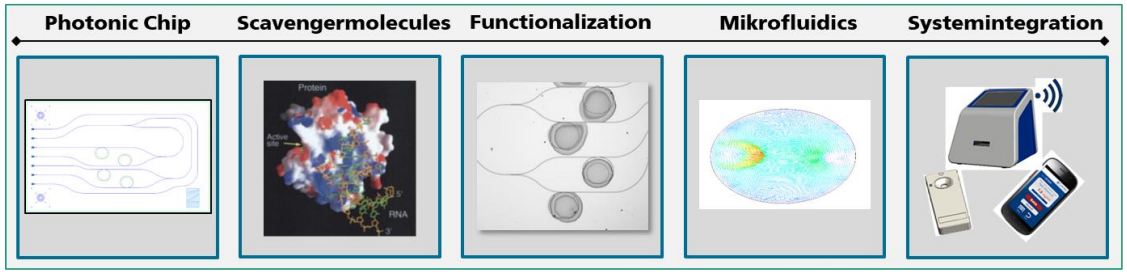
# Project PolyChrome Berlin

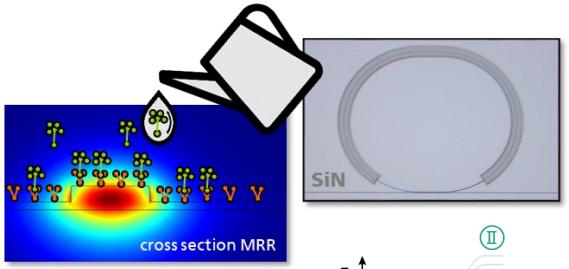
## Technical overview

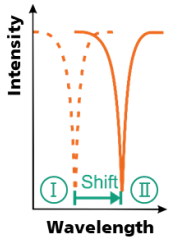
PolyChrome Berlin
Photonics for Sensing

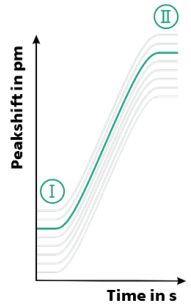
- **Photonic Integration Platform for Sensory and Analytical Applications**
  - Development of device that enables photonic sensor chip
  - Environmental analytics, life science, food analytics
  - Vitamin D, Ferritin, COVID-19 Ag, Cyanobacteria, …



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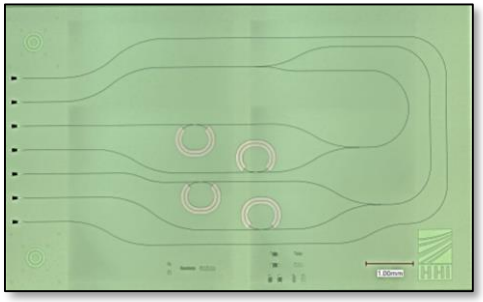
# Project PolyChrome Berlin

## Technical overview

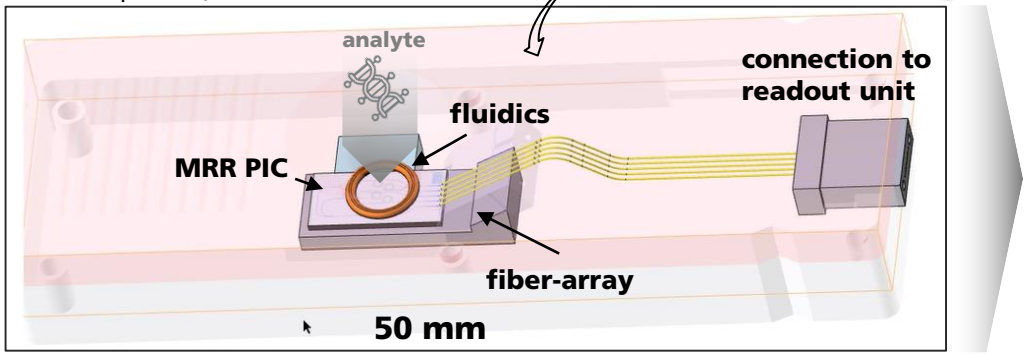
PolyChrome Berlin
Photonics for Sensing

- **Photonic Integration Platform for Sensory and Analytical Applications**
  - Photonic device that enables Point-of-Care disposable
  - Environmental analytics, life science, food analytics
  - Vitamin D, Ferritin, COVID-19 Ag, Cyanobacteria, …

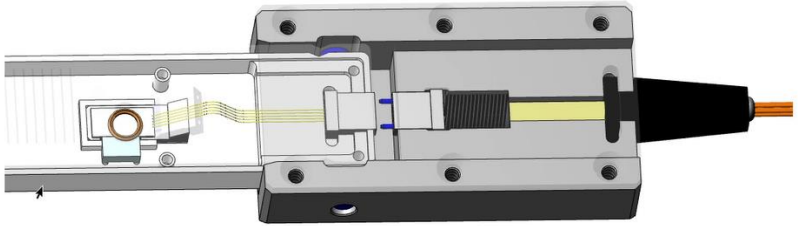
PIC-size: 10 x 6 mm



**Disposable rapid test**
(mechanically comparable with Corona rapid test)

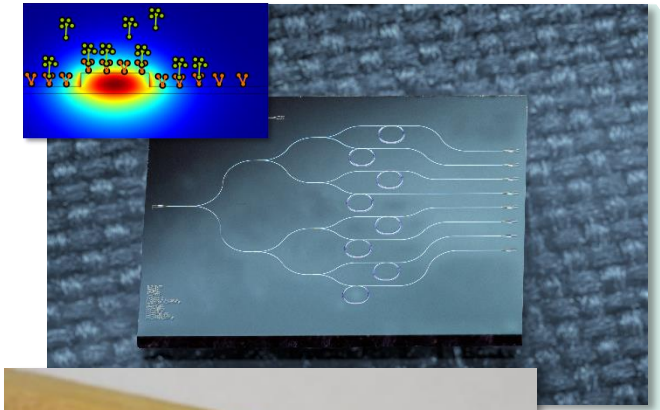



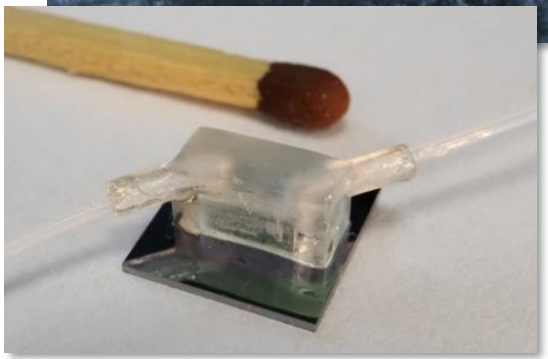

Readout unit



# Biosensors using Photonic Integrated Circuits (PICs)

## Photonic chips for environmental analysis, life science, diagnostics

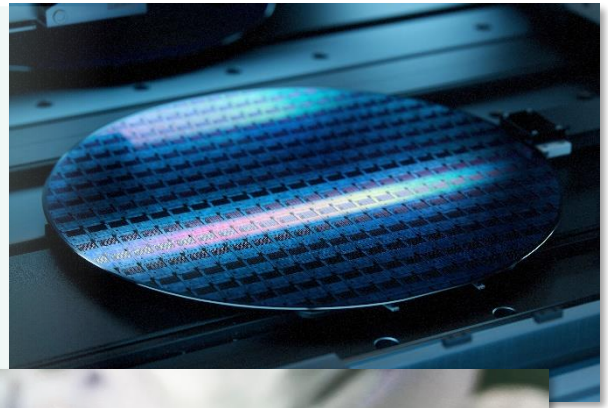


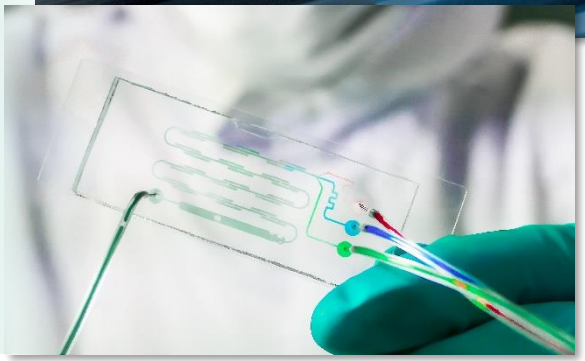


**On-Wafer Integration**

**Scale it up,**

**Make it smaller**







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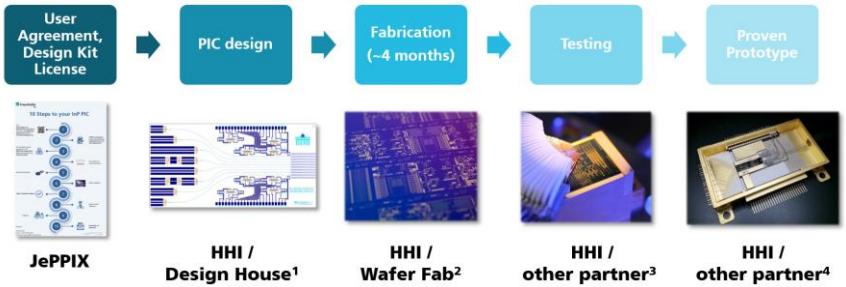
# What can WE do for you?

## InP PIC Supply Chain




## + SiN Technology

# *What can YOU do for us?*

- Becoming a partner in e.g. EU projects
- Supporting with know-how in microfluidics and surface functionalization
- Being an industrial partner for application
- Long-term: Qualification

**Contact**

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# Thank you!