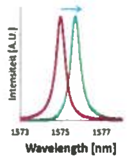
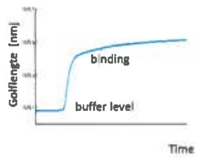
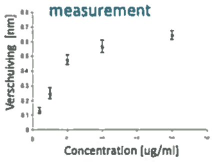
EOSAM- Berlin - Sept. 2016

Label-free ring resonator biosensor through refractive index sensing of antigen-antibody binding







Biosensors

Detect presence and concentration of

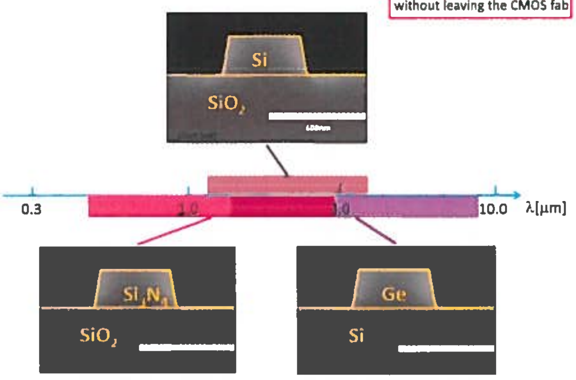
- Proteins
- Viruses
- Bacteria
- DNA
- ...

Two classes:

- Labeled: detection of label bound to biomolecule
- Label-free: direct detection of biomolecule

Silicon photonics: extending the wavelength range

without leaving the CMOS fab



R. Soref, Nature Photonics 2010

Outline

An introduction to silicon photonics

➡ Refractive index biosensors for immunoassays

Spectroscopy-on-a-chip

Absorption spectroscopy: Continuous Glucose Monitoring

Raman spectroscopy: virus detection?, enzyme detection?, exosome detection?, amyloid detection?

Point-of-care Pulse Wave Velocity measurement

What is silicon photonics?

The implementation of high density photonic integrated circuits by means of CMOS process technology in a CMOS fab

Enabling complex optical functionality on a compact chip at low cost

Universiteit Gent imec
Photonics Research Group
nb-photonics

Silicon Photonics and its applications in life science

Roel Baets
Photonics Research Group, Ghent University – IMEC
Center for Nano- and Biophotonics, Ghent University
roel.baets@ugent.be

EOSAM - Berlin - Sept 2016

erc

Outline

An introduction to silicon photonics

Refractive index biosensors for immunoassays

Spectroscopy-on-a-chip

Absorption spectroscopy: Continuous Glucose Monitoring

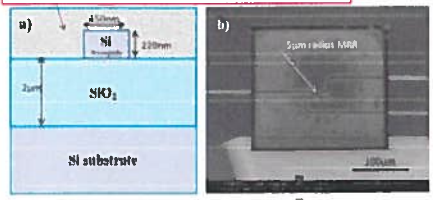
Raman spectroscopy: virus detection?, enzyme detection?, exosome detection?, Amyloid detection?

Point-of-care Pulse Wave Velocity measurement

Selective, reversible and fast ammonia gas detection

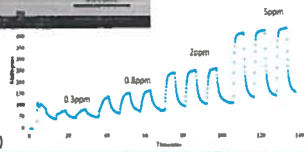
Application: breath analysis

Microporous silica layer, pores: 2nm; porosity: 45%
Functionalized for ammonia-selectivity



Sensitivity down to 100ppb demonstrated

No interference from H_2O and CO_2



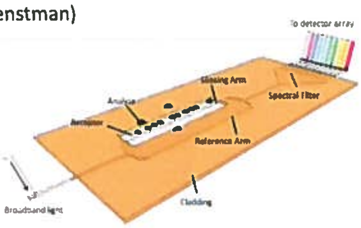
N. Yebo et al, Optics Express, 20(11), pp. 11855 (2012)

Pocket project (FP7)

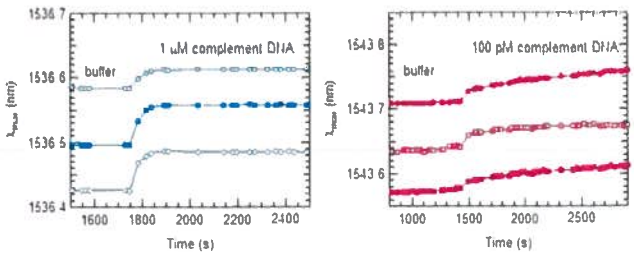
Pocket

- Detection of **Tuberculosis** biomarkers in urine
- SiN PIC-platform in visible: cheaper sources and detectors
- Cheap readout: broadband source + sensor + on-chip spectrometer
- Coordinator: UGent (P. Bienstman)
- Spin-off plans

UNIVERSITEIT GENT imec CSIC LIONEX microfluidic ChipShop trinean

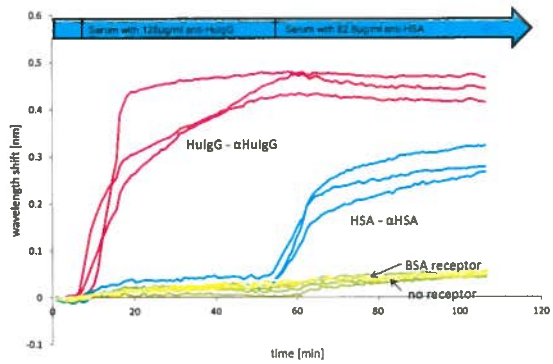


DNA hybridisation



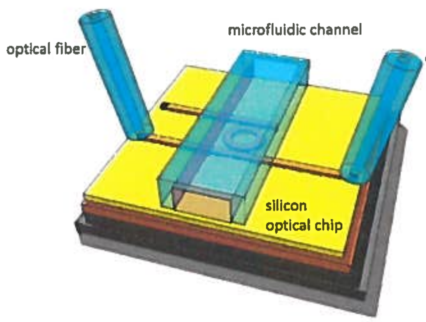
Concentrations down to 100 pM can be detected

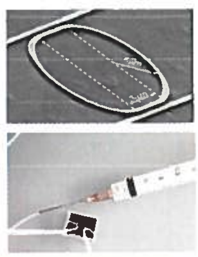
Multiplex sensing results



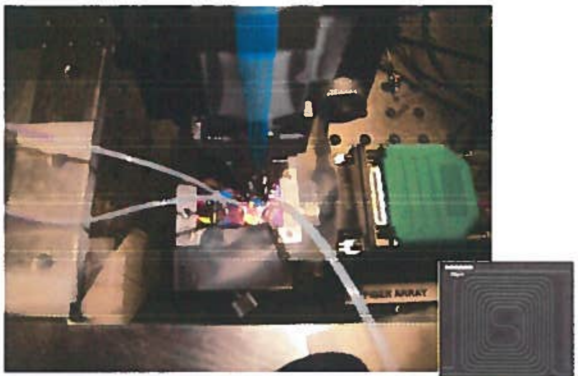
K. De Vos et al, Optics Express (2007)

Lab-on-chip concept

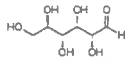




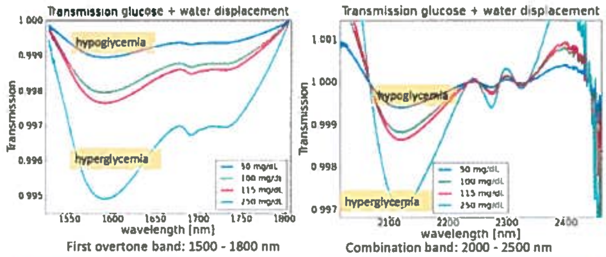
Proof-of-concept demonstration in the lab



Glucose absorption spectroscopy



Objective: Continuous Glucose Monitoring by means of **subcutaneous implant**

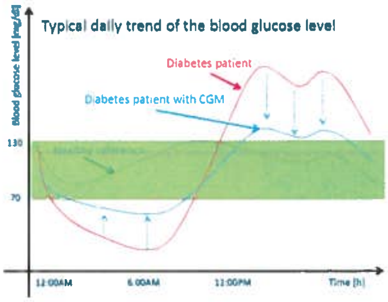


For glucose sensing in humans (3-15 mM): Largest change in transmission is 0.5 %
Required sensitivity : 0.02%

Continuous Glucose Monitoring (CGM) has proven to improve glycemic control of diabetes patients

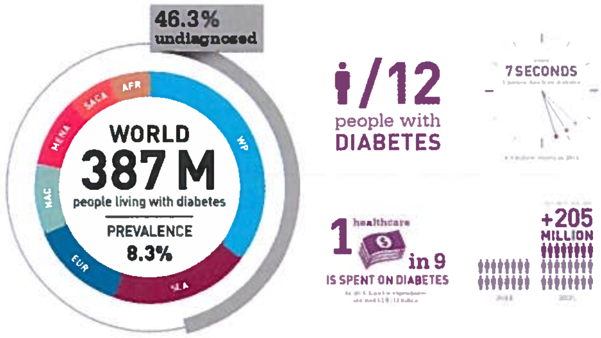
Multiple randomized, controlled studies* with usage of CGM systems show positive health impact:

- lower average blood glucose levels (reduction in HbA1c compared to the baseline value)
- Decrease of hypoglycemic frequency



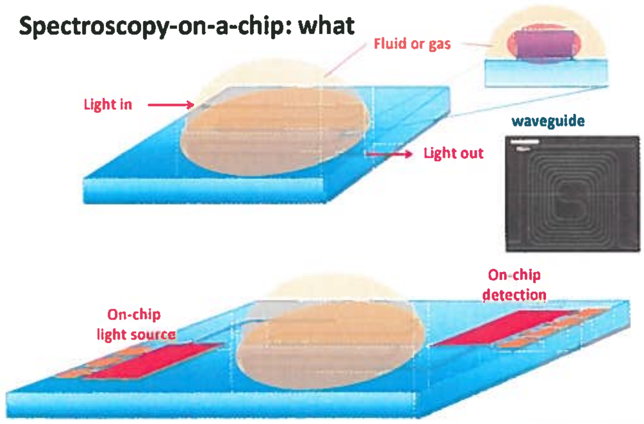
*Uebl A, Henrichs HR, Heinemann L, et al. Continuous glucose monitoring: evidence and consensus statement for clinical use. J Diabetes Sci Technol. 2013;7:500-519

Diabetes is the 21st century health challenge

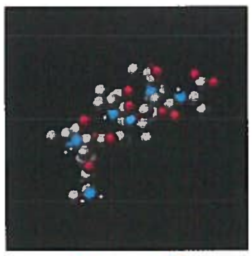


http://www.idf.org/diabetesatlas/update-2014

Spectroscopy-on-a-chip: what



Vibrational spectroscopy

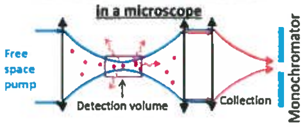


Infrared absorption spectroscopy
Very sensitive
"Poor" sources and detectors
Less compatible with biology

Raman spectroscopy
Very insensitive (but there are tricks)
Mainstream sources and detectors
More compatible with biology

Waveguide-enhanced Raman spectroscopy

Free space excitation and collection in a microscope

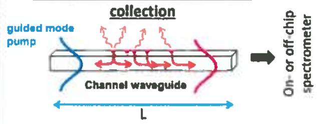


- Large étendue from particle cloud: ⇒ Resolution - sensitivity - size compromise for the spectrometer
- In a confocal microscope:

$$\frac{P_{coll}}{P_{pump}} = 2\frac{\lambda_0}{n}\rho\sigma_{scat}$$

density — scattering cross-section

Waveguide-based excitation and collection



- Cloud couples to single waveguide mode: smallest possible étendue! ⇒ Optimal performance of spectrometer

$$\frac{P_{coll}}{P_{pump}} = L\eta_0\rho\sigma_{scat}$$

$$\eta_0 = \frac{1}{n(\bar{r})k_0}\left(\frac{\pi n_g \lambda_0}{\varepsilon_0}\right)^2 \left(\frac{\iint_{clad} |\bar{e}_m(\bar{r})|^2 d\bar{r}}{\iint_{\infty} \varepsilon(\bar{r})|\bar{e}_m(\bar{r})|^2 d\bar{r}}\right)^2$$

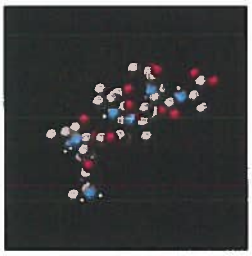
High index contrast matters

Raman signal strength: extremely weak

Typical molecular scattering cross-section: 10^{-29} cm²

After propagation through 1 cm of 100% dense analyte, one photon is scattered for 10^{6}- 10^{7} input photons

Vibrational spectroscopy

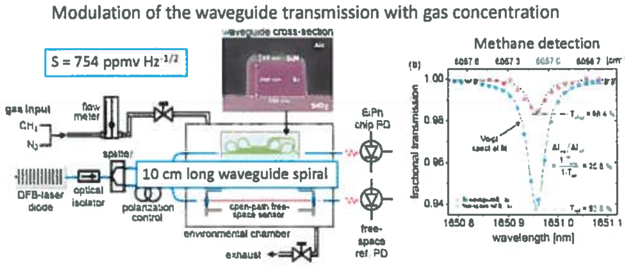


Infrared absorption spectroscopy
Very sensitive
"Poor" sources and detectors
Less compatible with biology

Raman spectroscopy
Very insensitive (but there are tricks)
Mainstream sources and detectors
More compatible with biology

Trace gas sensing with evanescent absorption spectroscopy

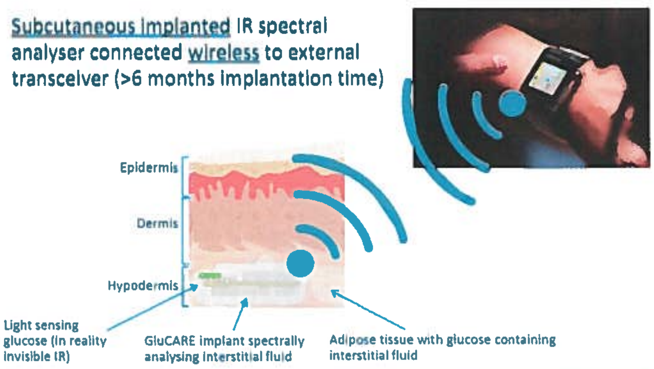
Modulation of the waveguide transmission with gas concentration



Zhang, Eric J., et al. *CLEO 2016.*

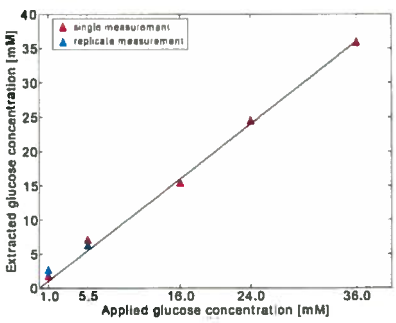
GluCARE enabled by "silicon photonics"

Subcutaneous implanted IR spectral analyser connected wireless to external transceiver (>6 months implantation time)



Glucose absorption spectroscopy: proof-of-concept

Use measured spectrum of 36 mM solution as the basic vector

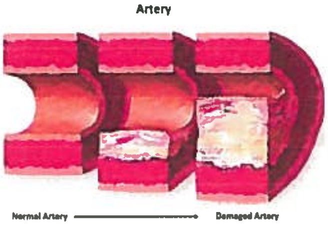


Demonstrated sensitivity of 1mM

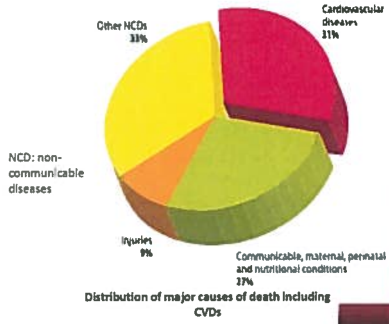
E. Ryckeboer et al, Biomedical Optics Express (2014)

Atherosclerosis

Deposition of plaque ⇒ higher arterial stiffness ⇒ higher pulse wave velocity



Cardiovascular diseases



Cardiovascular disease: The biggest killer in the world, responsible for **30%** of deaths (WHO, 2011)

Outline

An introduction to silicon photonics

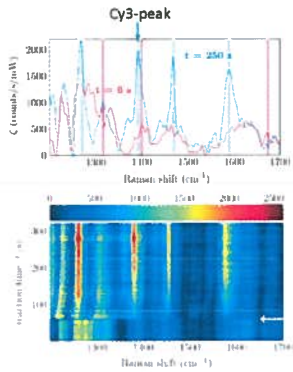
Refractive index biosensors for immunoassays

Spectroscopy-on-a-chip

- Absorption spectroscopy: Continuous Glucose Monitoring
- Raman spectroscopy: virus detection?, enzyme detection?, exosome detection?, amyloid detection?

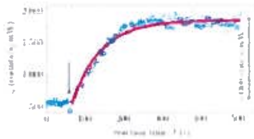
➡ Point-of-care Pulse Wave Velocity measurement

DNA hybridization kinetics



1. Waveguides functionalized with single strand DNA (here of a cancer-relevant gene K-Ras)

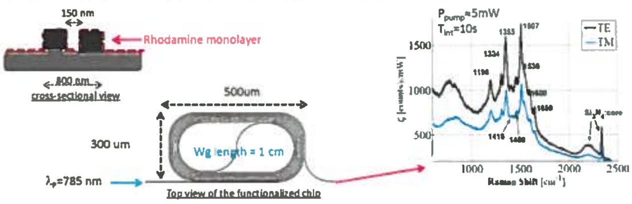
2. Real-time monitoring of the binding of complementary DNA, labeled with Cy3



A. Dhakal ea, http://arxiv.org/abs/1608.08002, 2016

Raman spectroscopy of Rhodamine monolayers

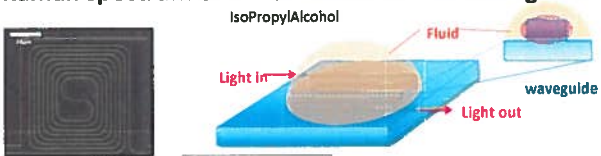
Si_3N_4 waveguides were silanized, reacted with amine-reactive NHS-Rhodamine and rinsed to get a monolayer of Rhodamine on the waveguide surface.

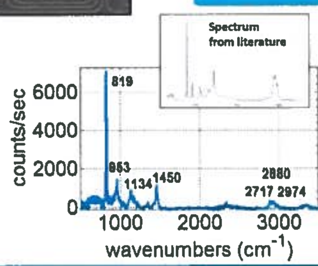


>10⁴ more collection efficiency than with Raman microscope.

A. Dhakal ea, http://arxiv.org/abs/1608.08002, 2016

Raman spectrum of IPA on silicon-nitride waveguide





Efficiency of collection 10-100x better than in Raman microscope

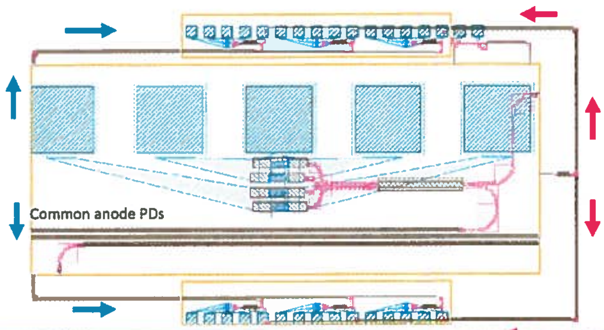
A. Dhakal et al, Opt. Lett. (2014)
A. Dhakal et al, Optics Express (2015)

Conclusion

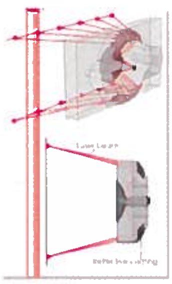
Silicon photonics:

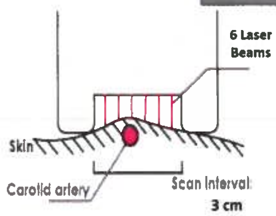
- Mature technology in CMOS-fab, low cost in high volume
- Strong industrial traction for telecom/datacom/interconnect applications
- From visible to mid-IR
- Very large potential for lab-on-chip applications, body implants and PoC tools
  - refractive index sensing for immunoassays
  - spectroscopic sensing
    - absorption spectroscopy
    - Raman spectroscopy
  - point-of-care diagnostic tools (LDV, OCT, …)

Photonic integrated circuit



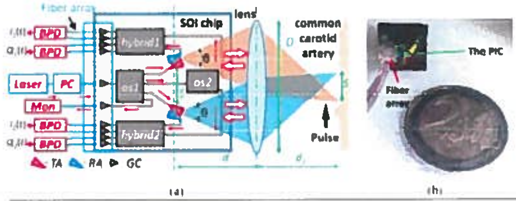
Many LDVs in one chip: easy alignment

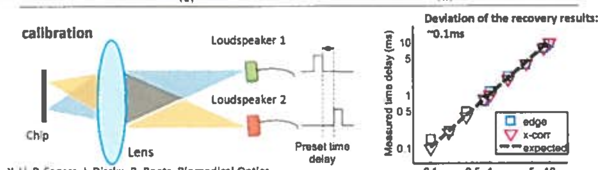




Cardis Medtronic Tyndall SIOS

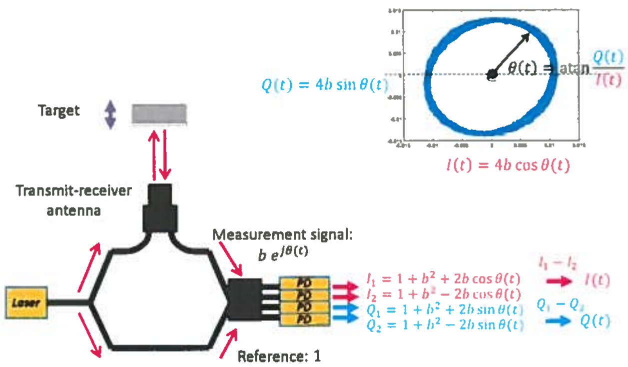
Our previous work: Dual-homodyne LDV for PWV measurements





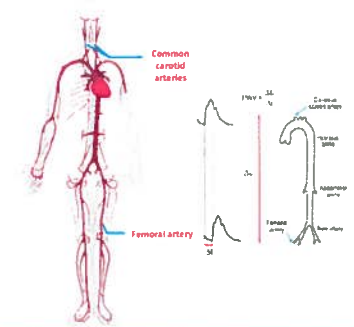
Y. Li, P. Segers, J. Dirckx, R. Baets, Biomedical Optics Express, 4(7), p.1229-1235 (2013) .

Principle of Homodyne Laser Doppler Vibrometry

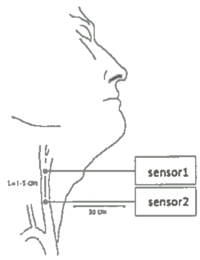


Pulse wave velocity

Gold standard: Carotid-femoral PWV



Point-of-Care approach: Local PWV



Acknowledgements

Photonics Research Group

professors P. Bienstman, W. Bogaerts, B. Kuyken, G. Morthier, G. Roelkens, N. Le Thomas, D. Van Thourhout

many postdocs and PhD's

IMEC CMOS process line

and ePIXfab www.epixfab.eu

Funding and collaborations through national and EU research projects

File Edit View History Bookmarks Tools Help

MNM | Herbeluister - MNM vi... | Publications | European Optical Society Annu... | EOSAM 2016 - ConfTool Pr...

ConfTool GmbH (DE) https://www.conftool.com/eosam2016/index.php?page=browseSessions&search=baets

EOS European Optical Society Coherence for Europe

EOSAM 2016

Berlin Adlershof, con. vent. Exhibition Centre, Germany • 26 - 30 September 2016

Login Conference Time: 13/Dec/2016 2:23:34 pm CET

Conference Agenda

Overview and details of the sessions of this conference. Please select a date or location to show only sessions at that day or location. Please select a single session for detailed view (with abstracts and downloads if available).

Authors Print View with Header baets

Presentations

TOM 1 S01: Silicon Photonics and Guided-Wave Optics: Integrated silicon and silicon-hybrid photonics
Time: 29/Sep/2016: 1:30pm-3:00pm · Location: Newton Cabinet

1:30pm - 2:00pm
Invited

Silicon photonics and its applications in life science

Roel Baets
Ghent University - imec, Belgium

A variety of silicon photonics applications such as refractive index biosensors and lab-on-a-chip sensors in a life science context will be given

Print View

Contact and Legal Notice · Contact Address: eosam2016@myeos.org
Conference: EOSAM 2016

Conference Software - ConfTool Pro 2.6.99+TC