20th Slovak - Czech - Polish

Optical Conference On Wave and Quantum Aspects of Contemporary Optics

Invited speakers

- Home
- Plenary speakers
- Committees
- Venue
- Proceedings
- Programme
- Registration
- Conference fees
- Social events
- Become an Exhibitor
- The Best Student Paper Award
- Contact

Registration & Abstract
Closed !

Paper submission
Extended !
15 October 2016

- **Karol Bartkiewicz**, Adam Mickiewicz University, Poznań, Poland: *How to measure the quantum properties of polarization-correlated photon pairs by interference*
- **Roel Baets**, Ghent University, Belgium: *Silicon photonics and its applications in life science*
- **Ivan Glesk**, University of Strathclyde, Glasgow, UK: *Tissue viability monitoring - a multi - sensor wearable platform approach*
- **Pavel Honzátko**, Institute of Photonics and Electronics of the Czech Academy of Sciences, Prague, Czech Republic: *Coherent sources for MIR laser spectroscopy*
- **Stanislav Jurečka**, University of Žilina,Slovakia: *Analysis of linear and nonlinear effects in optical fiber*
- **Václav Kubeček**, Czech Technical University in Prague, Czech Republic: *Femtosecond diode-pumped mode-locked neodymium lasers*
- **Petr Malý**, Charles University in Prague,Czech Republic: *Ultrafast laser spectroscopy of diamond*
- **Agnieszka Popiołek-Masajada**, Wroclaw University of Technology, Poland: *Optical vortices in microscopic imaging*
- **Roberto Morandotti**, Institut National de la Recherche Scientifique, Montreal, Canada: *On-chip Kerr frequency combs for scalable quantum state generation*
- **Jozef Novák**, Institute fof Electrical Engineering, Slovak Academy of Sciences, Bratislava, Slovakia: *GaP nanowires - properties and applications*
- **Norbert Pałka**, Institute of Optoelectronics, Military University of Technology, Warsaw, Poland: *Time domain terahertz spectroscopy and its applications*
- **Jan Peřina**, Ondřej Haderka: *Coherence and dimensionality of intense twin beams*
- **Kamil Postava**, VSB – Technical University Ostrava, Czech Republic: *Spectroscopy of materials for terahertz photonics*
- **Dušan Pudiš**, University of Žilina, Slovakia: *Siloxane based photonic structures and their application in optoelectronic devices*
- **Tomasz Stefaniuk**, Kings College, London, on leave from Warsaw University, Poland: *Silver grain metamaterials*
- **Maciej Trusiak**, Krzysztof Patorski and Lukasz Sluzewski, Warsaw University of Technology, Poland: *Adaptive single-frame automatic fringe pattern analysis using Hilbert-Huang transform aided by the principal component analysis method*
- **František Uherek**, Slovak University of Technology and International Laser Centre, Bratislava, Slovakia: *Hybrid organic-inorganic integrated photonics*
- **Maciej Wojtkowski**, Nicolaus Copernicus University, Toruń, Poland: *Spatio Temporal Optical Coherence phase manipulation*

Organizers

- **Institute of Aurel Stodola**
  Faculty of Electrical Engineering, University of Žilina
- **Department of Physics**
  Faculty of Electrical Engineering, University of Žilina
- **International Laser Centre**
  Bratislava
- **Slovak Electrotechnic Society**

Aurel Stodola

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20th Slovak - Czech - Polish

Optical Conference On Wave and Quantum Aspects of Contemporary Optics

5-9 September 2016
Jasná, Slovakia

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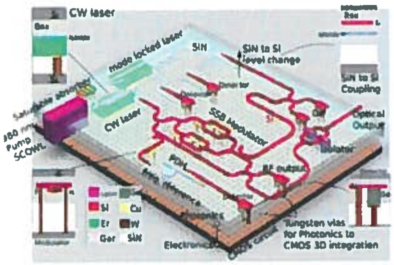
20th Slovak - Czech - Polish Optical Conf., Jasna, Slovakia, Sept 2016

Photonic Integrated Circuits (PIC's)



Source: EECS Berkeley

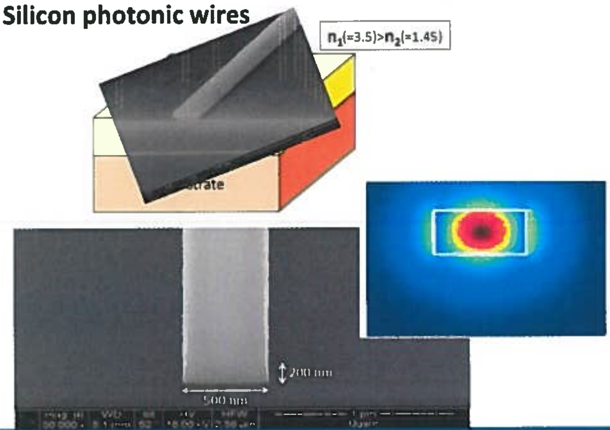
Need for photonic "wires"!

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

20th Slovak-Czech-Polish Optical Conference – Jasna, Slovakia - Sept 2016

Silicon photonic wires

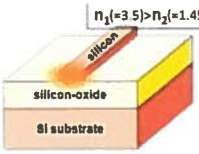


What is silicon photonics?

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

Why silicon photonics



- High index contrast ⇒ very compact PICs
- CMOS technology ⇒ nm-precision, high yield, existing fabs, low cost in volume
- High performance passive devices
- High bitrate Ge photodetectors
- High bitrate modulators
- Wafer-level automated testing
- Hierarchical set of design tools
- Light source integration (hybrid/monolithic?)
- Integration with electronics (hybrid/monolithic?)

Outline

An introduction to silicon photonics

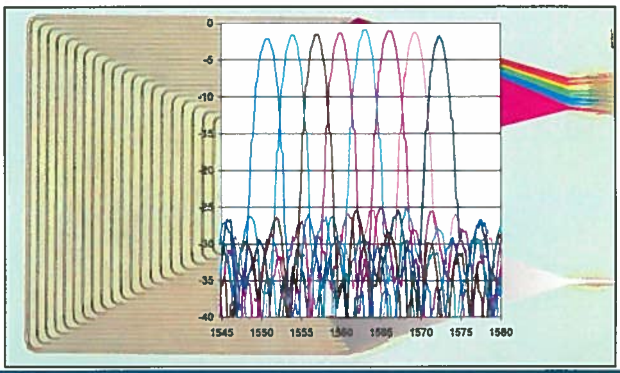
Refractive index biosensors for immunoassays

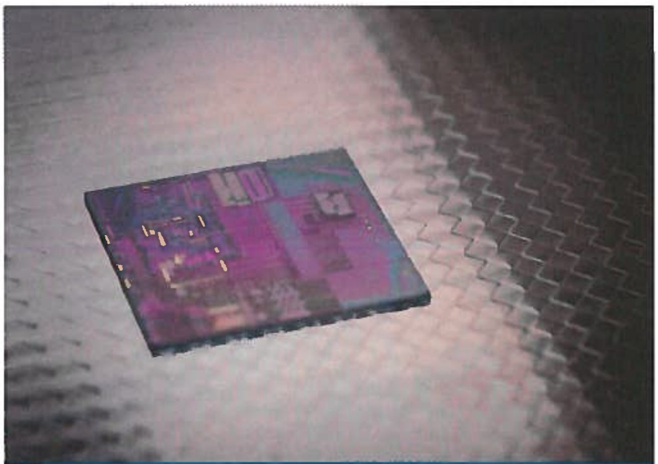
Spectroscopy-on-a-chip

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

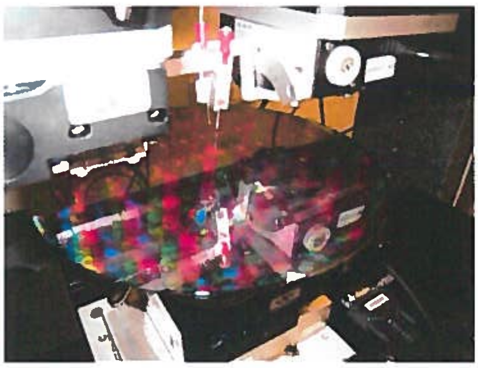
Point-of-care Pulse Wave Velocity measurement

On-chip spectrometer (200 x 350 µm²)





Automated wafer-scale measurement set-up



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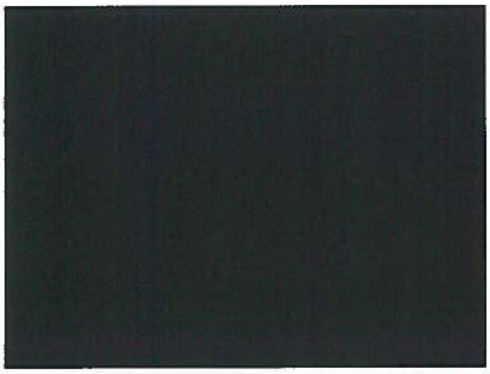

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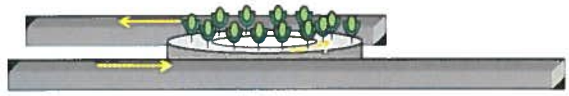
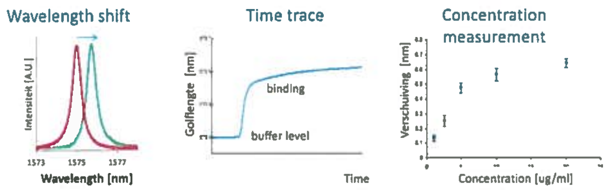
Biosensors

Detect presence and concentration of
- Proteins
- Viruses
- Bacteria
- DNA
- …

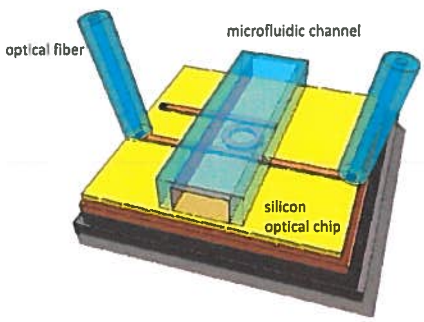
Two classes:
- Labeled: detection of label bound to biomolecule
- Label-free: direct detection of biomolecule

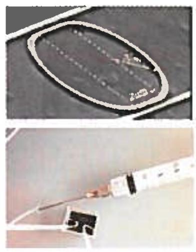
Label-free ring resonator biosensor through refractive index sensing of antigen-antibody binding



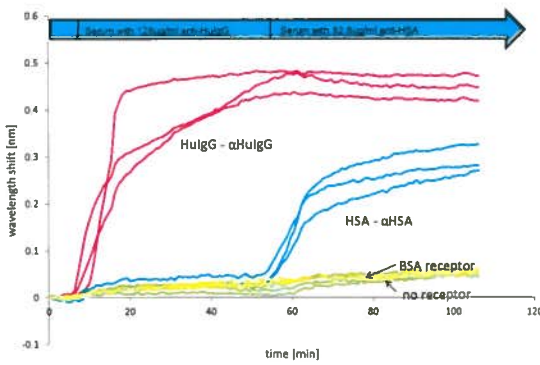


Lab-on-chip concept



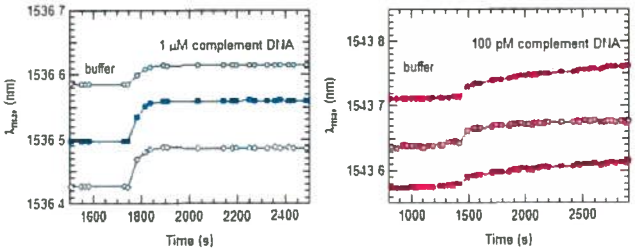


Multiplex sensing results



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

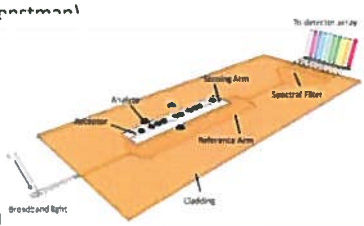
DNA hybridisation



Concentrations down to 100 pM can be detected

Pocket project (FP7)

- 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



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Refractive index biosensors for immunoassays

➡ Spectroscopy-on-a-chip

Absorption spectroscopy: Continuous Glucose Monitoring

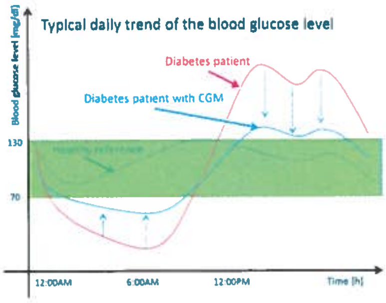
Raman spectroscopy: virus detection?, enzyme detection?, exosome detection?, Amyloid detection?

Point-of-care Pulse Wave Velocity measurement

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

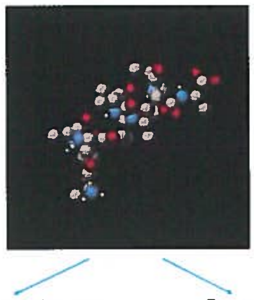
Multiple randomized, controlled studies* with usage of CGM systems show positive health impact:

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



* Liebl 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

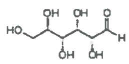
Vibrational spectroscopy



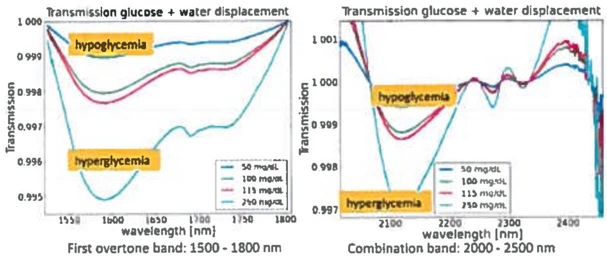
Infrared absorption spectroscopy
Very sensitive
"Poor" sources and detectors
Less compatible with biology

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

Glucose absorption spectroscopy



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

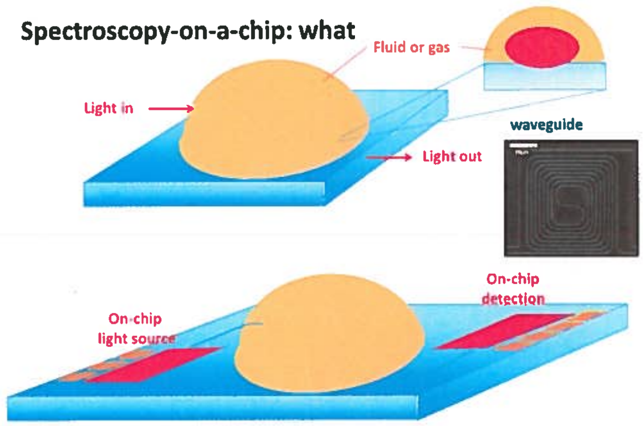


First overtone band: 1500 - 1800 nm

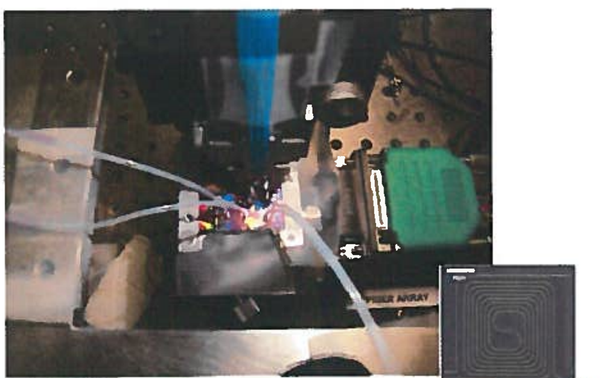
Combination band: 2000 - 2500 nm

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

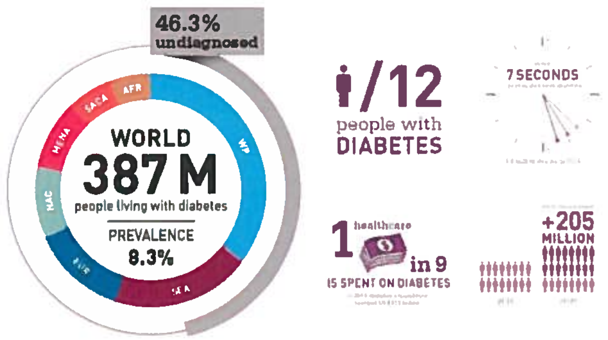
Spectroscopy-on-a-chip: what



Proof-of-concept demonstration in the lab



Diabetes is the 21st century health challenge



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

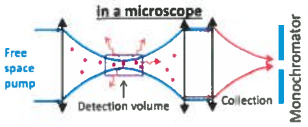
Raman signal strength: extremely weak

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

Waveguide-enhanced Raman spectroscopy

Free space excitation and collection in a microscope

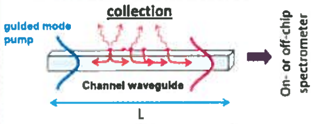


- Large étendue from particle cloud: ⇒ Resolution - sensitivity - size compromise for the spectrometer
- In a confocal microscope:

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

density — scattering cross-section

Waveguide-based excitation and collection

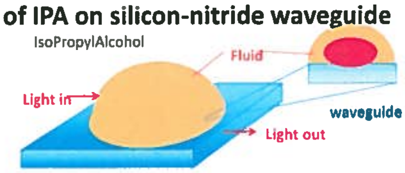


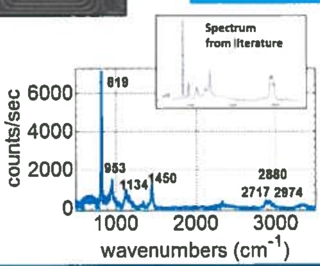
- Cloud couples to single waveguide mode: smallest possible étendue! ⇒ Optimal performance of spectrometer

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

High index contrast matters

Raman spectrum of IPA on silicon-nitride waveguide



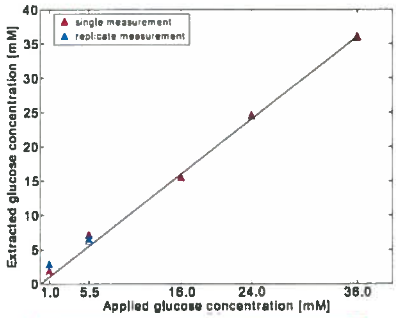


Efficiency of collection 10-100x better than in Raman microscope

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

Glucose absorption spectroscopy: proof-of-concept

Use measured spectrum of 36 mM solution as the basic vector

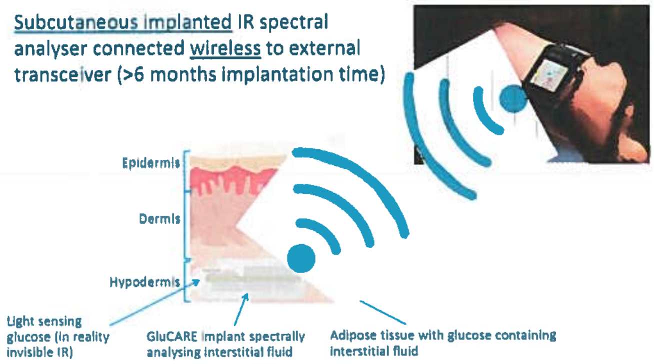


Demonstrated sensitivity of 1mM

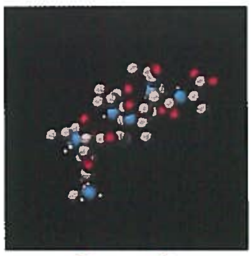
E. Ryckeboer et al, Biomedical Optics Express (2014)

GluCARE enabled by "silicon photonics"

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



Vibrational spectroscopy



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Very sensitive
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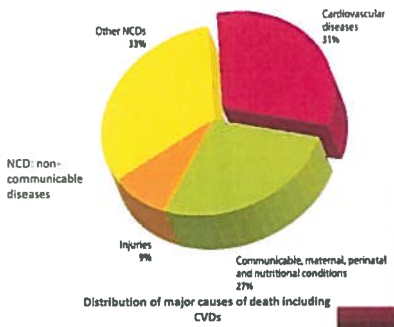
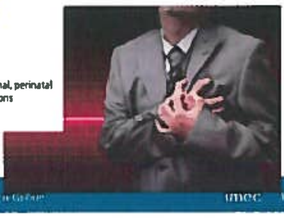
Cardiovascular diseases

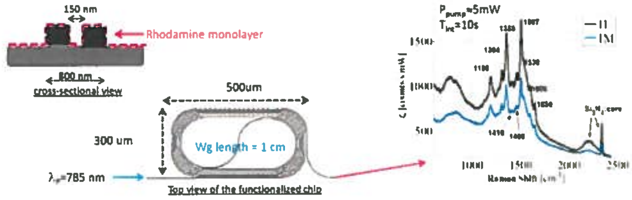


Cardiovascular disease: The biggest killer in the world, responsible for **30%** of deaths (WHO, 2011)



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.

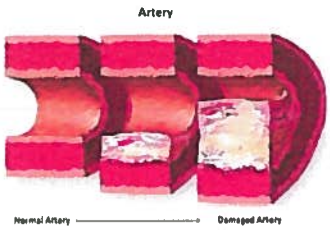


>10⁴ more collection efficiency than with Raman microscope.

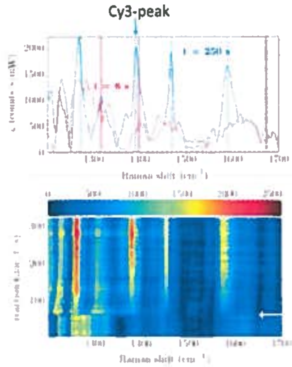
A. Dhakal ea, http://arxiv.org/abs/1606.08002, 2016

Atherosclerosis

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

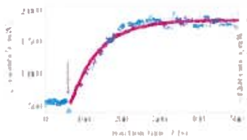


DNA hybridization kinetics



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

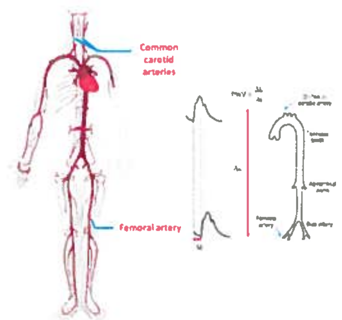
2. Real-time monitoring of the binding of complementary DNA, labeled with Cy3



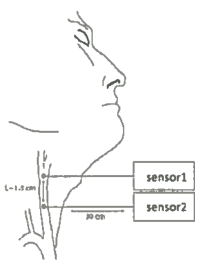
A. Dhakal ea, http://arxiv.org/abs/1606.08002, 2016

Pulse wave velocity

Gold standard: Carotid-femoral PWV



Point-of-Care approach: Local PWV



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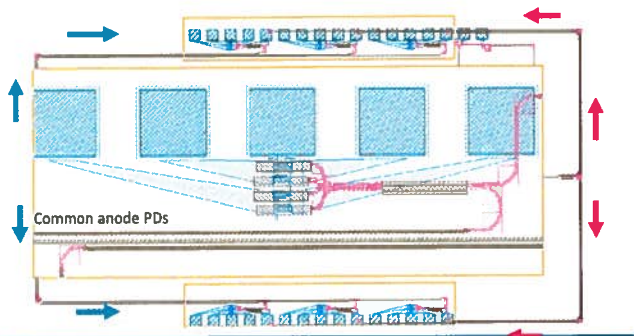
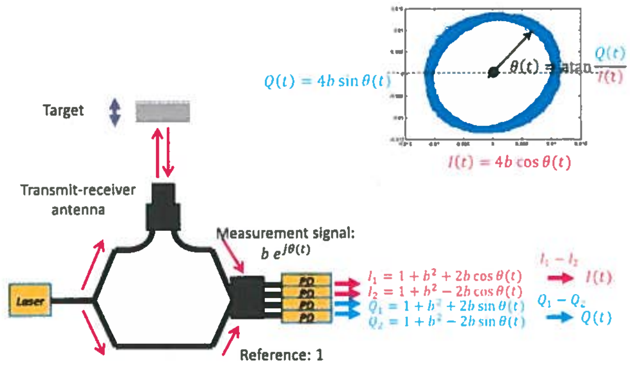
➡ Point-of-care Pulse Wave Velocity measurement

Photonic integrated circuit



Principle of Homodyne Laser Doppler Vibrometry

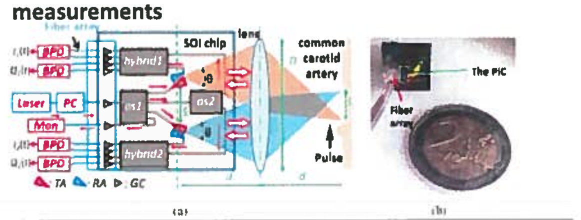


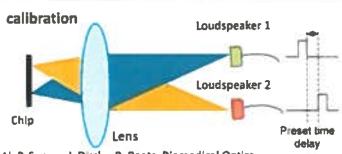
Conclusion

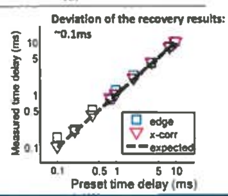
Silicon photonics:

- 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, ...)

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)

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

Many LDVs in one chip: easy alignment