Silicon photonics for application in life science

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What is silicon photonics?
The implementation of high density photonic integrated circuits by means of CMOS process technology in a CMOS fab

Outline
An introduction to silicon photonics
Biosensing and gas sensing
Laser Doppler vibrometry and optical coherence tomography
Spectroscopy-on-a-chip

Why silicon photonics matters

Evolution of energy usage by datacenters

Evolution of cost of health care

Affordable point of care solutions

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 performance Ge photodetectors
High performance modulators
Wafer level automated testing
Hierarchical set of design tools
Light source integration (hybrid/multichip?)
Integration with electronics (hybrid/multichip?)

Silicon photonic chips
Industrial take-up

Si photonic products

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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

Multiplex sensing results

DNA hybridisation

Concentrations down to 100 pM can be detected
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Doppler effect

\[ \frac{\Delta f_{\text{Doppler}}}{f_{\text{Doppler}}} = \frac{2v_{\text{target}}}{c} \]

Example:
- \( v_{\text{target}} = 15 \text{ cm/s} \)
- \( c = 3 \times 10^{8} \text{ m/s} \)
- \( f_{\text{Doppler}} = 10^{6} \text{ Hz} \)
- \( \Delta f = 200-2000 \text{ kHz} \)

Laser Doppler Vibrometer: measuring the velocity of a surface

\[ \frac{N_{\text{Doppler}}}{f_{\text{Doppler}}} = 2v_{\text{target}} \]

Pulse wave velocity measurement

- pulse wave velocity: measure for aortic stiffness, an important marker for atherosclerosis
- gold standard: carotid-femoral PWV
- not practical for general practitioner
- \( \text{ln} \) measurement in intracranial PWV
LDV-measurement of blood pulse velocity

- Blood pulse velocity increases when blood vessels become stiffer due to atherosclerosis.

CARDIS project (Horizon 2020)
- Goal: develop a prototype for a point-of-care LDV device
- Timeline: 2015-2018
- Budget: 3.5 Meuro

Silicon photonics circuit for swept source OCT
- Silicon chip: 0.75 x 5 mm² (waveguide loss: 0.35 dB/cm)
- Reference arm with 33 cm physical length (SOA 4 cm optical length)
- Sensitivity: -62 dB with 155 mW power delivered to the sample
- Axial resolution: 25 μm (limited by spectral bandwidth of fiber-chip grating couplers)

Si₃N₄/SiO₂ circuit for Fourier domain OCT
- Si₃N₄/SiO₂ waveguides (TriPleX) on silicon chip: 10 x 33 mm²
- Waveguide loss: 0.15 dB/cm
- Reference arm with 19 cm physical length
- Sensitivity: -65 dB with 200 mW power delivered to the sample

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