Tissue Optics Monte Carlo Analysis (TOMCA) for Wearables

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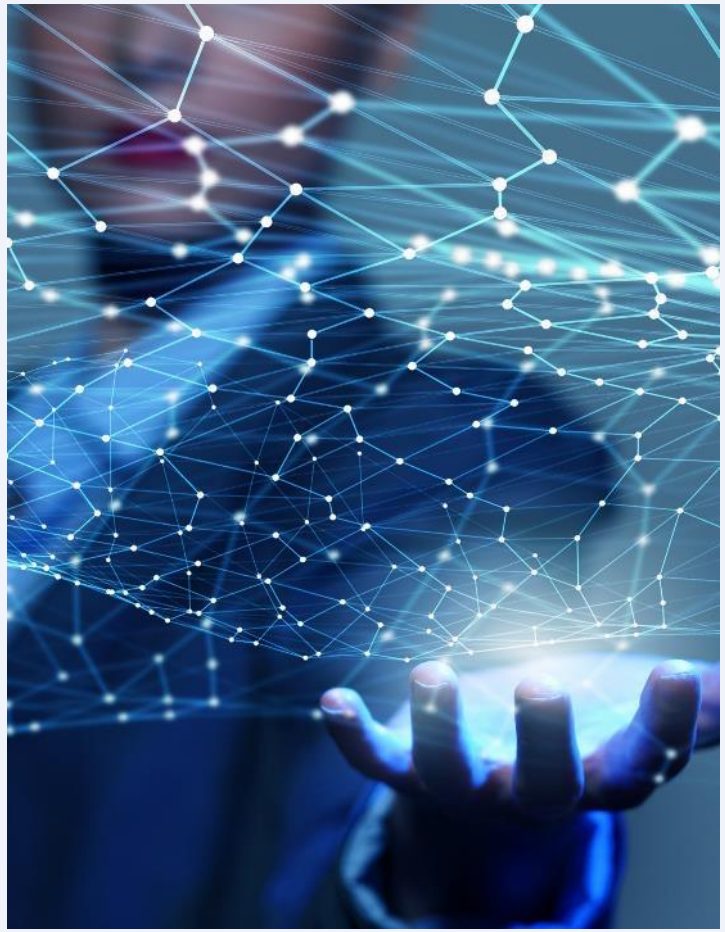
Fluence from a 650nm LED around a blood vessel

TNO: Netherlands Organisation for Applied Scientific Research

- Largest independent R&D organization in NL
  - Sustainable society
  - Healthy living
  - Safe and secure society
  - Digital society

- Take medical photonic devices from idea to clinical prototype
  - Medical/health wearables and retinal imaging



TOMCA

- TNO has invested heavily in **Tissue Optics: Monte Carlo Analysis** (TOMCA)

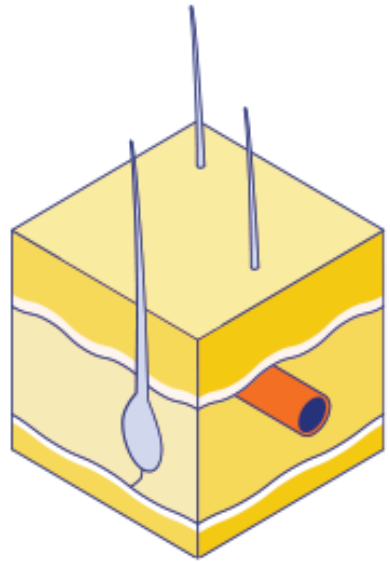
  Simulates millions of individual virtual photons travelling through a virtual tissue.

Kind of questions you can bring to TNO TOMCA:

- How much does placement error of a sensor above a blood vessel affect measurements at the surface?
- What spectral filters / LEDs should I build into my device to best probe deeper tissue?
- How robust is my measurement device to a diverse population group?

Transformation from real tissue

- Need to understand:
  - Optical properties of each material
  - Distribution of materials
    - Layers of skin
    - Blood vessel(s)

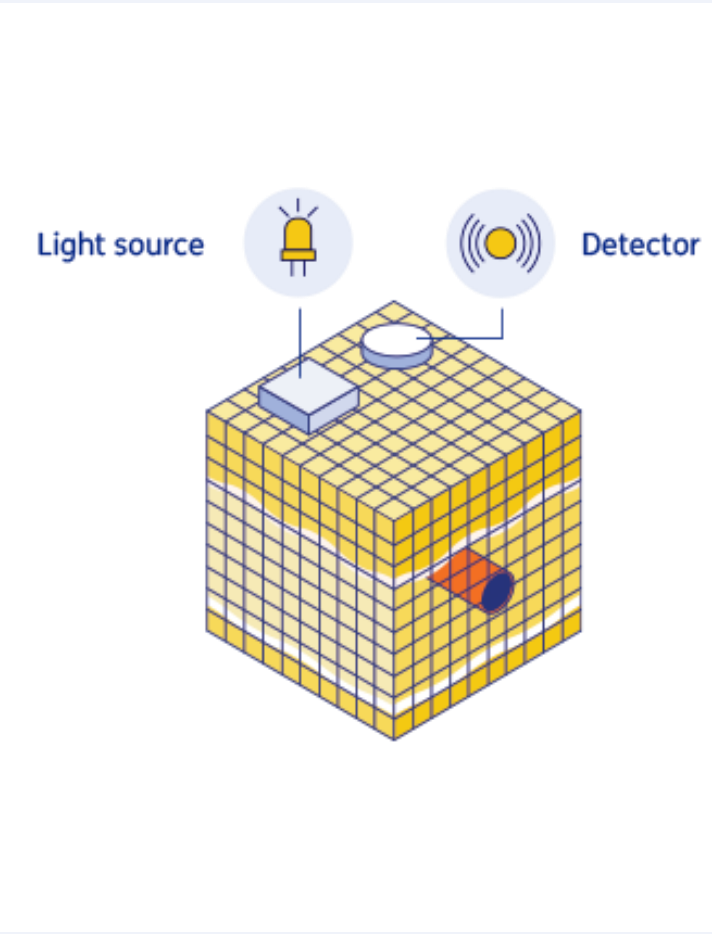


Building a reliable virtual model

- Optical properties of tissue at every point (“voxel”)
  - μ_a, μ_s, g, n
- Light source (pencil beam, square plane, LED…)
- Detector location(s)

This model can be modified for individual tissues, such as

- skin color
- age
- sex
- health status,
- etc.



Optical properties - absorption

Absorption coefficient (μ_a) is different for each layer and depends on the spectra and volume fraction of the main absorbers in each layer:

$$\mu_a^{general} = BS\mu_a^{oxy} + B(1-S)\mu_a^{deoxy} + W\mu_a^{water} + M\mu_a^{melansome} + F\mu_a^{fat} + \text{...other components*}$$

Where,

B = blood volume fraction – *age?*
S = oxygen saturating of haemoglobin
W = water volume fraction – *age, gender?*
M = melanosome volume fraction - *ethnicity*
F = fat volume fraction – *BMI, gender?*

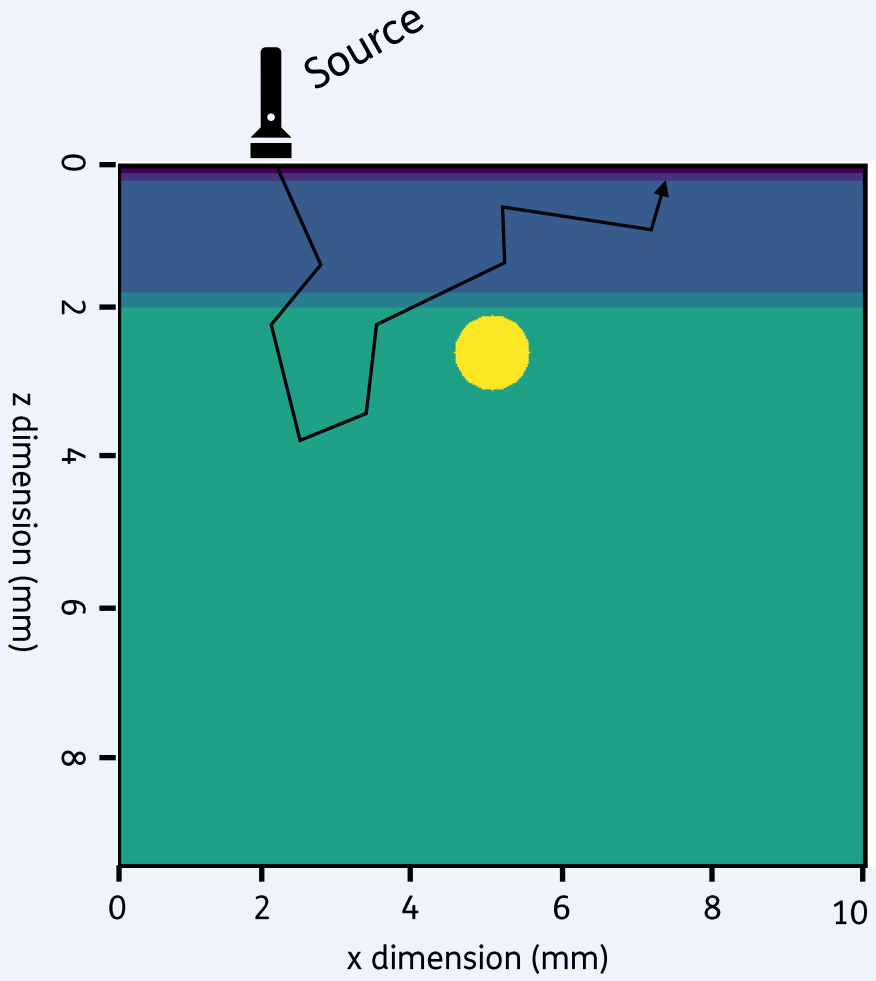
B+W+M+F +... < 1

We can test sensors on a diverse population before entering the clinic

* From: https://omlc.org/news/feb15/generic_optics/index.html

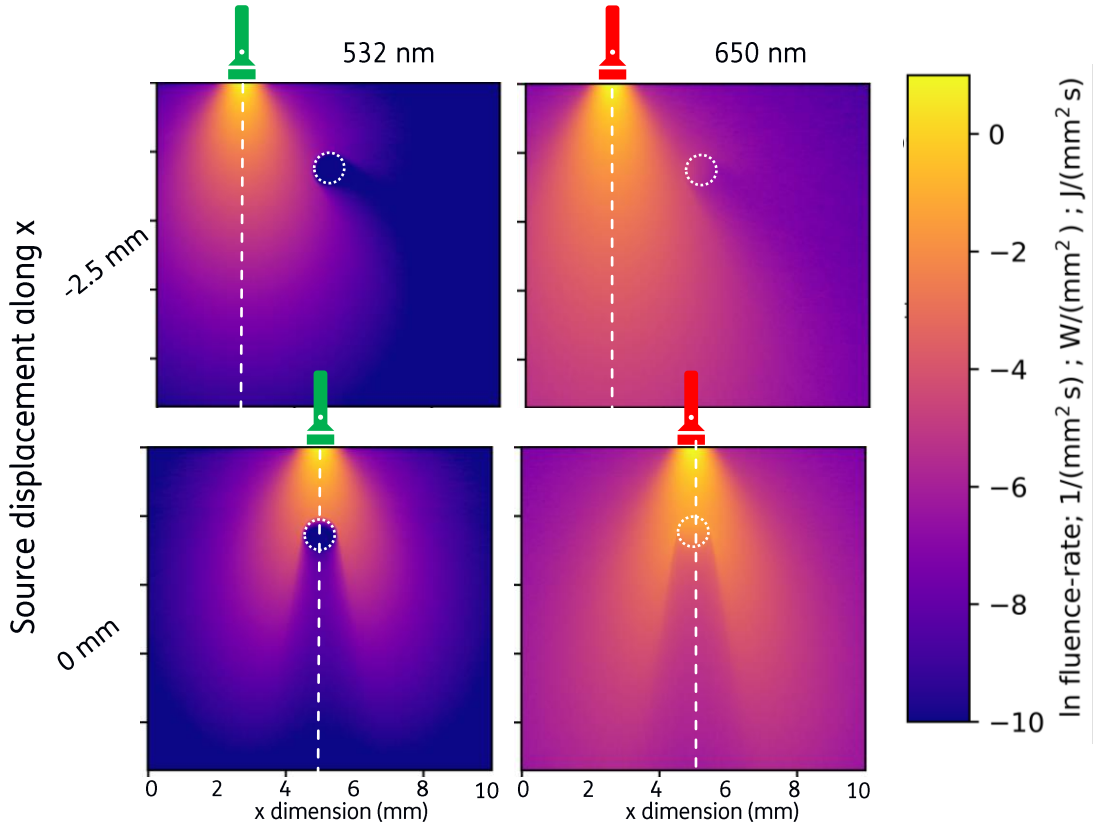
Skin Model Example

- Layers + features
  - Epidermis
  - Upper, Middle, Lower Dermis layers
  - Subcutaneous Fat
  - Blood vessel
    - 1mm diameter blood vessel
    - 2mm below surface of skin, in subcutaneous fat layer

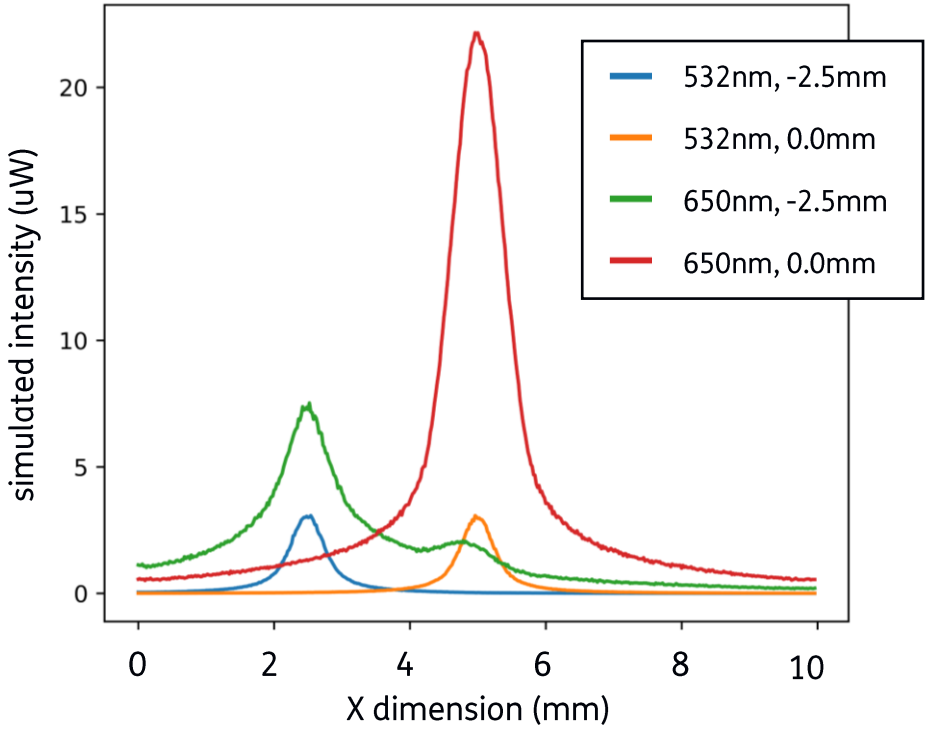


Skin Model Example: reflectance from a blood vessel

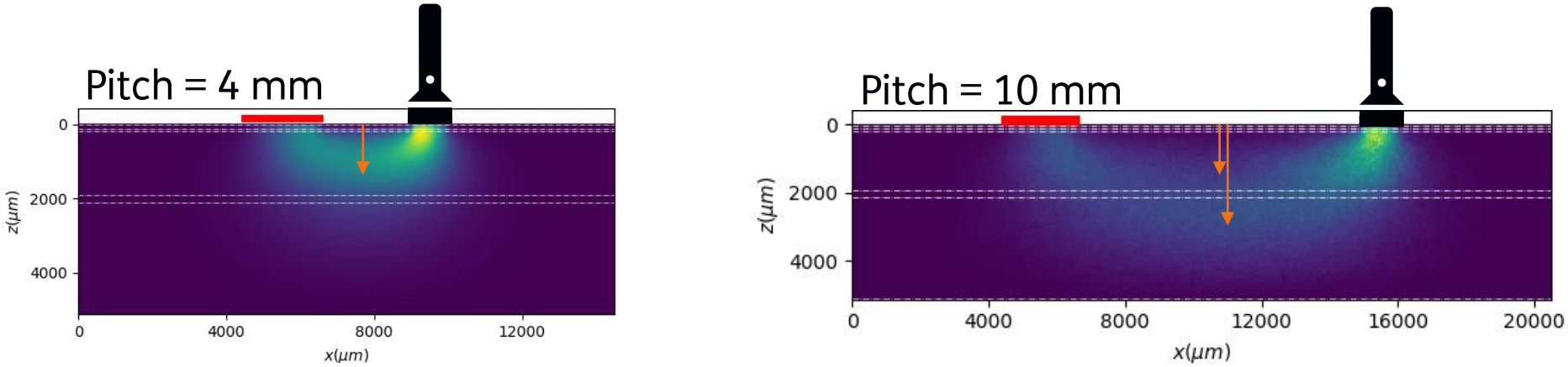
Flux of light through tissue



Light intensity profile at surface



Specific trajectory mapping from source to detector



- Able to show how different skin layers are probed
  - Deeper understanding of how biomarkers are being measured, with insight on limitations of sensing

Current Technologies

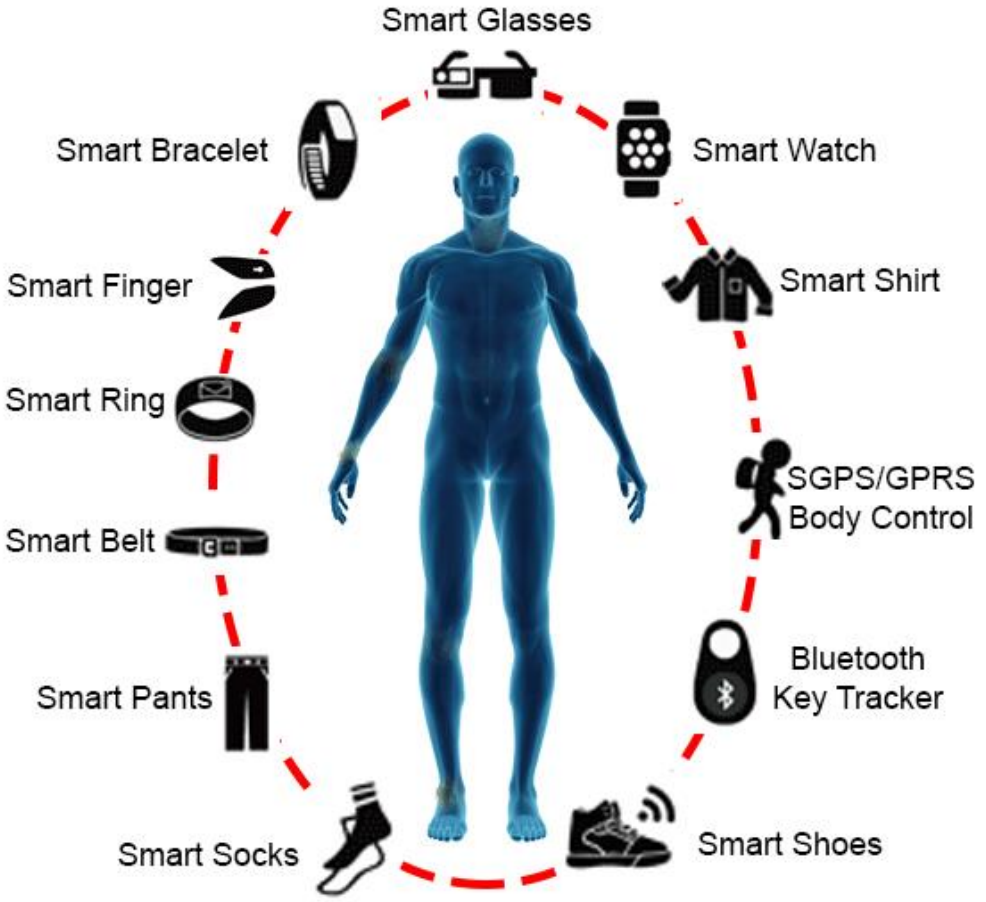
Heart Monitoring

Blood Pressure

BMI

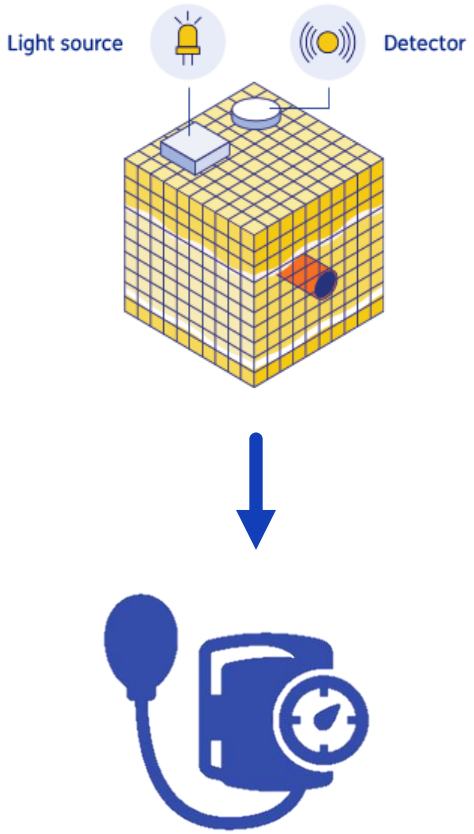
Movement

Sleep



TOMCA development pipeline for wearables

Concept	Identify target biomarker and its interaction with light
TOMCA Model	Model target tissue for a diverse simulated population
Sensor Design	Optimize biomarker measurement using machine learning algorithms to find robust sensor geometry
Hardware Development	Build and test physical sensor
Validation	Validate on realistic tissue phantoms; layered, stable, well-controlled blood flow if needed
Clinical Trials	Test on volunteer groups



TNO's Medical Photonics team can help with simulation and analysis at every step of this process

TNO innovation for life

Thank you for your attention

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