Monte Carlo Analysis of Near Infrared Wavelengths Towards an Optical NIR Blood Analyte Sensor

3D Monte Carlo (MC) light-tissue interaction simulations was conducted for seven near-infrared (NIR) wavelength LEDs, 1050, 1200, 1300, 1450, 1460, 1550, and 1650 nm, to assess the penetration depth, pathlength, and detected power to develop non-invasive sensing methods for blood analytes.

Methods: The MC simulations were performed using an adapted version of "MCmatlab: an open-source, user-friendly, MATLAB-integrated three-dimensional Monte Carlo light transport solver with heat diffusion and tissue damage". Figure 1 presents the emitter-detector geometry, and 7-layer tissue composition used.

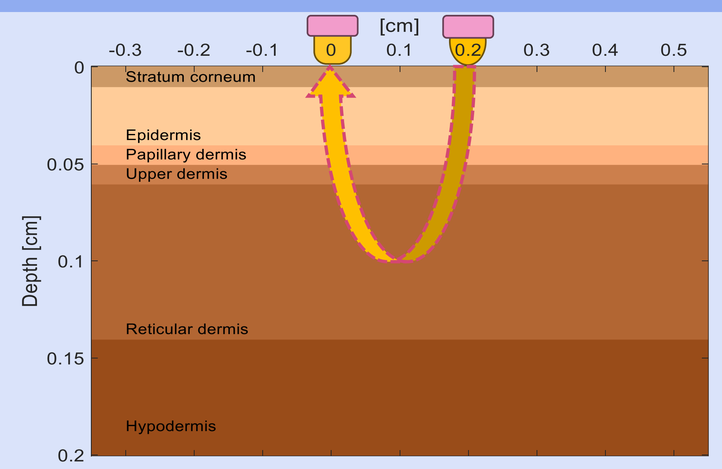

Figure 1: tissue and emitter-detector simulation

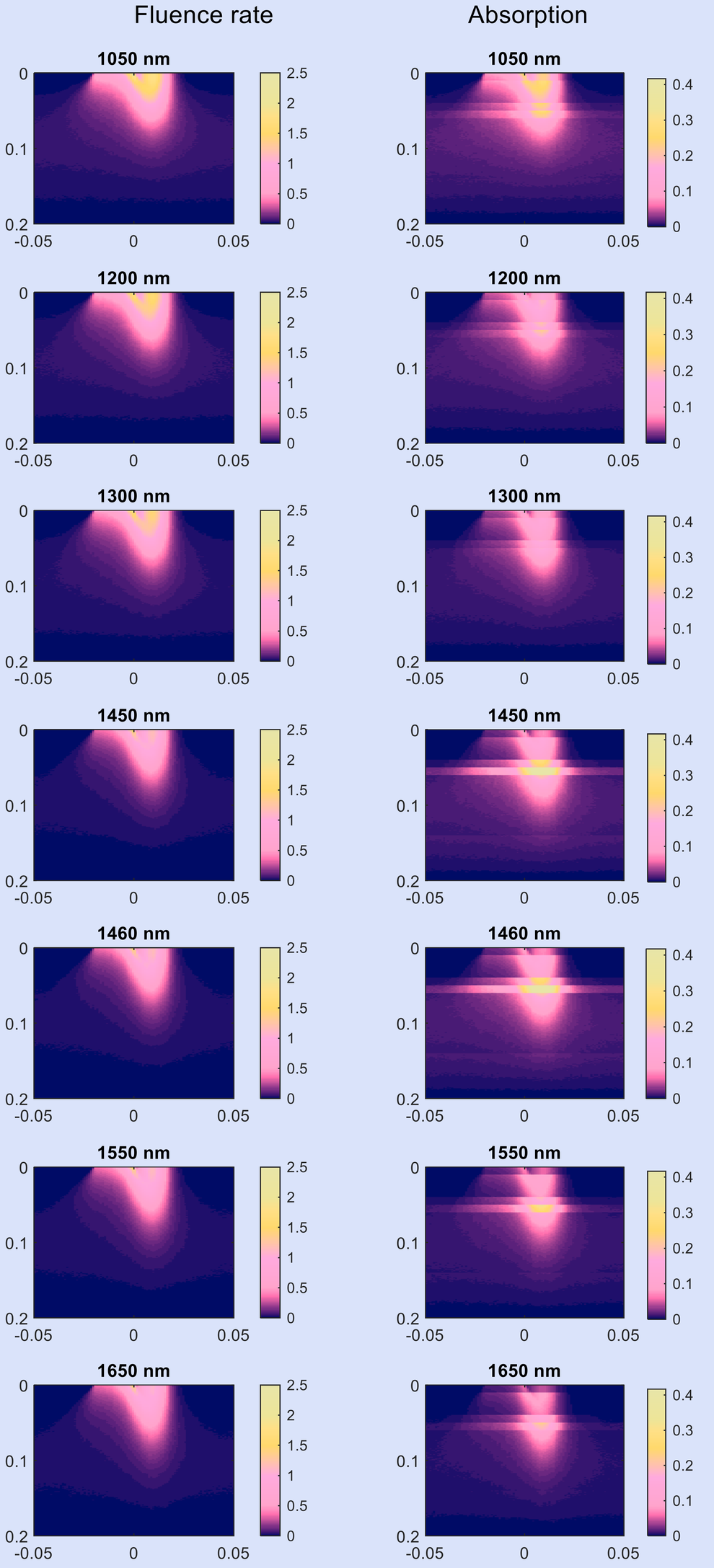

Figure 2: Fluence rate and absorption [W/m^2/W-incident] for each wavelength

Results: Each wavelength was simulated for 12 hours where 9e9 - 9e10 photon packets were launched. Figure 2 presents the fluence rate and absorption [W/m^2/W-incident] for each wavelength on the centre of the emitter-detector plane.

The mean photon pathlength was between 2.330 and 2.548 mm (Figure 3A). The mean maximum photon depth was between 0.986 and 1.141 mm (Figure 3B). The percentage of photons collected by the detector were all less than 0.1% (Figure 3C).

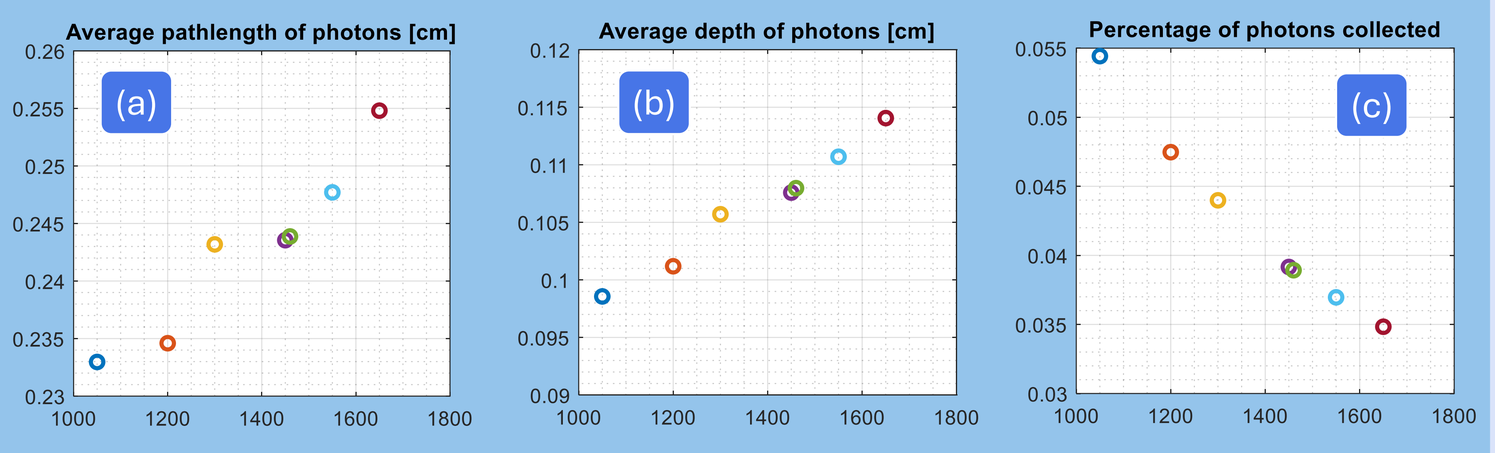

Figure 3: (a) Average pathlength, (b) depth, and (c) percentage of photons collected for each wavelength [nm].

The maximum sum normalised fluence rate was between 87.86 and 56.10 W/m2/W-incident located in the stratum corneum layer for all wavelengths (Figure 4A). The maximum normalised absorption was between 10.14, and 37.03 W/m2/W-incident located in the upper dermis (Figure 4B).

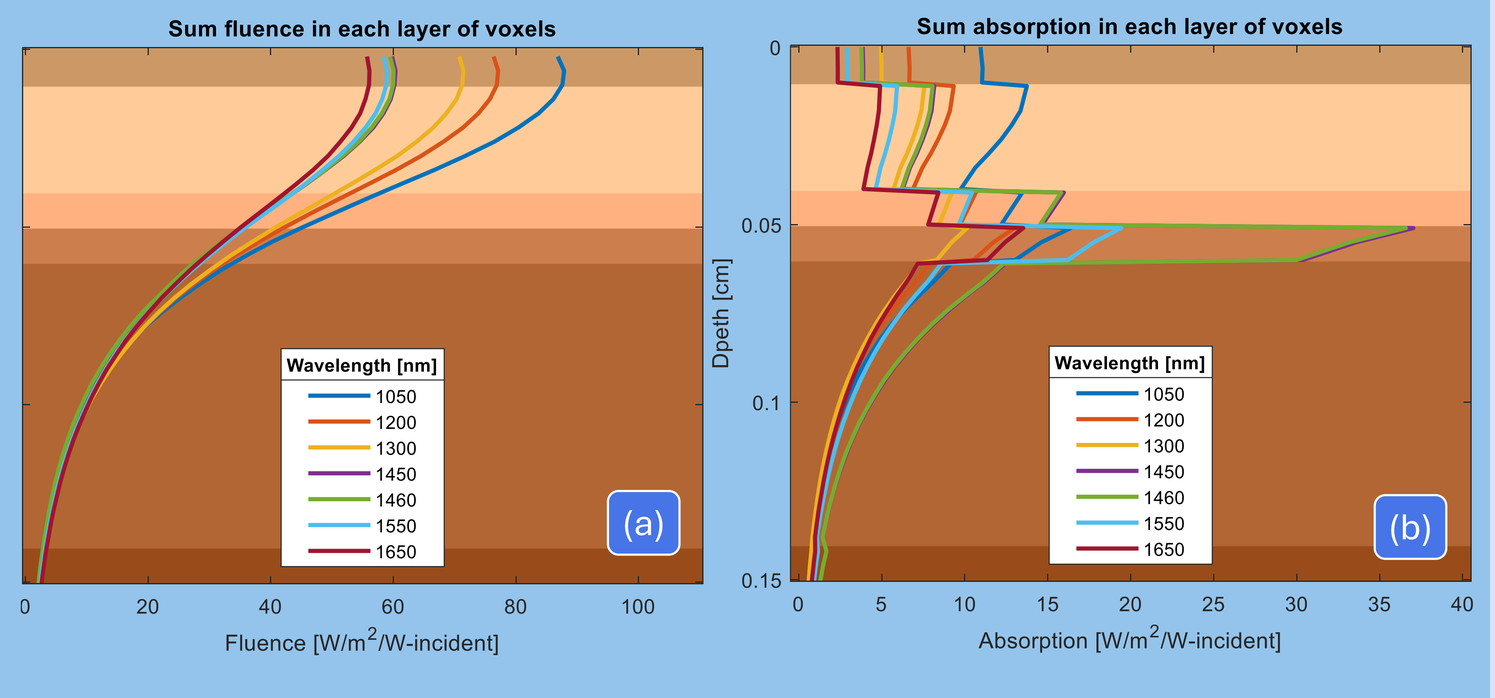

Figure 4: Normalised fluence rate and normalised absorption [W/m^2/W-incident] through each layer for each wavelength

Conclusions: The penetration depth increases with wavelength as suggested by the increase in penetration depth from visible to SWIR. The percentage of photons detected is less than 0.1%, highlighting the importance for highly sensitive photodetectors with these wavelengths. MC simulations were carried out on NIR wavelengths to better understand the light-tissue interaction. The pathlength and penetration depths found will be used to develop sensor emitter-detector separation and device selection, and post processing algorithms for a non-invasive blood analyte concentration sensor.

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VDE DGBMT
BMT 2024
18. – 20.09.2024 | Stuttgart/Germany
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