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Remitted photon path length in human skin, skin phantoms and cells cultures

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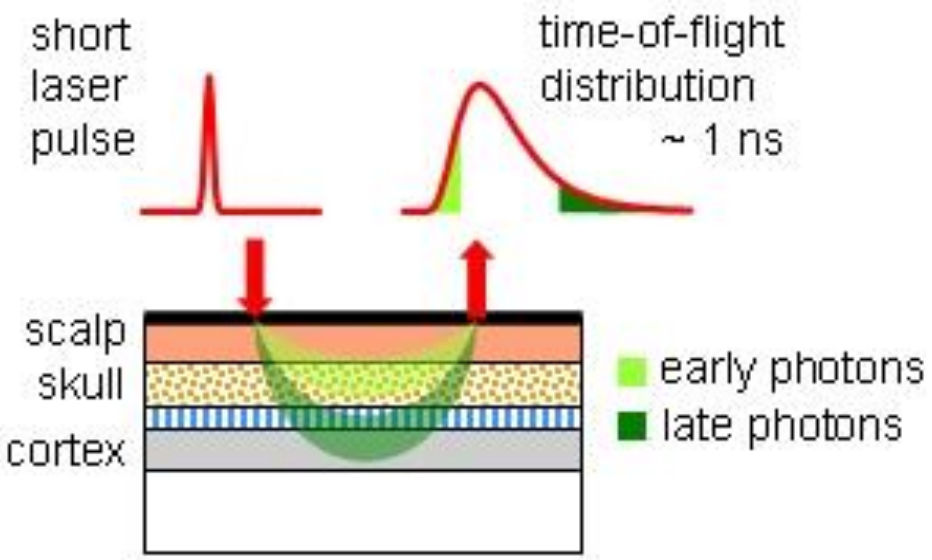
The goal of this study

The main goal of this study was to determine the photon path length in human skin and influence of skin chromophores.

- The photon time-of-flight (PTOF) measurement method was used in this study, where the photon travel time was converted into path length.
- An experimental method for remitted photon path length measurements has been developed and tested on human skin and skin neoplasms, skin phantoms and cell cultures.
- Measurements were performed at different wavelengths (VIS and NIR spectral range); they were taken from human skin and skin neoplasms, agar-based phantoms with different concentrations of intralipid and hemoglobin, and from cells cultures (DC3F, B16/F10).

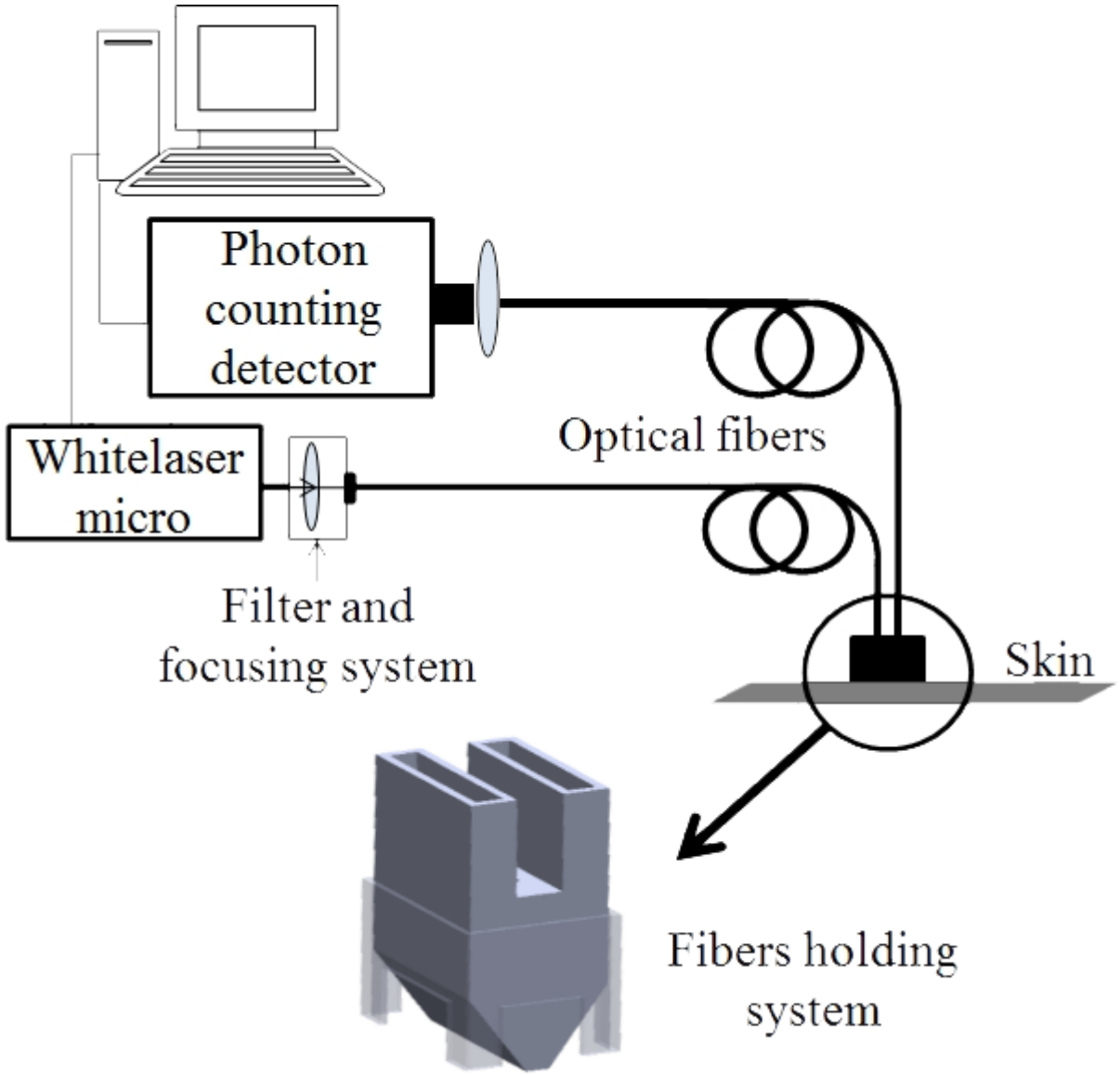
Time-of-flight (TOF) spectroscopy



Time-of-flight (TOF) spectroscopy is a tool for characterization and analysis of highly scattering (turbid) materials, such as biological tissue, powders, and pharmaceutical samples. The main principle is to deliver a very short laser pulse into the material, and to analyze the resulting pulse at some distance.

Online: https://www.ptb.de/cms/en/ptb/fachabteilungen/abt8/fb-83/ag-831/kopf.html

Measurements set-up



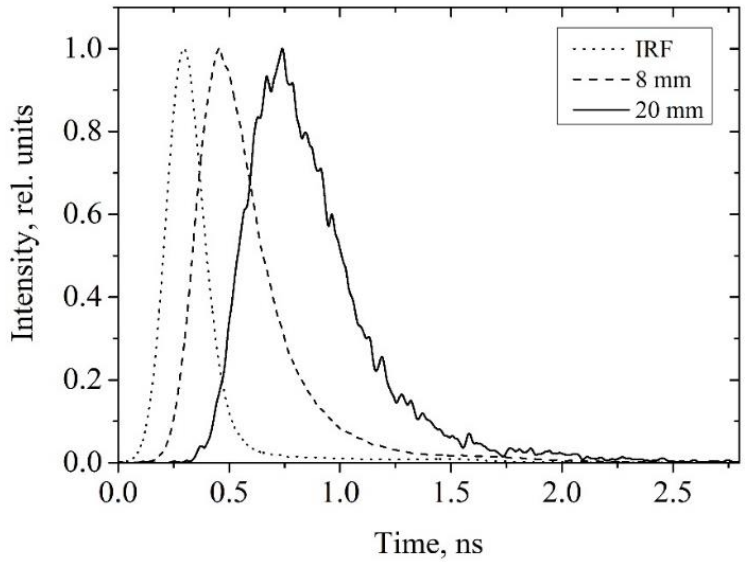
TCSPC

Detector - HPM-100-07 hybrid photon counting detector (Becker&Hickl, Germany).

Light sours - Whitelaser micro supercontinuum lasers (Fianium, FWHM 6ps, 20 MHz, 400 – 2000 nm)

Filters – 520, 560, 680, 760 nm (Andover Corporation, USA)

Optical fibers
and
Fibers holding system



Can it be measured directly?

If the distribution of remitted photon propogation time in skin *f(t)* is measured, the corresponding distribution of photon path lengths can be found as

$$f(s) = f(t) \cdot c/n$$

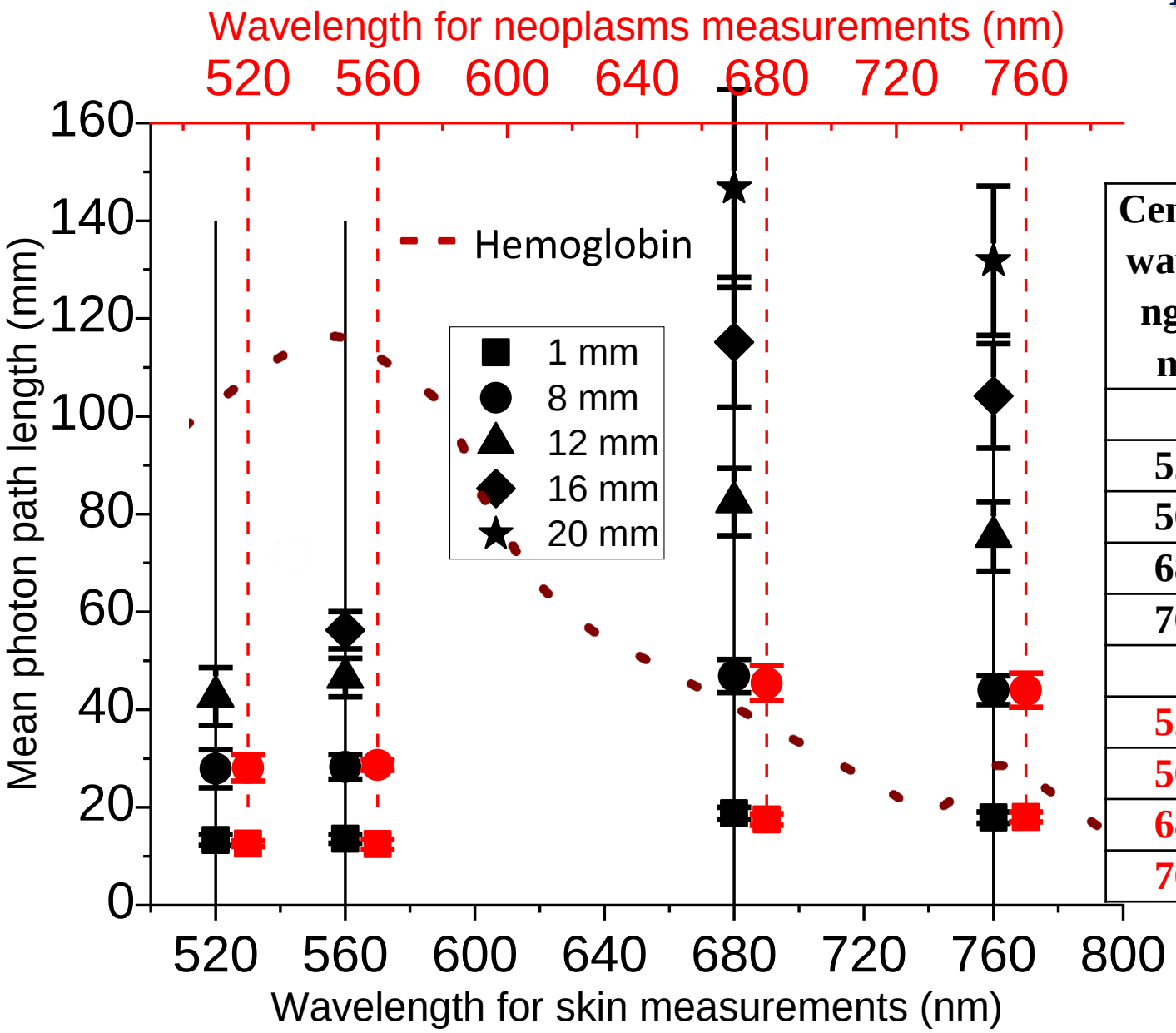
Where *c* is the speed of light in vacuum and *n* is the mean refraction index of superficial skin tissues (n~1.4)

The function $f(\tau)$ – response to delta-pulse – is "hidden", it can be found by de-convolution of integral

$$b(t) = \int_0^t a(t-\tau) f(\tau) d\tau$$

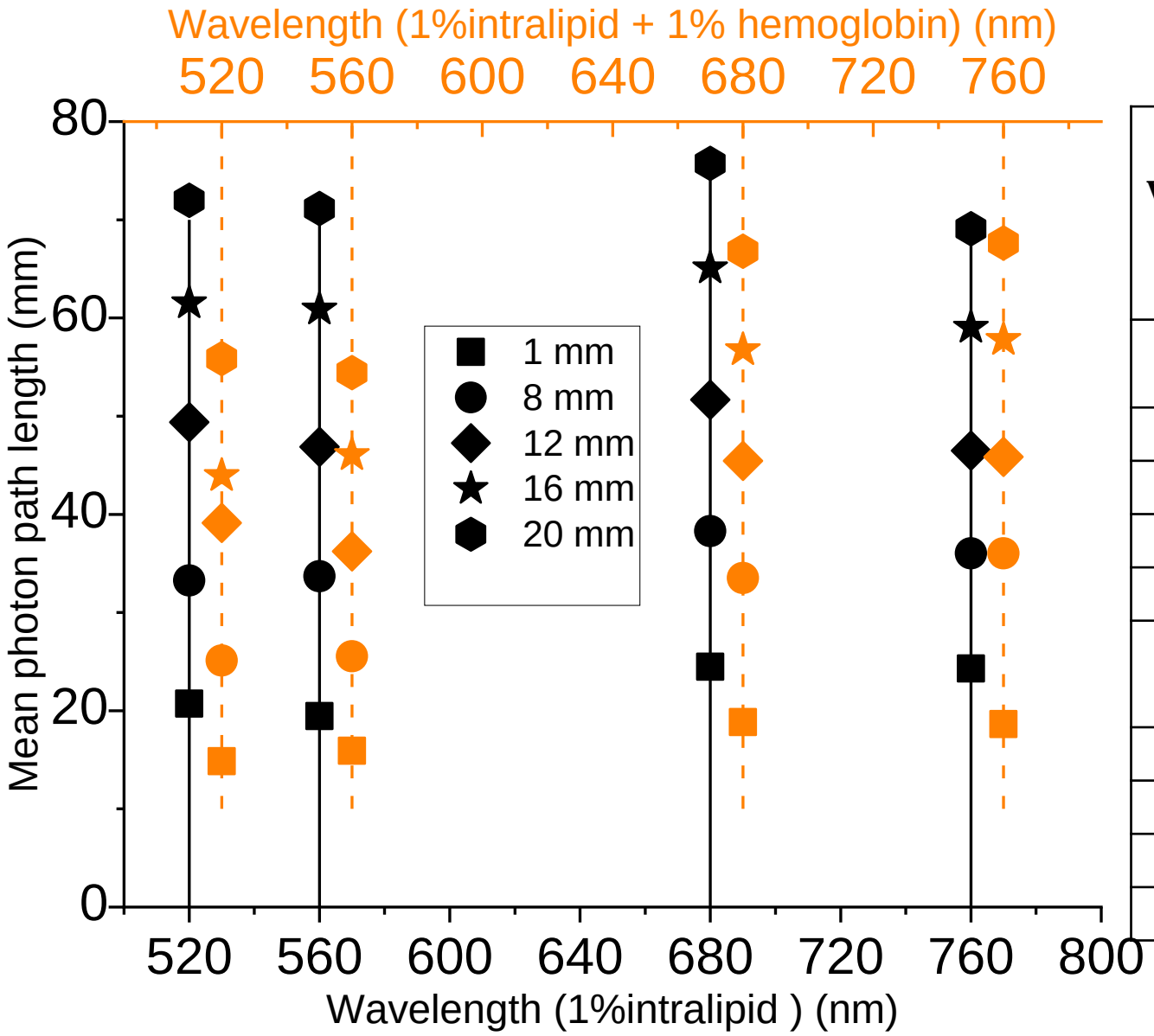
Where *a(t)* is the temporal shape of input laser pulse and *b(t)* – the shape of skin output pulse at the same wavelength.

Skin and neoplasms



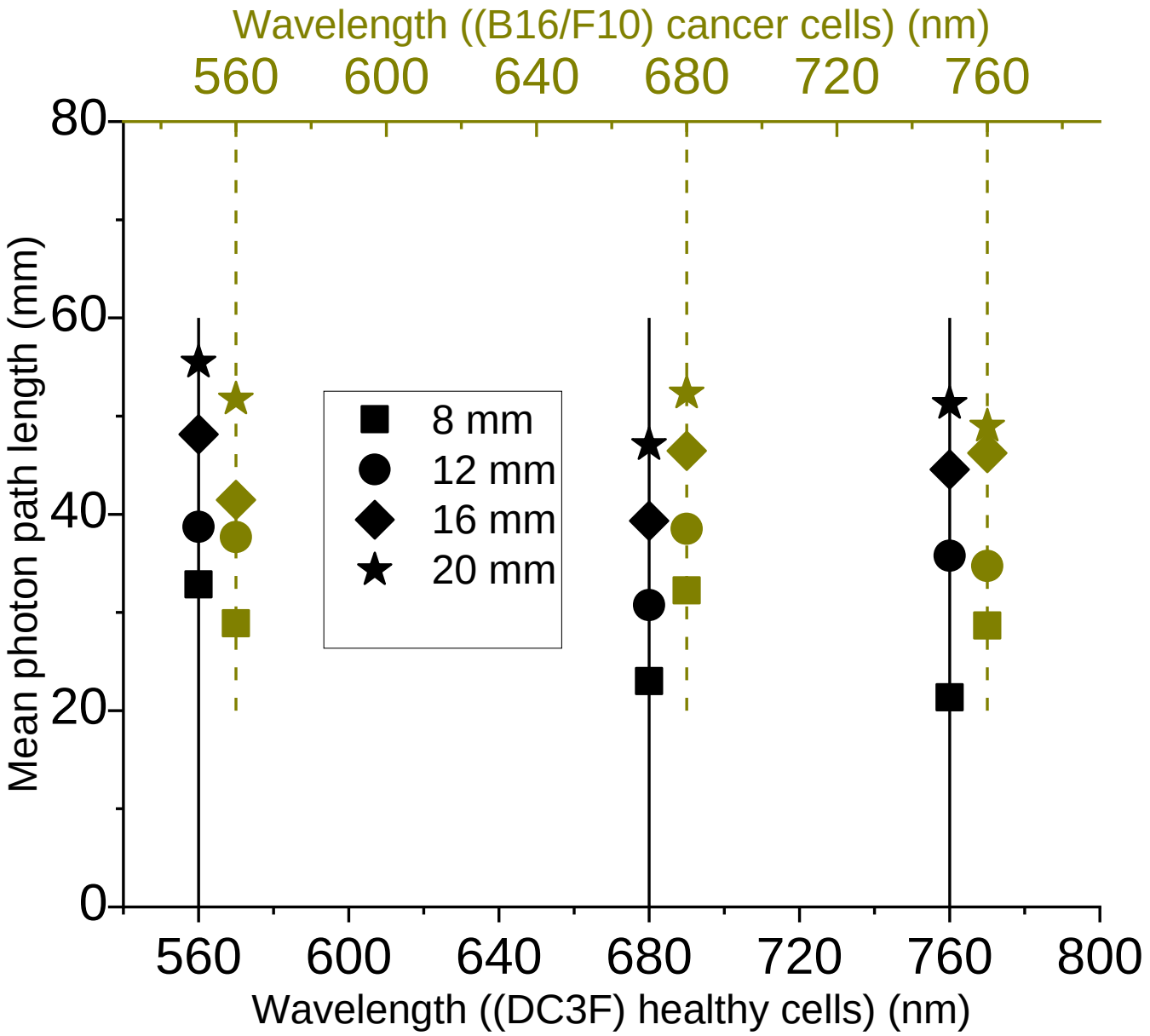
Central wavelength, nm	1 mm	8 mm	12 mm	16 mm	20 mm
Skin					
520	13 ± 1	28 ± 4	43 ± 6		
560	14 ± 1	28 ± 2	47 ± 4	56 ± 4	
680	19 ± 1	47 ± 3	82 ± 7	115 ± 13	147 ± 20
760	18 ± 1	44 ± 3	75 ± 7	104 ± 11	132 ± 15
Neoplasms					
520	13 ± 1	28 ± 3			
560	12 ± 1	29 ± 1			
680	18 ± 1	45 ± 4			
760	18 ± 1	44 ± 3			

Intralipid with/without hemoglobin



Central wavelength, nm	1 mm	8 mm	12 mm	16 mm	20 mm
Skin phantom with 1% intralipid concentration					
520	21	33	49	62	72
560	19	34	47	61	71
680	24	38	52	65	76
760	24	36	46	59	69
Skin phantom with 1% intralipid and 1% hemoglobin concentration					
520	15	25	39	44	56
560	16	26	36	46	54
680	19	34	45	57	67
760	19	36	46	58	68

Mean photon path length in cells cultures

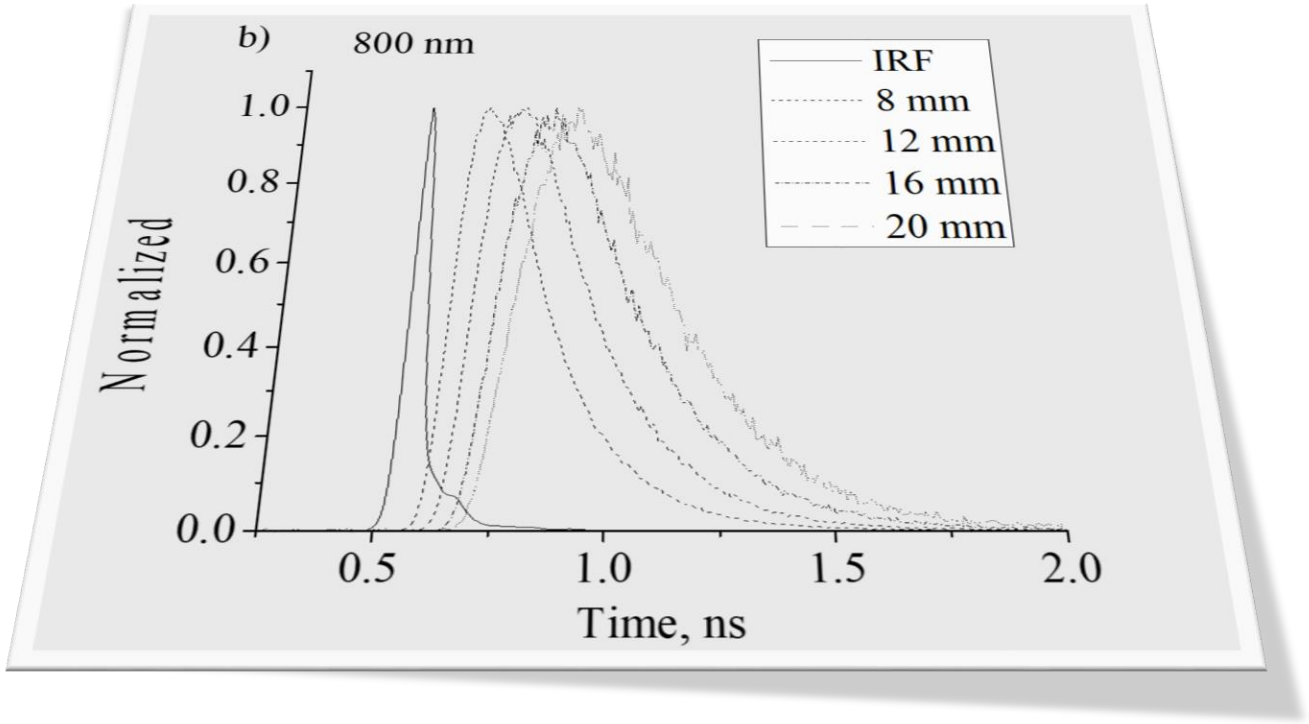


Central wavelength, nm	8 mm	12 mm	16 mm	20 mm
Healthy cells, DC3F				
560	33	39	48	55
600	27	37	45	53
640	26	41	48	57
680	23	31	39	47
720	26	34	41	50
760	21	36	45	51
800	30	40	48	54
Cancer cells, B161F10				
560	29	38	41	52
600	31	39	47	55
640	28	37	48	59
680	32	39	46	52
720	25	38	45	52
760	29	35	46	49
800	33	41	48	55

CONCLUSIONS

- The main conclusion of this study is that the remitted photon path length does not depend linearly on wavelength.
- Hemoglobin is the main chromophore which has influence on photon path length in human skin where melanin absorption is insignificant.
- Our further study will be targeted to measure different body locations at various thicknesses of skin and sub-dermal fat layer, with and without neoplasms.

Thank you for your attention



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