TOWARDS DIRECT MEASUREMENTS OF REMITTED PHOTON PATH LENGTHS IN SKIN: KINETIC STUDIES IN THE SPECTRAL RANGE 520-800 nm

V.LUKINSONE, M.OSIS, J.LATVELS, I.KUZMINA, U.RUBINS, N.ZORINA, A.MASLOBOJEVA, J.SPIGULIS

BIOPHOTONICS LABORATORY, INSTITUTE OF ATOMIC PHYSICS AND SPECTROSCOPY,

UNIVERSITY OF LATVIA

NATIONAL DEVELOPMENT PLAN 2020

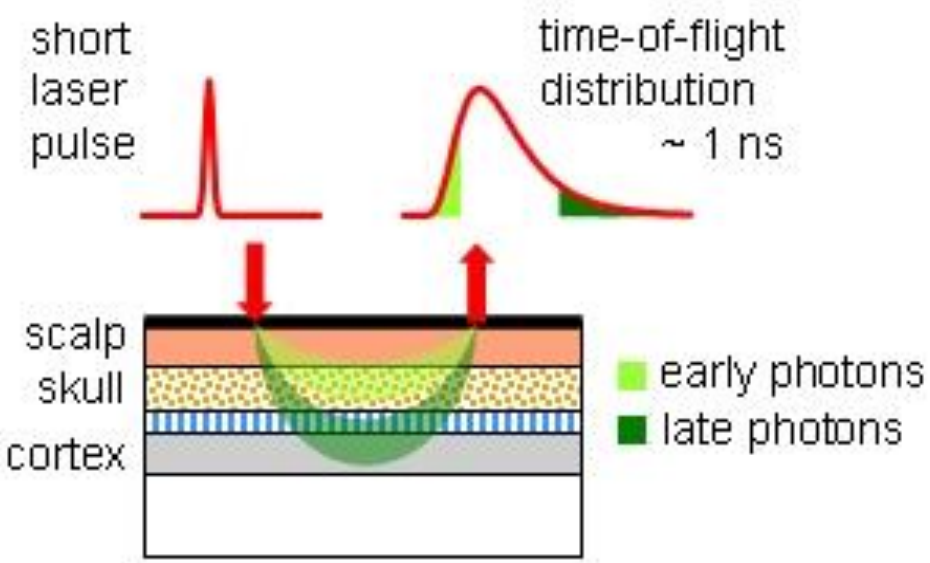
EUROPEAN UNION
European Regional Development Fund

INVESTING IN YOUR FUTURE

ASI

UNIVERSITY OF LATVIA
ANNO 1919

TIME-OF-FLIGHT (TOF) SPECTROSCOPY

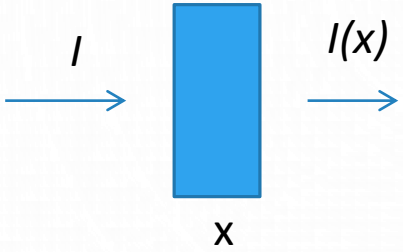


Time-of-flight (TOF) spectroscopy is a tool for characterization and analysis of highly scattering (turbid) materials, such as biological tissue, powders, and pharmaceutical samples. The main principle is to deliver a very short laser pulse into the material, and to analyze the resulting pulse at some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

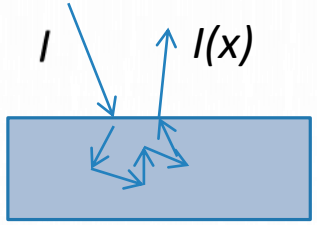
Online: https://www.ptb.de/cms/en/ptb/fachabteilungen/abt8/fb-83/ag-831/kopf.html

PROBLEM: SKIN-REMITTED PHOTON PATH LENGTH. MONTE-CARLO SIMULATIONS (A.BYKOV)

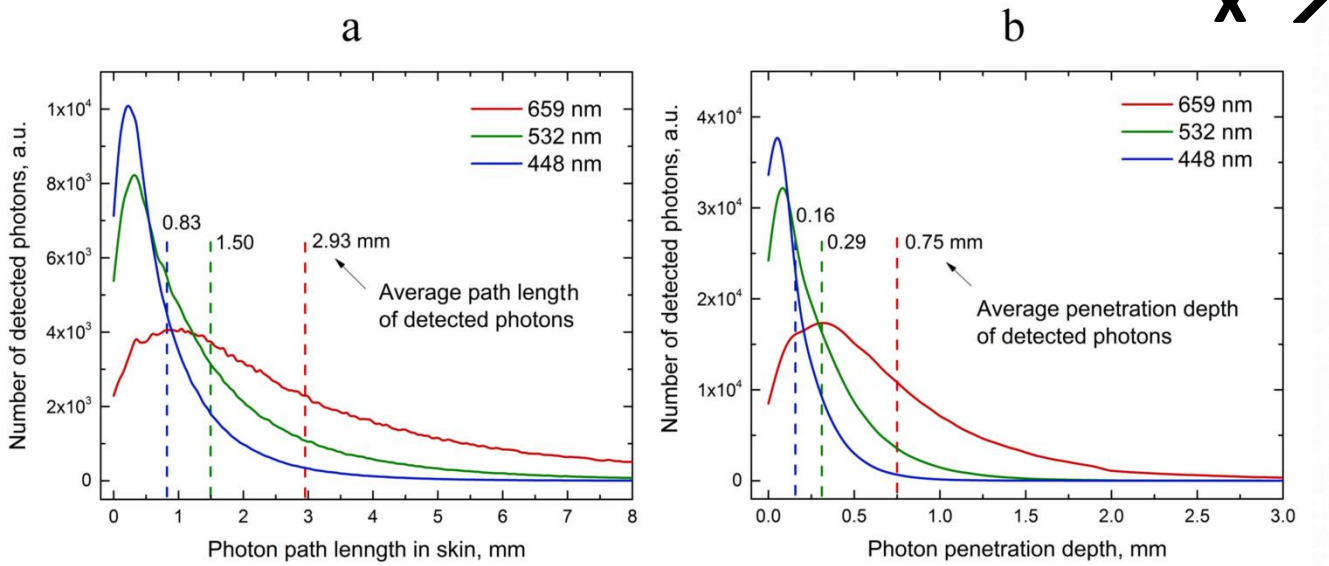
Slab absorption,
$I(x) = I \exp(-kx)$



Diffuse reflectance absorption:

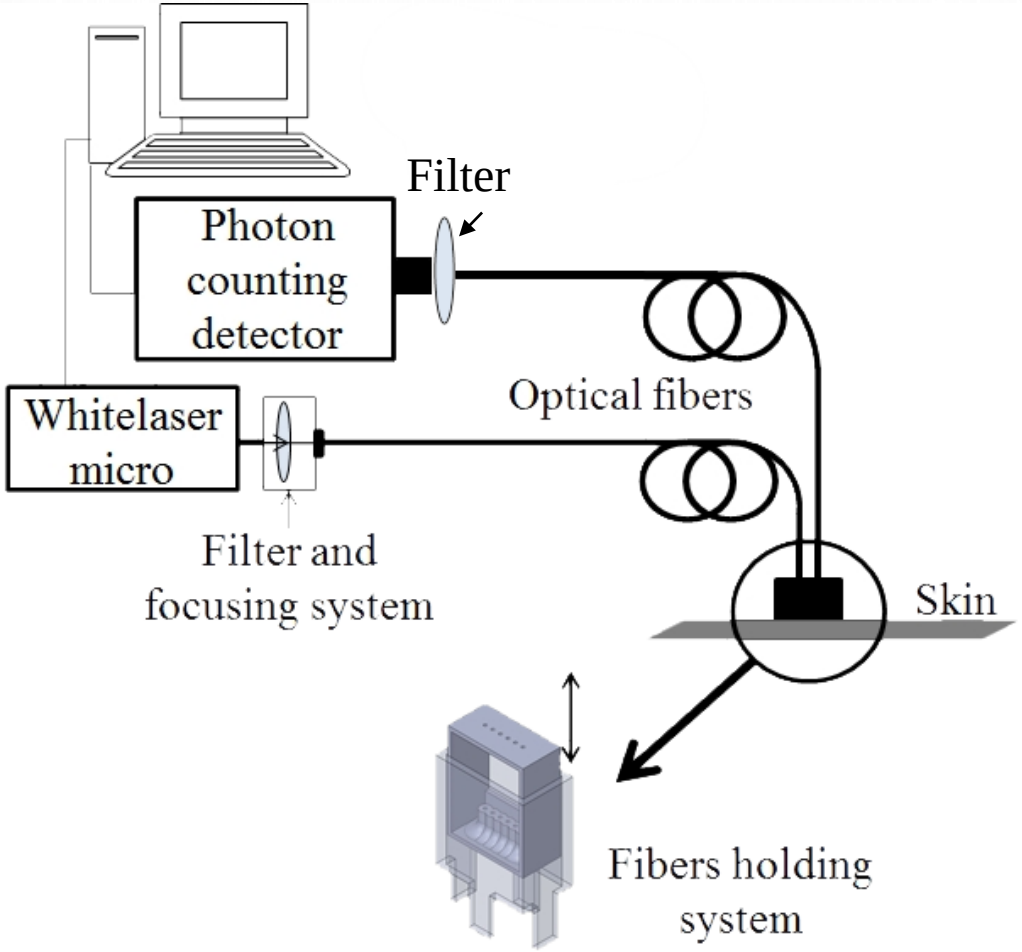


x → f(x) !



J.Spigulis, I.Oshina, A.Berzina, A.Bykov, "Smartphone snapshot mapping of skin chromophores under triple-wavelength laser illumination", *J.Biomed.Opt.*, **22**(9), 091508 (2017).

Time-Of-Flight set-up



PHOTON COUNTING DETECTOR

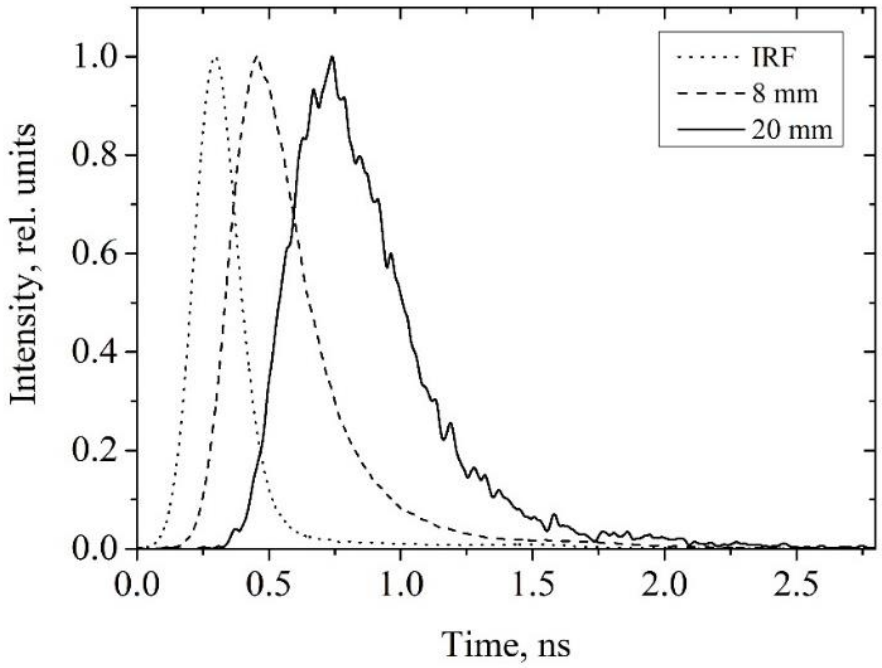
Hybrid Detector HPM-100-07,*Becker&Hickl GmbH*, DE

DATA PROCESSING CARD

SPC-150, all *Becker&Hickl GmbH*, DE

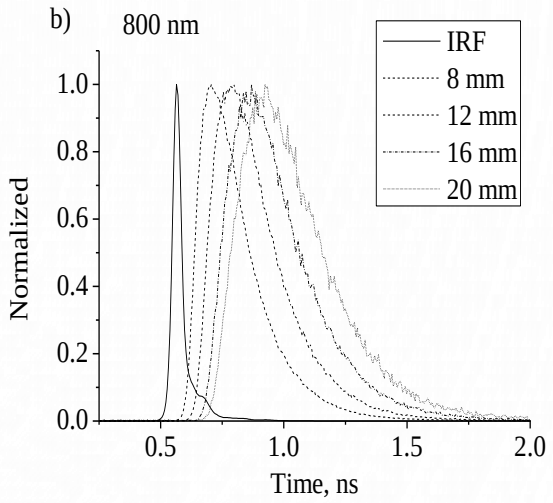
THE FILTERS SET

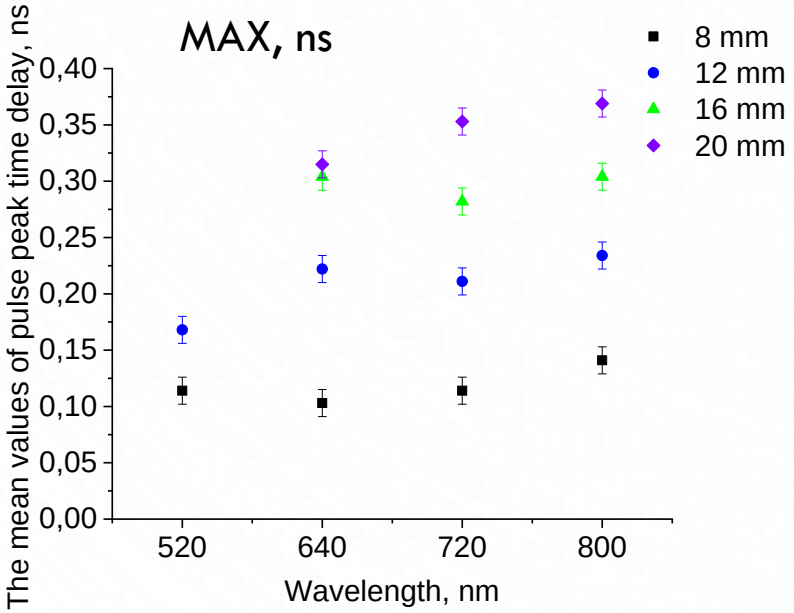
At 520 nm, 640 nm, 720 nm and 800 nm half-bandwidth 10 nm

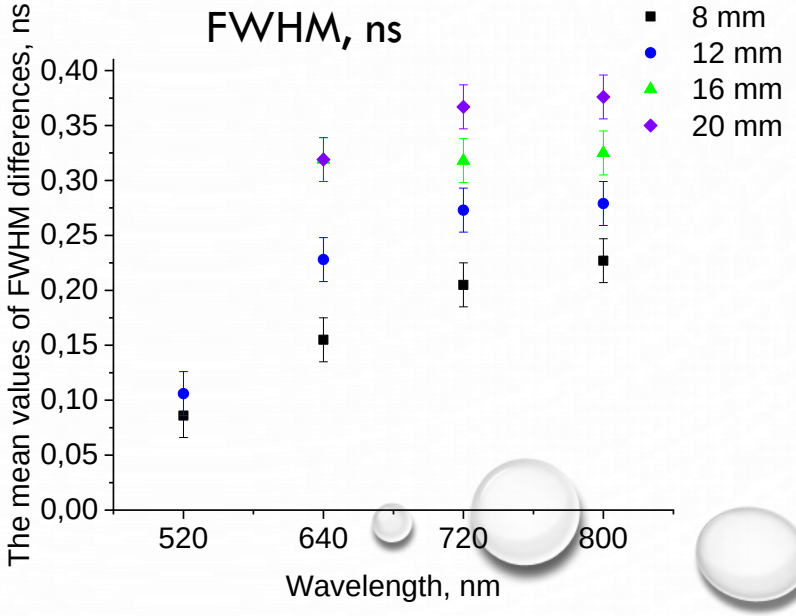


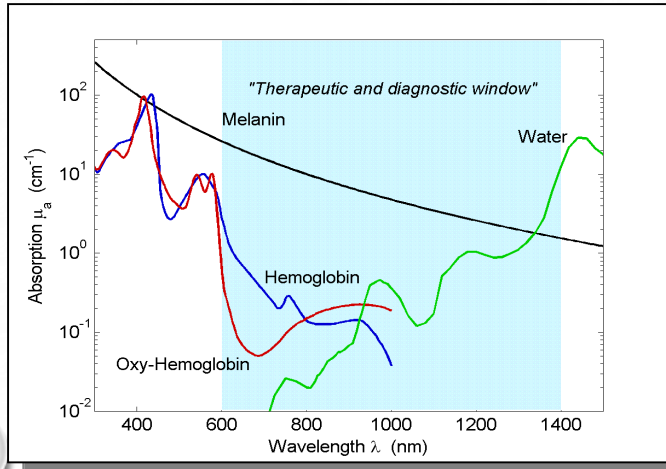
The mean values of pulse peak time delay and FWHM differences

λ, nm	MAX, ns (±0.012)				FWHM, ns (±0.02)			
	8 mm	12 mm	16 mm	20 mm	8 mm	12 mm	16 mm	20 mm
520	0.114	0.168	0.173	-	0.086	0.106	-	-
640	0.103	0.222	0.304	0.315	0.155	0.228	0.319	0.319
720	0.114	0.211	0.282	0.353	0.205	0.273	0.318	0.367
800	0.141	0.234	0.304	0.369	0.227	0.279	0.325	0.376









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

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

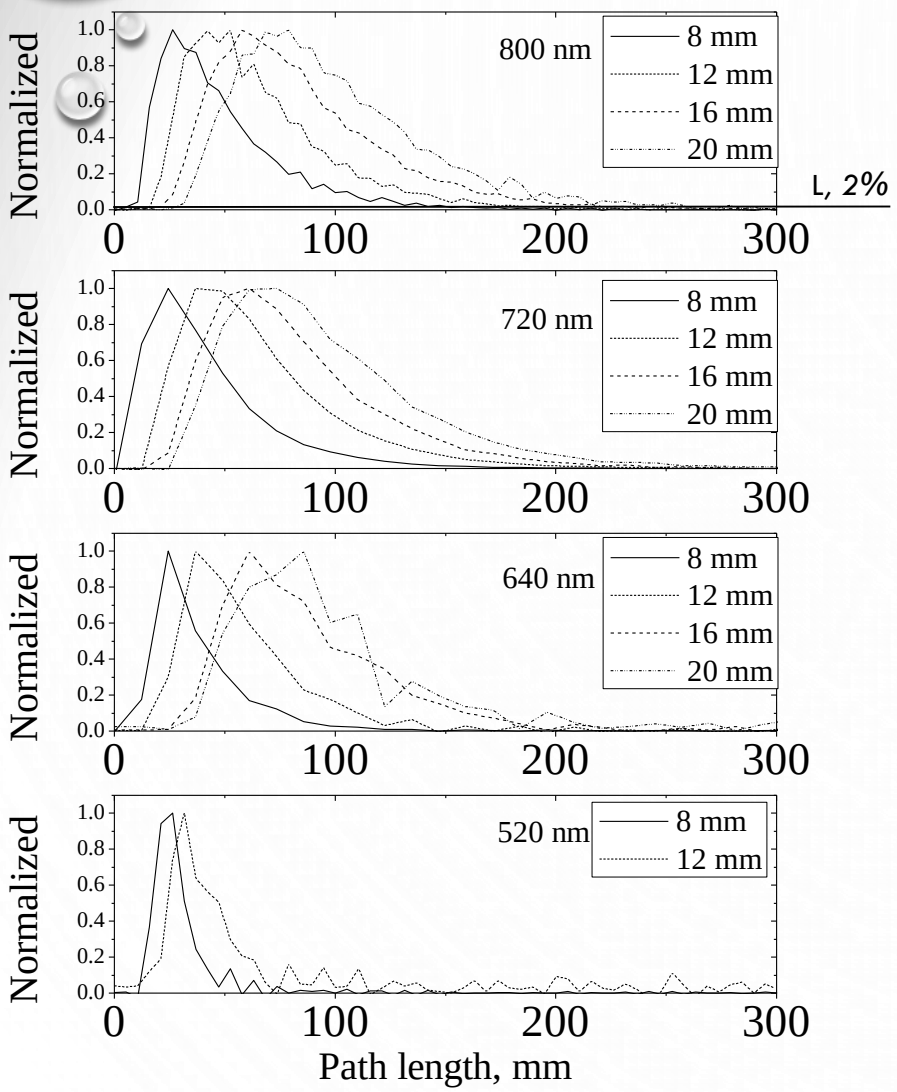
WHERE *c* IS THE SPEED OF LIGHT IN VACUUM AND *n* IS THE MEAN REFRACTION INDEX OF SUPERFICIAL SKIN TISSUES (n~1.4)

THE FUNCTION *f(τ)* – 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.

The propagation photon path length in normal skin



The skin-remitted photon path length distributions, calculated accordingly to

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

and

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

with the pulse measurement data.

λ, nm	L, mm (±12)			
	8 mm	12 mm	16 mm	20 mm
520	117	105	-	-
640	162	204	268	276
720	273	266	267	308
800	251	300	319	304

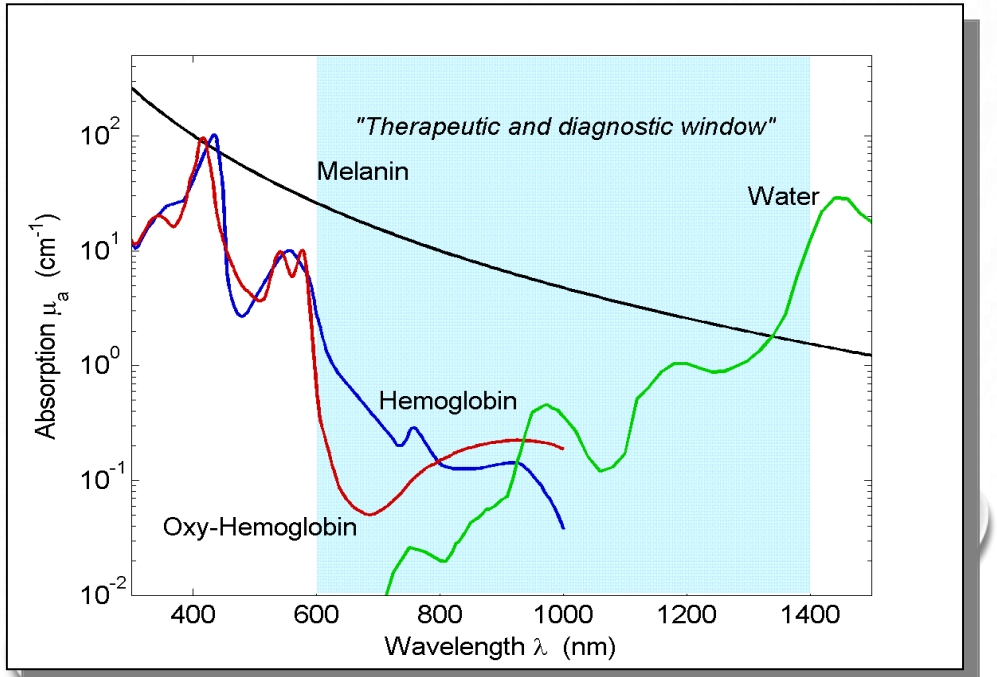
V.Lukinsone, M.Osis, J.Latvels, I.Kuzmina, U.Rubins, N.Zorina, A.Maslobojeva, J.Spigulis "Towards direct measurements of remitted photon path lengths in skin: kinetic studies in the spectral range 520-800 nm", Proc. SPIE 11075 – 4, (2019)

Discussion / Conclusion

- The obtained results are in general agreement with the diffusion theory for photon propagation in turbid media.
- Photon path lengths in skin critically depend on the chromophore absorption at particular wavelengths.

Next step:

- Measurements in spectral rang 400 nm – 840 nm
- Statistic measurements of skin and malformations.



ACKNOWLEDGMENT

THIS WORK HAS BEEN SUPPORTED BY EUROPEAN REGIONAL DEVELOPMENT FUND

PROJECT 'MULTIMODAL IMAGING TECHNOLOGY FOR IN-VIVO DIAGNOSTICS OF SKIN MALFORMATIONS' UNDER GRANT AGREEMENT # 1.1.1.1/18/A/132

NATIONAL DEVELOPMENT PLAN 2020

EUROPEAN UNION
European Regional Development Fund

INVESTING IN YOUR FUTURE

UNIVERSITY OF LATVIA
ANNO 1919

Thank you for your attention