UNIVERSITY OF LATVIA

UNIVERSITY OF LATVIA
INSTITUTE OF ATOMIC PHYSICS AND SPECTROSCOPY

Skin chromophore mapping from multispectral laser line imaging

Ilze Osina, Ilona Kuzmina, Uldis Rubins, Vanesa Lukinsone, Anna Maslobojeva, Laura Dambite, Margarita Matulenko, Zigmars Rupenheits, Janis Spigulis

University of Latvia, Institute of Atomic Physics and Spectroscopy, Riga, Latvia

ilze.osina@lu.lv

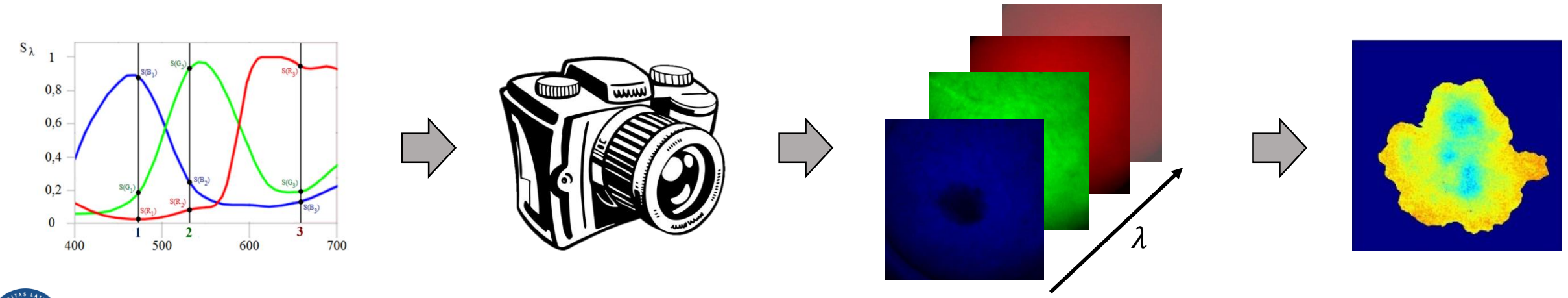
Skin diagnostics

- Non-invasive
- Informative
- Reliable
- Fast
- Easy to use

- MelaFind
- SIAscope
- SolarScan

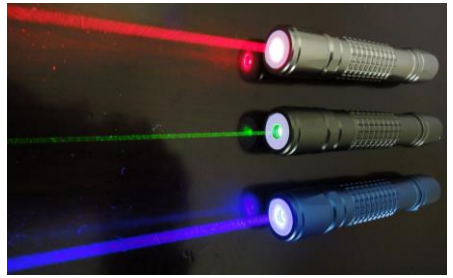
Main idea

- Narrow spectral bands for illumination
- One snapshot
- Images representing specific wavelengths
- Chromophore maps calculated using advanced Beer-Lambert law

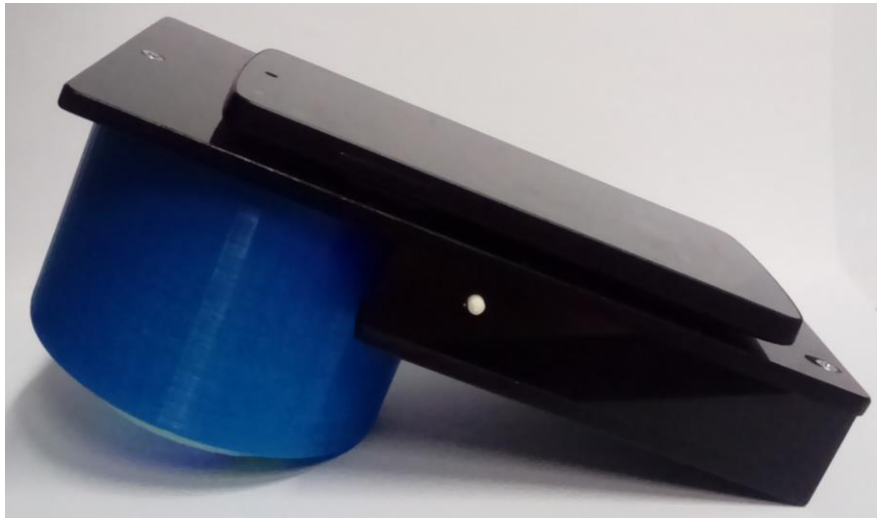


UNIVERSITY OF LATVIA

Our devices



- Multispectral laser line imaging with three (448 nm, 532 nm and 659 nm) and four (450 nm, 523 nm, 638 nm and 850 nm) different wavelength lasers.

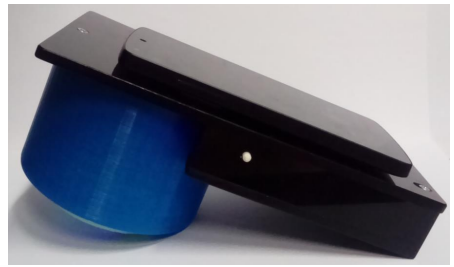


448 nm, 532 nm and 659 nm

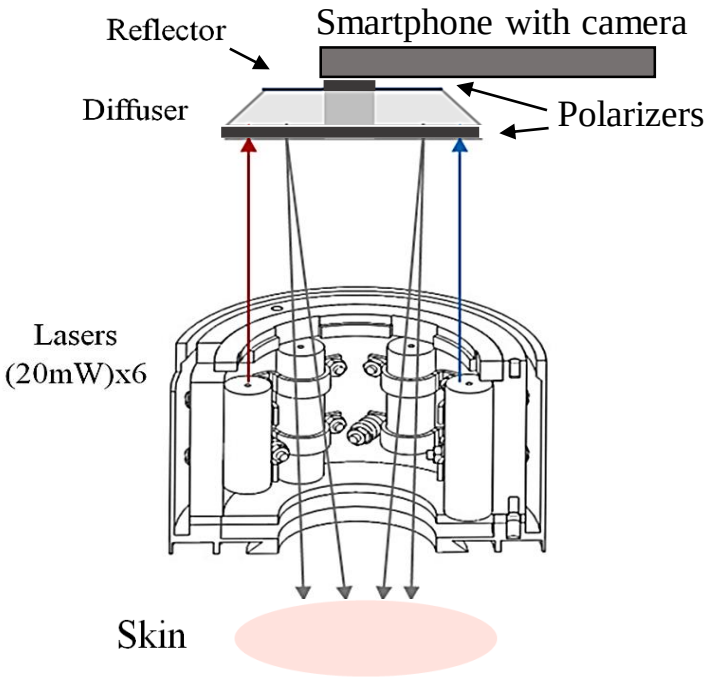
450 nm, 523 nm, 638 nm and 850 nm

UNIVERSITY OF LATVIA

Three different wavelength laser device

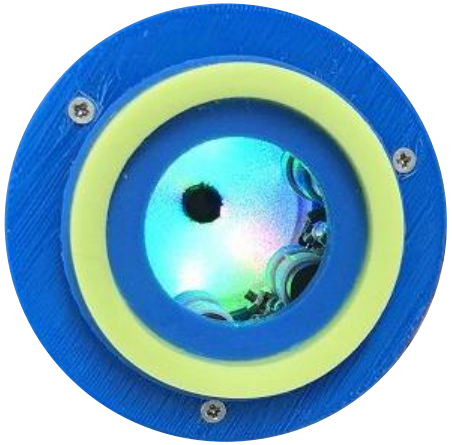


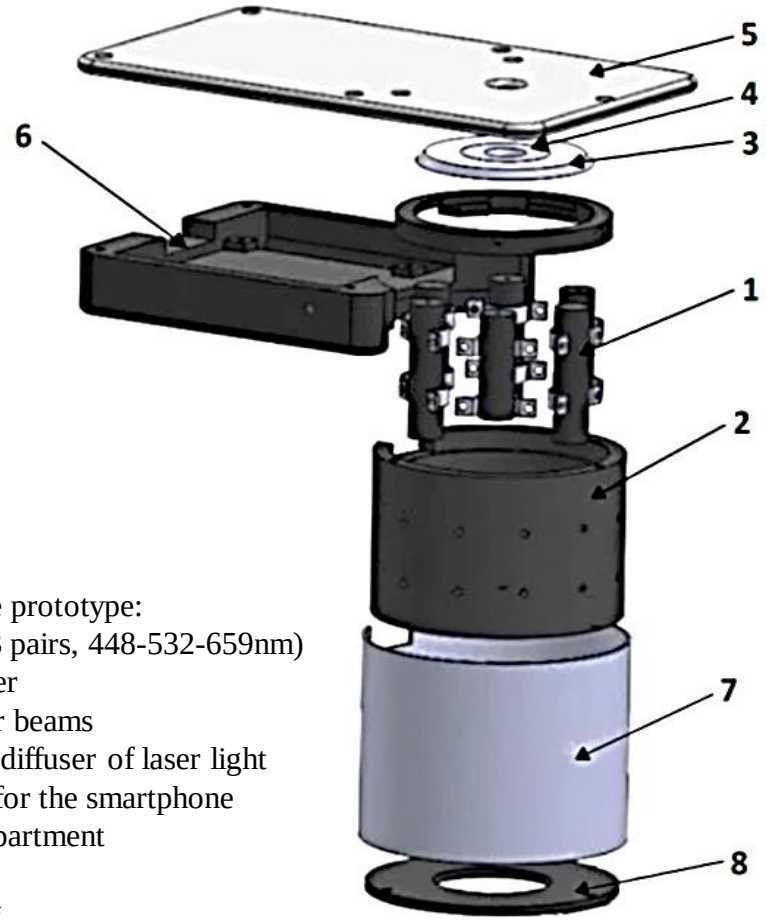
448 nm, 532 nm and 659 nm



Laser beam path in the prototype

The prototype device

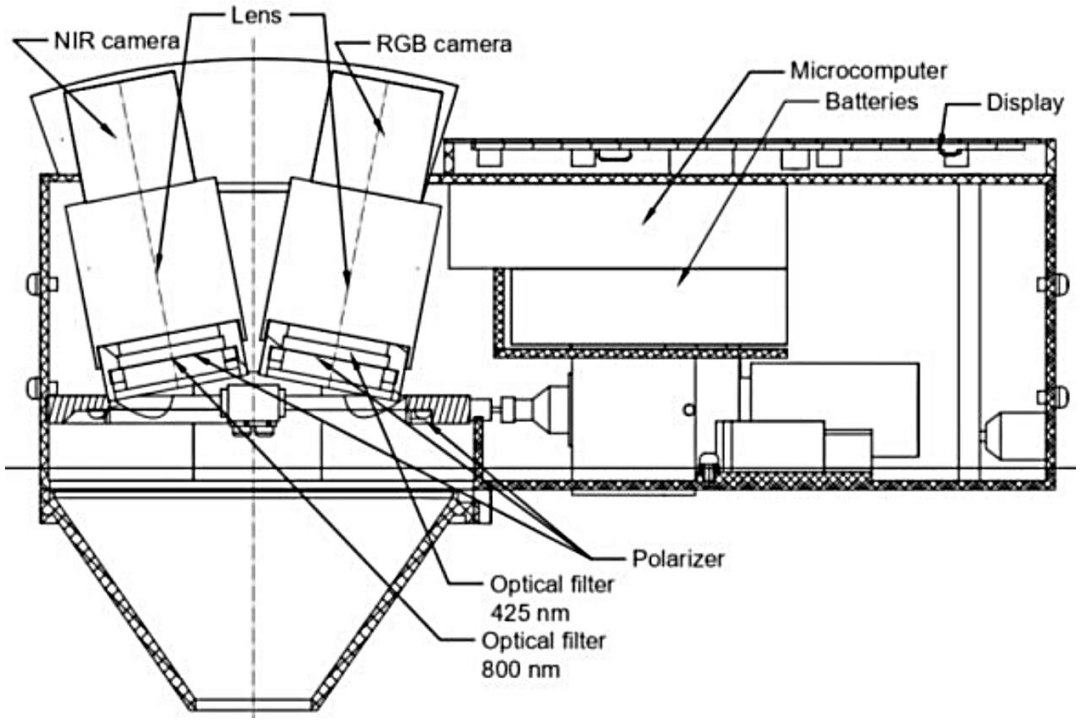


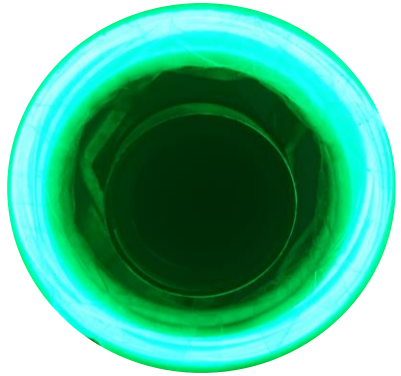


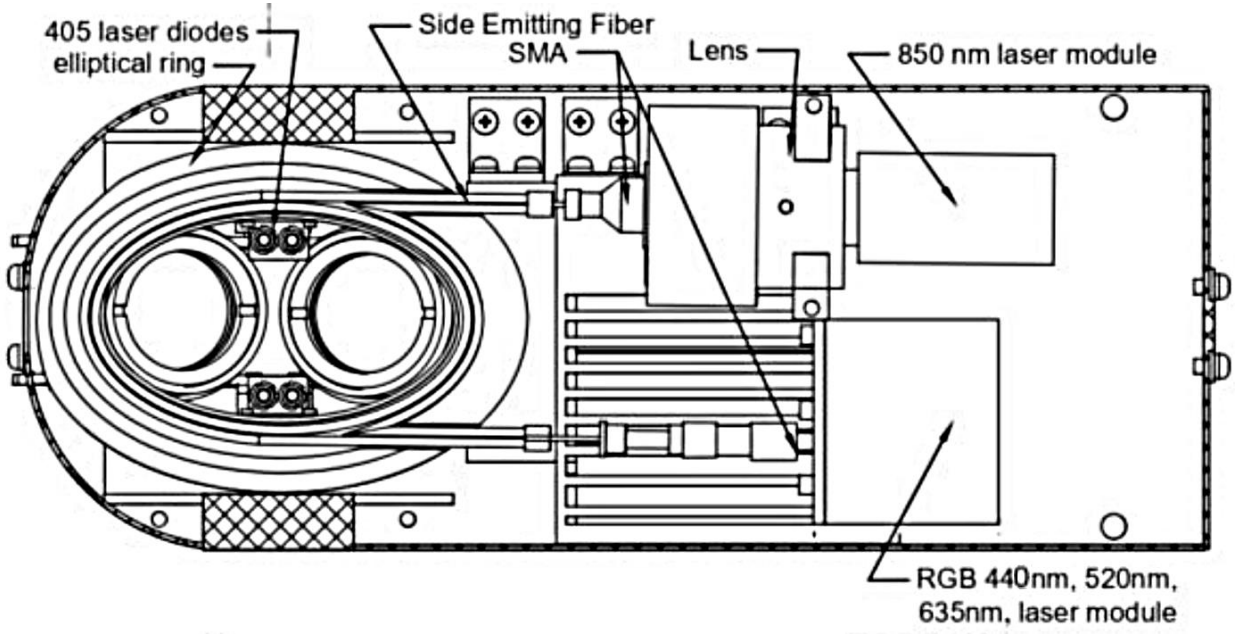
Design scheme of the prototype:
1 — laser modules (3 pairs, 448-532-659nm)
2 — shielding cylinder
3 — collector of laser beams
4 — flat ring-shaped diffuser of laser light
5 — sticky platform for the smartphone
6 — electronics compartment
7 – outer cylinder
8 – image border ring

UNIVERSITY OF LATVIA

Four different wavelength laser device







450 nm, 523 nm, 638 nm and 850 nm

Image processing scheme, part 1

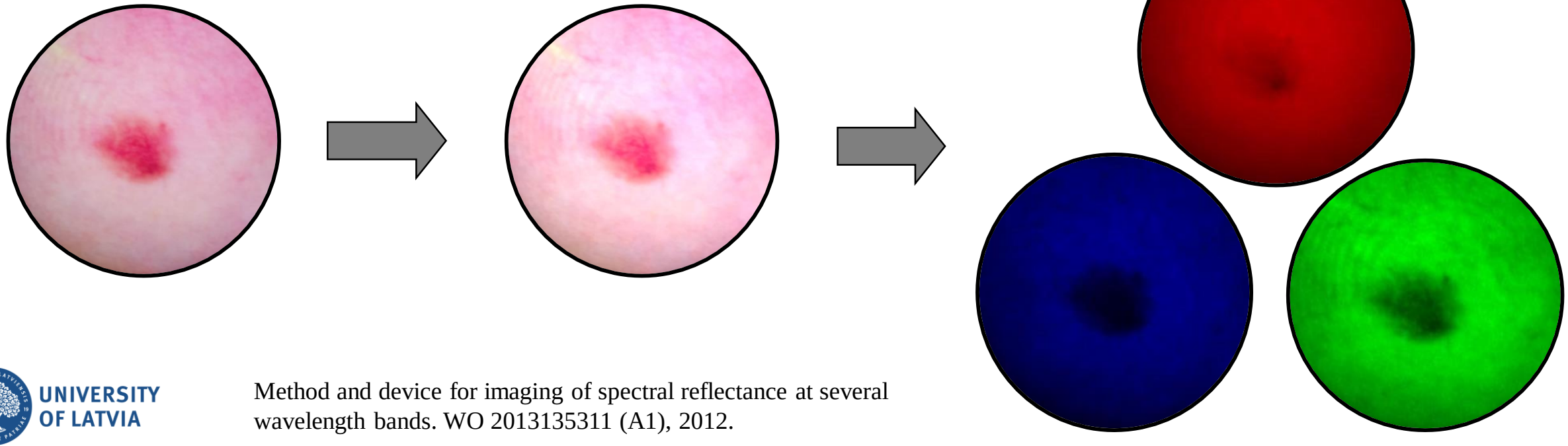
Captures an image in 3 different wavelengths illumination

Subtracts noise from images

Captured image without background noise

Using the RGB crosstalk correction algorithm, three images – one for each wavelength – are extracted

Three separated monochromatic images



UNIVERSITY OF LATVIA

Method and device for imaging of spectral reflectance at several wavelength bands. WO 2013135311 (A1), 2012.

Image processing scheme, part 2

Three separated mono-chromatic images

Images are segmented to separate healthy skin, and pathology

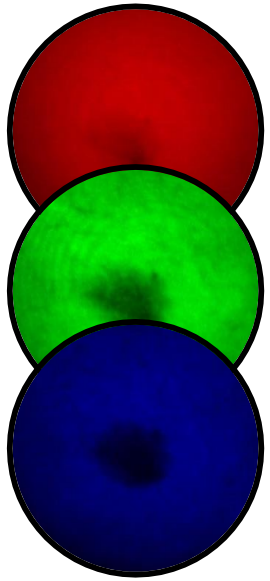
Separated healthy skin and pathology

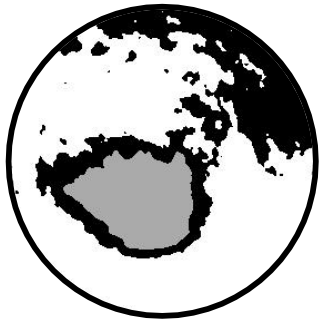
Calculate the mean values from the healthy skin area for each of the wavelengths and divide the area of interest by them to obtain three attenuation coefficients k_i

Attenuation coefficient maps at each of the used wavelengths: k_1, k_2 and k_3

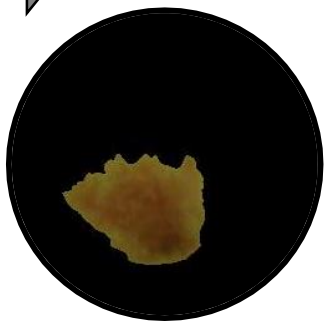
Calculate three chromophore maps and mean values in pathology

Melanin, oxyhemoglobin and deoxyhemoglobin concentration maps



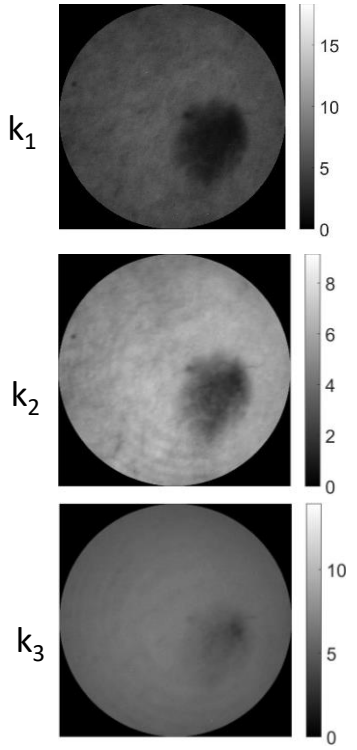


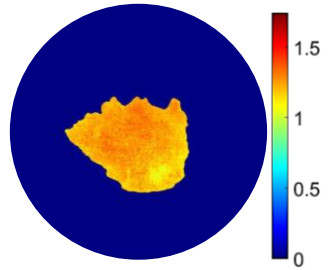
Clustered image



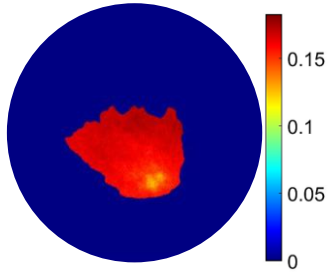
Pathology

Healthy skin

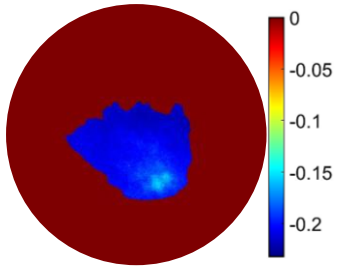




Melanin



Oxyhemoglobin



Deoxyhemoglobin

UNIVERSITY OF LATVIA

Algorithm

Beer-Lambert law: $I = I_0 e^{-\mu_a \cdot l}$

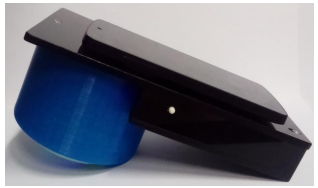
$$z_i = 0{,}01 \cdot (1 - k_i)\ , \quad k_i = \frac{I_i}{I_{0_i}}$$

$$\begin{cases} c_{\text{Mel}} \cdot \varepsilon_{\text{Mel}}(\lambda_1) \cdot \mathrm{d}_1 + (c_{\text{Ox}} \cdot \varepsilon_{\text{Ox}}(\lambda_1) + c_{\text{Deox}} \cdot \varepsilon_{\text{Deox}}(\lambda_1)) \cdot (1 - \mathrm{d}_1) + z_1 = \dfrac{ln \dfrac{I_0(\lambda_1)}{I(\lambda_1)}}{2.303 \cdot l(\lambda_1)} \\ c_{\text{Mel}} \cdot \varepsilon_{\text{Mel}}(\lambda_2) \cdot \mathrm{d}_2 + (c_{\text{Ox}} \cdot \varepsilon_{\text{Ox}}(\lambda_2) + c_{\text{Deox}} \cdot \varepsilon_{\text{Deox}}(\lambda_2)) \cdot (1 - \mathrm{d}_2) + z_2 = \dfrac{ln \dfrac{I_0(\lambda_2)}{I(\lambda_2)}}{2.303 \cdot l(\lambda_2)} \\ c_{\text{Mel}} \cdot \varepsilon_{\text{Mel}}(\lambda_3) \cdot \mathrm{d}_3 + (c_{\text{Ox}} \cdot \varepsilon_{\text{Ox}}(\lambda_3) + c_{\text{Deox}} \cdot \varepsilon_{\text{Deox}}(\lambda_3)) \cdot (1 - \mathrm{d}_3) + z_3 = \dfrac{ln \dfrac{I_0(\lambda_3)}{I(\lambda_3)}}{2.303 \cdot l(\lambda_3)} \end{cases}$$

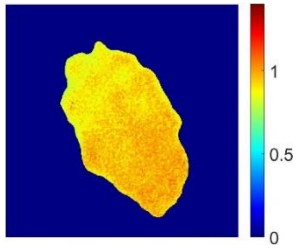
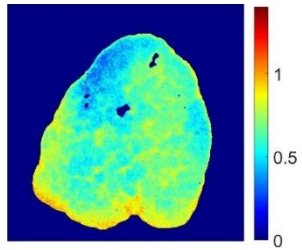
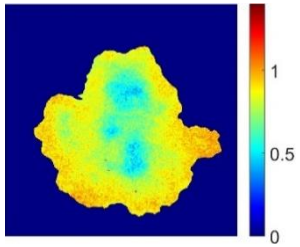
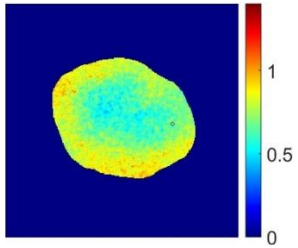
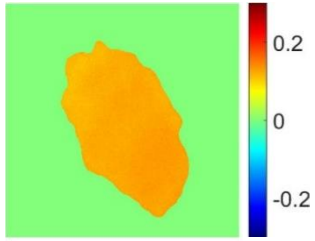
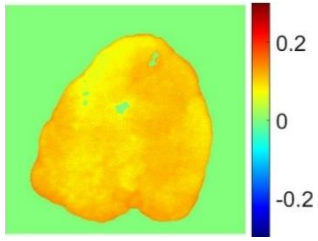
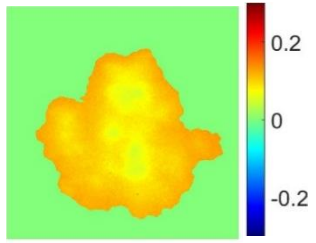
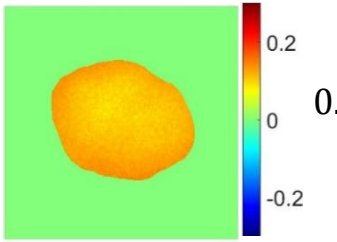
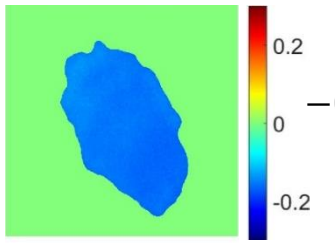
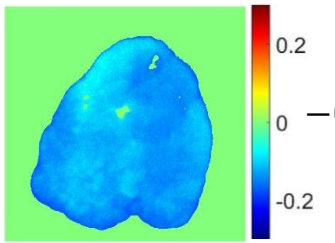
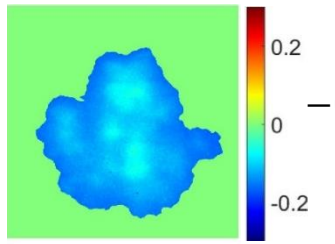
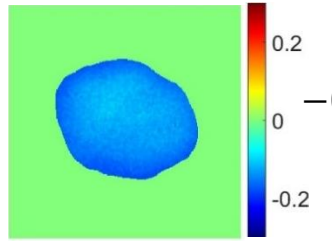
μ_a – absorption coefficient
l – photon mean path length in the skin
ε – extinction coefficient
c – chromophore concentration
$\mathrm{k_i}$ – attenuation coefficient

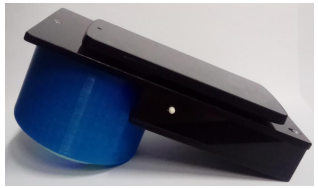
Mel – melanin, Ox – oxyhemoglobin, $Deox$ – deoxyhemoglobin
I – intensity of diffused reflected light from the skin pathology
I_0 – intensity of diffused reflected light from the healthy skin
$\mathrm{d_i}$ – part of the light that is absorbed in the epidermis at the wavelength λ_i,
$\mathrm{z_i}$ – loss coefficient – describes the part of the light absorbed by other chromophores

Results

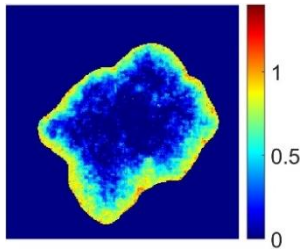
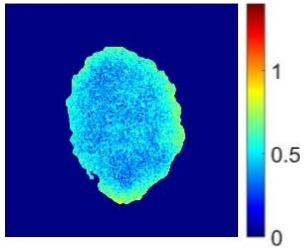
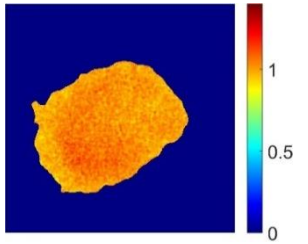
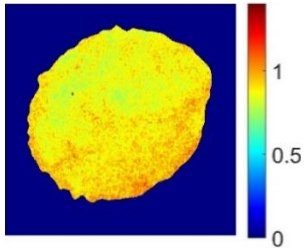
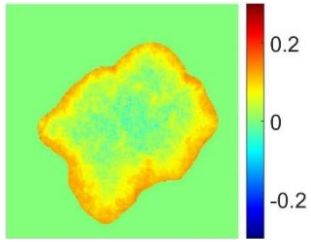
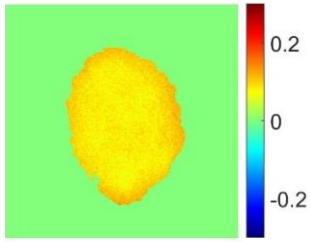
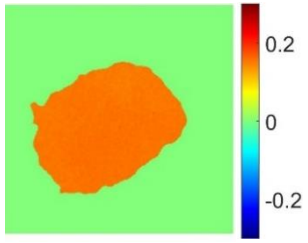
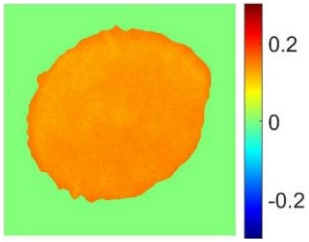
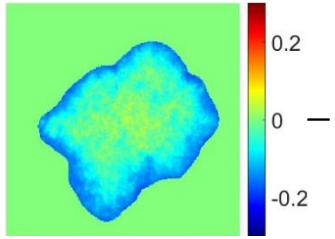
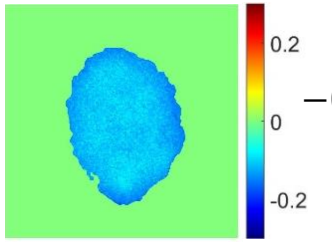
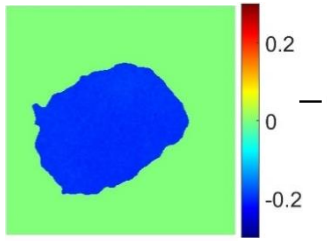
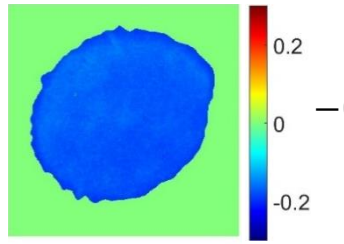


Chromophore maps

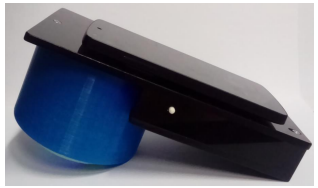
	Combined nevus	Seborrheic keratosis	Dysplastic nevus	Heman−gioma
$\overline{c_{Melanin}}$	 0.93 ± 0.06 mM	 0.66 ± 0.13 mM	 0.81 ± 0.13 mM	 0.73 ± 0.12 mM
$\overline{c_{Oxyhem}}$	 0.12 ± 0.01 mM	 0.10 ± 0.02 mM	 0.10 ± 0.02 mM	 0.12 ± 0.01 mM
$\overline{c_{Deoxyhem}}$	 -0.16 ± 0.01 mM	 -0.13 ± 0.02 mM	 -0.13 ± 0.02 mM	 -0.14 ± 0.02 mM

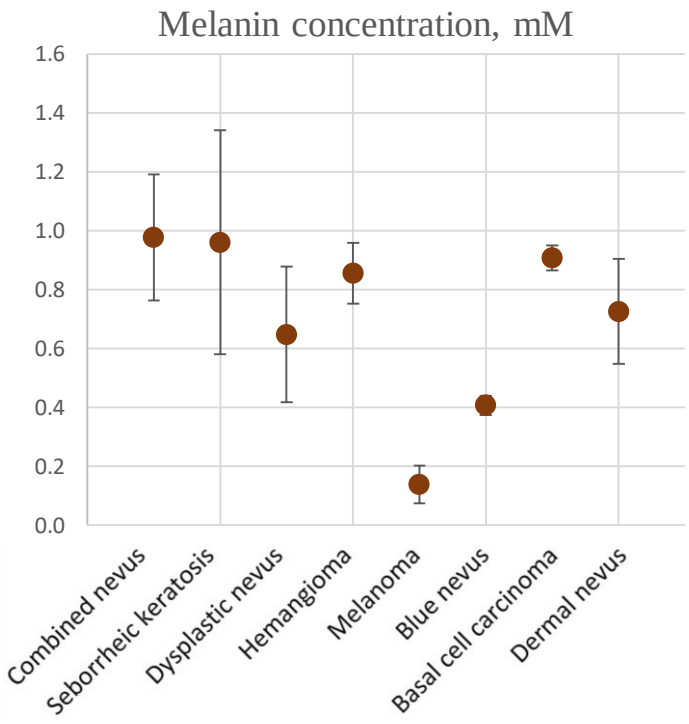


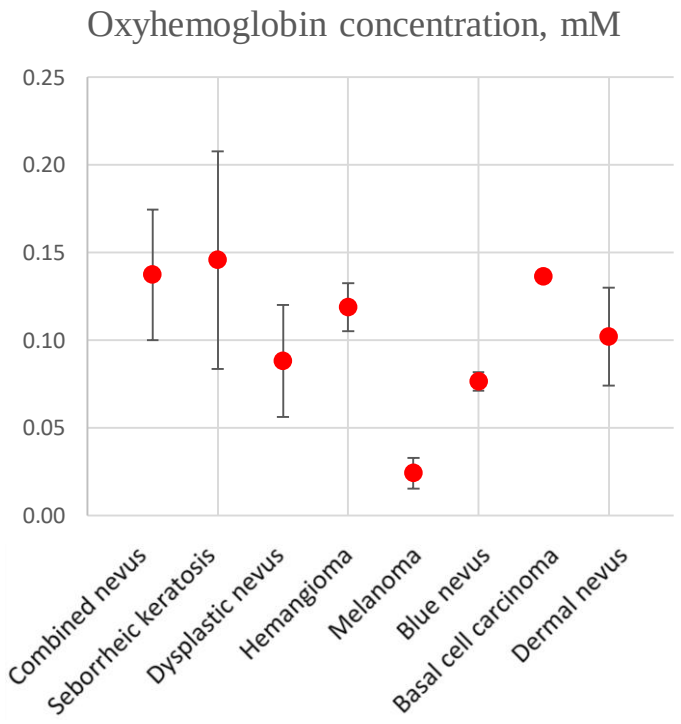
Chromophore maps

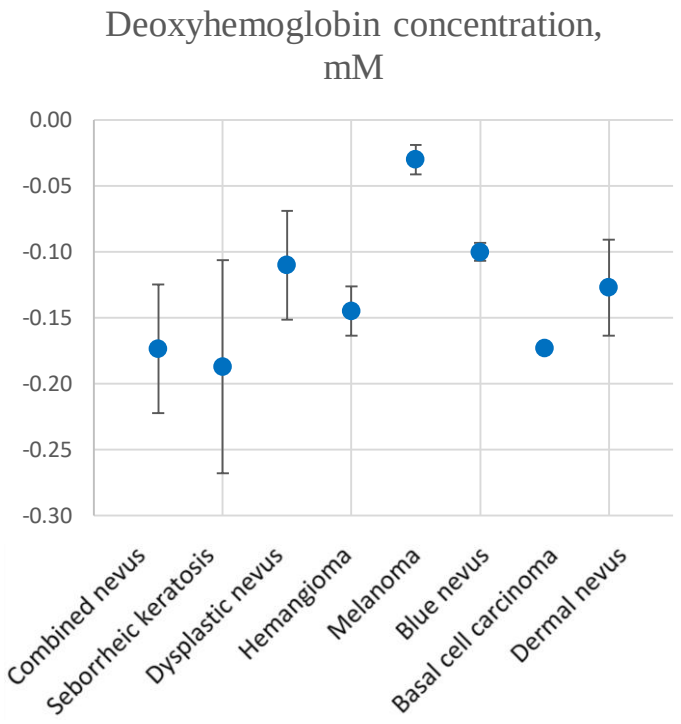
	Melanoma	Blue nevus	Basal cell carcinoma	Dermal nevus
$\overline{c_{Melanin}}$	 0.33 ± 0.34 mM	 0.48 ± 0.11 mM	 1.02 ± 0.04 mM	 0.89 ± 0.06 mM
$\overline{c_{Oxyhem}}$	 0.05 ± 0.04 mM	 0.09 ± 0.02 mM	 0.15 ± 0.00 mM	 0.14 ± 0.01 mM
$\overline{c_{Deoxyhem}}$	 -0.07 ± 0.05 mM	 -0.12 ± 0.02 mM	 -0.20 ± 0.00 mM	 -0.17 ± 0.01 mM

Chromophore concentrations



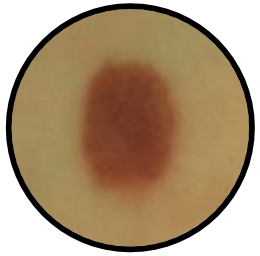
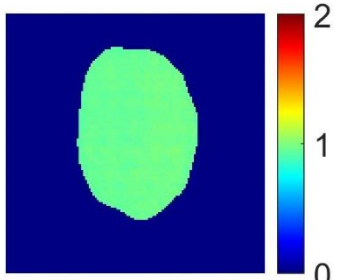
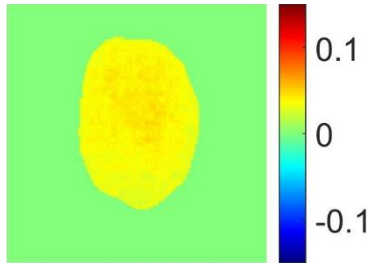
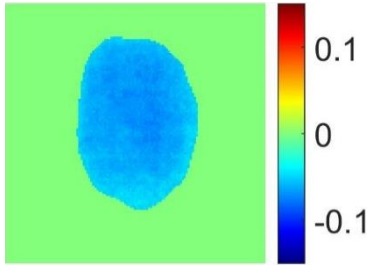
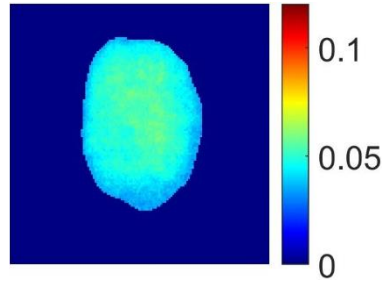
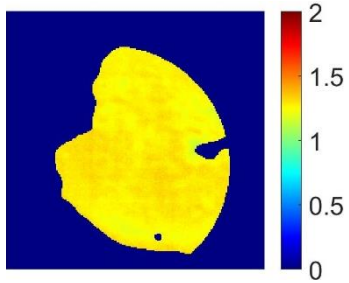
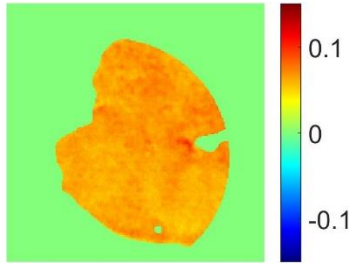
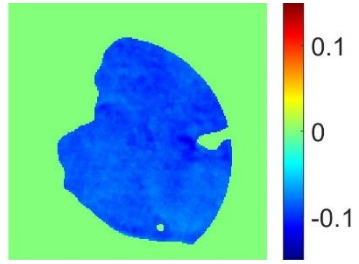
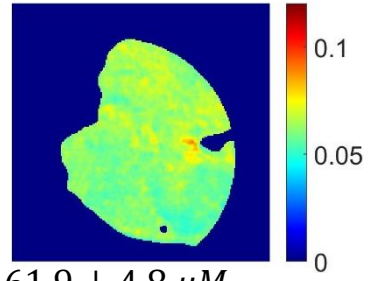
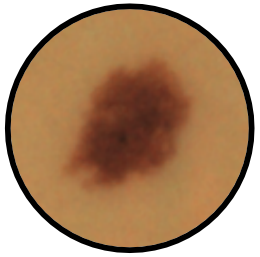
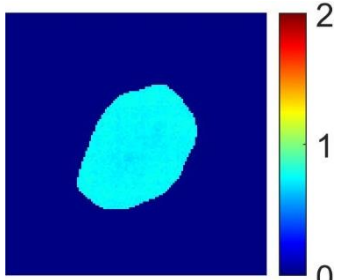
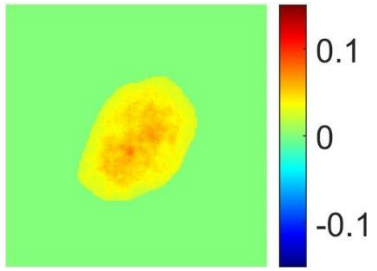
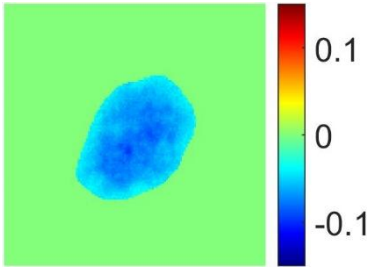
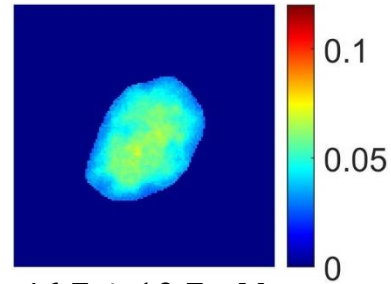




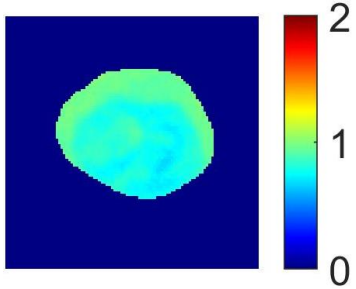
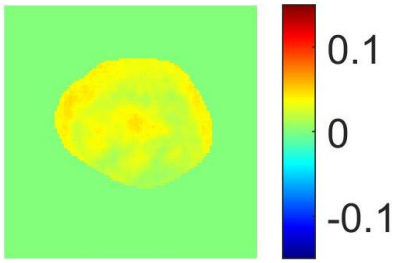
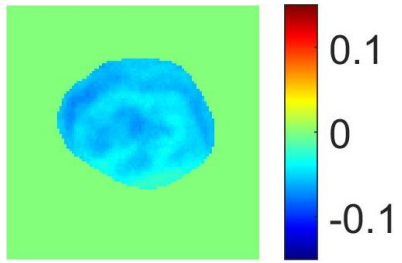
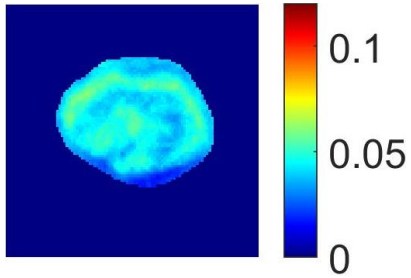
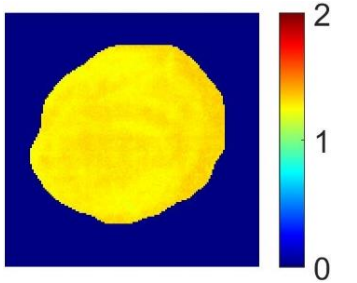
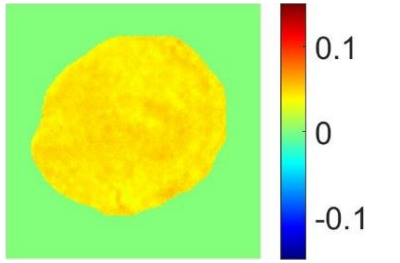
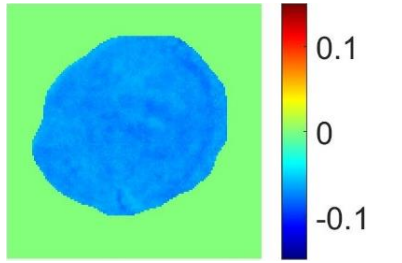
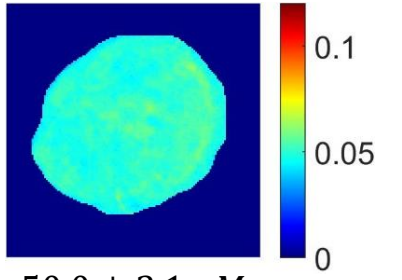


UNIVERSITY OF LATVIA

Chromophore maps

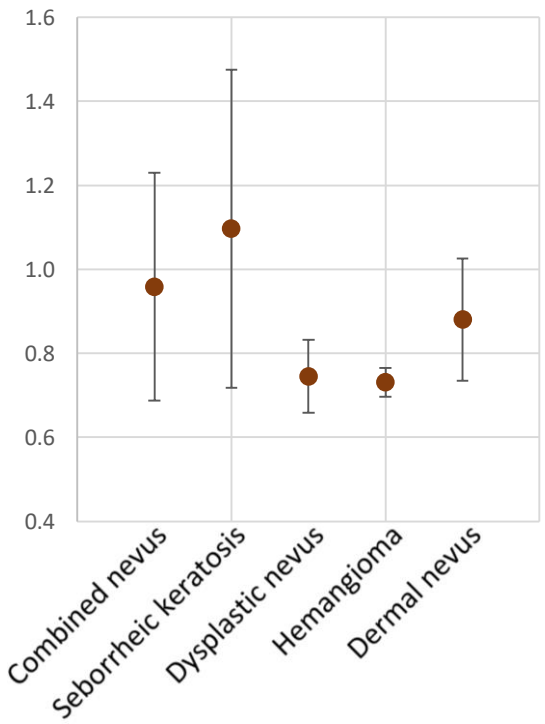
	$\overline{c_{Melanin}}$	$\overline{c_{Oxyhem}}$	$\overline{c_{Deoxyhem}}$	$\overline{c_{Bilirubin}}$
Combined nevus 	 $0.96 \pm 0.02\ mM$	 $37.0 \pm 4.7\ \mu M$	 $-61.5 \pm 6.9\ \mu M$	 $46.9 \pm 6.4\ \mu M$
Seborrheic keratosis 	 $1.27 \pm 0.03\ mM$	 $64.4 \pm 5.6\ \mu M$	 $-88.7 \pm 6.2\ \mu M$	 $61.9 \pm 4.8\ \mu M$
Dysplastic nevus 	 $0.74 \pm 0.02\ mM$	 $40.0 \pm 10.2\ \mu M$	 $-61.9 \pm 4.8\ \mu M$	 $46.7 \pm 10.7\ \mu M$

Chromophore maps

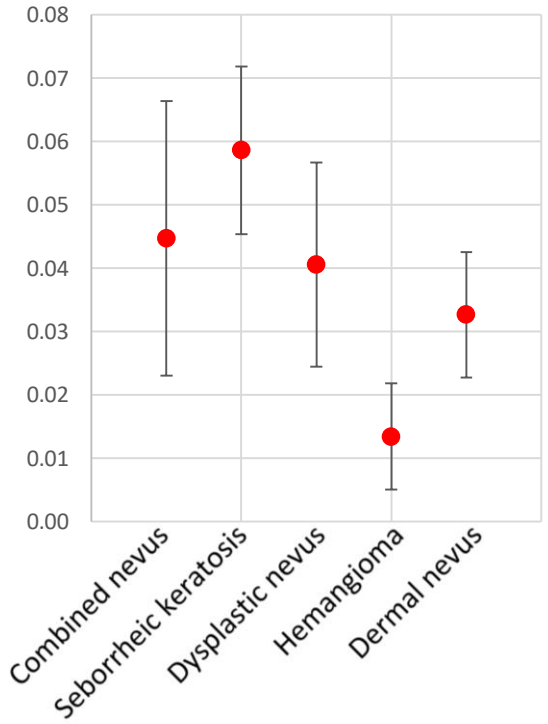
	$\overline{c_{Melanin}}$	$\overline{c_{Oxyhem}}$	$\overline{c_{Deoxyhem}}$	$\overline{c_{Bilirubin}}$
Heman−gioma 	 $0.84 \pm 0.08\ mM$	 $28.4 \pm 8.5\ \mu M$	 $-50.9 \pm 9.6\ \mu M$	 $42.5 \pm 8.1\ \mu M$
Dermal nevus 	 $1.28 \pm 0.02\ mM$	 $44.1 \pm 3.5\ \mu M$	 $-69.3 \pm 3.7\ \mu M$	 $50.0 \pm 3.1\ \mu M$

Chromophore concentrations

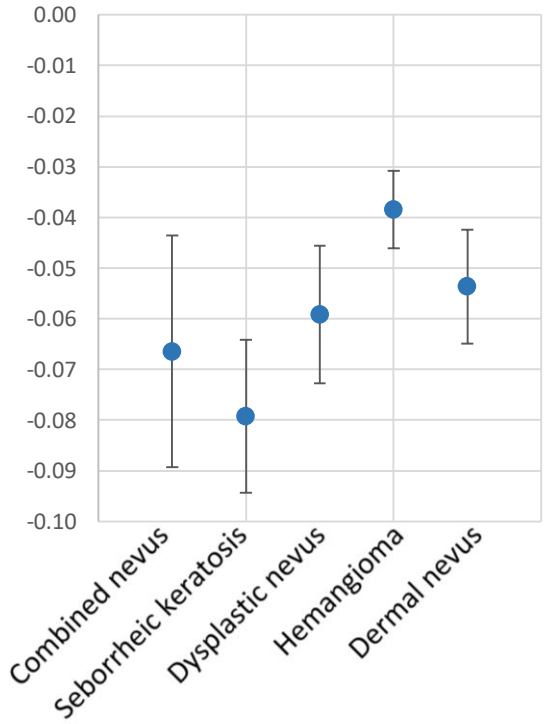
Melanin concentration, mM



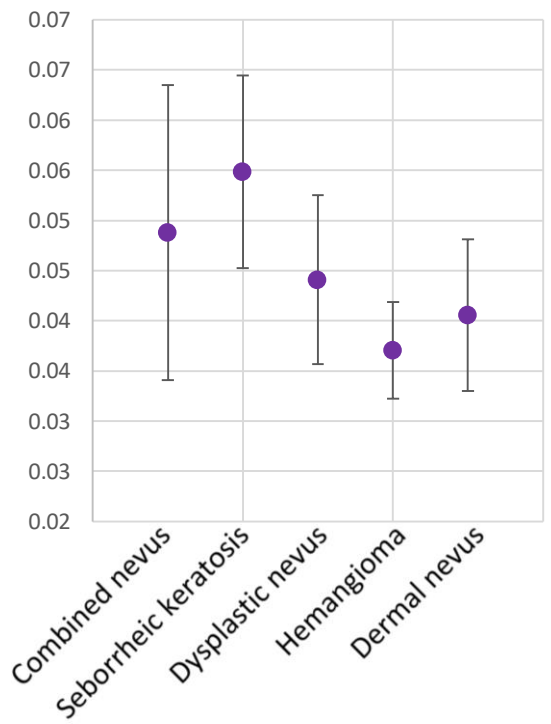
Oxyhemoglobin concentration, mM



Deoxyhemoglobin concentration, mM



Bilirubin concentration, mM



UNIVERSITY OF LATVIA

Conclusion

- The spectral line imaging technology has a potential for skin diagnostic
- Two devices provide three and four monochromatic spectral images by a single snapshot
- It was possible to distinguish melanoma from other data using three different wavelength device
- It was possible to distinguish hemangioma from other data using four different wavelength device
- Future plans: collection of more data; development of protocol and methodology for skin chromophore mapping

Acknowledgments

This study was supported by

- the Latvian Council of Science, grant # lzp-2018/2-0006 “Advanced spectral imaging technology for skin diagnostics”,
- the ERDF project #1.1.1.1/18/A/132 “Multimodal imaging technology for in-vivo diagnostics of skin malformations”

FLPP
FUNDAMENTAL AND APPLIED RESEARCH PROJECTS

NATIONAL DEVELOPMENT PLAN 2020

EUROPEAN UNION
European Regional Development Fund

INVESTING IN YOUR FUTURE