Remote optical assessment of in-vivo skin: methods, prototype devices and clinical applications

Janis Spigulis
www.lanet.lv/~spigulis

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

NBC-17, Tampere, 12/06/2017

Towards better skin assessment

- Skin cancer, other diseases → clinicians pefer **compact, patient-friendly** and **informative** devices for skin diagnostics;
- Commercial skin imaging devices – still with drawbacks:
  - Low sensitivity/specificity;
  - Insufficient reliability;
  - Bulky design, cable/PC;
  - Able to collect spectral information, but too slowly – motion artifacts create problems; image conversion undeveloped;
  - Expensive, ~20-40 kEUR.

Siascope

DermaLite

MelaFind

Biophotonics Laboratory in Riga

(5...40 co-workers, strongly depending on projects)

Aim – to develop handy and **affordable for end-users** methods, devices and technologies for clinical diagnostics and monitoring by exploiting **optical** features of ***in-vivo*** **skin**.

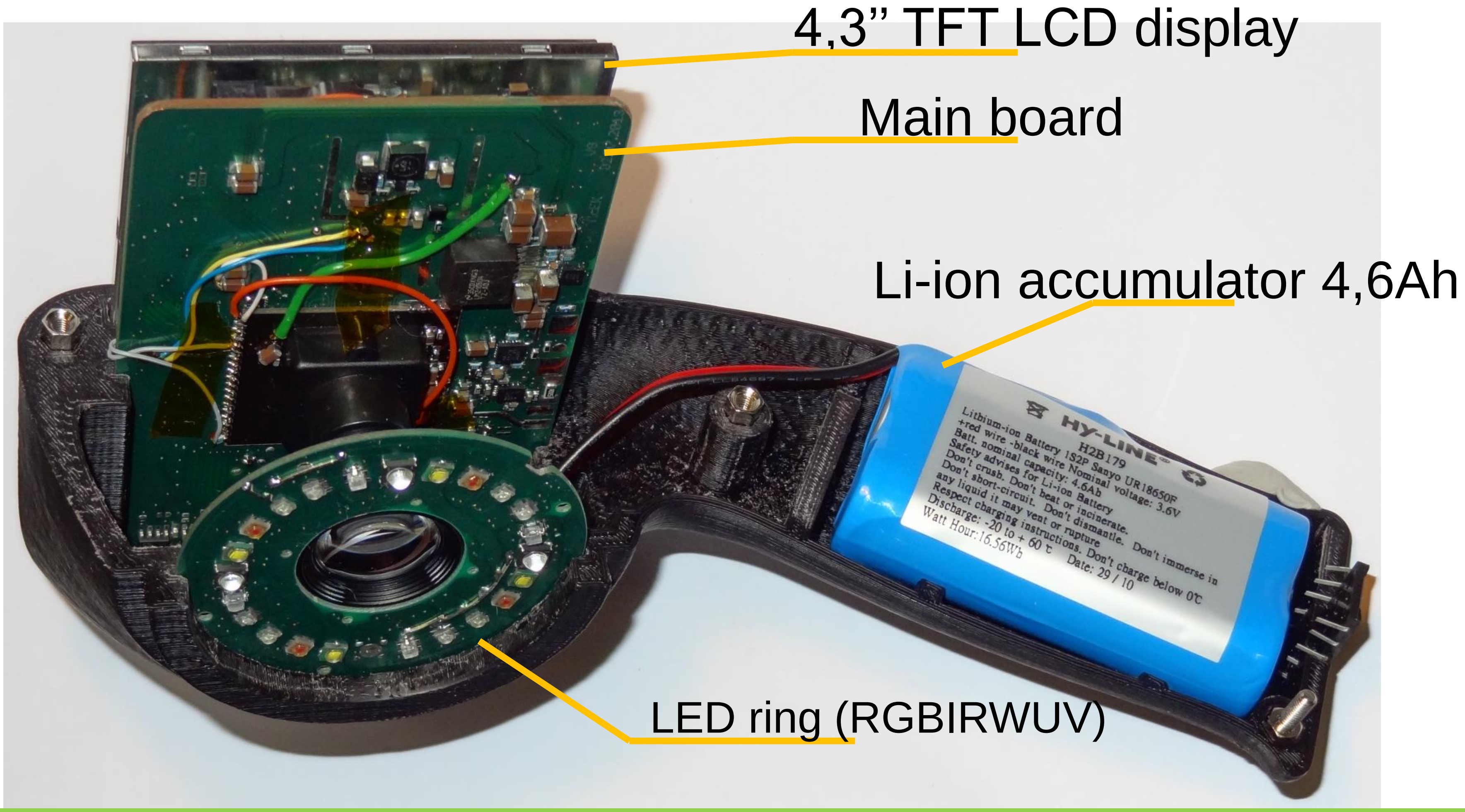
Non-invasive → **non-contact imaging** technologies:

- **Multi-spectral reflectance imaging** → skin chromophore mapping for diagnostics, follow-up and self-monitoring
- **Autofluorescence intensity, lifetime and photobleaching rate imaging** → skin cancer diagnostics
- **Photoplethysmography imaging** → distant cardiovascular monitoring - e.g. heart rate and arrythmia, anaesthesia control (Marta Lange, tomorrow)

SkImager: a proof-of-concept prototype

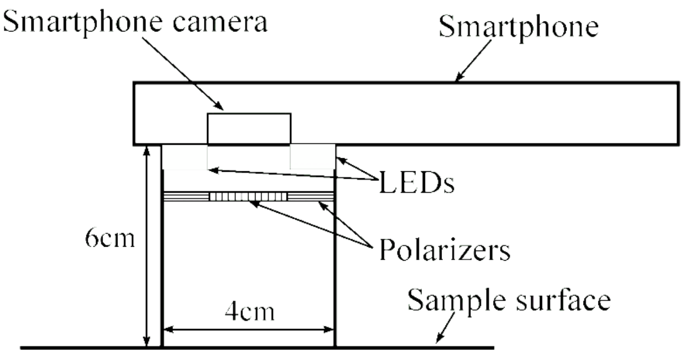
- Wireless, touch-screen, microcomputer
- Performs complex multimodal skin imaging by recording:
  - RGB reflectance image at white polarized illumination → revealing subcutaneous structures
  - 4 spectral images (450, 540, 660, 940nm) → distribution maps of melanin, haemoglobin, bilirubin, erythema index, melanoma/nevus index
  - Photoplethysmography video-image at green illumination → PPG amplitude distribution → skin blood perfusion map
  - Autofluorescence video-image at UV-excitation → map of photo-bleaching rates → skin fluorophore map

Inside

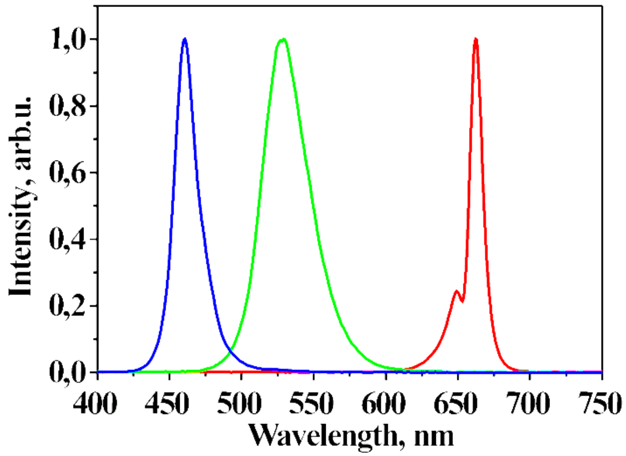


J.Spigulis, et al. SkImager: a concept device for *in-vivo* skin assessment by multimodal imaging. *Proc.Est.Acad.Sci*., 63(3), 213-220 (2014).

RGB-LED smartphone system for multispectral skin imaging



(a)

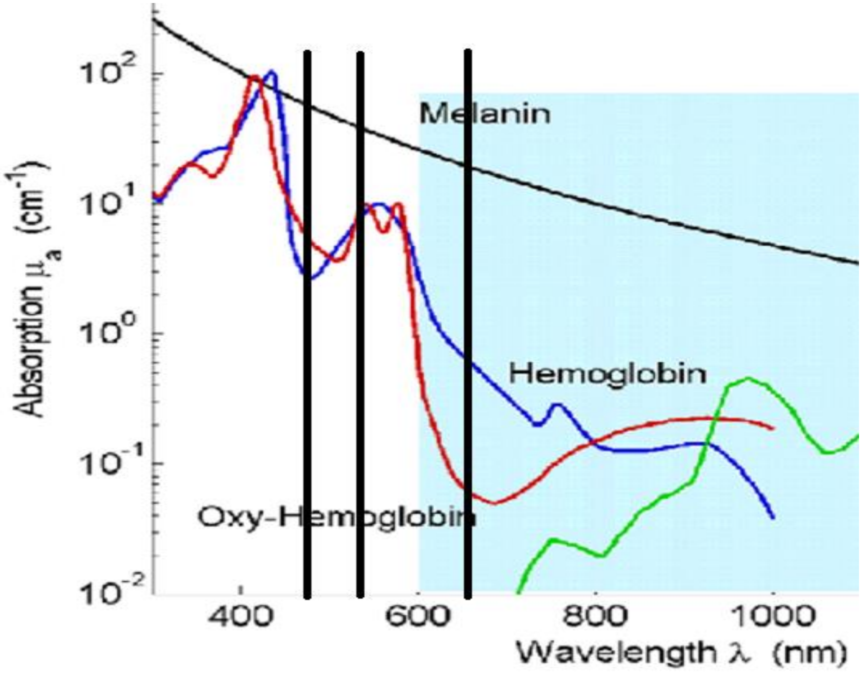


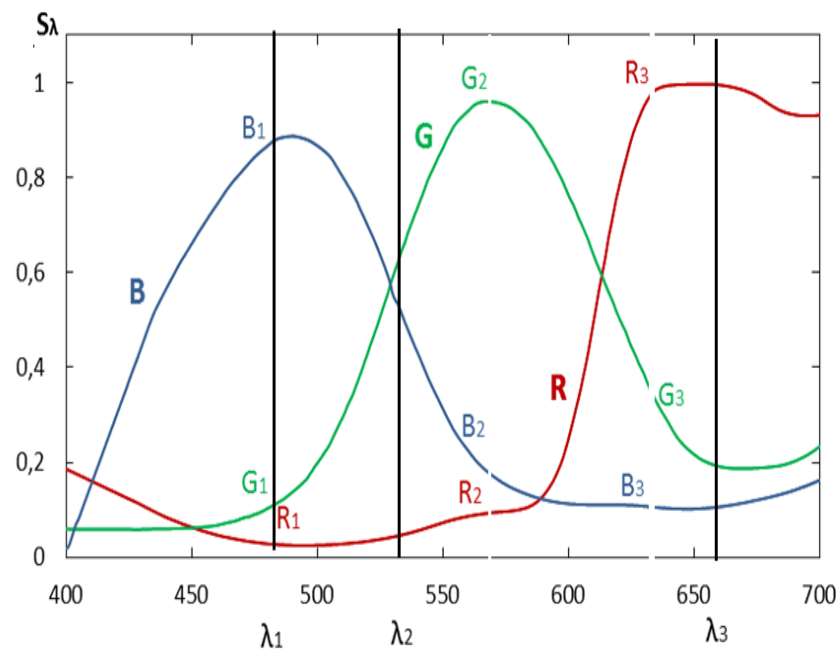
(b)

Kuzmina I., et al. Study of smartphone suitability for mapping of skin chromophores. *J.Biomed.Opt*., **2015**, 20(9): 090503

Multi-monochromatic spectral imaging

- 3 **monochromatic spectral images** from a **single-snapshot** RGB image data can be extracted if object (skin) is <u>illuminated simultaneously by 3 laser lines,</u> and the RGB-band sensitivities of the image sensor are known
- Next step – conversion of 3 monochromatic spectral images into distribution maps of 3 main skin chromophores (Beer's-Lambert law → 3 equations)

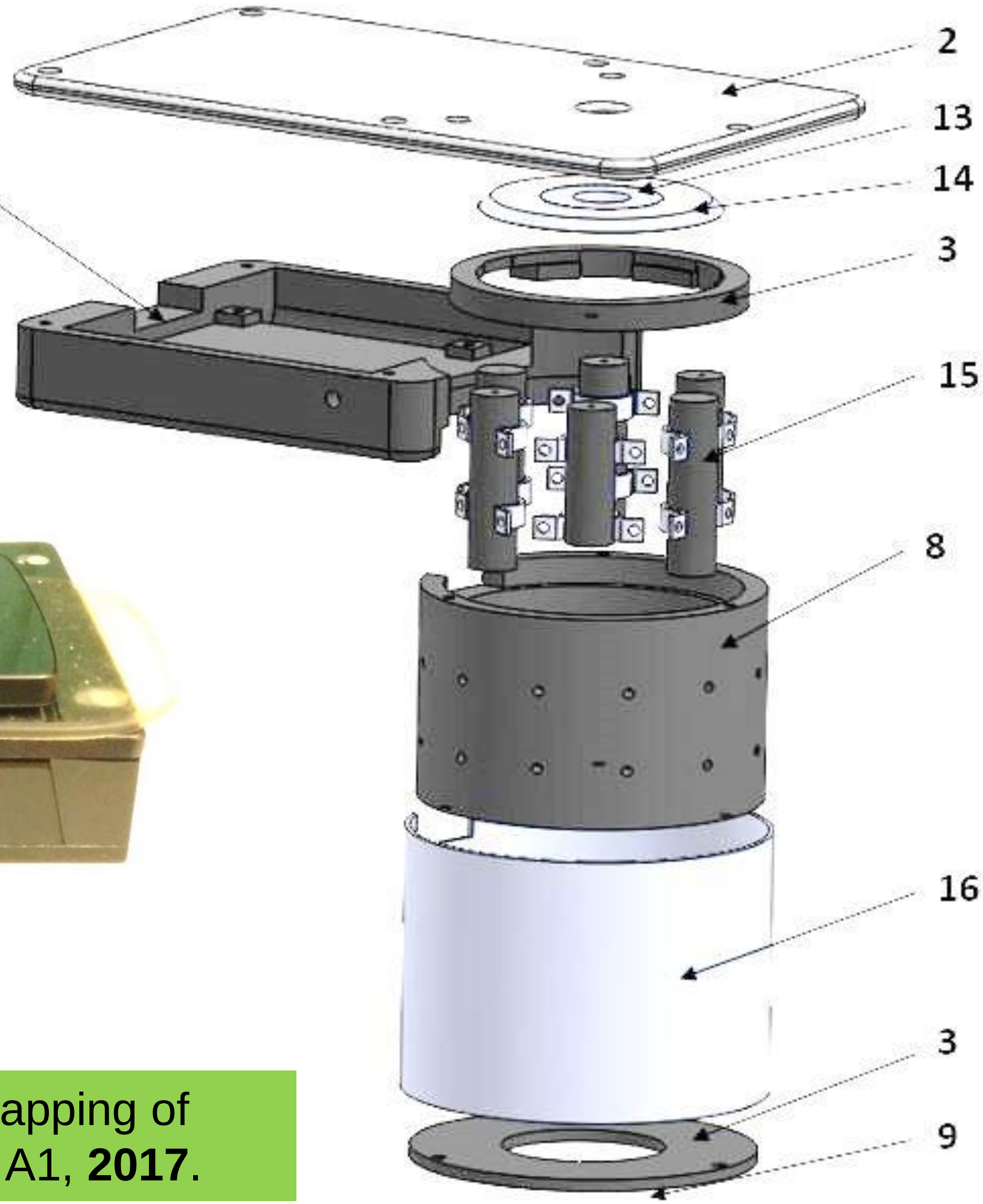




Method and device for imaging of spectral reflectance at several wavelength bands. WO 2013135311 (A1), 2012.

Smartphone add-on triple wavelength laser illuminator:

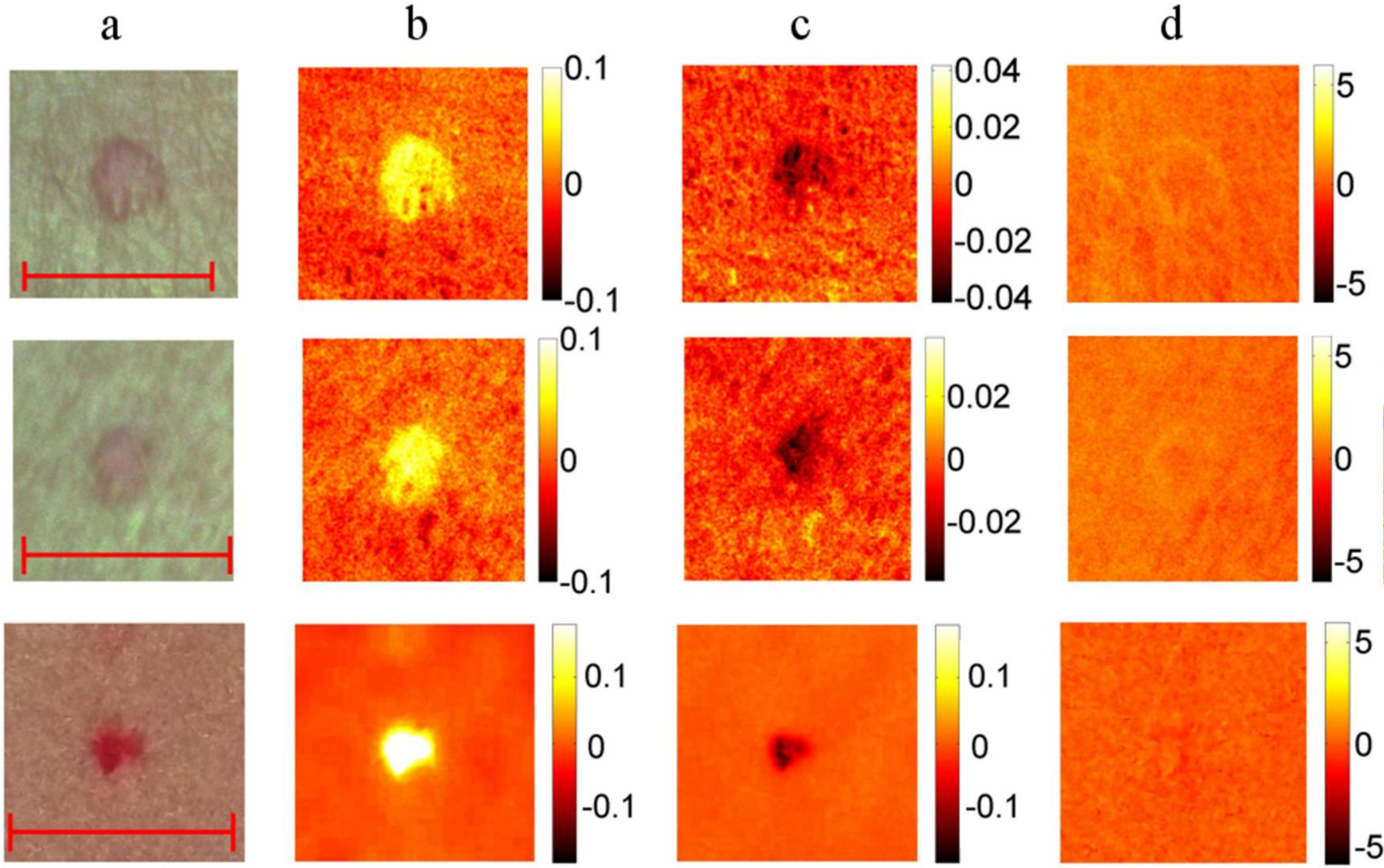
450nm, 532nm, 659nm

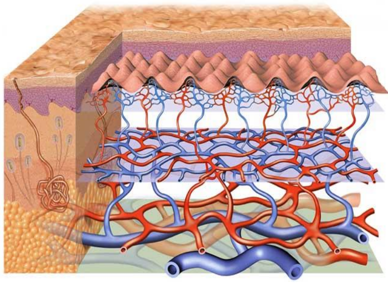


Method and device for smartphone mapping of tissue compounds. WO 2017/012675 A1, **2017**.

RGB image (a) and maps of chromophore content changes for 3 vascular hemangiomas:

b – oxy-hemoglobin, c – deoxy-hemoglobin, d – melanin

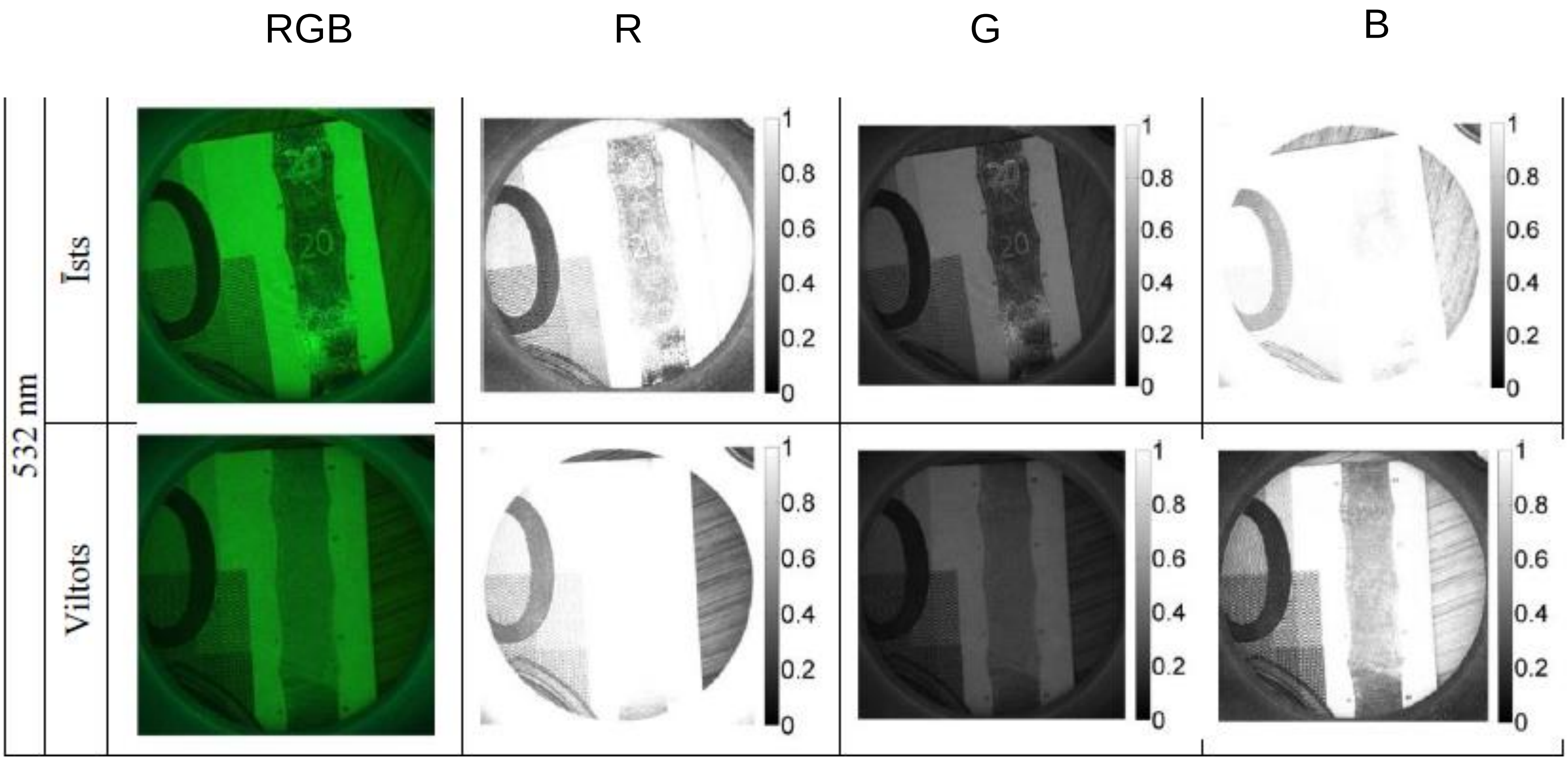




Spigulis J., et al. Smartphone snapshot mapping of skin chromophores under triple-wavelength laser illumination. *J.Biomed.Opt.*, **2017**, 22(9): 091508.

Smartphone forensics:

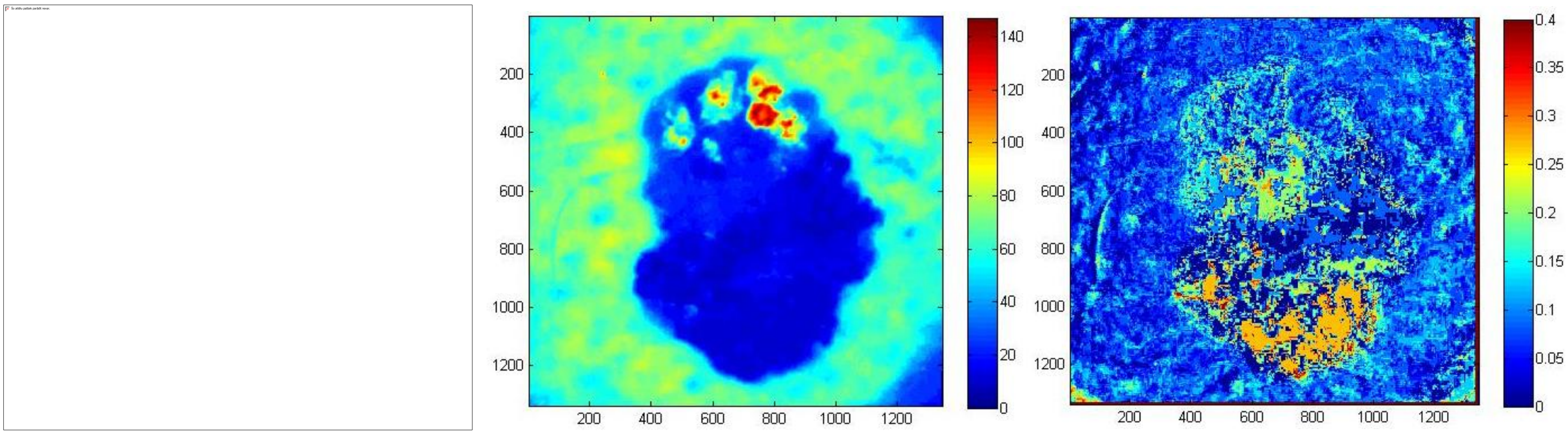
532nm monochromatic spectral images of authentic (upper row) and counterfeit (lower row, withdrawn by Bank of Latvia) 20 EUR banknotes



Smartphone fluorescent skin diagnostics

Atypical skin nevus

Smartphone RGB photo under 405nm LED irradiation



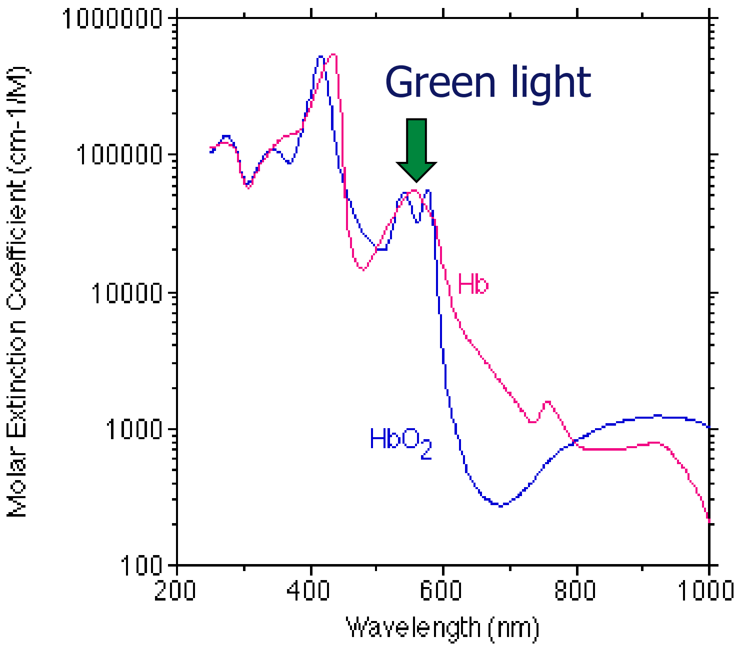
a b c

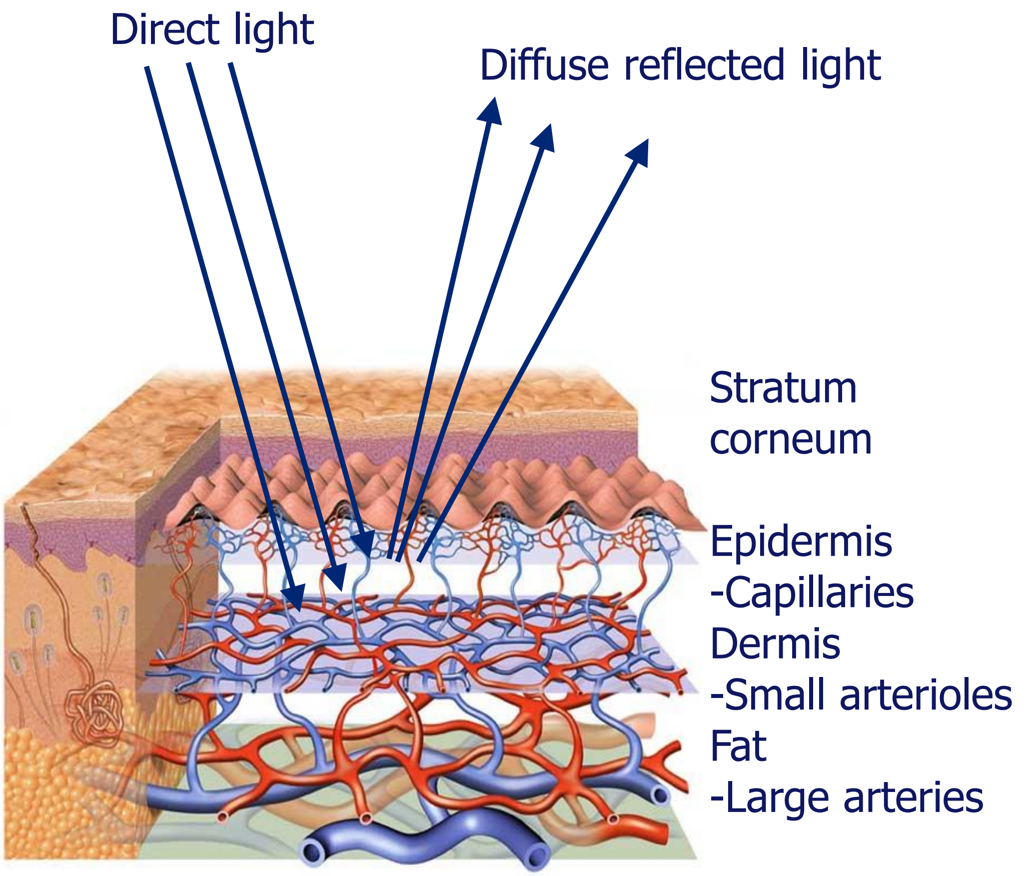
Filtered color image (a), AF intensity G-band image (b) and photobleaching rate map (c).

Histological analysis of the removed tissue samples confirmed three different types of tissue cells within the lesion area: the upper part mostly prevailed by intradermal nevus, the middle part by dysplastic nevus, and the lower part by junctional nevus.

A.Lihachev, et al. Autofluorescence imaging of Basal Cell Carcinoma by smartphone RGB camera. *J.Biomed.Opt*., 20(12), 120502 (2015).

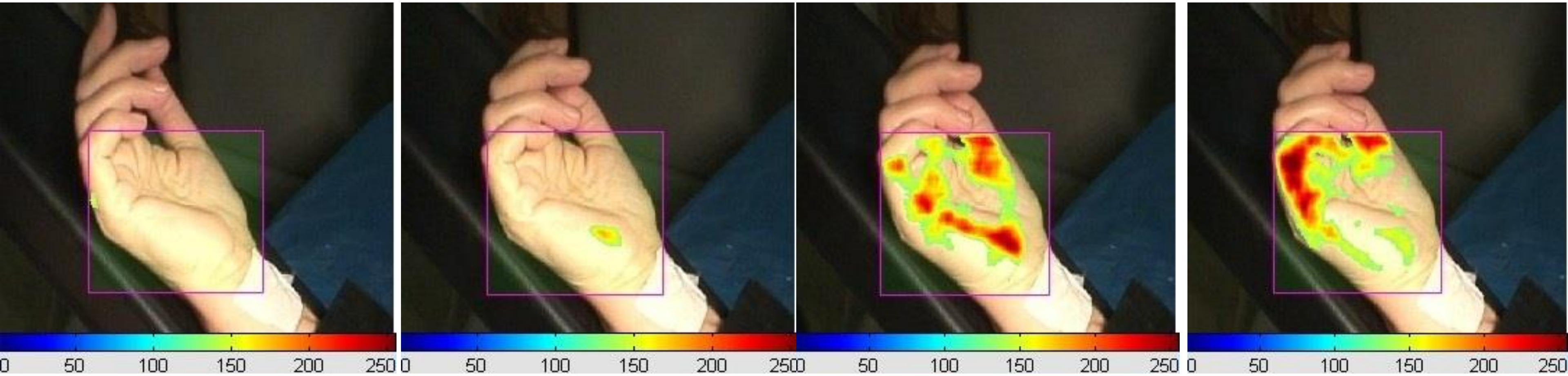
Photolethysmography imaging: principle



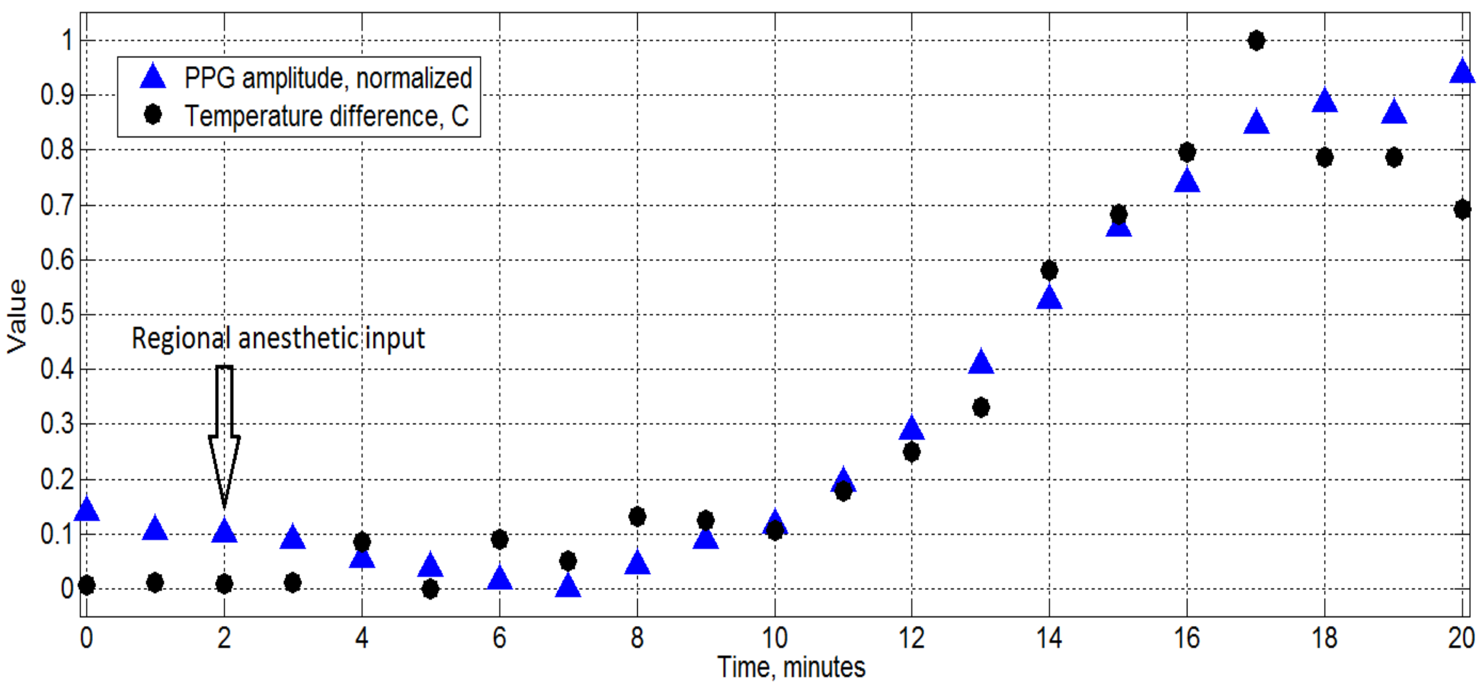


PPGI: non-invasive technique for distant detection of blood flow pulsations in skin by analysis of backscattered optical radiation

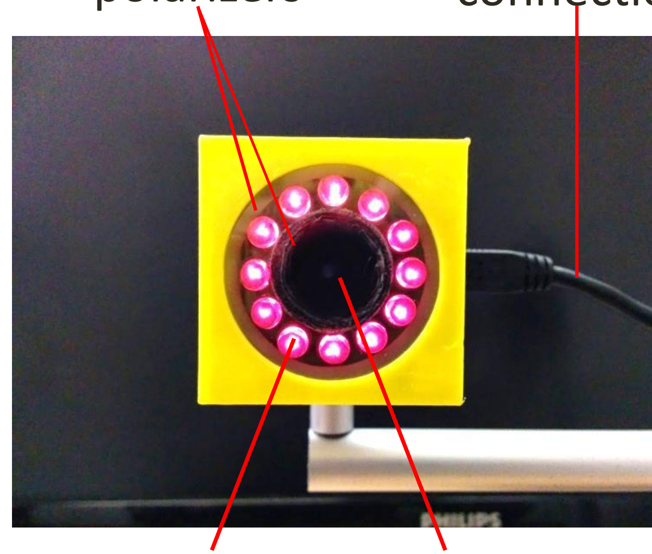
PPGI for remote anaesthesia monitoring



RA injection 8 minutes 12 minutes 16 minutes



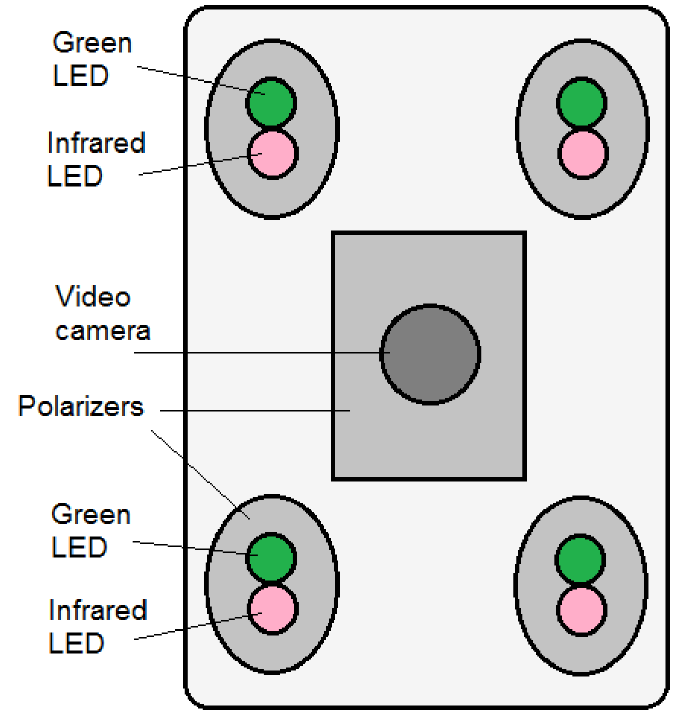
Compact (4x4x4 cm) prototype for remote blood perfusion mapping



IR LED (760nm) – for measurements of deep layers of skin; green LED (540nm) – for measurements of upper layers of skin

Clinical prototype for remote anaesthesia control before/during palm surgeries

1. The device has vacuum pillow for fixing of palm in steady position.
2. Four bispectral illuminators perform uniform illumination of skin.



IR LED (810nm) – for measurements of deeper layers of skin; green LED (530nm) – for measurements of superficial layers of skin

Recent review paper: more details

sensors

MDPI

Review

Multispectral, Fluorescent and Photoplethysmographic Imaging for Remote Skin Assessment

Janis Spigulis

Biophotonics Laboratory, Institute of Atomic Physics and Spectroscopy, University of Latvia, Riga LV-1586, Latvia; janis.spigulis@lu.lv; Tel.: +371-2948-5347

Academic Editor: Dragan Indjin
Received: 12 April 2017; Accepted: 17 May 2017; Published: 19 May 2017

Sensors **2017**, *17*, 1165; (open access)

Summary

- Optical imaging techniques show promising potential for distant evaluation of *in-vivo* skin:
  - Multispectral imaging-based skin chromophore mapping
  - Fluorescence photobleaching-based skin fluorophore mapping
  - Remote photoplethysmography-based skin blood perfusion mapping
- Clinical applications: patient-friendly skin cancer screening, anaestesiology control, burns, recovery monitoring, forensics, ...
- Research and commercial partners are welcomed!

Acknowledgments

This study was supported by the European Regional Development Fund and Latvian National Reserch programme SOPHIS (#10-4/VPP-4/11).

Thank You!

- janispi@latnet.lv
- www.lanet.lv/~spigulis