Laser Illumination Designs for Snapshot Multi-Spectral-Line Imaging

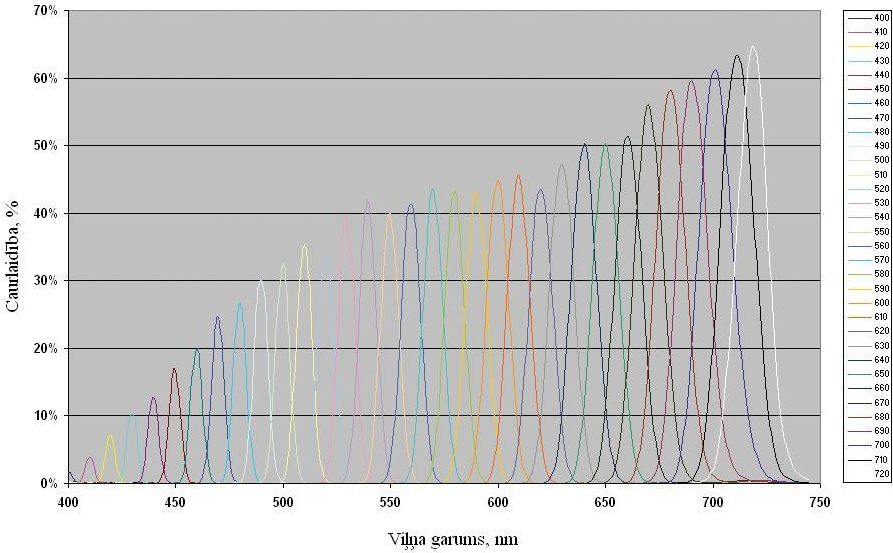
Janis Spigulis, Ilze Oshina, Margarita Matulenko

Institute of Atomic Physics and Spectroscopy
University of Latvia, Riga

CLEO-Europe, Munich, 24/06/2019

Motivation: improved spectral imaging

- **Hyperspectral imaging**: nice technology, but with some disadvantages:
  - insufficient **spectral purity** - bandwidth ~10-20nm, overlapping bands
  - **Acquisition time** - tens of seconds to minutes → motion artefacts (in-vivo)
  - Huge **computing resources** required
  - A number of spectral images **non-informative**
  - **Expensive**, tens of kEUR

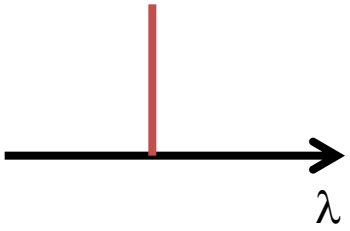


Single and multi- spectral line imaging

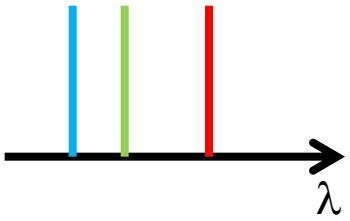
- Narrower spectral band → monochromatic (< 0.1nm) **single spectral line image** can be obtained if the object is illuminated by a single spectral line, e.g. emitted by laser
- Faster acquisition of a set of spectral images → 3 **monochromatic spectral images** from a **single-snapshot** RGB image data can be extracted if object is illuminated simultaneously by 3 laser lines, and the RGB-band sensitivities of the image sensor are known → crosstalk corrected R-, G- and B-band images can be extracted*
- Advantages - radically improved spectral selectivity of images, avoided motion artefacts
- Applications: dermatology (mapping of skin chromophores); forensics (counterfeit detection); …

Illumination spectra:

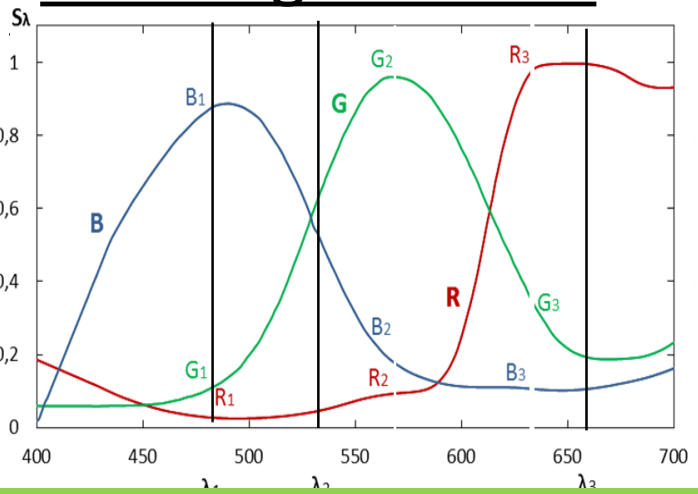
Single-wavelength



Triple-wavelength

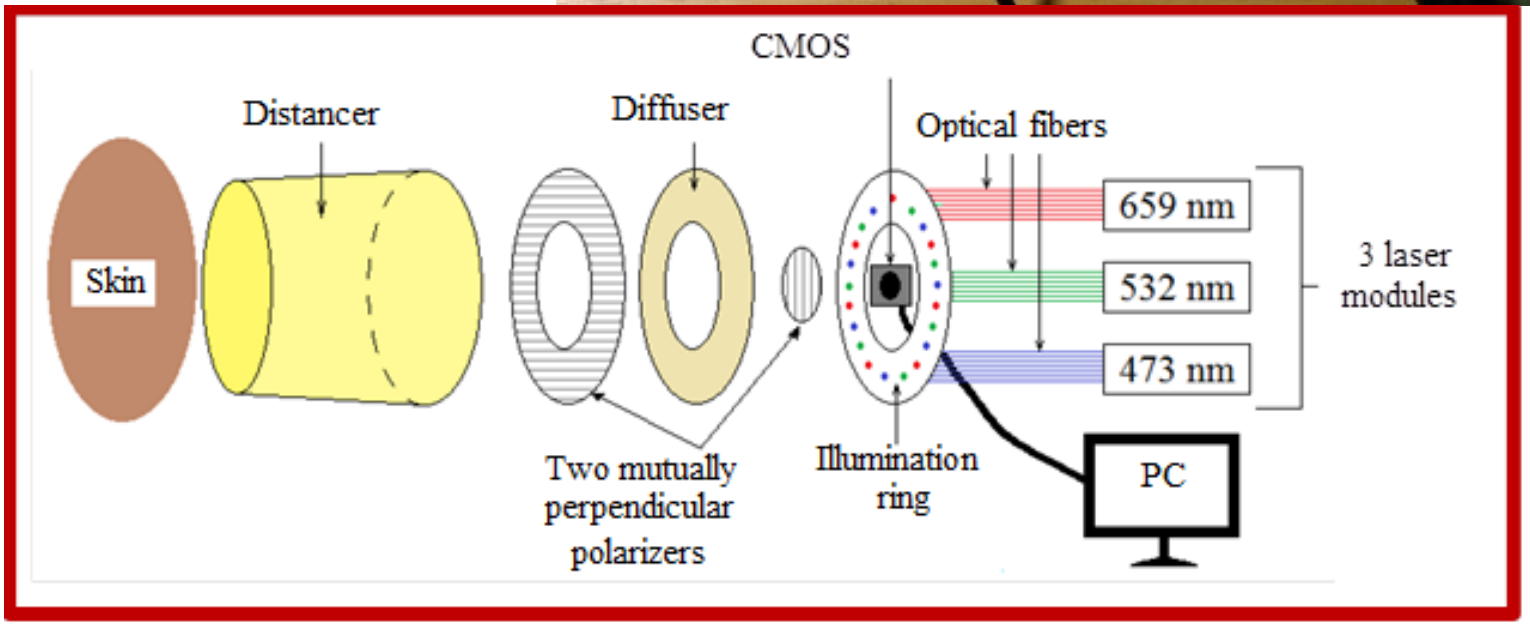


RGB sensitivities of the image sensor :



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

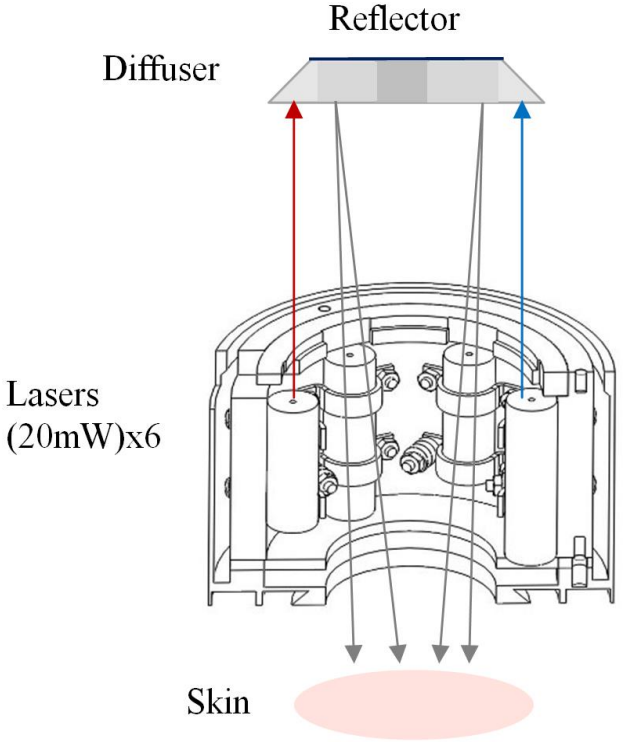
1st design: forward illumination by a 21 fiber system, 473/532/659nm

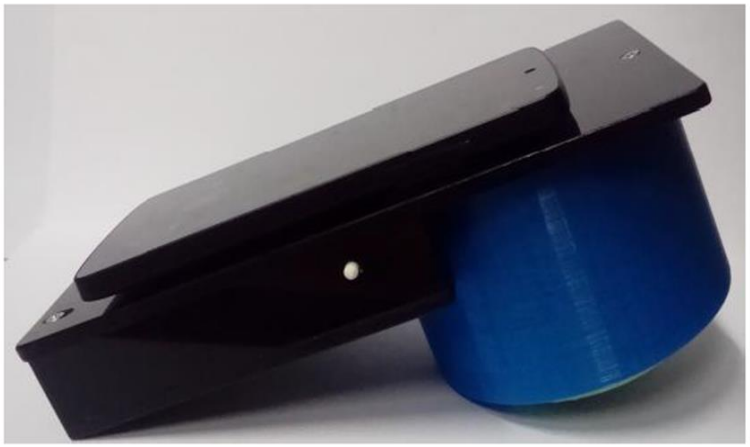


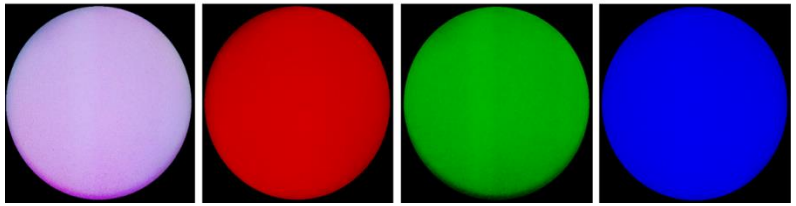
Acceptable uniformity of target illumination; drawback - too bulky, inconvenient for out-of-lab use

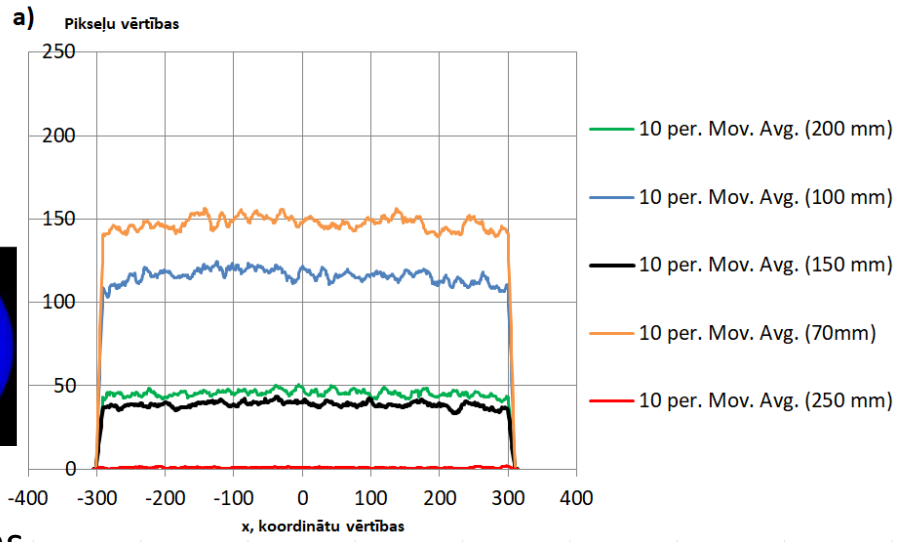
J.Spigulis, I.Oshina. Snapshot RGB mapping of skin melanin and hemoglobin. *J.Biomed.Opt.*,20(5), 050503 (2015

2nd design: free space laser backward illumination (448/532/659nm) by a ring-shaped diffusing reflector





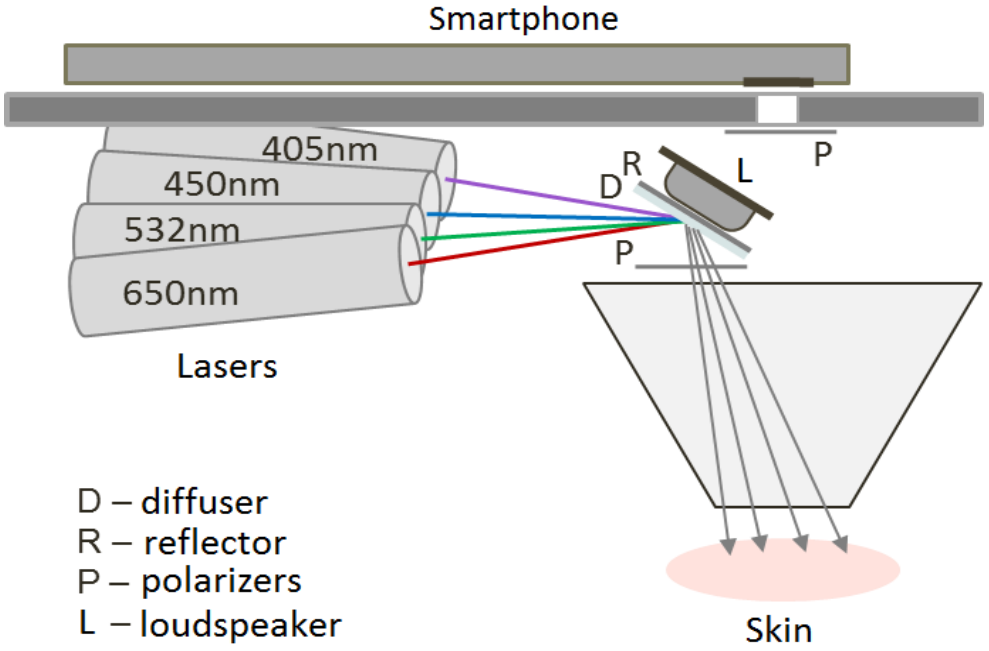


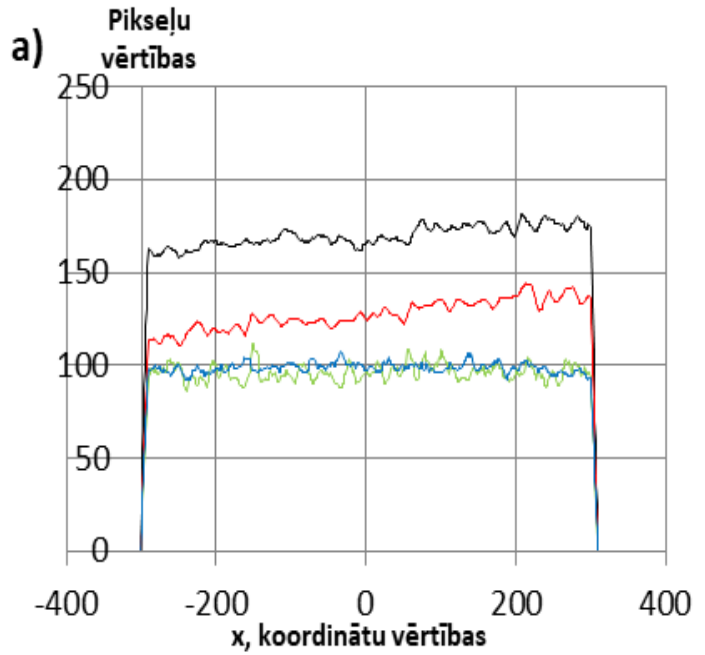


Portable, used in dermatology and forensics;
Drawback – images with laser speckle patterns

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).

3rd design: four laser line illuminator with sloped diffusing reflector



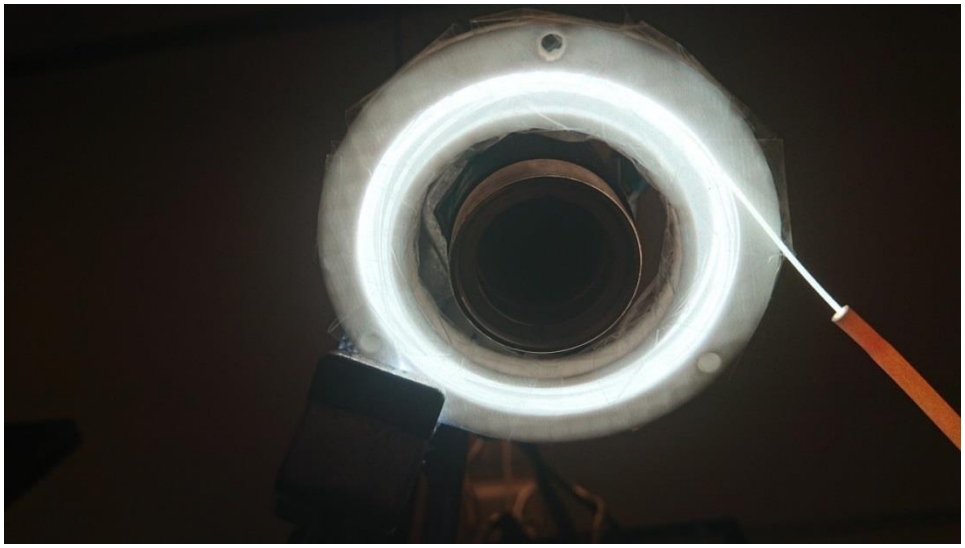


No speckle patterns, but uneven illumination

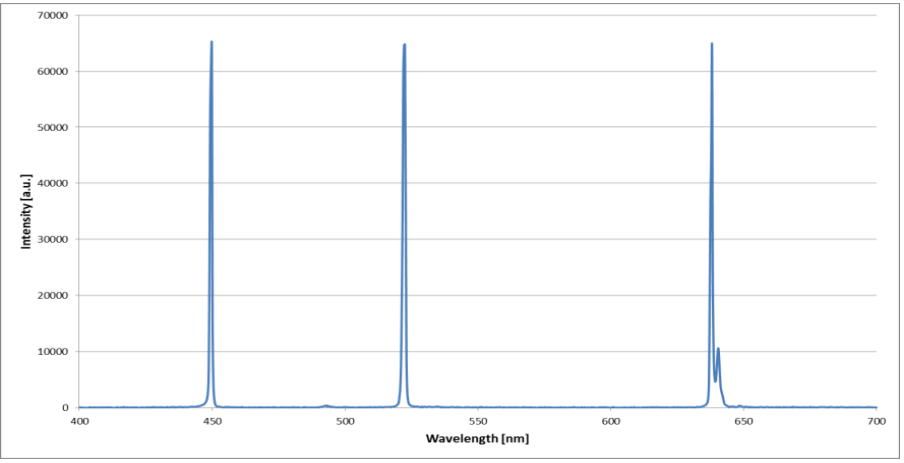
WO 2018/177565 A1, 2018. Device for speckle-free imaging under laser illumination (U.Rubins, E.Kviesis-Kipge, J.Spigulis)

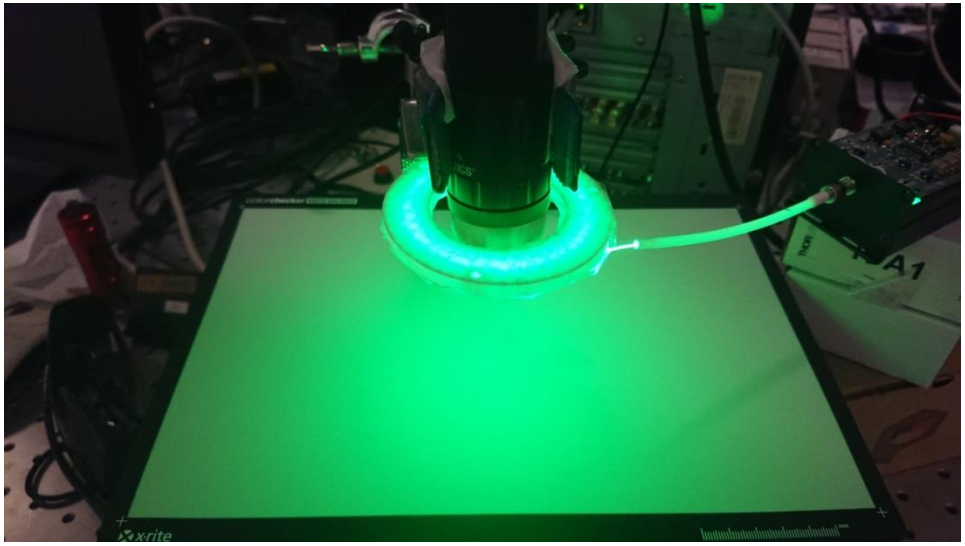
Current project: RGB laser illumination by a side-emitting optical fiber ring

(dia. 55...65 mm)



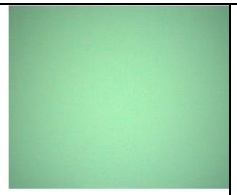
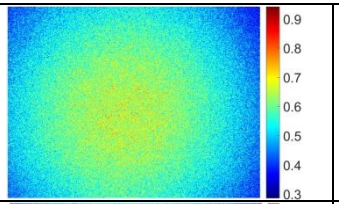
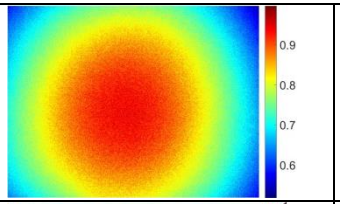
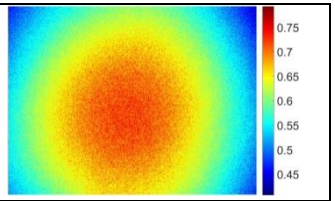
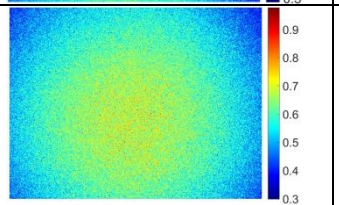
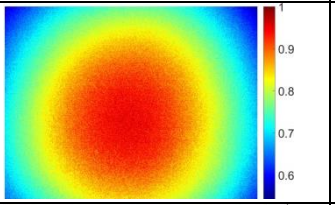
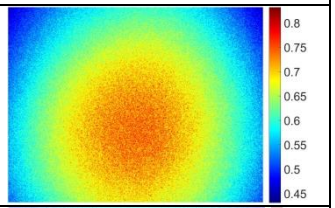
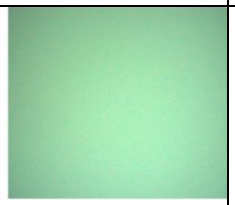
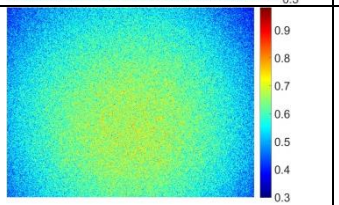
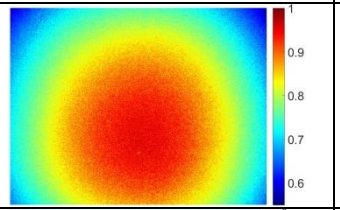
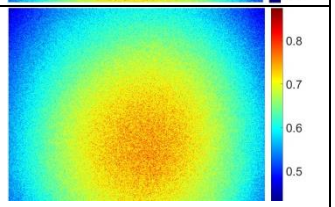
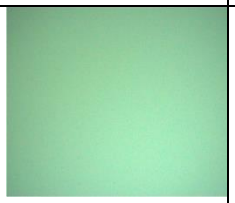
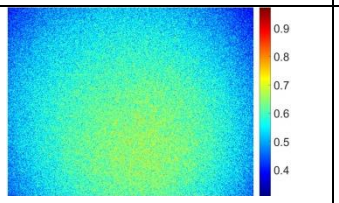
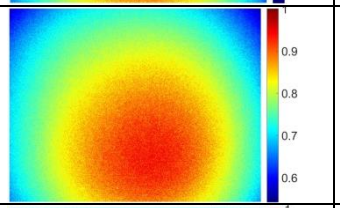
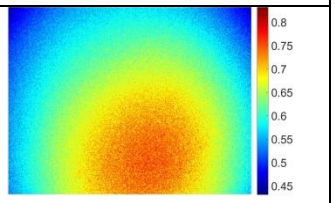
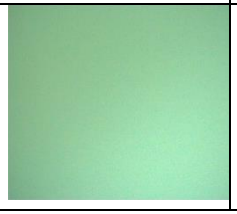
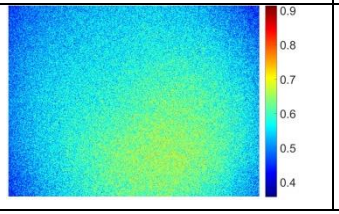
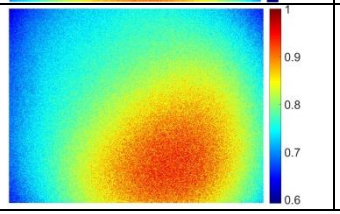
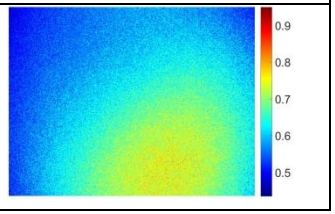
450/523/638 nm



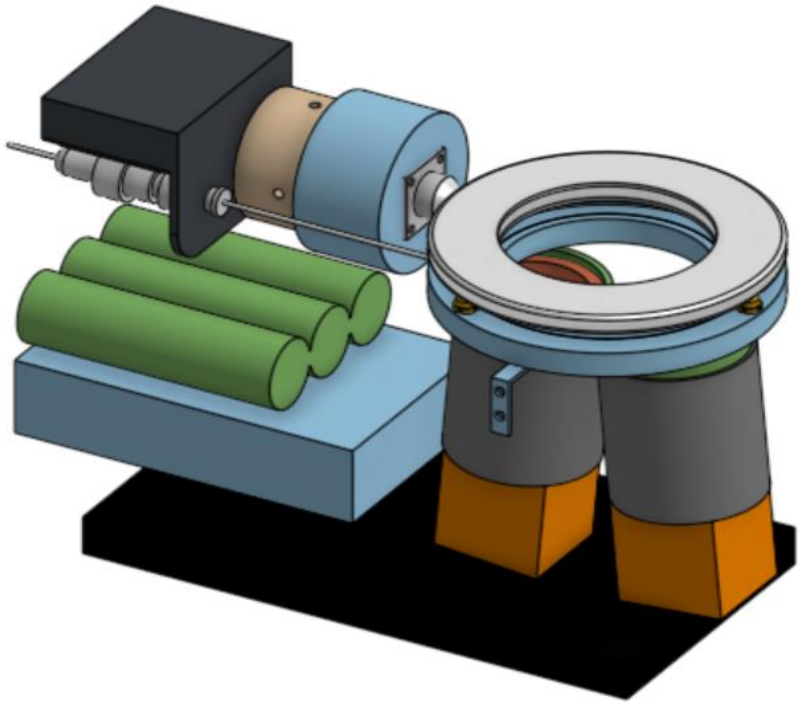


LV 11644 B, 1995. Side-emitting optical fiber (D. Pfafrods, M. Stafeckis, J. Spigulis, D. Boucher).

Illumination profiles at various distances from the fiber ring plane

	Image	R channel	G channel	B channel
80 mm				
70 mm				
60 mm				
50 mm				
40 mm				

Design concept
of the new prototype device



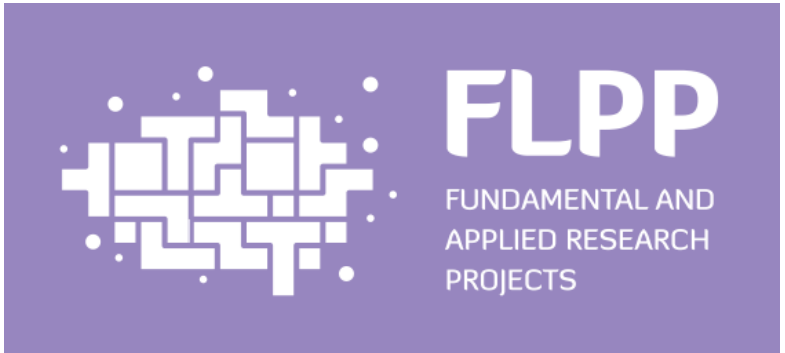
Summary

- Non-conventional multi-laser designs for even illumination of centimeter-sized areas discussed
- Applications – spectral imaging of increased performance for dermatology, forensics, etc.
- Four design options developed:
  - Multi-fiber forward illumination
  - Backward illumination by a planar light-scattering ring
  - Reflection of laser beams by a sloped planar diffuser
  - Illumination by a ring of side-emitting fibers
- All designs implemented and tested in prototype devices for snapshot multi-spectral-line imaging; advantages and drawbacks identified.

Acknowedgements

This study was supported by the Latvian Council of Science, grant # LZP-2018/2-0006 «Advanced spectral imaging technology for skin diagnostics». Travel support from the ERDF project # 1.1.1.1/18/A/132 is highly acknowledged.

Latvian Council of Science



Thank You!

- janispi@latnet.lv
- http://home.lu.lv/~spigulis