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

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

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

Diffuse reflectance absorption:

\[ x \rightarrow f(x) ! \]

**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

<table>
<thead>
<tr>
<th>λ, nm</th>
<th>MAX, ns (±0.012)</th>
<th>FWHM, ns (±0.02)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8 mm</td>
<td>12 mm</td>
</tr>
<tr>
<td>520</td>
<td>0.114</td>
<td>0.168</td>
</tr>
<tr>
<td>640</td>
<td>0.103</td>
<td>0.222</td>
</tr>
<tr>
<td>720</td>
<td>0.114</td>
<td>0.211</td>
</tr>
<tr>
<td>800</td>
<td>0.141</td>
<td>0.234</td>
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</table>

The mean values of pulse peak time delay, ns

The mean values of FWHM differences, ns
IF THE DISTRIBUTION OF REMITTED PHOTON PROPAGATION 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 ($n \approx 1.4$)

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.
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.

<table>
<thead>
<tr>
<th>(\lambda), nm</th>
<th>8 mm</th>
<th>12 mm</th>
<th>16 mm</th>
<th>20 mm</th>
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</thead>
<tbody>
<tr>
<td>520</td>
<td>117</td>
<td>105</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>640</td>
<td>162</td>
<td>204</td>
<td>268</td>
<td>276</td>
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<tr>
<td>720</td>
<td>273</td>
<td>266</td>
<td>267</td>
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<tr>
<td>800</td>
<td>251</td>
<td>300</td>
<td>319</td>
<td>304</td>
</tr>
</tbody>
</table>

\[ \text{Path length, mm} \]

• 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
Thank you for your attention