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In-vivo diagnostics of skin malformations using multimodal RGB imaging

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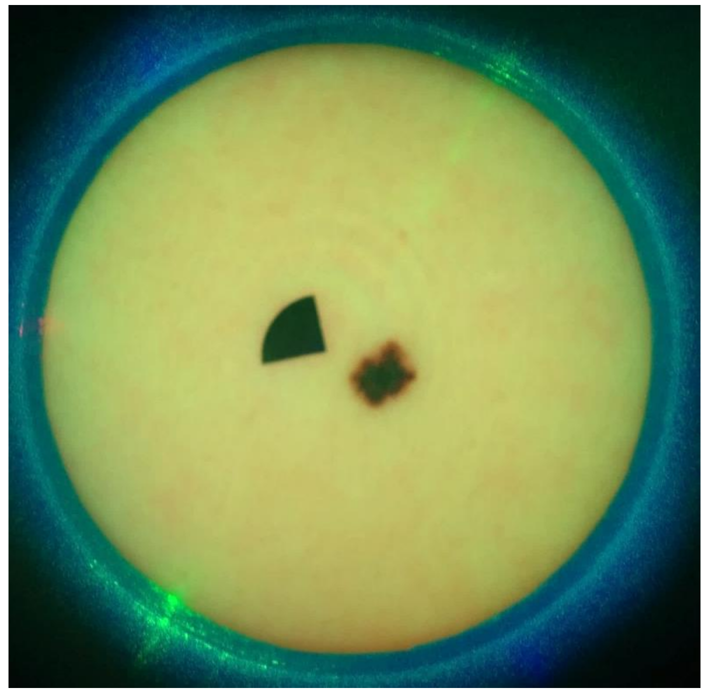
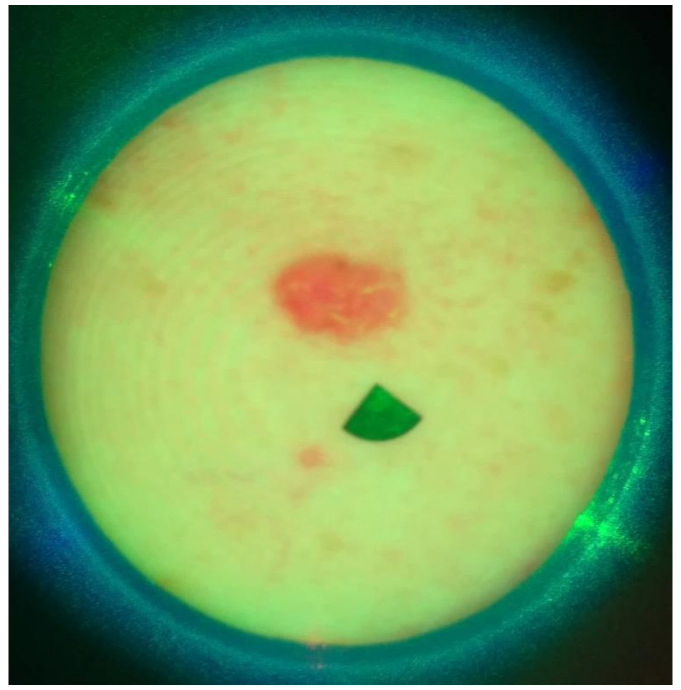
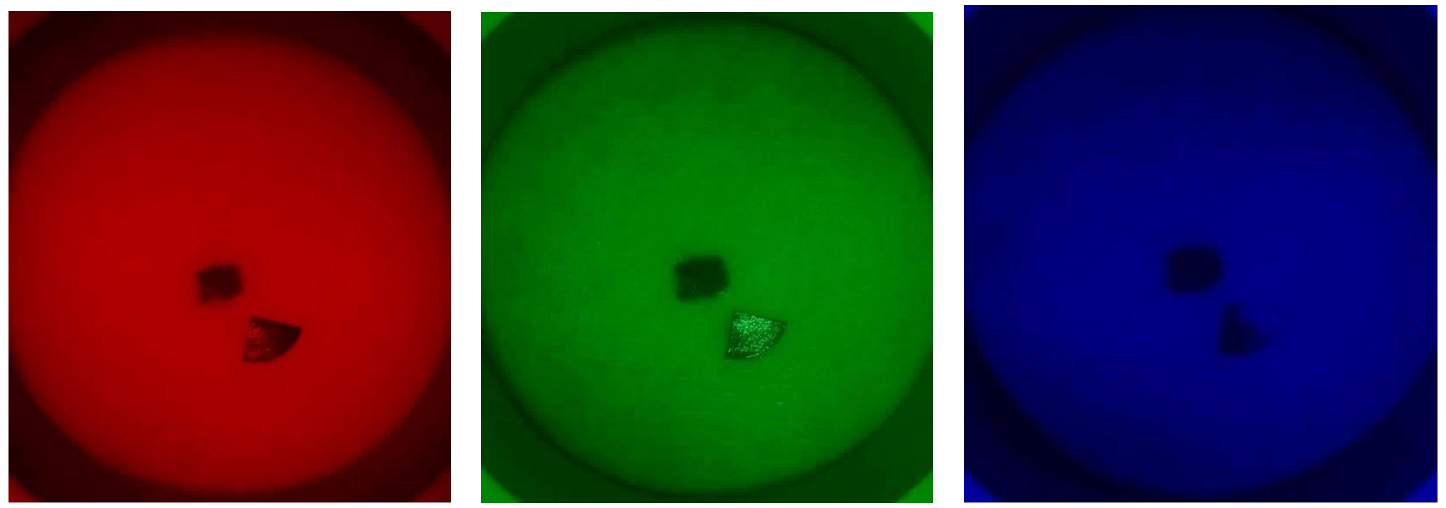
Melanoma

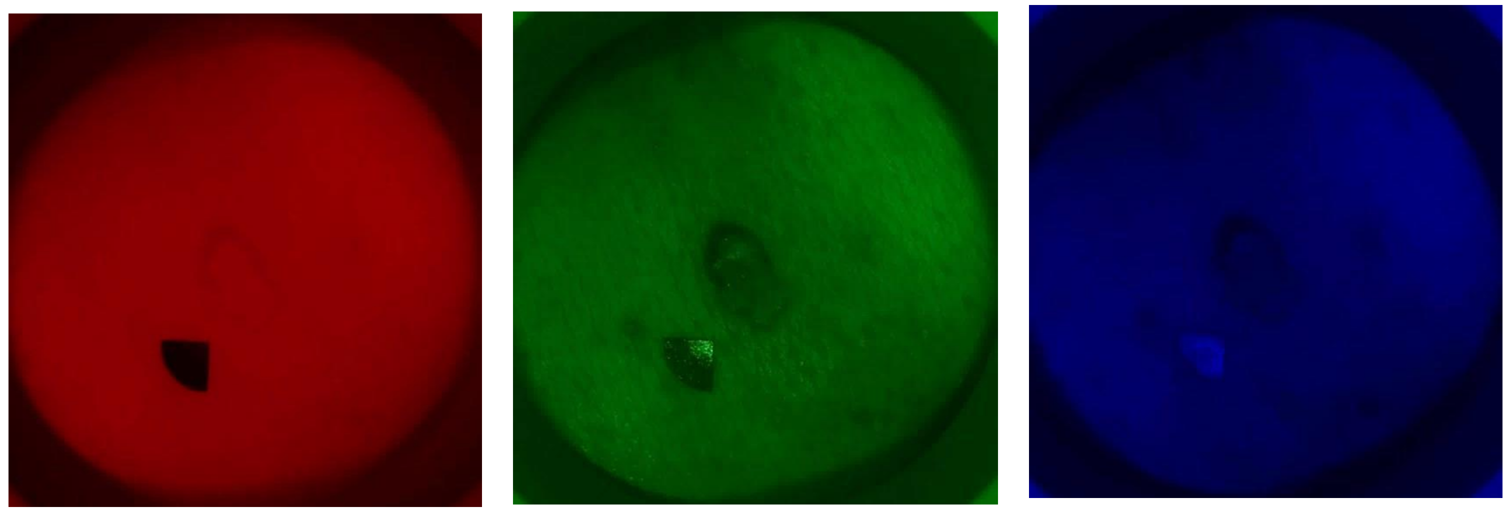
Basal cell carcinoma





Laser device





LED device

Suspicious skin malformations such as melanoma and basal cell carcinoma requires a histological examination that is precise, but invasive.

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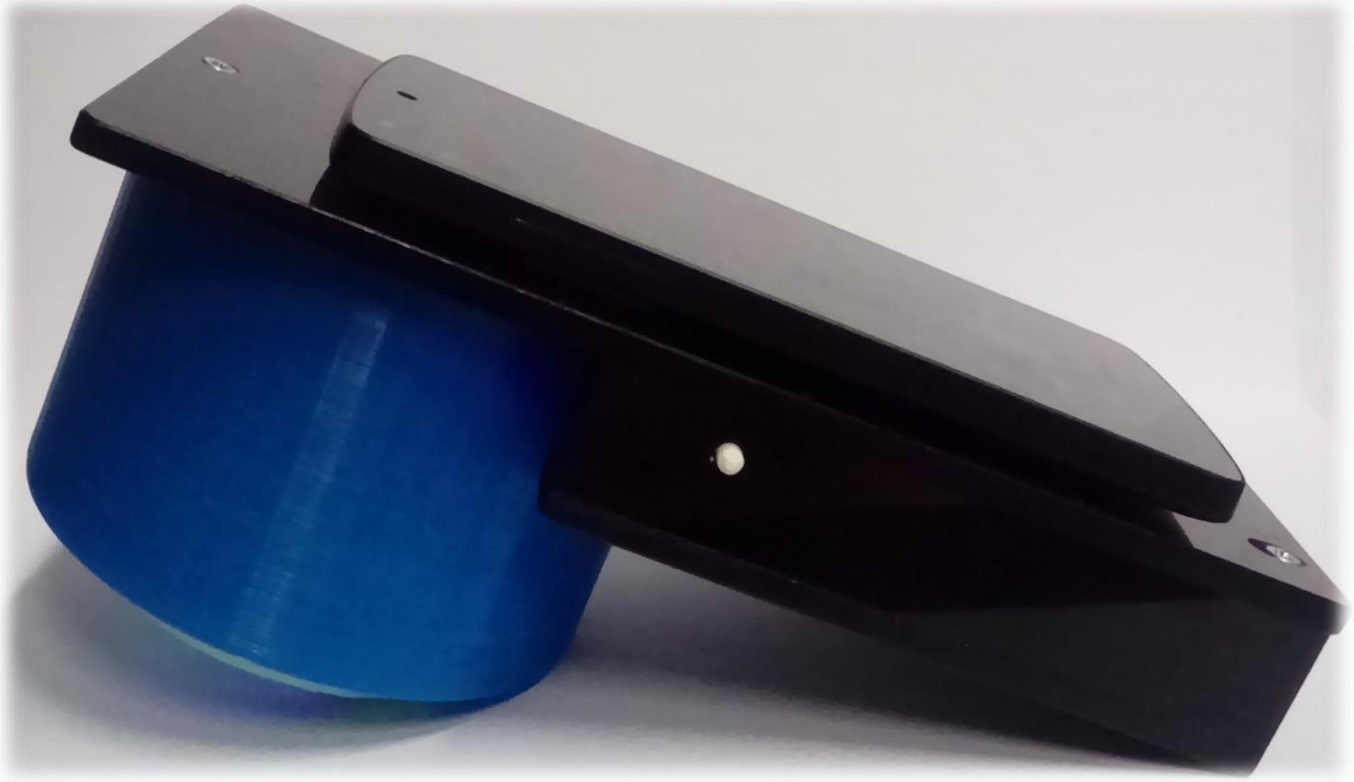
Our devices



Multispectral laser device
(448 nm, 532 nm, 659 nm)

Multispectral LED device
(460 nm, 535 nm, 663 nm)

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Chromophore concentration calculation

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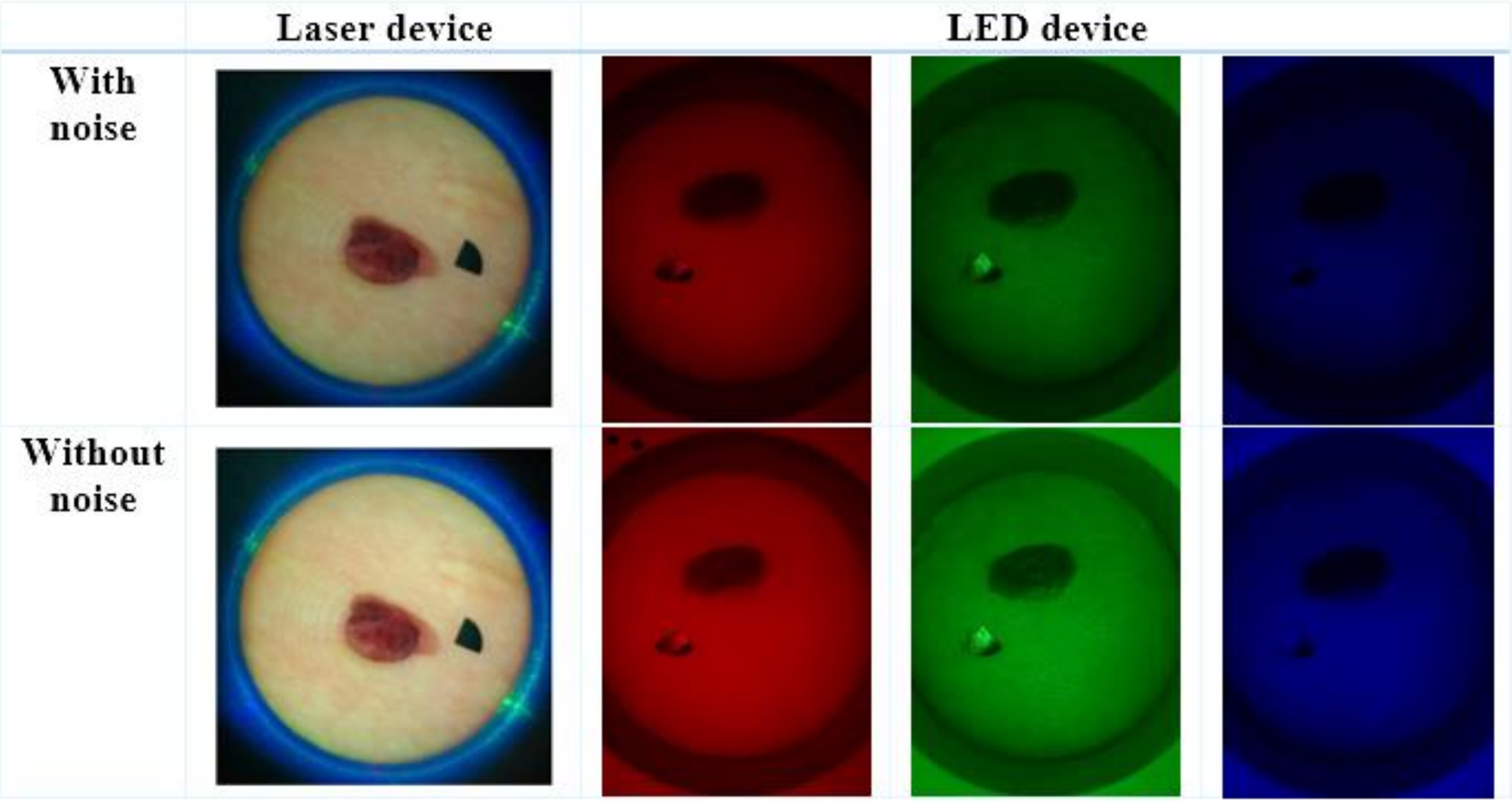

Subtracts noise from images

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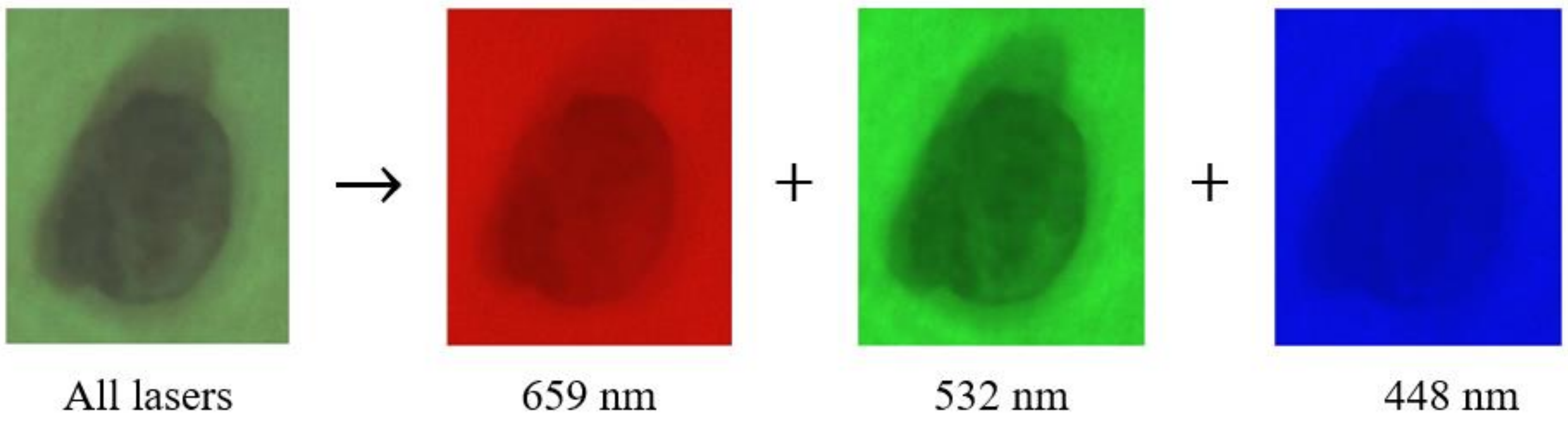

Using the RGB crosstalk correction algorithm, three images – one for each wavelength – are extracted in laser device case

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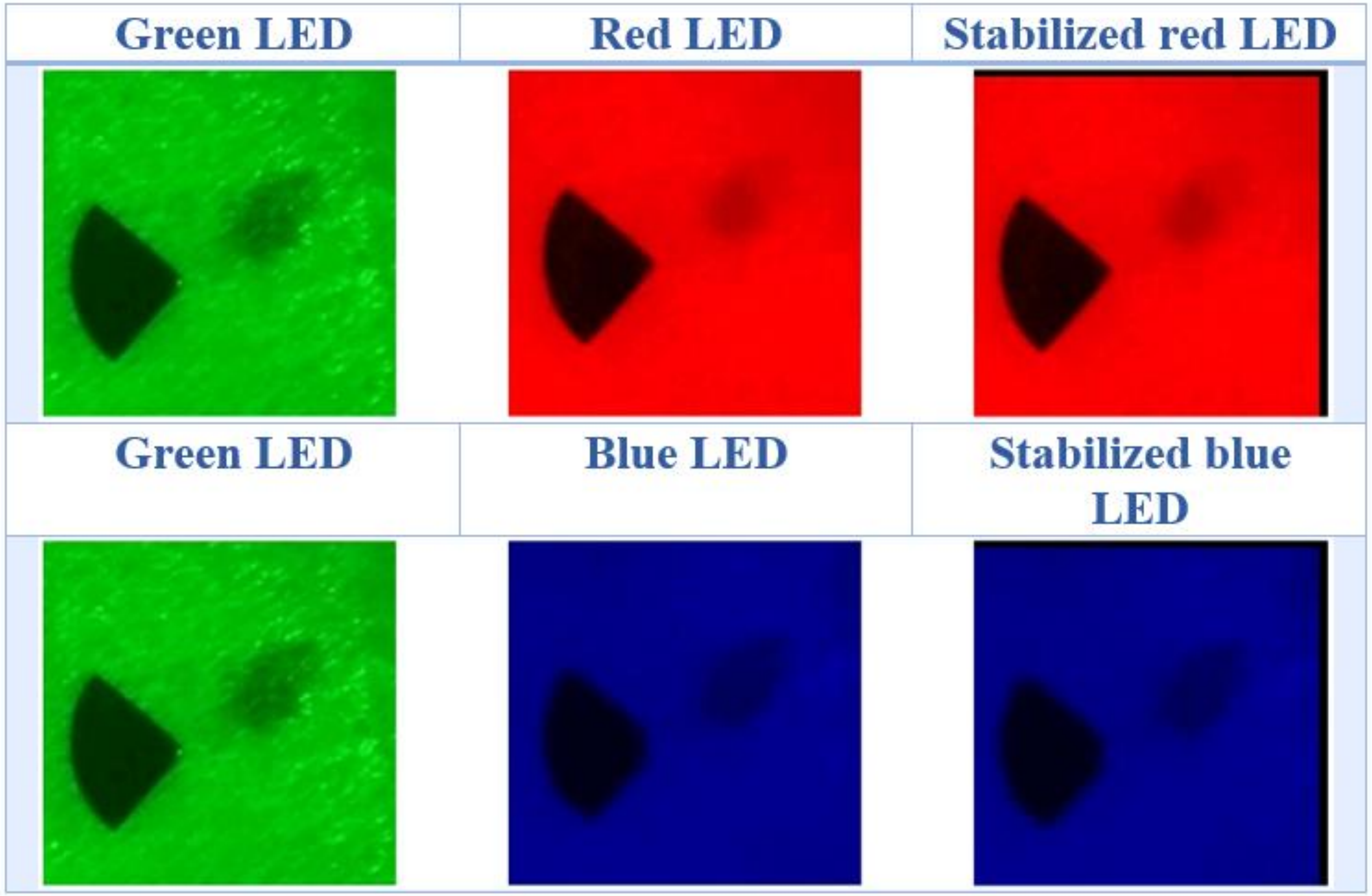

Using a stabilization algorithm and black marker, the images are combined to prevent motion artefacts in LED device case

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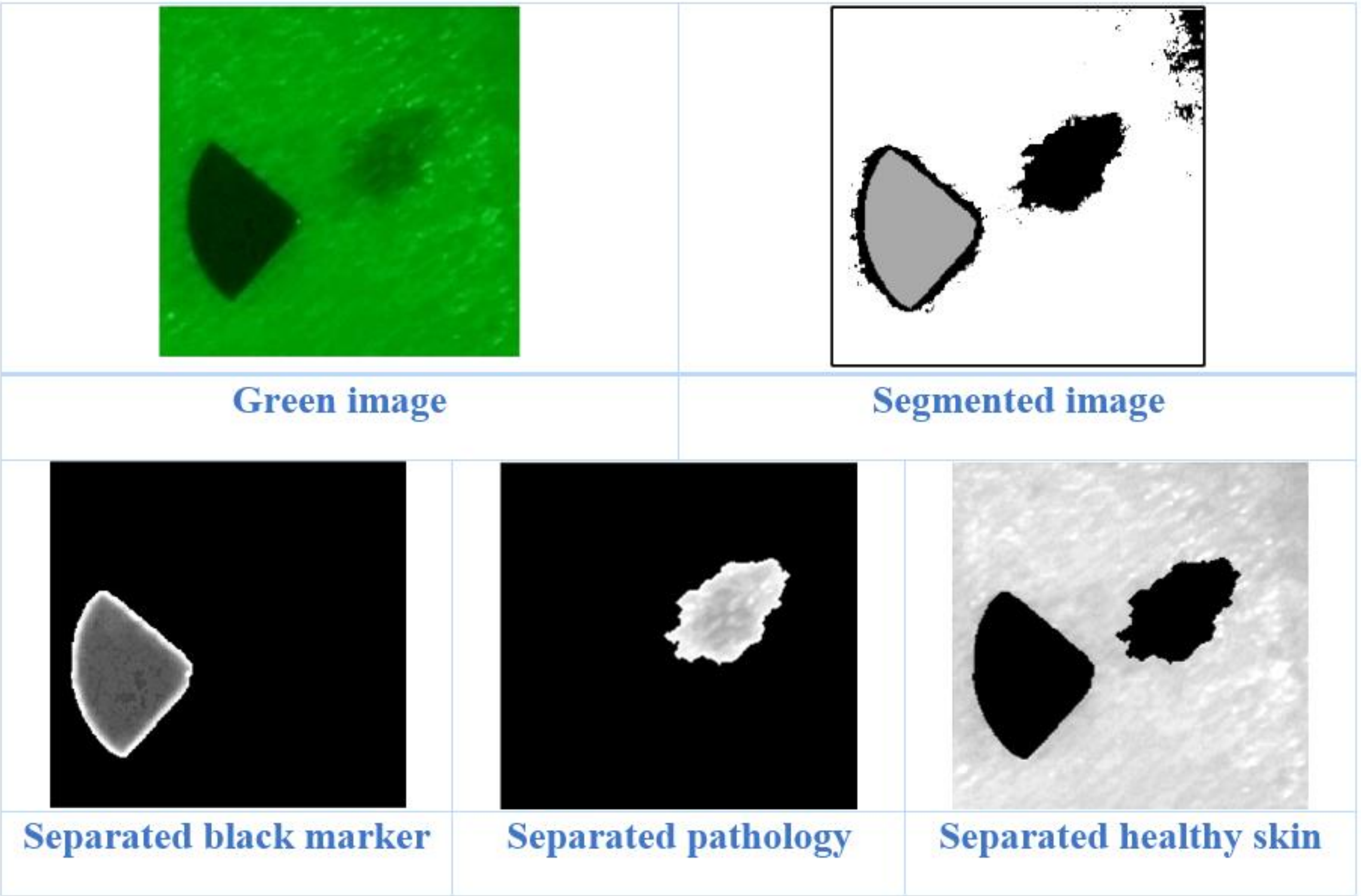

Images are segmented to separate healthy skin, pathology and black marker for LED device case, and healthy skin and pathology for laser device case

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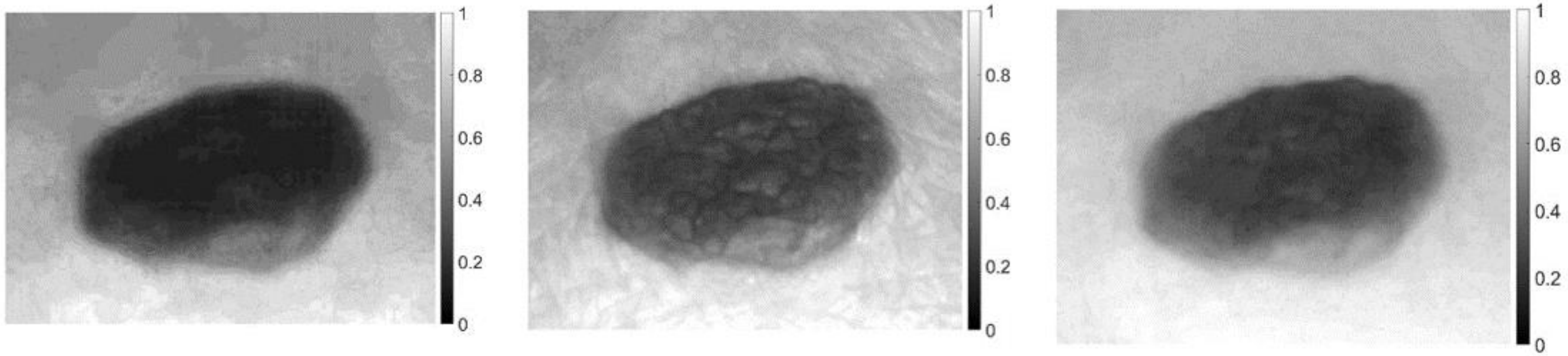

k_1 k_2 k_3

$$k_i = \frac{I_i}{I_{0_i}}$$

I_i – intensity of diffused reflected light from the skin pathology,
I_{0_i} – intensity of diffused reflected light from the healthy skin,

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

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Algorithms for skin chromophore mapping

Beer-Lambert law:

$$I = I_0 e^{-\mu_a \cdot l}$$

I – intensity of diffused reflected light from the skin malformation,

I_0 – intensity of diffused reflected light from the healthy skin,

l –photon mean path length in the skin

μ_a – absorption coefficient

First approach

$$\begin{cases} c_{\mathrm{Mel}} \cdot \varepsilon_{\mathrm{Mel}}(\lambda_1) + c_{\mathrm{Oks}} \cdot \varepsilon_{\mathrm{Oks}}(\lambda_1) + c_{\mathrm{Deoks}} \cdot \varepsilon_{\mathrm{Deoks}}(\lambda_1) = \dfrac{ln\dfrac{I_0(\lambda_1)}{I(\lambda_1)}}{2,303 \cdot l(\lambda_1)} \\ c_{\mathrm{Mel}} \cdot \varepsilon_{\mathrm{Mel}}(\lambda_2) + c_{\mathrm{Oks}} \cdot \varepsilon_{\mathrm{Oks}}(\lambda_2) + c_{\mathrm{Deoks}} \cdot \varepsilon_{\mathrm{Deoks}}(\lambda_2) = \dfrac{ln\dfrac{I_0(\lambda_2)}{I(\lambda_2)}}{2,303 \cdot l(\lambda_2)} \\ c_{\mathrm{Mel}} \cdot \varepsilon_{\mathrm{Mel}}(\lambda_3) + c_{\mathrm{Oks}} \cdot \varepsilon_{\mathrm{Oks}}(\lambda_3) + c_{\mathrm{Deoks}} \cdot \varepsilon_{\mathrm{Deoks}}(\lambda_3) = \dfrac{ln\dfrac{I_0(\lambda_3)}{I(\lambda_3)}}{2,303 \cdot l(\lambda_3)} \end{cases}$$

Mel – melanin, Oks – oxyhemoglobin, $Deoks$ – deoksihemoglobin,

ε – extinction coeficient, c – chromophore concentration,

I – intensity of diffused reflected light from the skin malformation,

I_0 – intensity of diffused reflected light from the healthy skin,

l –photon mean path length in the skin

$$k_i = \frac{I_i}{I_{0_i}}$$

k_i – attenuation coefficient

Positive chromophore concentration values 1,4%

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Second approach

$$\begin{cases} c_{\mathrm{Mel}} \cdot \varepsilon_{\mathrm{Mel}}(\lambda_1) \cdot \mathrm{d}_1 + (c_{\mathrm{Oks}} \cdot \varepsilon_{\mathrm{Oks}}(\lambda_1) + c_{\mathrm{Deoks}} \cdot \varepsilon_{\mathrm{Deoks}}(\lambda_1)) \cdot (1 - \mathrm{d}_1) + z_1 = \dfrac{ln \frac{I_0(\lambda_1)}{I(\lambda_1)}}{2,303 \cdot l(\lambda_1)} \\ c_{\mathrm{Mel}} \cdot \varepsilon_{\mathrm{Mel}}(\lambda_2) \cdot \mathrm{d}_2 + (c_{\mathrm{Oks}} \cdot \varepsilon_{\mathrm{Oks}}(\lambda_2) + c_{\mathrm{Deoks}} \cdot \varepsilon_{\mathrm{Deoks}}(\lambda_2)) \cdot (1 - \mathrm{d}_2) + z_2 = \dfrac{ln \frac{I_0(\lambda_2)}{I(\lambda_2)}}{2,303 \cdot l(\lambda_2)} \\ c_{\mathrm{Mel}} \cdot \varepsilon_{\mathrm{Mel}}(\lambda_3) \cdot \mathrm{d}_3 + (c_{\mathrm{Oks}} \cdot \varepsilon_{\mathrm{Oks}}(\lambda_3) + c_{\mathrm{Deoks}} \cdot \varepsilon_{\mathrm{Deoks}}(\lambda_3)) \cdot (1 - \mathrm{d}_3) + z_3 = \dfrac{ln \frac{I_0(\lambda_3)}{I(\lambda_3)}}{2,303 \cdot l(\lambda_3)} \end{cases}$$

Mel – melanin, Oks – oxyhemoglobin, $Deoks$ – deoksihemoglobin,

ε – extinction coeficient, c – chromophore concentration,

I – intensity of diffused reflected light from the skin malformation,

I_0 – intensity of diffused reflected light from the healthy skin,

l –photon mean path length in the skin

$k_i = \frac{I_i}{I_{0_i}}$ k_i – attenuation coefficient

$\mathrm{d_i}$ – 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

Positive chromophore concentration values 0,03%

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Third approach

Positive chromophore concentration values 2,57%

$$\begin{cases} c_{\mathrm{Mel}} \cdot \varepsilon_{\mathrm{Mel}}(\lambda_1) \sqrt{1+\frac{\mu'_{s_{11}}}{\mu_{a_{11}}}} \cdot l_{11} + (c_{\mathrm{Oks}} \cdot \varepsilon_{\mathrm{Oks}}(\lambda_1) + c_{\mathrm{Deoks}} \cdot \varepsilon_{\mathrm{Deoks}}(\lambda_1)) \sqrt{1+\frac{\mu'_{s_{12}}}{\mu_{a_{12}}}} \cdot l_{12} = \frac{ln\frac{I_0(\lambda_1)}{I(\lambda_1)}}{\sqrt{3}\cdot 2,303} \\ c_{\mathrm{Mel}} \cdot \varepsilon_{\mathrm{Mel}}(\lambda_2) \sqrt{1+\frac{\mu'_{s_{21}}}{\mu_{a_{21}}}} \cdot l_{21} + (c_{\mathrm{Oks}} \cdot \varepsilon_{\mathrm{Oks}}(\lambda_2) + c_{\mathrm{Deoks}} \cdot \varepsilon_{\mathrm{Deoks}}(\lambda_2)) \sqrt{1+\frac{\mu'_{s_{22}}}{\mu_{a_{22}}}} \cdot l_{22} = \frac{ln\frac{I_0(\lambda_2)}{I(\lambda_2)}}{\sqrt{3}\cdot 2,303} \\ c_{\mathrm{Mel}} \cdot \varepsilon_{\mathrm{Mel}}(\lambda_3) \sqrt{1+\frac{\mu'_{s_{31}}}{\mu_{a_{31}}}} \cdot l_{31} + (c_{\mathrm{Oks}} \cdot \varepsilon_{\mathrm{Oks}}(\lambda_3) + c_{\mathrm{Deoks}} \cdot \varepsilon_{\mathrm{Deoks}}(\lambda_3)) \sqrt{1+\frac{\mu'_{s_{32}}}{\mu_{a_{32}}}} \cdot l_{32} = \frac{ln\frac{I_0(\lambda_3)}{I(\lambda_3)}}{\sqrt{3}\cdot 2,303} \end{cases}$$

Mel – melanin, Oks – oxyhemoglobin, $Deoks$ – deoksihemoglobin,

ε – extinction coeficient, c – chromophore concentration,

I – intensity of diffused reflected light from the skin malformation,

I_0 – intensity of diffused reflected light from the healthy skin,

l –photon mean path length in the skin

μ_a – absorption coefficient

μ'_s – reduced scattering coefficient

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Fourth approach

Positive chromophore concentration values 1,35%

$$\begin{cases} c_{\text{Mel}} \cdot \varepsilon_{\text{Mel}}(\lambda_1)\sqrt{1+\dfrac{\mu'_{s_{11}}}{\mu_{a_{11}}}} \cdot l_{11} + (c_{\text{Oks}} \cdot \varepsilon_{\text{Oks}}(\lambda_1) + c_{\text{Deoks}} \cdot \varepsilon_{\text{Deoks}}(\lambda_1)) \cdot B_1 = \dfrac{ln\dfrac{I_0(\lambda_1)\cdot Nn_1}{I(\lambda_1)}}{\sqrt{3}\cdot 4{,}606} \\ c_{\text{Mel}} \cdot \varepsilon_{\text{Mel}}(\lambda_2)\sqrt{1+\dfrac{\mu'_{s_{21}}}{\mu_{a_{21}}}} \cdot l_{21} + (c_{\text{Oks}} \cdot \varepsilon_{\text{Oks}}(\lambda_2) + c_{\text{Deoks}} \cdot \varepsilon_{\text{Deoks}}(\lambda_2)) \cdot B_2 = \dfrac{ln\dfrac{I_0(\lambda_2)\cdot Nn_2}{I(\lambda_2)}}{\sqrt{3}\cdot 4{,}606} \\ c_{\text{Mel}} \cdot \varepsilon_{\text{Mel}}(\lambda_3)\sqrt{1+\dfrac{\mu'_{s_{31}}}{\mu_{a_{31}}}} \cdot l_{31} + (c_{\text{Oks}} \cdot \varepsilon_{\text{Oks}}(\lambda_3) + c_{\text{Deoks}} \cdot \varepsilon_{\text{Deoks}}(\lambda_3)) \cdot B_3 = \dfrac{ln\dfrac{I_0(\lambda_3)\cdot Nn_3}{I(\lambda_3)}}{\sqrt{3}\cdot 4{,}606} \end{cases}$$

$$B_{\text{i}} = \sum_{n=2}^{5}\sqrt{1+\frac{\mu'_{s_{in}}}{\mu_{a_{in}}}} \cdot l_{\text{in}}$$

Mel – melanin, Oks – oxyhemoglobin, $Deoks$ – deoksihemoglobin,

ε – extinction coeficient, c – chromophore concentration,

I – intensity of diffused reflected light from the skin malformation,

I_0 – intensity of diffused reflected light from the healthy skin,

l –photon mean path length in the skin

μ_a – absorption coefficient

μ'_s – reduced scattering coefficient

Nn – interlayer reflection coefficient

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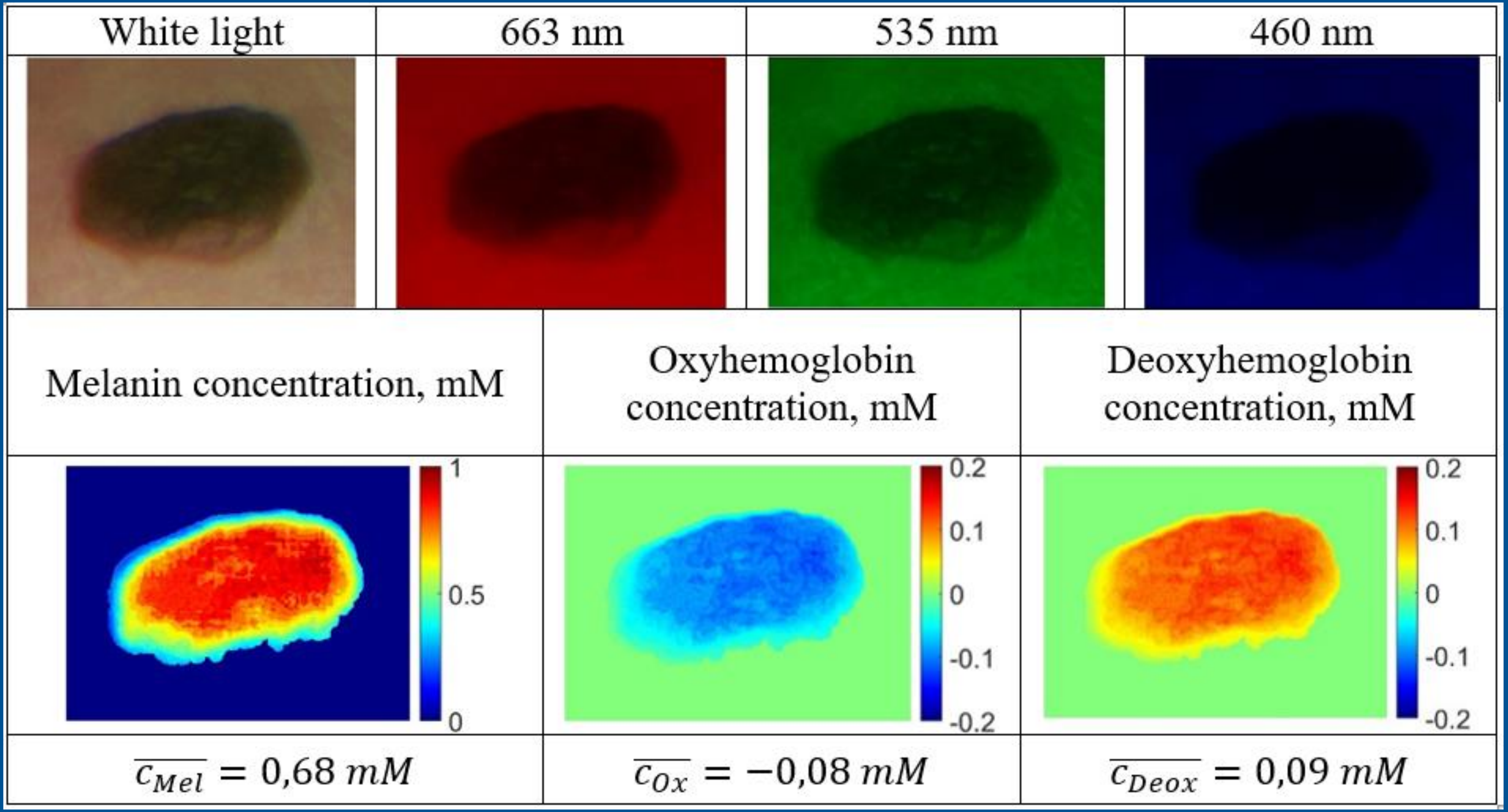
Results

Chromophore maps



First approach for *LED* images

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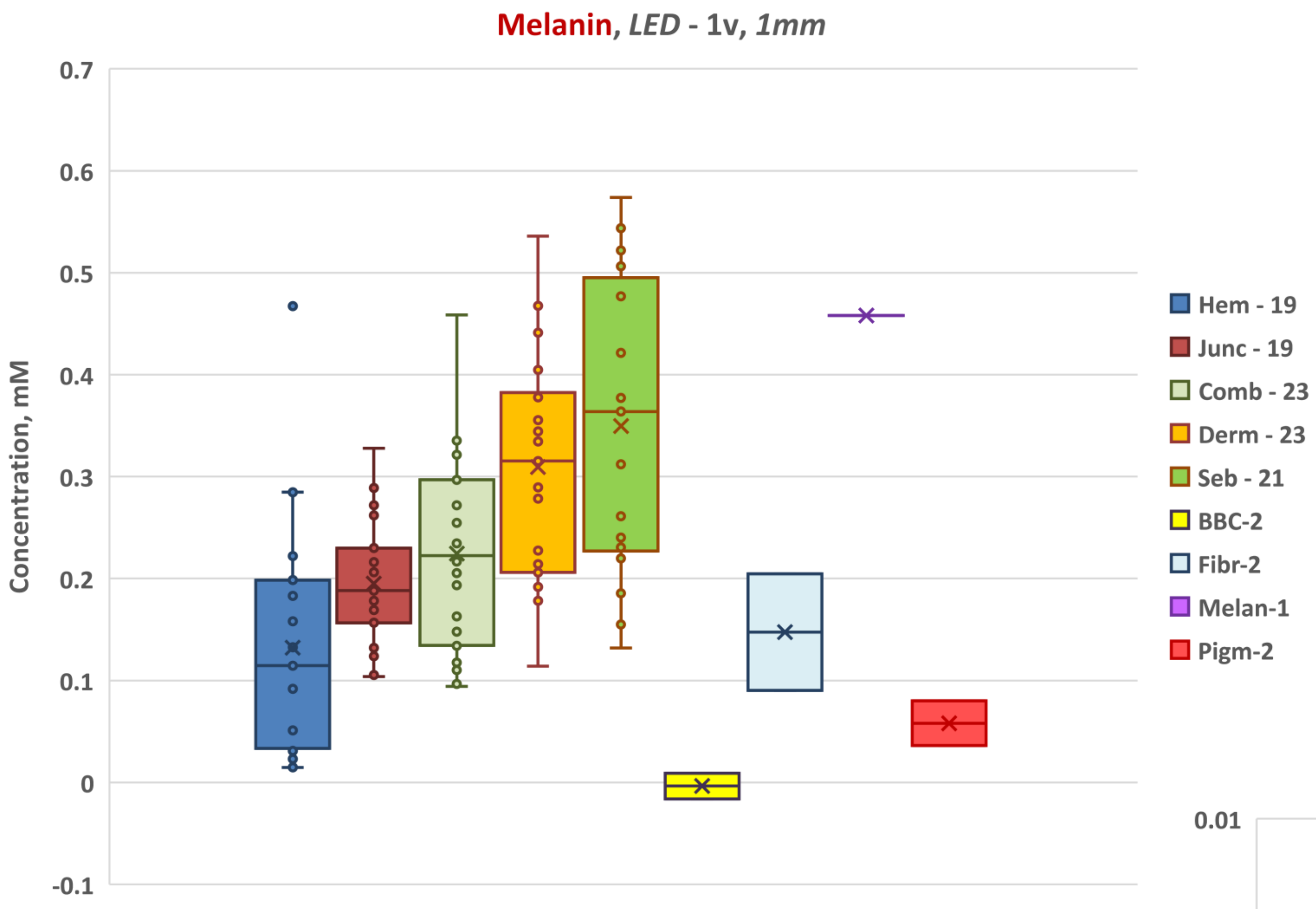

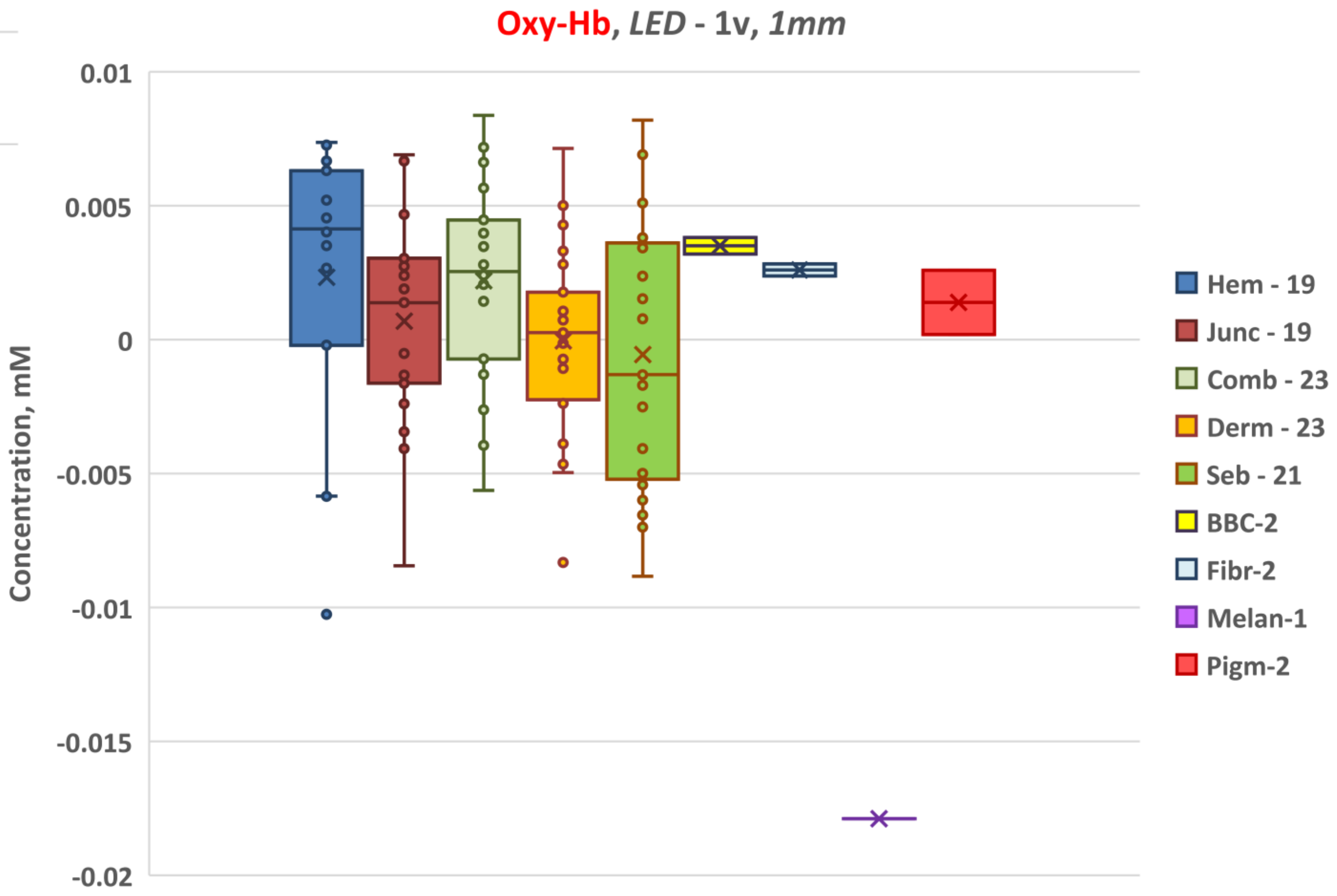

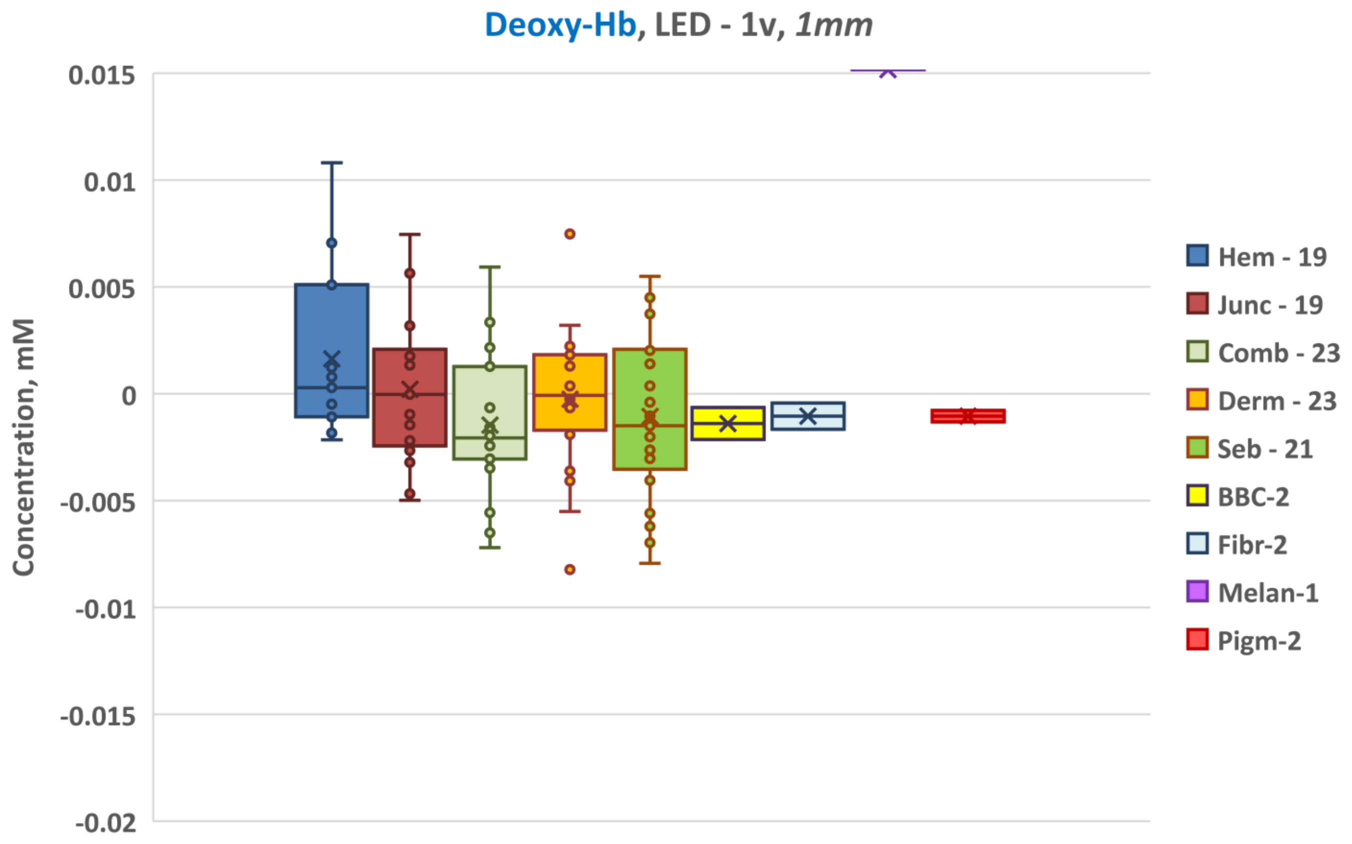

First approach for *Laser* images

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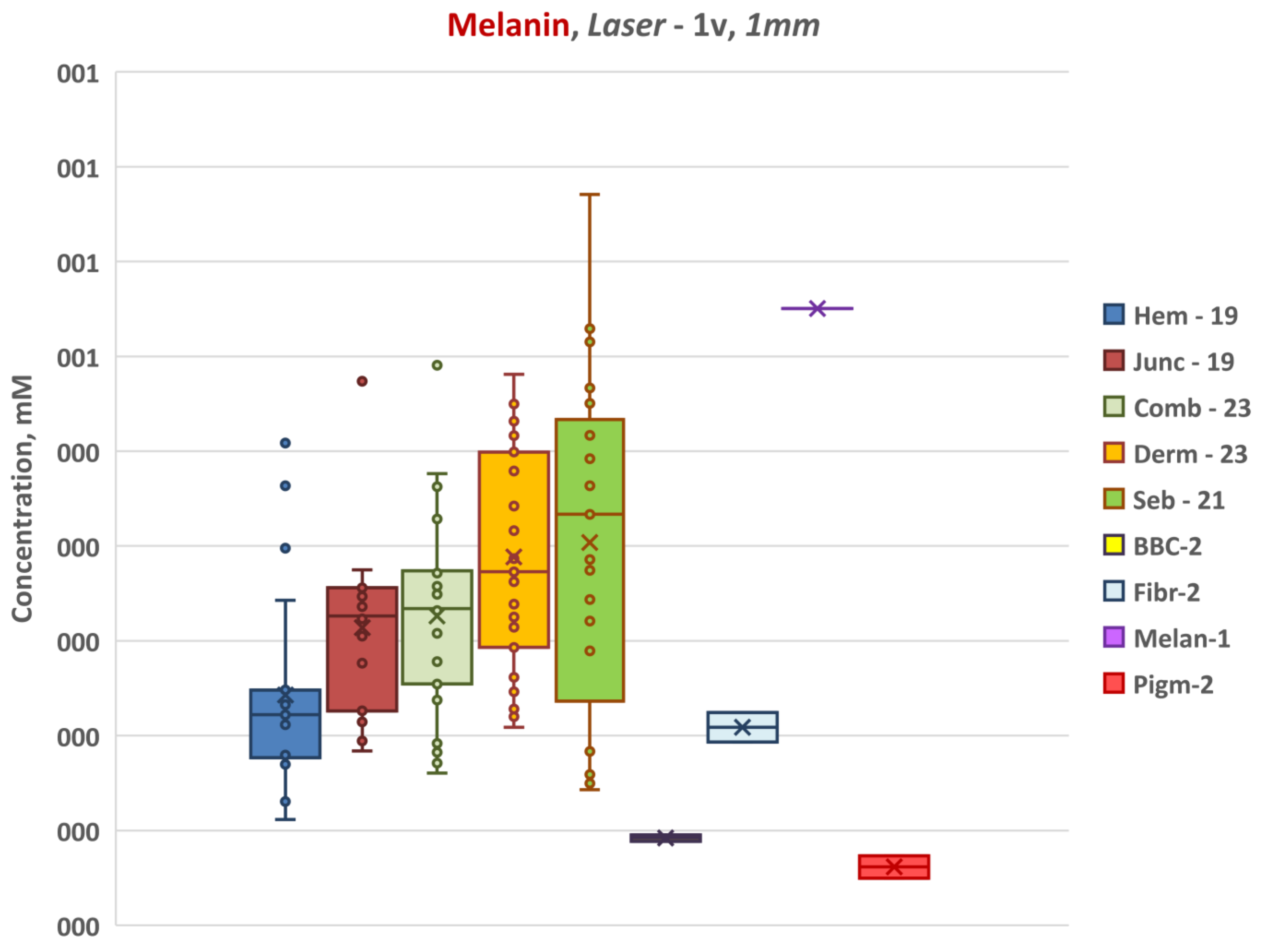

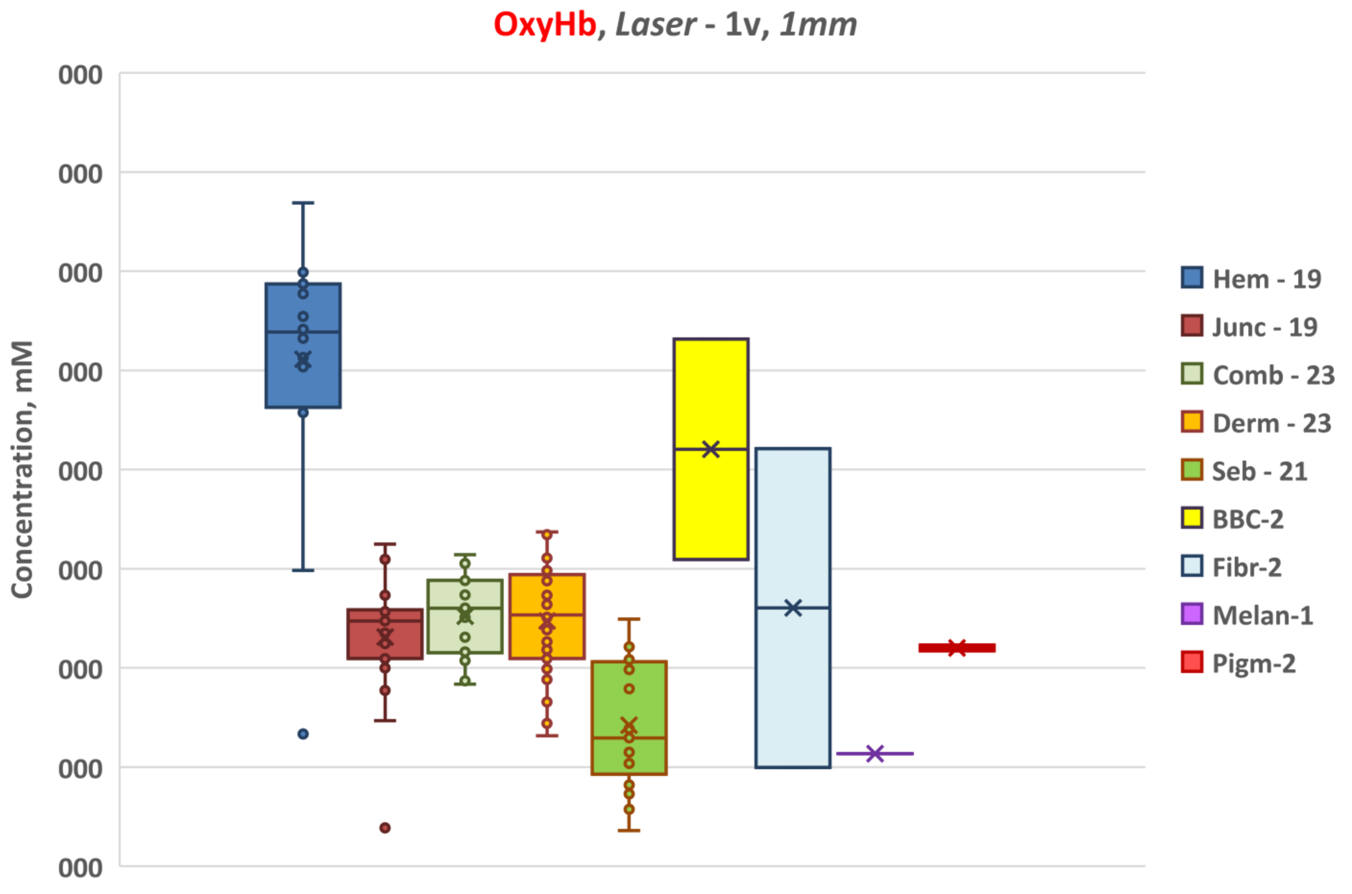

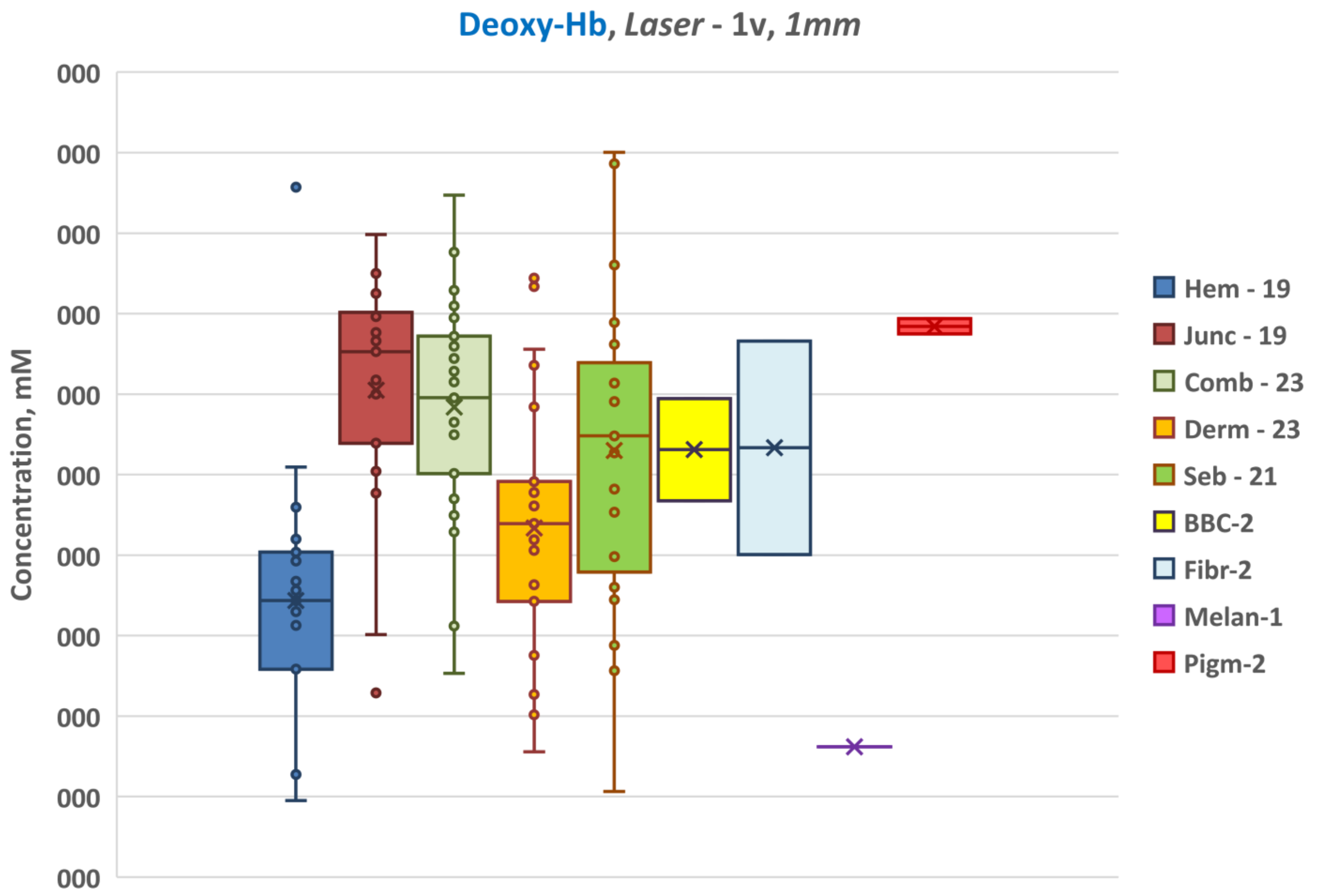

Second approach for *LED* images

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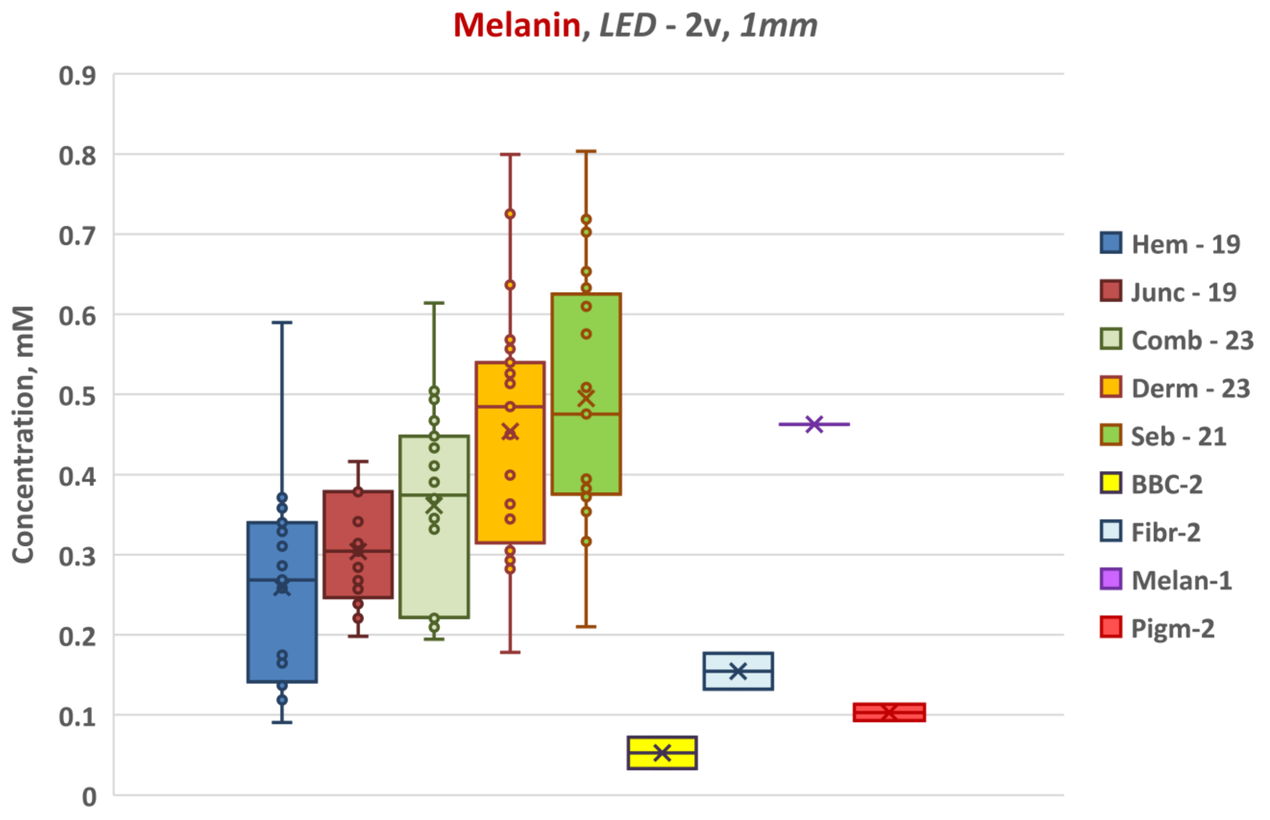

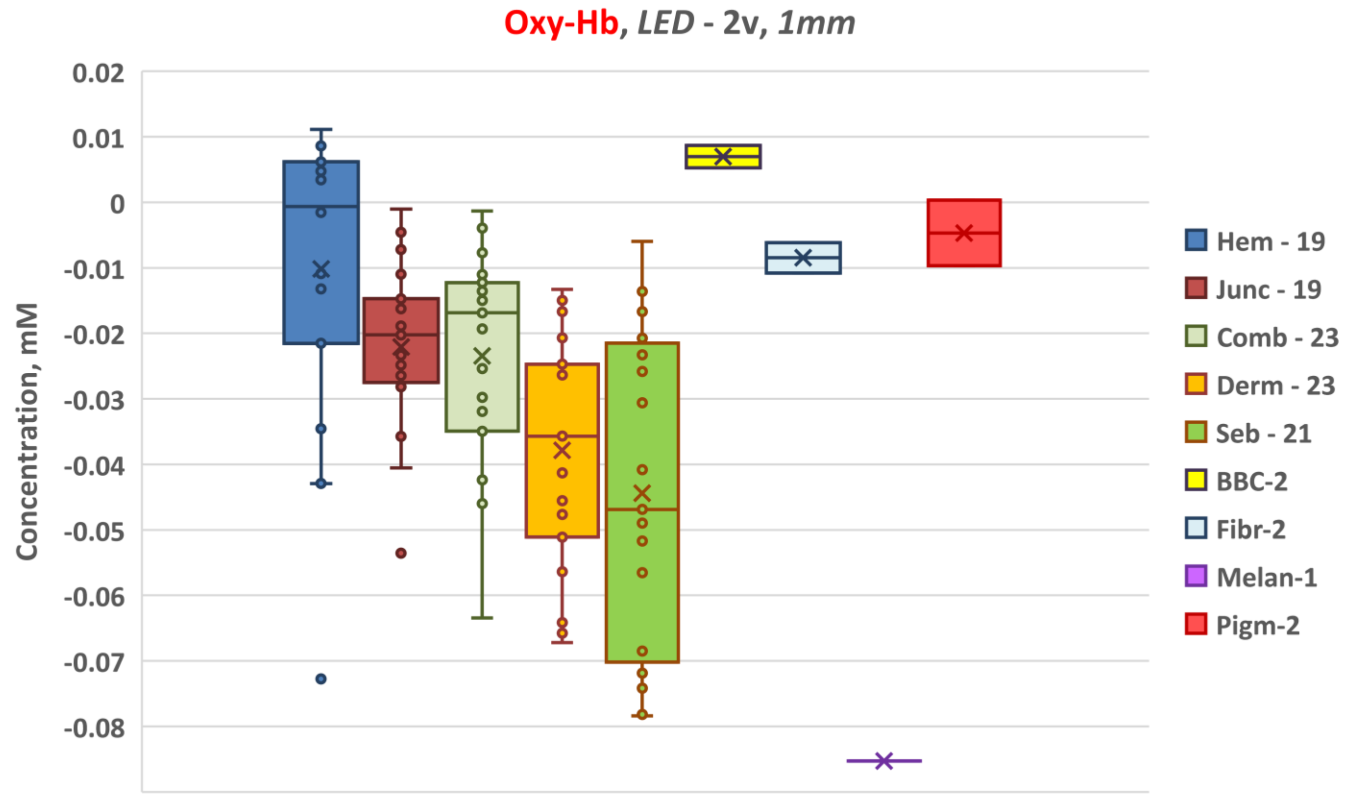

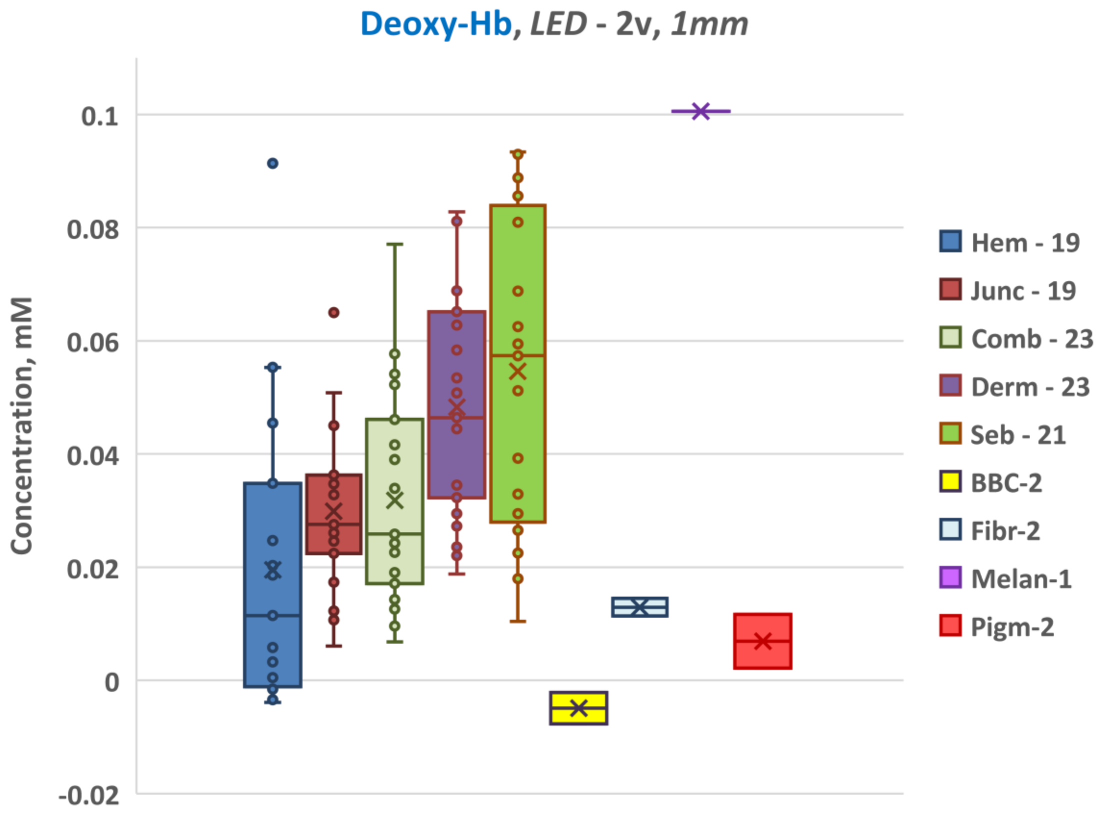

Second approach for *Laser* images

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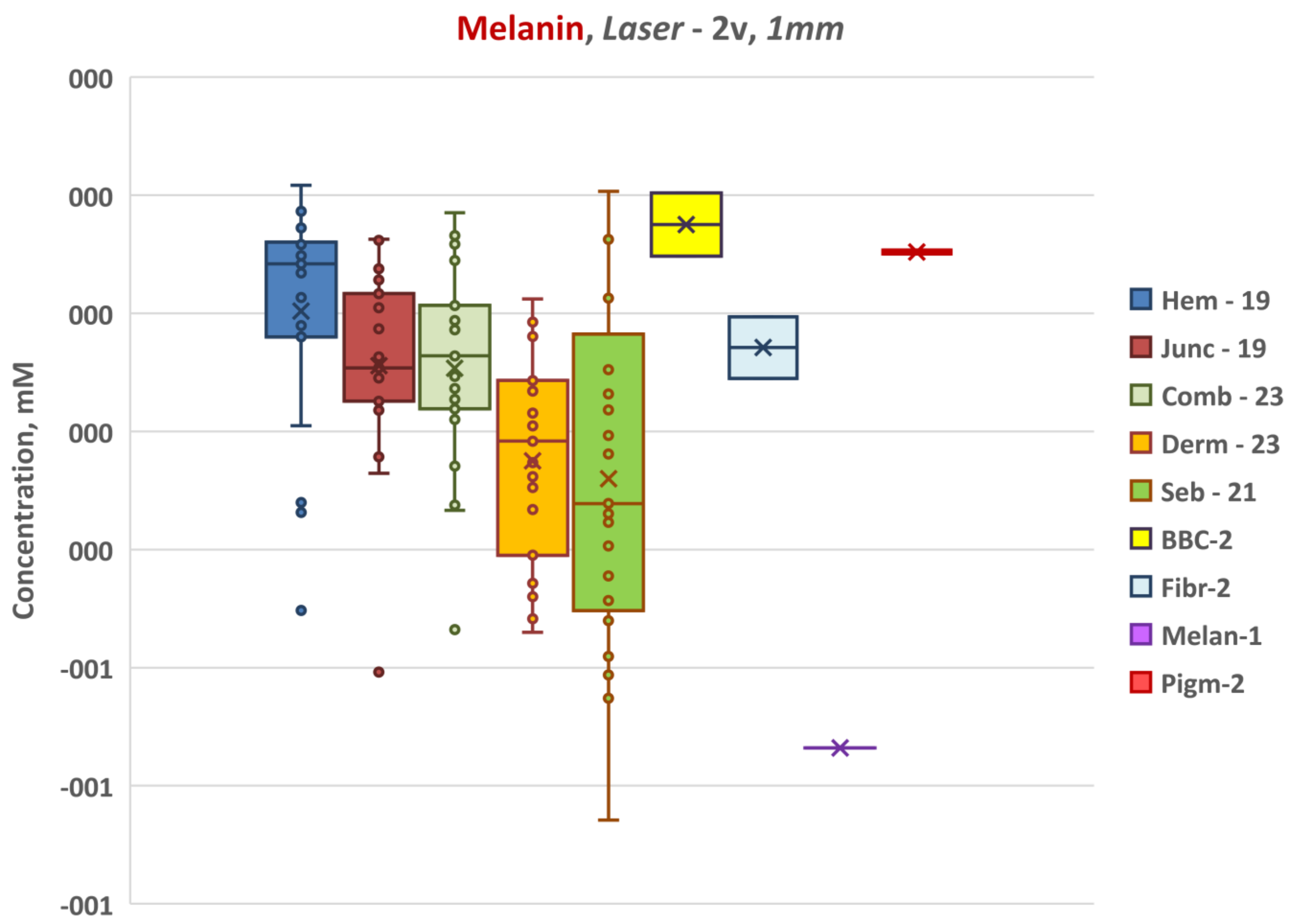

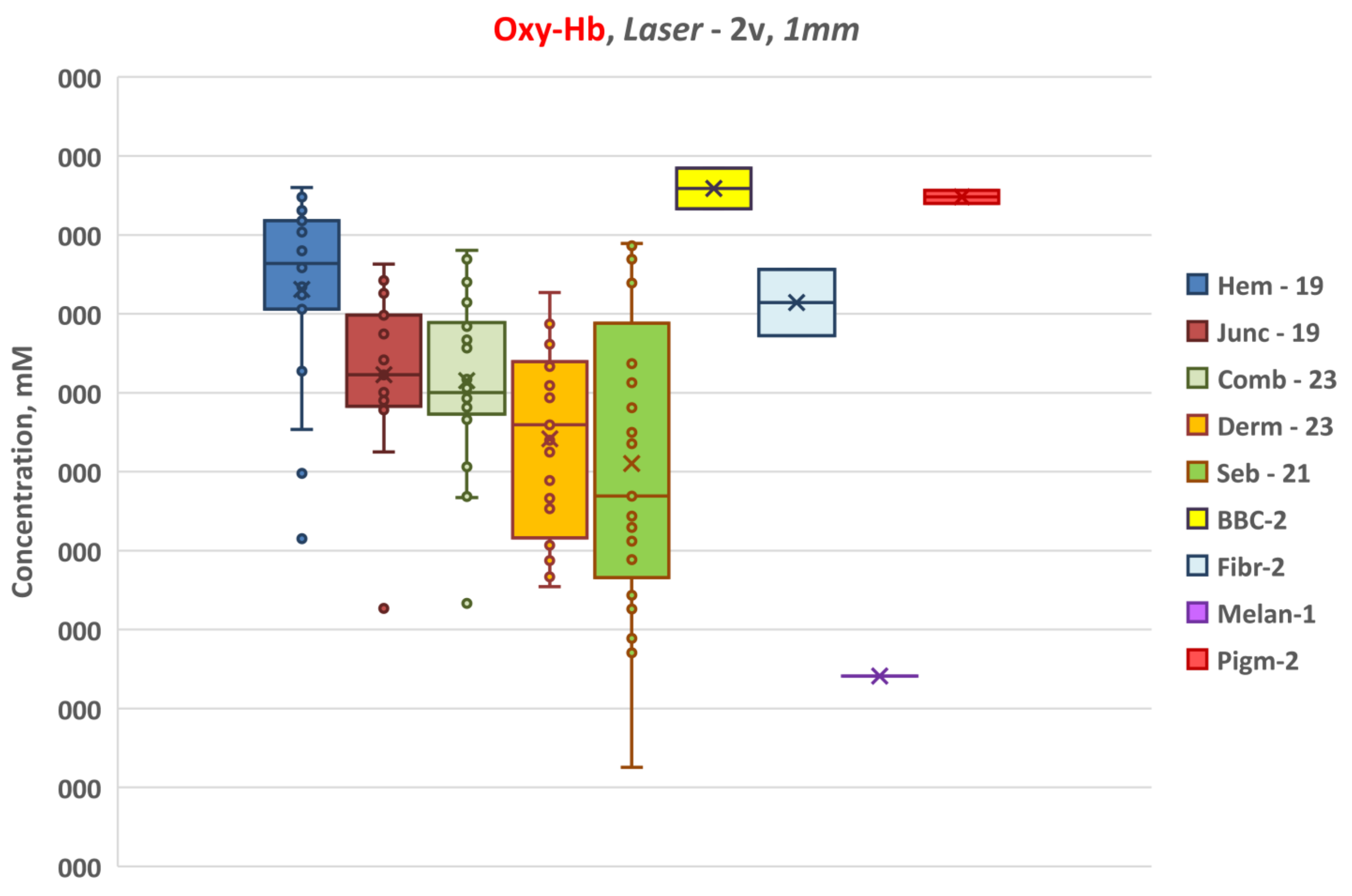

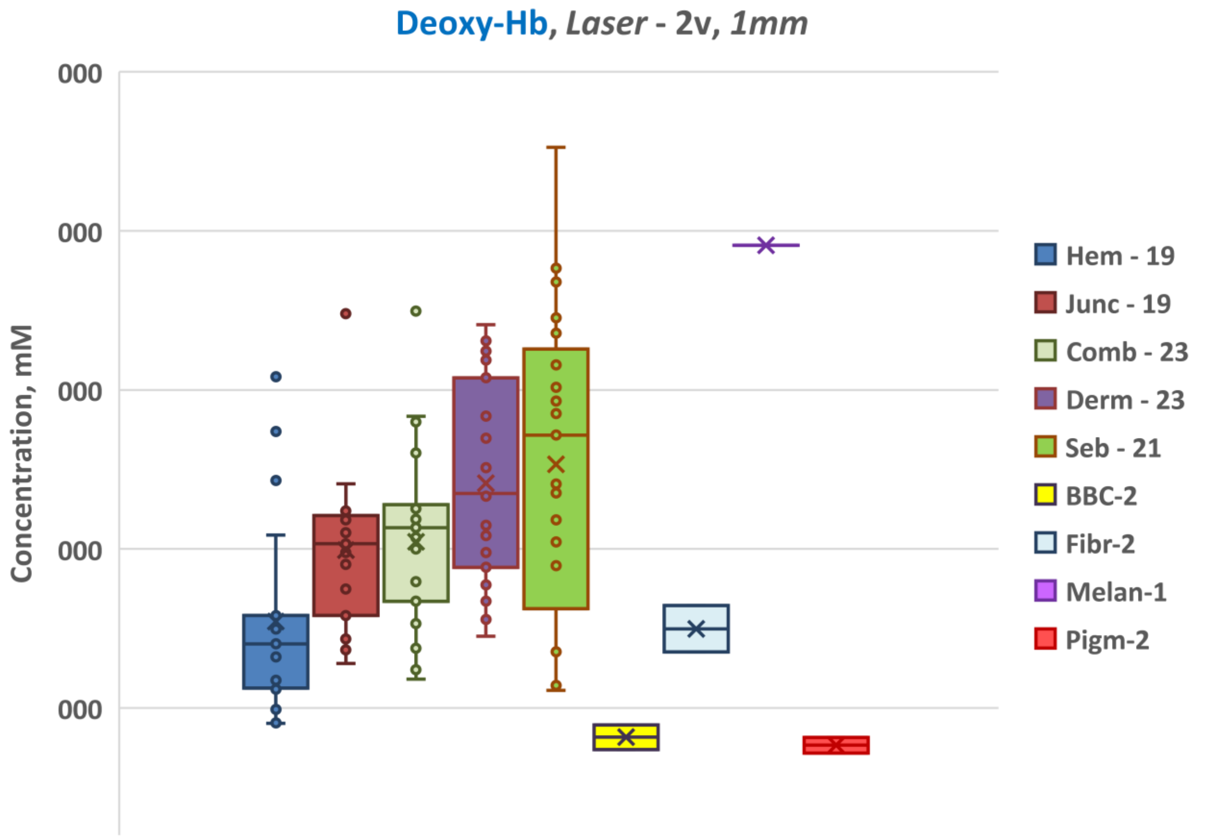

Third approach for *LED* images

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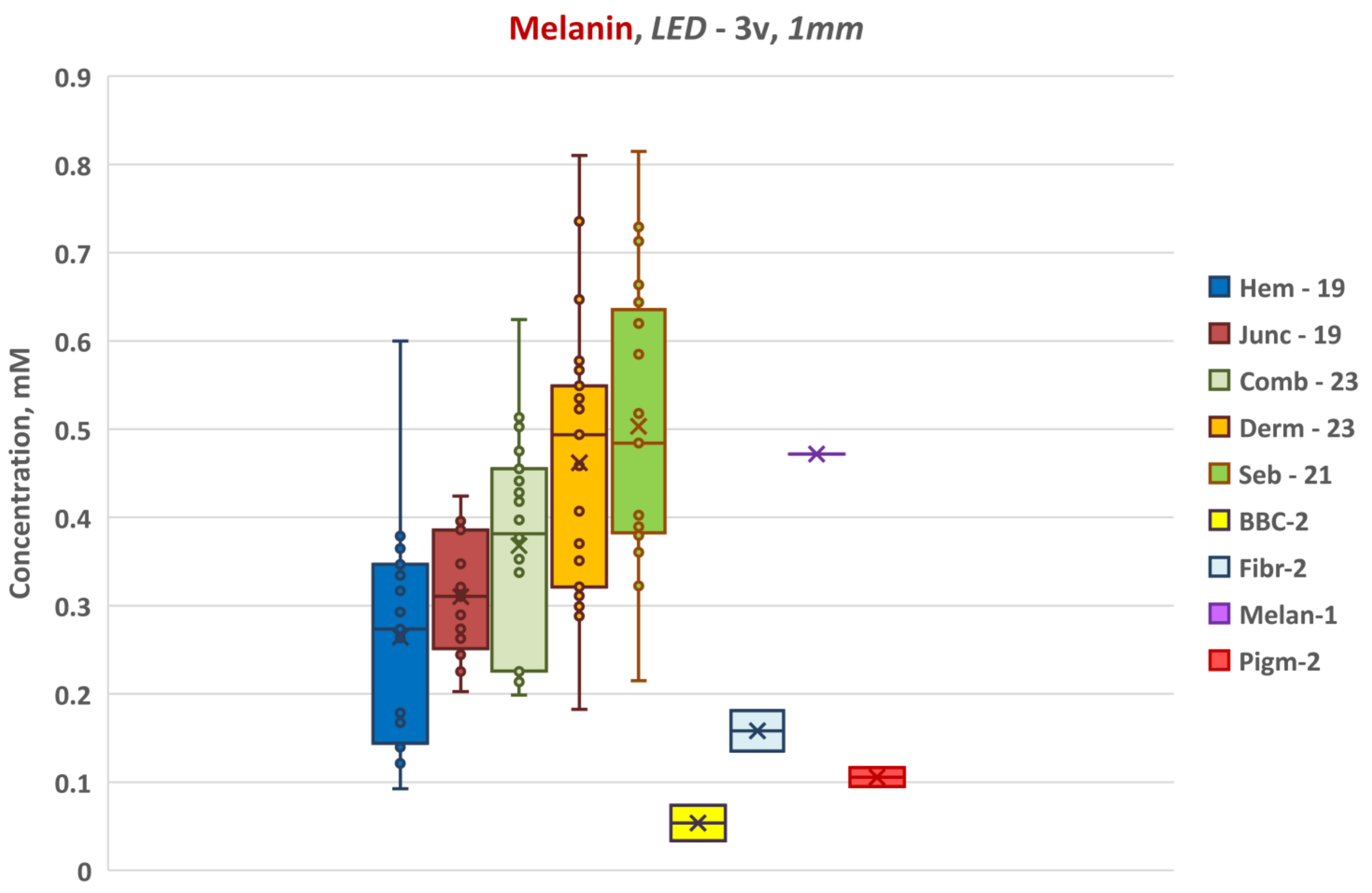

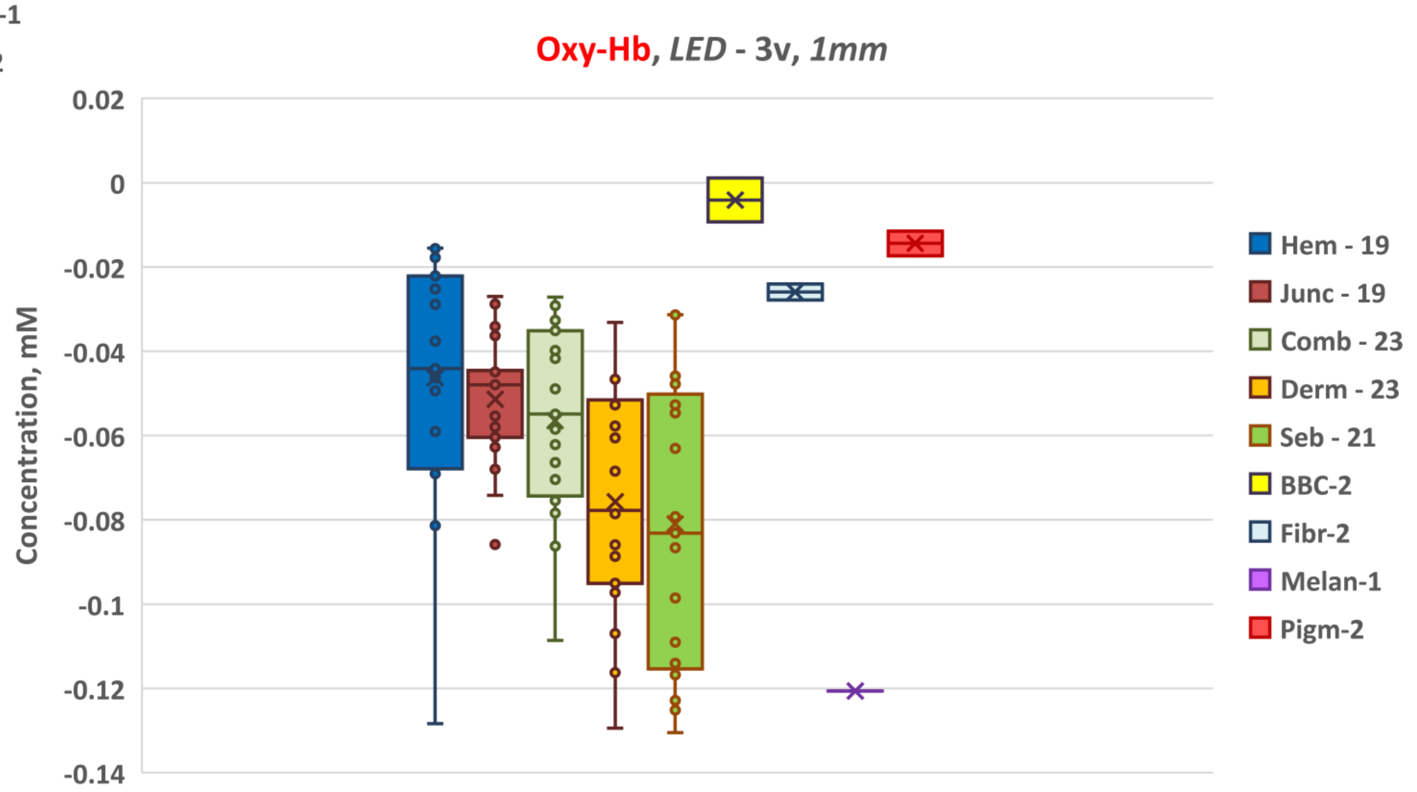

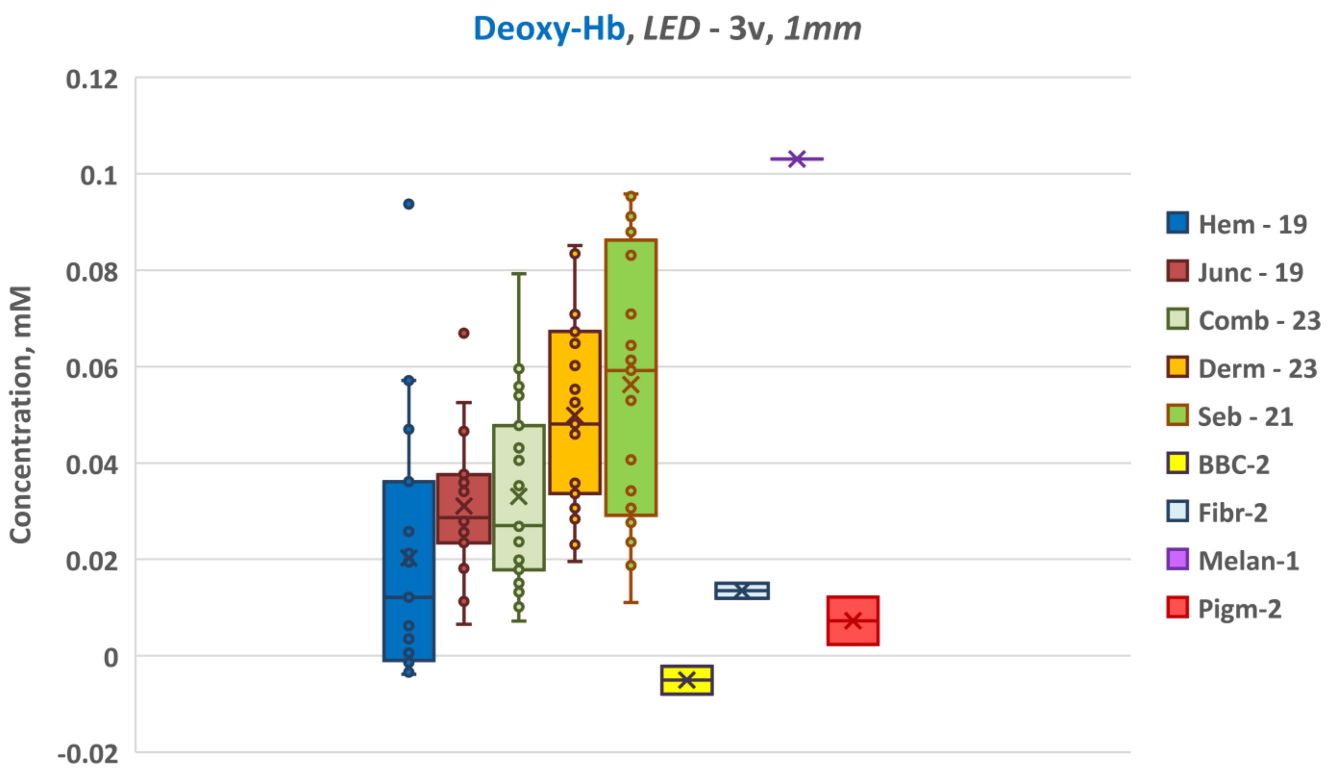

Third approach for *Laser* images

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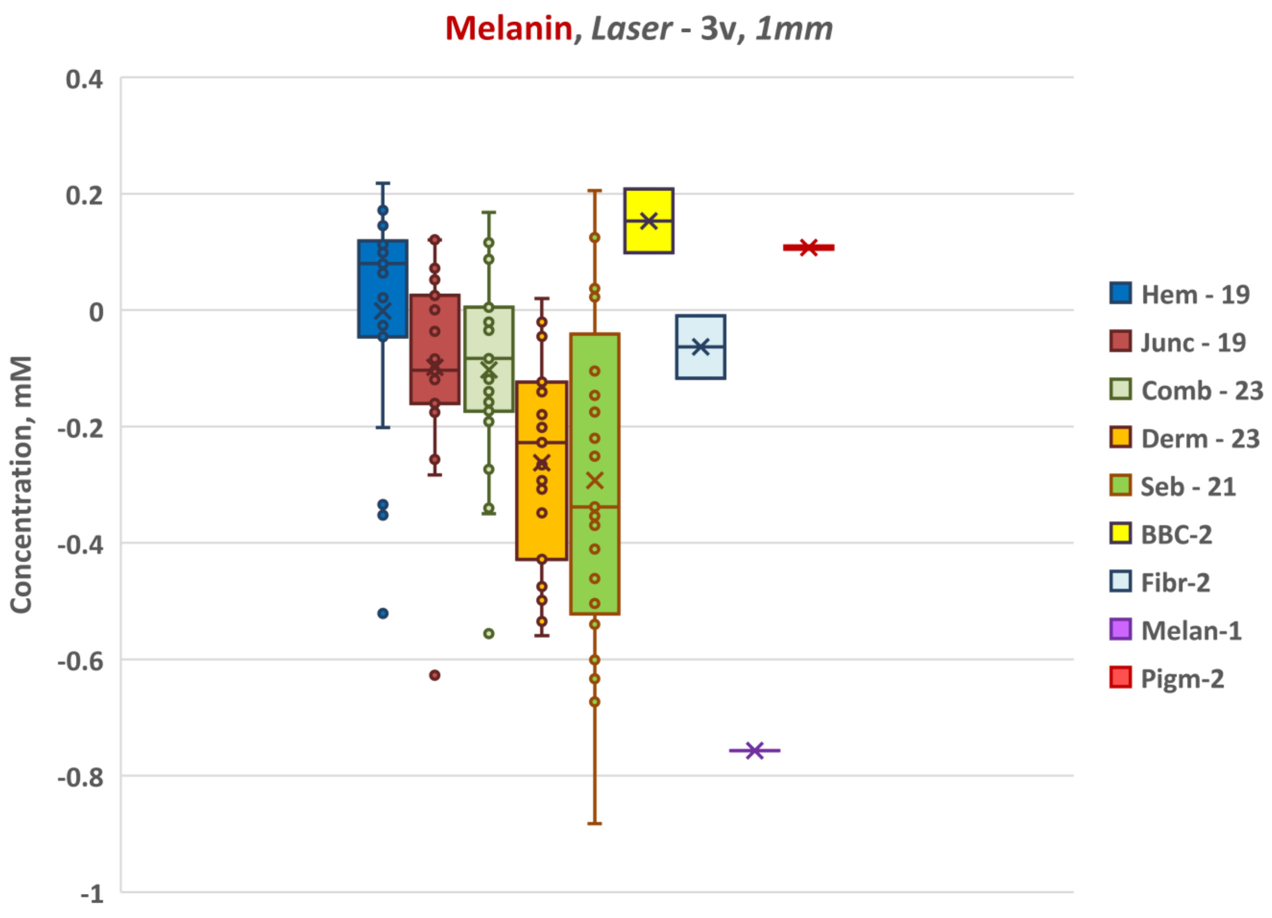
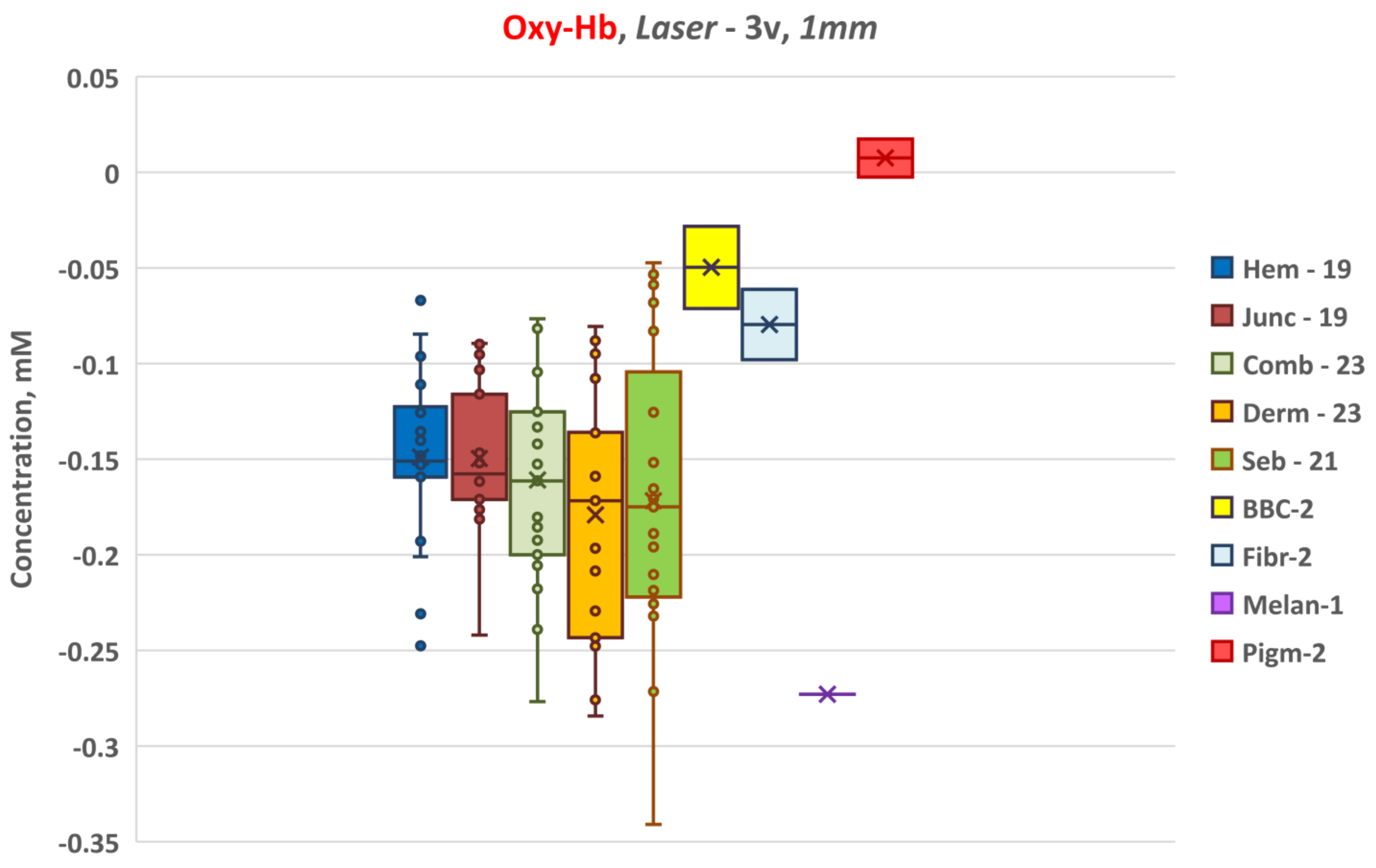
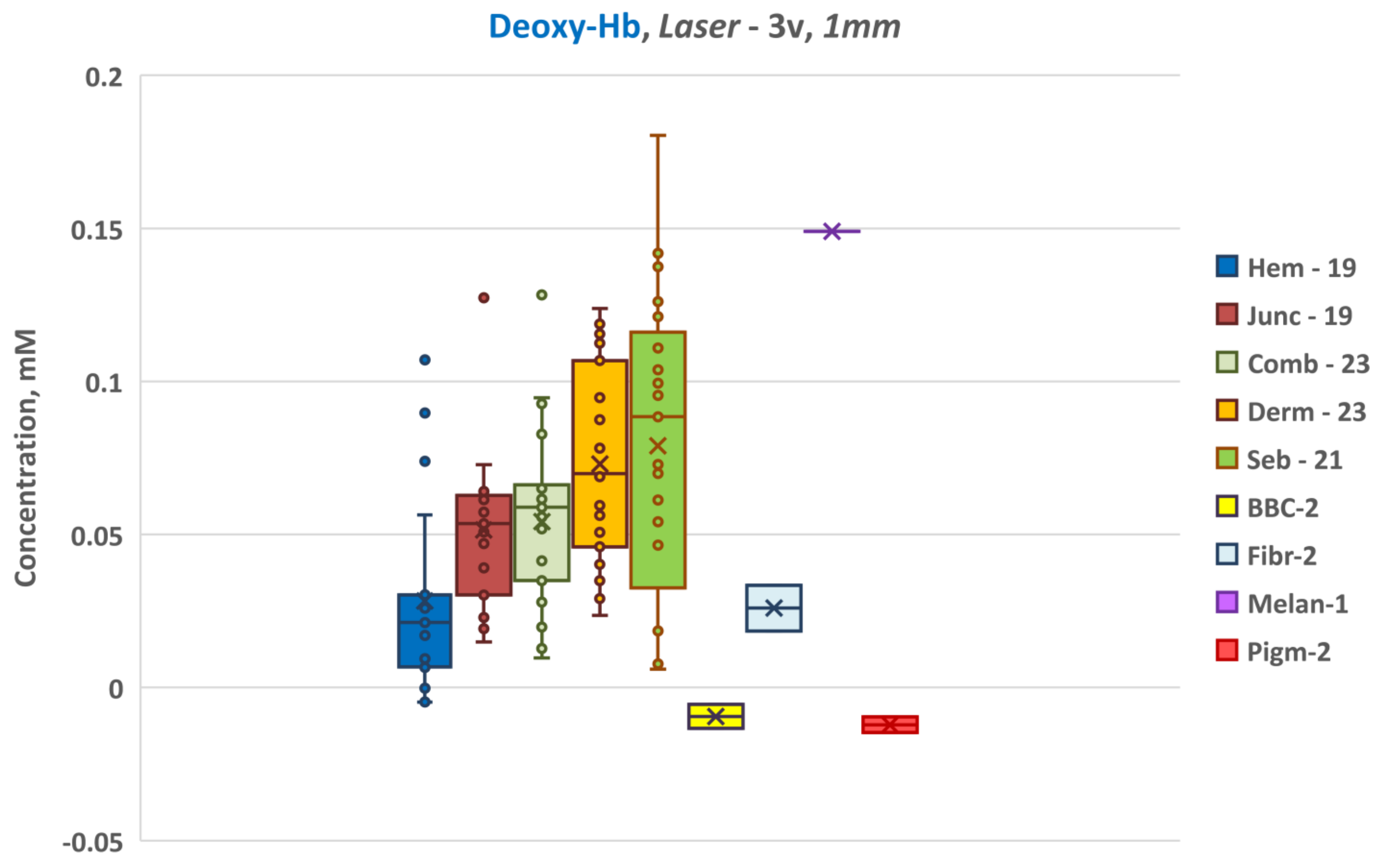
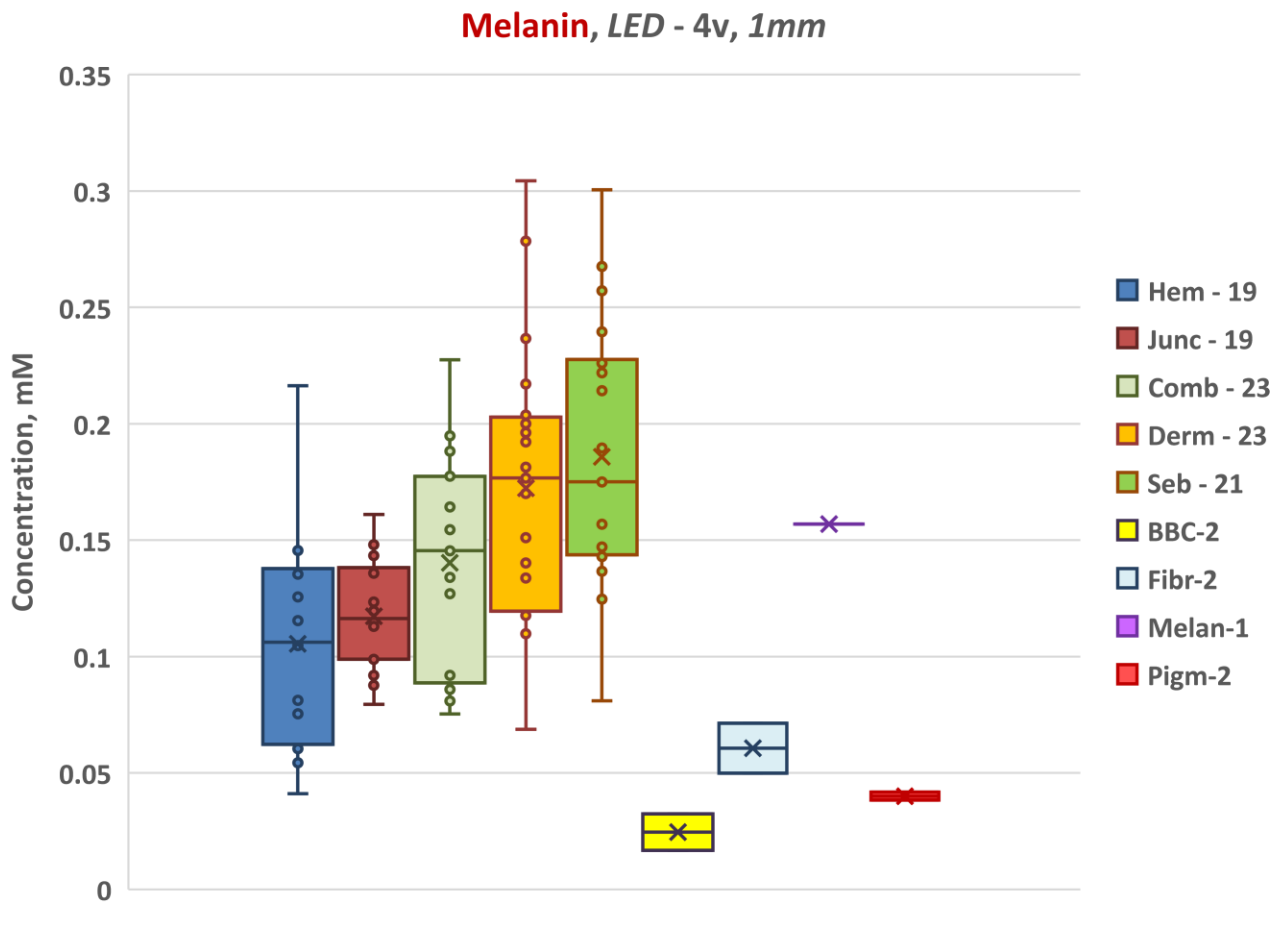
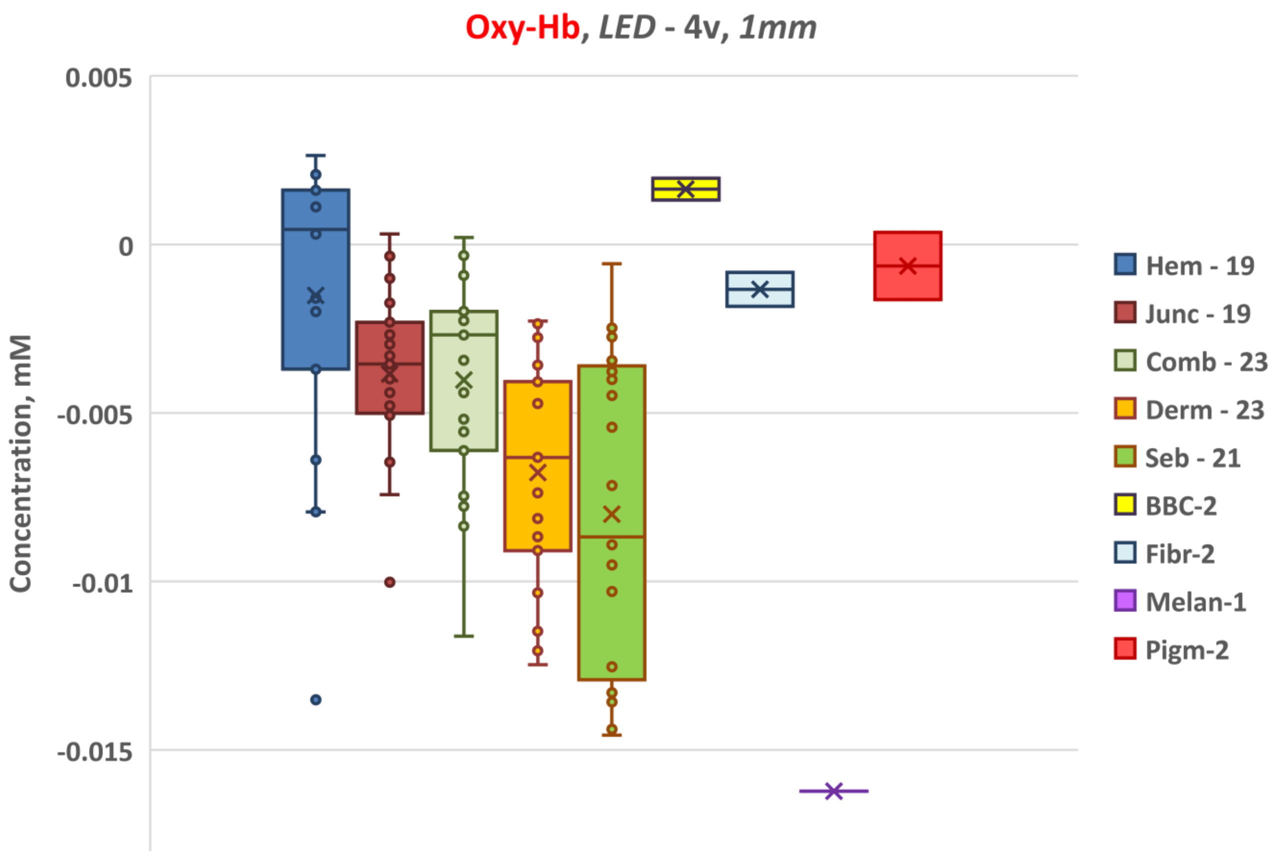


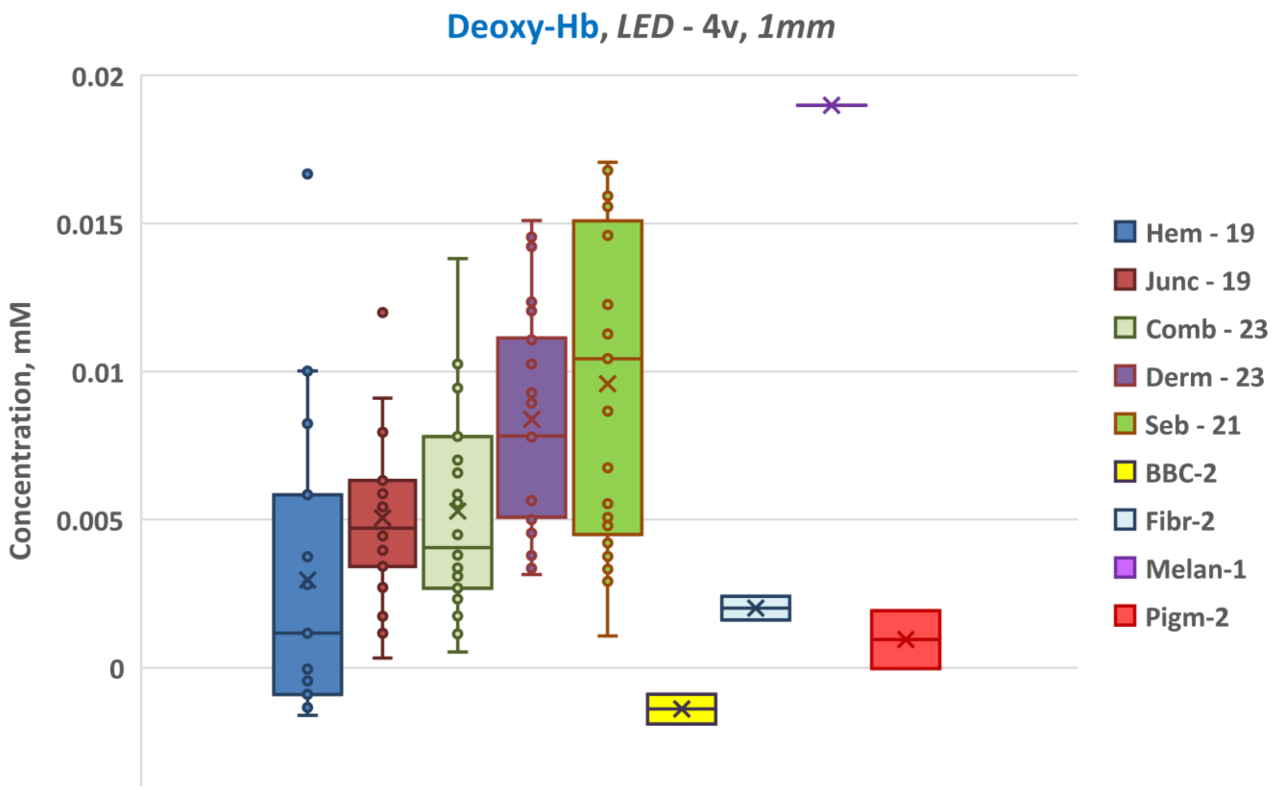




Fourth approach for *LED* images







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Fourth approach for *Laser* images

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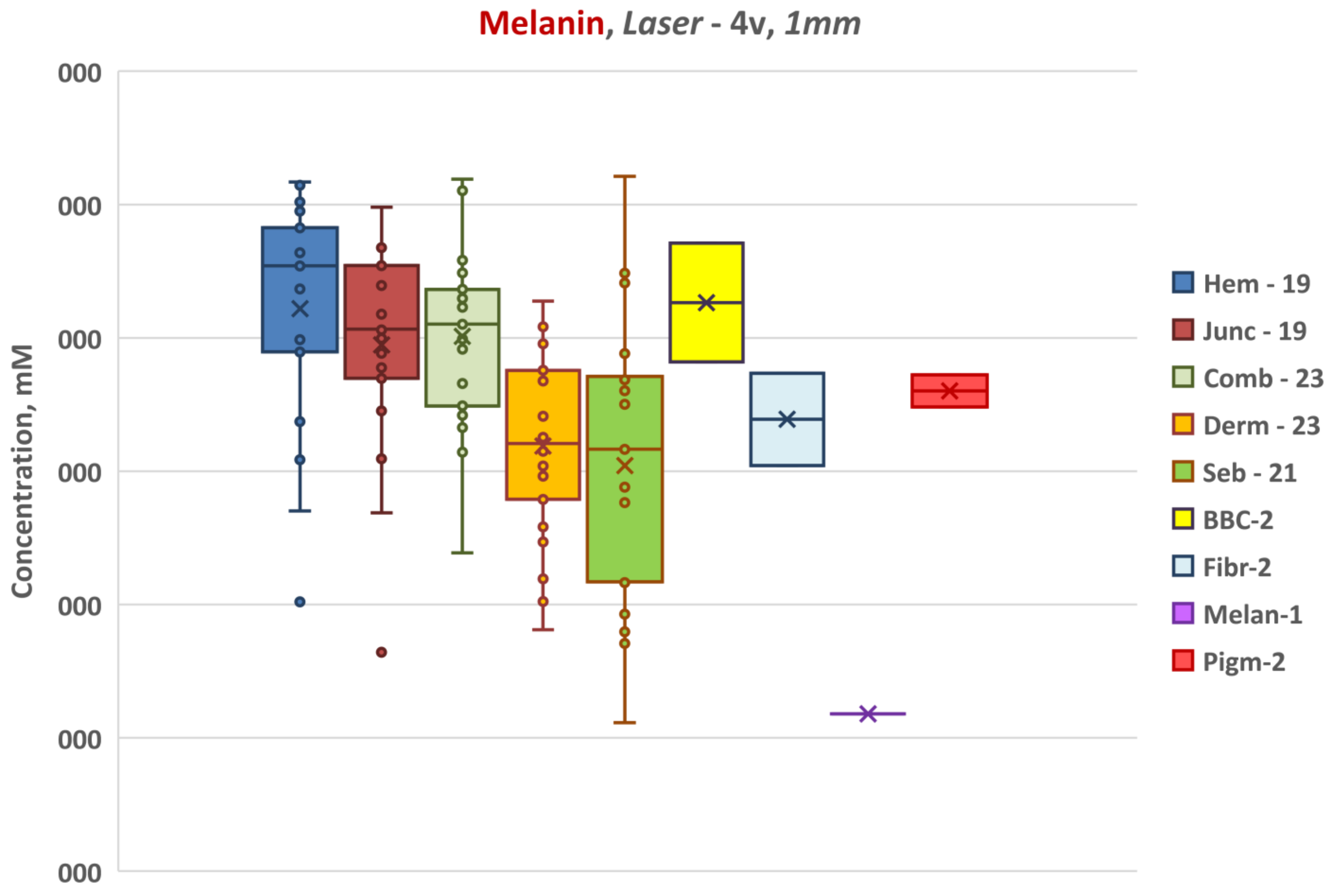

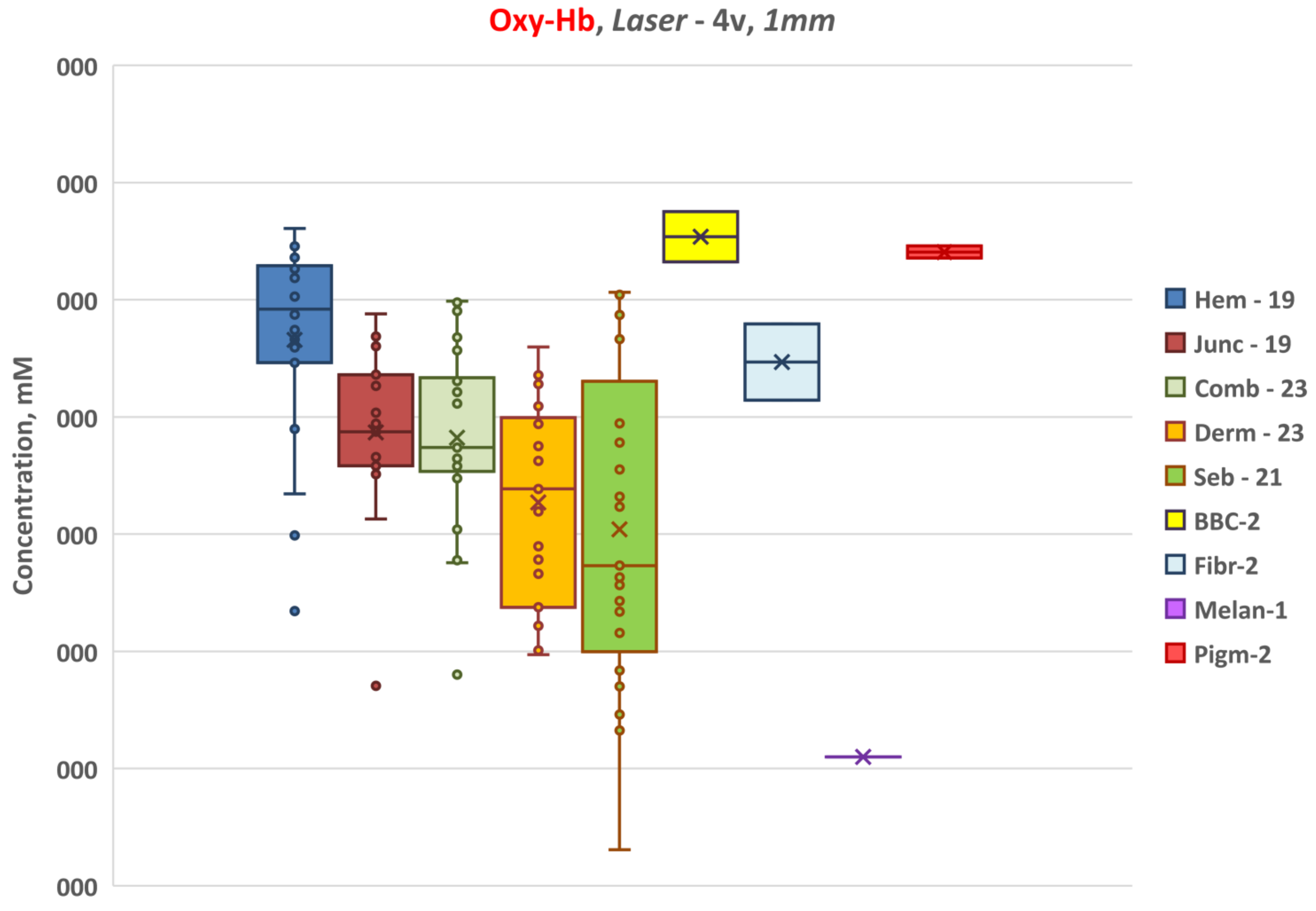

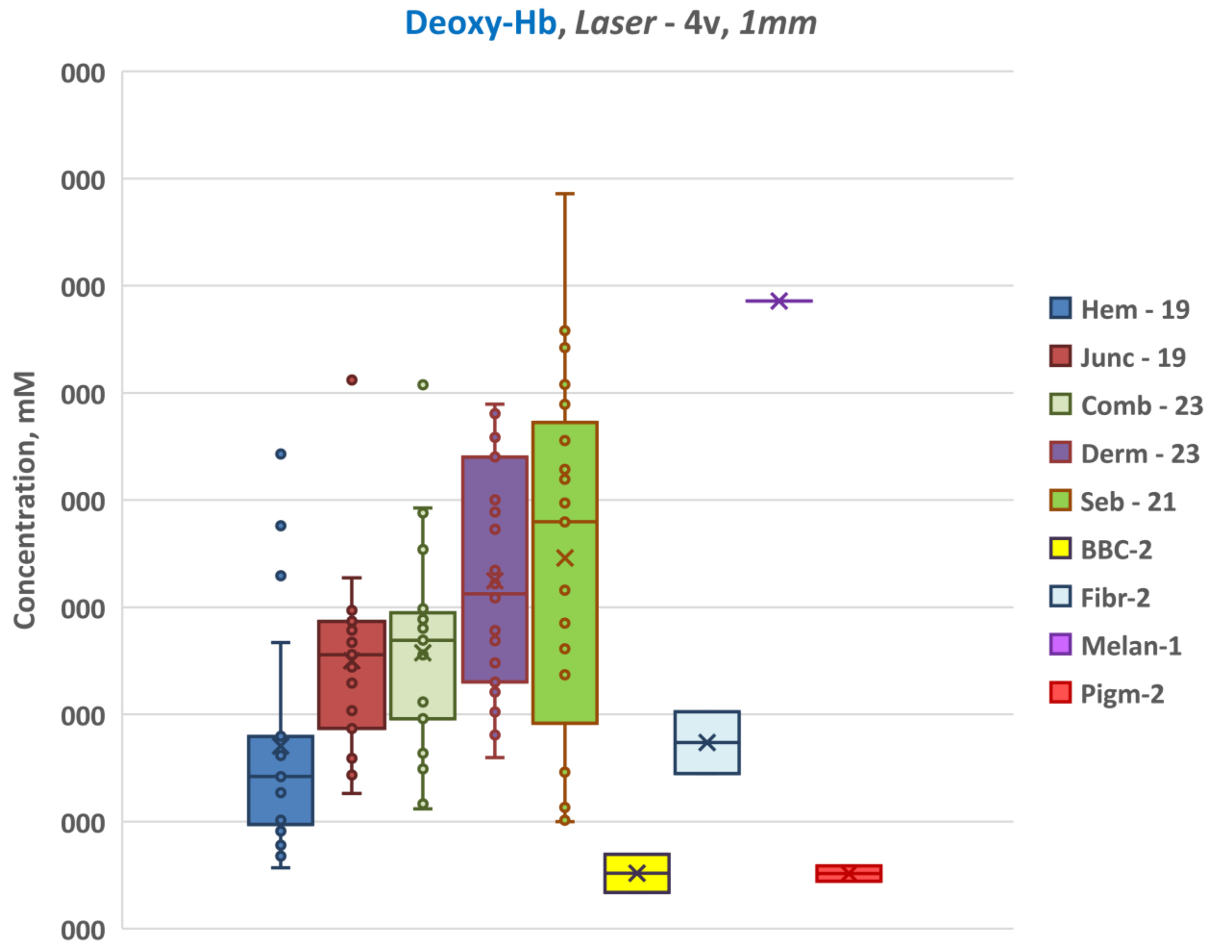

Conclusion

- The results showed that it is possible to distinguish different types of malformations by comparing the mean values, however the standard deviations overlaps.
- The first approach distinguishes hemangiomas quite well by comparing the hemoglobin and oxyhemoglobin values.
- The third approach showed better results compared to the others due to the largest number of positive concentration values.
- Additional measurements of skin malformations including malignant and suspicious malformations are required for further evaluation of the algorithm.

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Acknowledgments

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Thank you for your attention!

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