Hyperspectral measurement system for characterization of healthy and malignant tissue spectra

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In cancer treatment the resection of the tumor is one of the main therapeutic methods. For a complete resection, knowledge of the tumors boundaries is essential. With the aim of developing a multispectral intraoperative sensor in this context, this paper presents a measurement system for the characterization of healthy and malignant tissue spectra.

1 Introduction

Breast, bladder and cervical cancer belong to the most occuring cancer types in Germany [1]. One of the main therapeutic methods is the resection of the tumor. To reduce the risk of recurrences a complete resection of the tumor is necessary, where knowledge of the tumor boundaries plays a decisive role. In order to differentiate better between healthy and malignant tissue, the Research Training Group 2543 "Intraoperative Multisensory Tissue Differentiation in Oncology" focusses on the development of novel, intraoperatively endoscopically applicable sensor concepts.
One of these sensor concepts uses the spectral information to recognize altered tissue. For finding characteristic spectral signals, at first the tissue spectra has to be analysed. Therefore a measurement system is necessary, which will be introduced in this article.

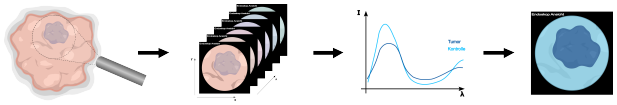

Fig. 1 *Schematic procedure of the final endoscopic multispectral sensor.*

2 Reference system for spectral measurements

To measure the different tissue spectra a reference system was developed. Because of the need of high spectral and spatial resolution as well as short measuring time, a monochromatic-scanning hyperspectral imaging setup was chosen. The setup consists of a monochromator for monochromatic illumination of the tissue and two monochromatic cameras (VIS/NIR (Ximea, MQ013MG-E2) and SWIR (Raptor Photonics, Ninox 640 SU)) for spatial detection. A dichroic mirror (Thorlabs, DMSP950T) splits the incoming light at λ = 950 nm. Figure 2 shows the schematic and real laboratory setup.
In order to react to unevenness of the tissue surface, a sufficient depth of field of approximately Δz = 3 mm, as well as the object-sided telecentricity was implemented. Table 1 shows the specifications of the measurement system.

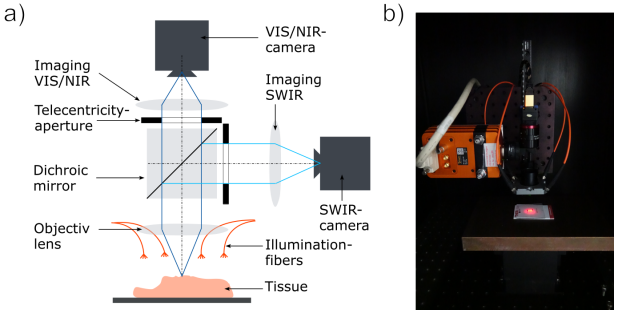

Fig. 2 *Schematic and lab setup of reference system.*

Properties	Values
Spectral range	400 - 1500 nm
Spectral resolution	10.5 nm
Pixel size VIS/NIR	5.3 µm
Pixel size SWIR	15 µm
Object field	9 x 9 mm
Diameter telecentricity aperture	7 mm
Depth of field	3 mm
Aspect ratio	0.32
NA_{obj}	0.022
Max. lateral resolution VIS/NIR	19 µm
Max. lateral resolution SWIR	33 µm

Tab. 1 *Specifications of the measurement system.*

3 Characterization results

To analyse the properties of the measurement systems, several characterization measurements were carried out.

3.1 Spectral signals and spectral resolution

The single spectral signals of the monochromator were analysed by two spectrometer in 10 nm stepsize. Due the spectral sensitivity of the sensors and

DGaO Proceedings 2024 – http://www.dgao-proceedings.de – ISSN: 1614-8436 – urn:nbn:de:0287-2024-P019-4
submitted: 31.07.2024 – published: 13.08.2024

the spectrum of the light source, the usable range is limited to to 450 - 1450 nm (see figure 3).

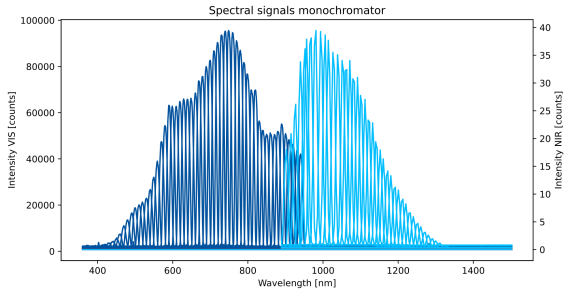

Fig. 3 *Spectral signals of the complete measurement range.*

For evaluating the spectral resolution the mean full-width-half-maximum of each spectral range (VIS: 450 - 950 nm and SWIR: 920 - 1450 nm) is calculated and results in $\overline{FWHM_{vis}}$ = 12.53 $\pm$ 0.59 nm for VIS and $\overline{FWHM_{swir}}$ = 9.1 $\pm$ 2.93 nm for SWIR.

3.2 Spectral sensitivity

To gain a first estimation about the spectral sensitivity, a spectralon surface was measured for each spectral channel. The corresponding exposure time of the cameras was adjusted to obtain approximately 75 % of the maximal count value. Using these exposure times an overall measurement duration of approximately eight minutes can be achieved, including 100 spectral channels with ten exposures per channel and image.

3.3 Lateral resoultion and signal-to-noise ratio

The lateral resolution was measured for four spectral channels by using an USAF target. The corresponding images are shown in figure 4 and 5. For the VIS/NIR camera element four of group four can be resolved, which equals a object detail size of approx. 22 µm.

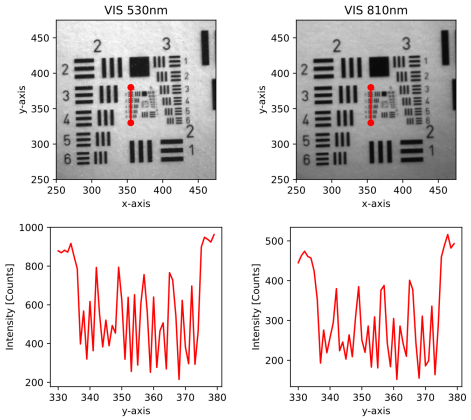

Fig. 4 *USAF target used to characterize the lateral resolution of the reference system in visible range.*

The SWIR camera can resolve element two of group three and thereby a object detail of size 56 µm. The signal-to-noise ratio was 55.75 for VIS/NIR and 43.02 for SWIR.

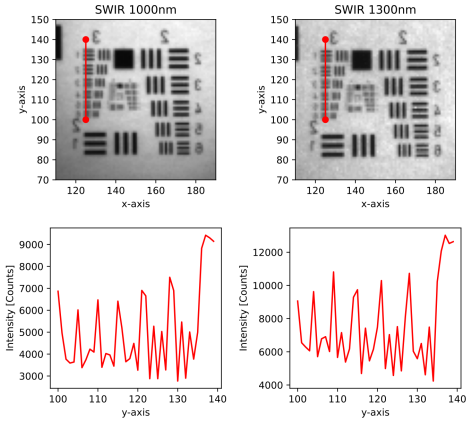

Fig. 5 *USAF target used to characterize the lateral resolution of the reference system in swir range.*

4 Conclusion and next steps

Based on the characterization, it was shown that the developed measuring system is suitable for measuring tissue spectra. Due to the large spectral range, in addition to the known biomarkers in the VIS, potentially promising biomarkers in the NIR/SWIR can also be investigated.
In the future, the measurement system will first be validated on suitable phantoms and then tissue samples of the various tumor entities will be examined. In view of the expected amount of data, approaches based on machine learning may prove to be effective to optimize the tissue spectra.

5 Funding

The work described in this paper was conducted in the framework of the Graduate School 2543/1 “Intraoperative Multi-Sensory Tissue Differentiation in Oncology" (project ID 40947457) funded by the German Research Foundation (DFG - Deutsche Forschungsgemeinschaft).

References

[1] Koch-Institut, Robert (Mitarb.), "Krebs in Deutschland für 2019/2020" in 14. Ausgabe, Robert Koch-Institut (Hrsg) und die Gesellschaft der epidemiologischen Krebsregister in Deutschland e.V. (Hrsg), Berlin, 2023, p. 16, DOI: 10.25646/11357