2025.

Laser light–tissue interaction. — Accurate real-time identification of pathological targets is a major challenge during laser-assisted laparoscopic surgical procedures. Misdelivery of laser energy can result in severe thermal or mechanical damage to healthy tissues. To address this issue, the tissue-specific optical scattering properties of different samples were investigated to improve the accuracy and safety of such interventions. The physical foundations of an optical system capable of distinguishing healthy and pathological tissues based on changes in light scattering across a broad wavelength range were developed. The approach is based on micro-reflection spectroscopy and is designed to be easily integrated into existing fiber-optic laser laparoscopic platforms. Experimental investigations were conducted on various porcine tissues, chosen due to their close anatomical and physiological similarity to human tissues, particularly in urological applications. Using a microscope-based optical setup combined with a broadband halogen light source, spectrometer, and imaging camera, backscattered light spectra were recorded between 200 and 1000 nm. The results demonstrate distinct and reproducible scattering signatures for different tissue types, including fat, muscle, periosteum, liver, and gallstones. Differences were observed both in scattering intensity and spectral shape, reflecting variations in tissue composition, microstructure, and surface morphology (Fig.1.).

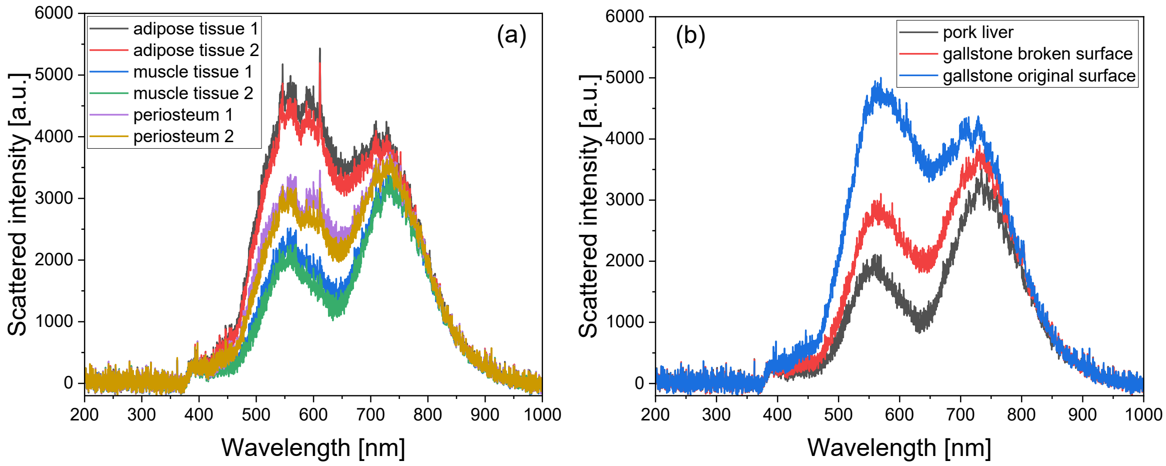

Figure 1. Micro-reflection spectra measured on porcine tissues: (a) components of the rib (adipose tissue, muscle tissue, peritoneum) measured at two representative points; (b) curves recorded on the liver and gallbladder (on broken and original surfaces).

Overall, the findings indicate that micro-reflection spectroscopy is a promising non-invasive technique for in situ tissue characterization. It has strong potential to enhance surgical precision, improve safety in laser-based procedures, and contribute to future intelligent decision-support systems in minimally invasive surgery. [1]

Health effects of aerosols. — The suitability of low-cost air quality sensors for monitoring smoke generated during laser surgical procedures was investigated in the laboratory. Optical particle counters for PM_1, $PM_{2.5}$, and PM_{10} measurement, VOC-sensor, and a CO_2 sensor were applied in the test. Measurements revealed clear and reproducible increases in $PM_{2.5}$ and VOC concentrations during active laser intervention phases, followed by characteristic decay patterns after the procedure. Short-term concentration peaks frequently exceeded healthrelated limit values reported in the literature. Temporal analysis demonstrated that the system could identify distinct surgical phases and correlate smoke emission profiles with the type and duration of laser activity. Comparison with laboratory-grade reference instruments showed that, while the low-cost sensors lack the accuracy and chemical specificity required for quantitative risk assessment, they provide reliable trend detection and real-time indication of elevated exposure levels. Overall, the results confirm that low-cost sensor systems are suitable for supplementary monitoring of surgical smoke, enabling early risk detection and supporting the optimization of ventilation strategies and surgical protocols, but they cannot replace professional analytical instrumentation for detailed hazard evaluation.

Bioaerosol detection. — The design of a compact bioaerosol monitoring system combining size-selective inertial aerosol particle separation with fluorescence-based detection was investigated, and the feasibility of the proposed method was experimentally evaluated. Fluorescence measurements demonstrated that the system could detect biologically relevant particles in real time based on their intrinsic fluorescence response. The recorded signals showed clear correlation with bioaerosol presence, confirming the feasibility of combining physical size discrimination with optical fluorescence excitation (Fig.2.). The liquid collection approach further allowed post-measurement laboratory analysis of the samples, extending the applicability of the system beyond immediate detection.

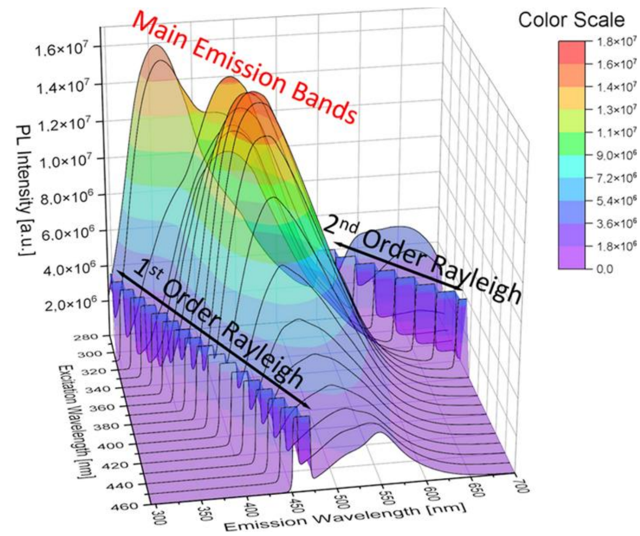

Figure 2. The 3D fluorescence excitation–emission matrix for E. coli bacterial aerosols containing suspension recorded at ambient conditions using an excitation wavelength step of 10 nm.

The obtained results verify that the proposed system can provide reliable real-time indication of airborne biological contamination. These findings support the suitability of the approach as a low-cost, scalable early-warning solution for bioaerosol monitoring in environmental and occupational health applications. [2]

[1] In: Kvantumelektronika 2025 - Szimpózium a hazai kvantumelektronikai kutatások eredményeiből; Szerkesztő: Prof. Dr. Hopp Béla, ISBN 978-963-688-064-4, Kiadó: Szegedi Tudományegyetem (2025), pp.40-43.
[2] https://doi.org/10.1007/s10453-025-09867-9