From the very beginning, man has been in constant contact with bacteria that belong to the simplest cellular organisms. The majority of microorganisms can coexist with humans with beneficial relations (as physiological bacterial microflora), some of them are pathogenic and can be the cause of diseases such as sepsis, pneumonia, abscess, meningitis, gastroenteritis and food poisoning require rapid cures which are appropriate for the invaded bacterial species. Moreover, it was reported, that also the bacterial biofilms are implicated in more than 80 % of chronic inflammatory and infectious diseases (e.g. Catheter-Related Blood Stream Infection) caused by bacteria, including ear infections, gastrointestinal ulcers, urinary tract infections and pulmonary infections in cystic fibrosis patients. Recent, COVID-19 pandemic caused by the severe acute respiratory syndrome coronavirus 2 have shown that the bacteria-related chronic inflammatory and infectious diseases (particularly pulmonary infections) can be responsible for high mortality. It was reported, that 50% of patients with COVID-19 who have died had secondary bacterial infections or both bacterial and fungal co-infections.

The discussed above reasons were the main motivation of the proposed research project, which is focused on registration and integration of new multi-parametric bio-signatures of different spatial structures formed by bacteria, from a single cell, through bacterial biofilms formed in medical catheters, and ending on micro-/macro-colonies, which are commonly used in microbiological diagnostics. Depending on bacteria species or strain, their cells, biofilms and colonies have specific morphological, optical and chemical properties. The exact characteristics of the individual bacterial cells and more complex spatial structures formed by them, can find potential use in microbiological diagnostics.

In the proposed research project, the examination will be performed by various measuring and imaging techniques and will be focused on the acquisition of novel bacterial signatures i.e. 'optical- and chemical-fingerprints' of bacteria. By means of digital holo-tomographic microscopy, it will be possible to reconstruct the three-dimensional spatial distribution of the refractive index that is characteristic of given bacterial species/strains. This is a relatively new imaging technique and such examination was not performed yet. The technique of the optical coherent tomography will be used to measure the morphology, i.e. the spatial geometry of multi-cellular structures formed by bacteria. Spectral imaging techniques together with the results obtained by coherent optical tomography will be used to characterize the spatial distribution of the absorption properties of bacterial structures, which are dependent on the absorption properties of the cells themselves, as well as the extracellular material produced by them, which chemical composition depends on the metabolic preferences of a given bacteria species/strain. In addition, infrared microscopy and spectroscopy techniques will enable investigation of the chemical composition of these bacterial structures. A comparative analysis of the results obtained from all these measurement/imaging techniques will provide a complex, multi-parametric characterization of the morphological, optical and chemical properties contained in the registered bacterial bio-signatures in order to differentiate them. In addition, the possibility of using these bio-signatures to analyse the effectiveness of antibacterial agents will be explored by demonstrating their effect on changing the characteristics of registered bacterial signatures.

Positive project results may contribute to proposing new diagnostic tools enabling more complex and comprehensive microbiological diagnostics focused not only on bacterial differentiation but also conducting research on new modalities of combating them. This may contribute to reducing the risk of spreading drug-resistant strains of bacteria and the resulting threats to human health and life.