We will develop a new type of optical microscope that will advance the field of biomedical optics and will enable scientific discoveries in biology and clinical medicine. Most microscopes form images of a sample's optical properties, instead we will image a sample's mechanical properties; for example, it’s stiffness. The reason our novel approach is needed is that tissue’s mechanical properties on the microscopic scale play an important role in tissue function and are often modified by disease. Because of this, our novel microscope can help improve both our understanding and diagnosis of diseases, including cancer and cardiovascular disease.

For centuries, physicians have exploited the link between mechanical properties and disease through the process of palpation, where the suspicious region is interrogated using the sense of touch. Whilst palpation provides useful diagnostic information and is still used in a range of clinical scenarios, such as identification of breast cancer tumours and assessment of burn scars, it is very subjective and cannot detect small regions of disease. To address this, researchers developed a new type of medical imaging called elastography. In this approach, images are formed where each pixel represents the stiffness of the tissue at that location. To perform elastography, a mechanical force is applied to the tissue, usually using some form of external actuator, and the resulting deformation is measured using an imaging technique. Algorithms that are based on mathematical models that describe how tissue deforms in response to an applied force are then used to convert measured deformation to a mechanical property, such as stiffness.

Initially, ultrasound or magnetic resonance imaging (MRI) was used as the underlying imaging modality in elastography. These approaches have been very successful and are now routinely used in the hospital to detect diseases such as breast cancer and liver cirrhosis. However, although these techniques provide much more information than simple palpation with the finger, they cannot detect microscopic changes in a tissue’s mechanical properties. Importantly, it is on this small scale that diseases first develop. For this reason, researchers have begun to look at ways to develop elastography techniques that can visualise these microscopic changes in mechanical properties. This has led to the development of optical elastography, which is the use of optical imaging to measure tissue mechanics.

A lot of progress has been made in optical elastography, but currently there are fundamental problems with the methodology used. The reason for this lies in the algorithms used to generate values of tissue mechanical properties. These algorithms rely on overly simplistic assumptions about the nature of tissue mechanics on the microscopic scale that are clearly incorrect. For example, it is often assumed that the tissue is mechanically uniform, i.e., that there are no variations in mechanical properties in the tissue. Also, current models break down in regions of tissue that are not solid, for example, in blood vessels. Because of this, in many cases, optical elastography techniques are unreliable and unsuitable for use by physicians. If we remove these assumptions by implementing more realistic algorithms of tissue deformation and improve the accuracy of the measurements obtained, we may eventually be able to provide a new method to detect and characterise disease. The development of this novel methodology in optical elastography is the main aim of our project. We will take advantage of the latest developments in optical imaging, particularly in optical coherence tomography, to dramatically improve the experimental implementation of optical elastography and the reliability of the algorithms used to calculate mechanical properties.

Once we have successfully developed the novel optical elastography imaging capabilities, we will collaborate with physicians, particularly pathologists and surgeons, to test the imaging system on human tissue excised during cancer surgery. For each tissue scanned, we will validate the image contrast obtained by comparing our images with those obtained through histopathology, the gold standard in assessment of cancer specimens. We will focus on tissue excised during breast cancer, prostate cancer and colorectal surgeries, which are three areas of surgery where innovative surgical instrumentation is needed.

Achieving a successful outcome in our project requires a number of different scientific competencies, including in optics, mechanics, computer science and clinical science. We plan to assemble a team that covers each of the skills and expertise required. The team will comprise researchers that are proven experts in their field. We believe that our project will significantly advance the development of optical elastography, placing Poland at the forefront of global efforts in this technology and paving the way for new diagnostic tools that will be used to improve health outcomes for people in Poland and internationally.