Breast cancer is the most common cancer among women in Europe and the leading cause of cancer-related deaths. In 2022 alone, an estimated 374,800 women were diagnosed, and 95,800 lost their lives to the disease. One of the main treatments for early-stage breast cancer is breast-conserving surgery, in which the tumor is removed while preserving as much healthy breast tissue as possible. To ensure all cancerous tissue is removed, surgeons take out the tumor with a small margin of surrounding healthy tissue. However, current surgical techniques cannot reliably confirm whether any cancer remains at the edges of the removed tissue. As a result, one in five women who undergo breast-conserving surgery require a second operation because some cancer cells were left behind. These repeat surgeries cause additional physical and emotional stress, increase the risk of complications, and place a significant burden on healthcare systems.

The challenge lies in detecting cancerous tissue at the time of surgery. Current imaging methods are either too slow, lack sufficient detail, or cannot effectively distinguish between healthy and cancerous tissue. Optical coherence tomography (OCT) is a promising high-resolution imaging technique that can capture three-dimensional (3D) images of breast tissue with microscopic detail. In early studies, it showed potential for detecting cancer but its effectiveness in real-world breast-conserving surgery has been significantly lower. This is because current OCT methods struggle to differentiate subtle cancerous changes from normal tissue. A promising solution is dynamic OCT (dOCT), an advanced version of OCT that improves contrast by measuring microscopic changes in cellular motion, which are different between healthy and cancerous tissue. Preliminary studies suggest that dOCT can identify microscopic tumors more clearly than standard OCT with very high accuracy. However, the technique is currently too slow for real-time use during surgery. A full scan of the removed breast tissue would take over 200 hours, making it impractical in the operating room. Until this challenge is solved, dOCT cannot be used in hospitals, meaning its potential to improve breast cancer surgery remains unavailable.

Our project aims to develop a new and improved dOCT system that can scan an entire excised breast specimen within the limited time available during surgery. To achieve this, we will:

1. Increase imaging speed – we will develop a high-speed dOCT system that can scan all six sides of the removed tissue within 20 minutes.
2. Reduce the number of required scans – we will integrate deep learning (a form of artificial intelligence) to optimize imaging, allowing us to gather the necessary information in fewer scans.
3. Improve image interpretation – We will introduce a novel imaging approach that maps tissue biomechanics, which are known to change in cancerous cells. This will make the images easier for surgeons to interpret during surgery, leading to more accurate decisions.

By combining these advancements, our technology will allow surgeons to assess tumor margins in real-time, reducing the number of patients who need a second surgery. To test our system, we will conduct a pilot study on freshly removed breast tissue samples at the Oncology Centre in Bydgoszcz, working closely with expert pathologists. The results will be compared with standard histology (the current gold-standard cancer detection method) to evaluate dOCT's accuracy in identifying tumor margins. If successful, this research could pave the way for dOCT to become a standard tool in breast cancer surgery.

This project brings together international leading experts from Nicolaus Copernicus University, The University of Western Australia, and University College London. Our team includes specialists in medical imaging, optical system design, artificial intelligence, and breast cancer pathology. This collaboration will help turn dOCT from an experimental technique into a practical surgical tool that improves patient outcomes. Our research aims to significantly reduce the number of women needing a second surgery, leading to better patient experiences, fewer complications, and lower healthcare costs.

If successful, this technology could be expanded to other types of cancer surgeries, improving outcomes for even more patients in the future. With this grant, we will take the critical steps needed to bring dOCT from the lab to the operating room and improve breast cancer surgery for people in Poland and internationally.