This project will be realized in collaboration between two groups at the Jagiellonian University in Kraków and at the Jožef Stefan Institute in Ljubljana. It aims at the joint study of cutting-edge problems in superconductivity using modern optical magnetometry techniques. This ambitious research is enabled by the synergy and complementing knowledge of both teams.

We will use diamonds with nitrogen-vacancy colour centres, which are typically responsible for rose diamond colouring, as sensors for probing magnetic fields generated by the superconducting samples with a high-sensitivity and in a very detailed way. In particular, we will use with colour-centres' spins inside nanodiamonds to achieve nanometric spatial resolution that will enable us to observe vortices in the superconductor. Our goal is to develop novel type of instrumentation that will foster versatile and robust optical magnetometry as an alternative approach for studies of condensed-matter systems at cryogenic temperatures.

Our scientific motivation stems from the existence of many fundamental open-questions in the physics of unconventional superconductors, that is recently discovered materials in which superconductivity cannot be explained by the well-established BCS and Bogoliubov theories. For example, we will study properties of, so-called, topological superconductors (like β-$PdBi_2$) and quasi-1D superconductors ($A_2Mo_3As_3$, here A is an alkali metal). We are interested in imaging the presence of vortices and observing their so-called pinning and transitioning to a dynamic behaviour. In this way, we will determine vortex matter excitation spectrum and it will allow us to address the major open question on the origin of the Cooper pairing mechanisms in such unconventional superconductors. Finally, we anticipate this project will also shed some light onto the possibilities for practical applications of unconventional superconductors.