The project aims to the development of a material platform for new, low-energy-consuming and micro-scale polariton lasers for telecommunications and optical data processing. The project is a synergy of technological innovation and fundamental research on the properties of matter and advanced light-matter coupling and was created in response to the growing demand for digital data processing in the information society, the limits of currently used solutions, and the policy of saving energy resources affecting the state of the natural environment.

The material platform selected for the project is molybdenum ditelluride ($MoTe_2$) and molybdenum tungsten ditelluride ($MoWTe_2$) crystals belonging to a newly discovered class of direct-gap semiconductors from the group of transition metal dichalcogenides embedded between two flat mirrors made of classical semiconductor based on GaAs or oxides based on SiO_2 and TiO_2. The mirror system creates a microresonator, in which the light (photons) interact strongly at the quantum level with the components of matter (electron-hole pairs = excitons) in the selected crystals. As a result of this interaction, new quasi-particles of matter called polaritons are formed having partly light partly matter properties. Thanks to the employed architecture of a layered system, the interaction between photons and excitons can be tailored and lead to aggregation of polaritons to a one, quantum-mechanical state called polaritonic condensate. The condensate is a direct emanation of quantum world interactions in a micro scale, and it is able to emit photons with characteristics similar to a conventional laser but under much lower energy consumption for the process.

The atomically-thin layered crystals $MoTe_2$ and $MoWTe_2$ Their properties are closely related to the thickness of the crystal layer reaching almost three times the diameter of an atom. These crystals have two essential features that can result in the production of a polariton laser useful for communication applications. Theoretical predictions and partly experimental results show that the components of matter necessary for the generation of polaritons (electron-hole pairs called excitons) can survive in these materials well above room temperature and do not dissociate, and excitons emit light near the telecommunication-important spectral range.

The research goals aim to answer several essential questions:

- Are atomically-thin $MoTe_2$ and $MoWTe_2$ crystals good candidates for micro-size emitters for spectral range above 1 μm photon wavelength;
- To what limits can the properties of excitons be controlled in these crystals to obtain the light emission in the telecommunications-oriented spectral range near 1.3 μm of the photon wavelength?
- How to get a good quality optical microresonator necessary to obtain strong coupling between excitons in $MoTe_2$ or $MoWTe_2$ and photons enclosed in the microresonator resulting in the production of polaritonic emission in the spectral range important for the project?
- Is it possible to achieve polariton condensation on this material platform?
- Is it possible and what needs to be done for this to happen to produce a micro-size coherent light source based on the proposed crystals operating at room temperature and emitting photons in the telecommunications range?

Although many fascinating properties of polaritonic condensate are already known, even more remain unexplored or incomprehensible both in theory and experience. Research on the properties of condensates using layered atomically-thin crystals of transition metal dichalcogenides including $MoTe_2$ $MoWTe_2$ are just at the beginning of their path. Finding answers to many questions about such condensates will help to understand the effects at the quantum level in layered semiconductor systems. The use of $MoTe_2$ and $MoWTe_2$ crystals may pave the way for new designs of optoelectronic devices using the unique properties of strong light-matter interaction in the infrared spectral range of the electromagnetic radiation spectrum, which is vital for applications.

The project is implemented in close cooperation between the Wrocław University of Science and Technology and the University of Würzburg, Germany, including a cooperating technology partner from the Arizona State University, Tampa, USA. Experiments in the field of linear and quantum optics in the near-infrared spectral range are carried out using world-class apparatus available in the Polish research group. A team from the University of Würzburg is a world-renowned leader in the technology of producing advanced nanostructures in hybrid multi-material technology, and the American partner is a world-class producer of transition metal dichalcogenide crystals