The project is devoted to creating a new research team for developing a new experimental platform to enable probing fundamental physics and search for new physics beyond the Standard Model utilizing an ultracold mixture of mercury and rubidium atoms. The proposal is divided into objectives that make a coherent research programme ranging from searching for new physics with precise isotope shift measurements, through ultracold atomic and molecular spectroscopy, up to developments in metrology based on a two-species system. The goals will be realized with the unique experimental system capable of simultaneous collecting ultracold Hg and Rb atoms already working in the National Laboratory of Atomic, Molecular and Optical Physics (KL FAMO).

The main research goal of the project is to make use of one of the most promising methods for probing physics beyond the Standard Model, namely looking for breaking of linearity in so-called King plot, applied for Hg isotope shift. A significant improvement proposed in this project is to take advantage of the extremely narrow so-called clock transitions with natural linewidths much below 1 Hz. This, together with the high isotopic diversity of Hg, provides excellent conditions to perform state-of-the-art King-plot based measurements and may pave the way for experimental verification of the Standard Model.

Another project's research goal is to perform the first step towards the experimental platform for quantum simulations based on absolute ground-state molecules in an optical lattice. To create ultracold RbHg molecules, we will use an already existing and operating unique experimental system that has been proven to efficiently cool and trap Hg and Rb atoms in a dual-species magneto-optical trap reaching the temperatures of the order of 10 μK. Our research on ultracold molecules will be based on two experimental methods: photoassociation (PA) and stimulated Raman adiabatic passage (STIRAP). Photoassociation spectroscopy will be carried out near the D1 (795 nm) transition in Rb. Using the optical frequency comb coupled with our system, we will measure the absolute frequency of PA resonances for various Rb-Hg isotopologues.