

The main goal of the project is to build a new experimental set-up and a research group that will allow to study the interaction of light with atoms in a very specific arrangement, where the atoms are placed between two mirrors with a high reflectivity. The long-term plan assumes the construction of a new type of optical atomic clock - an active optical clock, a device for studying fundamental physics and for practical applications in the future.

Atomic clocks are deeply ingrained in our daily lives, although we are often unaware of their existence. These devices allow for precise synchronization of devices and standardization of measurements. Currently, without precise synchronization, it is hard to imagine secure online banking or wireless telecommunications, but most likely we could not rely on the power grid either. Another application of atomic clocks is satellite navigation (e.g. GPS). Already today, in several selected laboratories around the world (including the FAMO National Laboratory in Toruń), a better generation of clocks, the so-called optical atomic clocks, operates. They will not only allow for even better synchronization of devices, but also open up new possibilities - thanks to a hundred to a thousand times better accuracy and precision compared to even the best microwave clocks. Among the new possibilities of practical use of optical clocks there is, for example, geodesy, where better clocks will allow for remote mineral exploration, study of volcanoes and movements of continental plates (perhaps even predicting volcanic eruptions or earthquakes), or remote monitoring of groundwater levels. In addition to utilitarian applications, optical clocks are now also a very important tool in the study of fundamental physics and are used, for example, to search for dark matter, study the invariance of physical constants, test our current knowledge of the world and search for new laws of physics. We know that, as it was in the past, so in the future we will need better and better clocks - frequency standards. This is particularly visible through financial outlays on optical clocks, especially in the most technologically developed countries such as the USA, Great Britain, Germany, France and Japan. Optical clocks are currently a scientific challenge, but also a technological challenge, and it is clear that we are approaching the barrier limiting their further development. The idea in the proposed project is that instead of constantly polishing the current technology and improving our capabilities by a factor of two, we circumvent the limitations with a new method and again have the prospect of improving the clocks' capabilities by orders of magnitude. The classic passive clock works by comparing the frequency of the laser light with the resonant effect in the atoms. The atoms, identical all over the world, ensure excellent accuracy and repeatability, and the laser light provides high short-term stability. The new active clock will work by omitting the laser from its design and forcing the atoms directly to produce both stable and frequency-accurate laser light. This will be possible thanks to the construction of a new experimental system, allowing for comprehensive research and, in the future, a functional active atomic clock. Currently, there are theoretical models that allow to describe the operation of such a clock (among others published by the author of this application), which allowed to describe and explain the first research conducted in this direction. The theoretical model has been tested on simpler experimental systems and the next step is to build a complete and universal system that is a tester of new solutions. Simultaneously with the construction, knowing fully the conditions, possibilities and limitations of the system, it will be possible to determine the potential of the clock, e.g. to search for dark matter, new physics or utilitarian applications.

The ultimate goal of this project will be the construction of a continuous optical atomic clock for both basic physics and utilitarian applications. This project aims to open a new chapter in research by circumventing the current limitations that optical clocks are approaching.