DESCRIPTION FOR THE GENERAL PUBLIC (IN ENGLISH)

The interaction of light and matter is one of the finest tools used by the scientists in modern laboratories. It allows to measure interaction of atoms and molecules, have a look into their internal structure, giving the capabilities to look at distances at levels of nanometers (one millionth of a millimeter) and trace events with time resolution of femtoseconds (one quadrillionth of a second).
Recent development of photonics and laser technologies pushed the capabilities of the scientific devices significantly. One of the major achievements was the development of the optical frequency comb. Produced by ultrafast lasers, frequency combs precisely measure individual frequencies (colors) of light. It enabled the development of the optical atomic clocks – most precise clocks in the world, which will not gain or lose a full second for more than 15 billion years. For development of such a precise tool professors John L. Hall and Theodor W. Hänsch have received the Nobel Prize in Physics in year 2005.

Like many measurement tools, the laser frequency combs, outside the frequency metrology lab, seemed at first the curiosity, but in last decade has found more scientific and practical uses than imagined, including atmospheric research or biomedicine. In the proposed project we use such a comb to measure precisely which light, or comb "teeth," are absorbed by the molecular gas, and in what amounts. This technique is generally called molecular spectroscopy. Since we know precisely the colors or absorbed comb "teeth", therefore we can look in detail in relation between the frequency of the absorbed light and energy absorbed. This relation is called line shape, which carries the information about the internal structure and dynamics of the molecule, and its interactions with environment. Our measurements will deliver the line shape parameters CO-Ar and CO-N_2 molecular systems, which then will be used for comparison with the results of theoretical calculations, verifying our description of the physical processes and behavior of single molecules.

The spectral line shape parameters are available for scientists in open-access databases. They are used in various fields, which use molecular spectroscopy as a routine tool for detection and quantitative measurements of the molecules in gaseous samples, for example: in Earth’s atmosphere, in human’s breath - looking for the biomarkers of the diseases or in the airports - looking for trace of hazardous substances. They are also used in research on atmospheres of the planets in the solar system as well as exo-planets. The progress in the measurement techniques makes the databases obsolete, as higher precision and accuracy is required for new applications. The experimental verification of theoretical parameters proposed in the project is important step for the databases and associated utilities. It will verify the possibility to calculate line shape parameters theoretically, so it is of big importance in respect to filling the databases with parameters for millions of lines.

The newly developed comb-based technique used in the project, brakes the spectral resolution limitation of similar broadband setups used before .The demonstration of its capabilities will have impact on a multitude of applications of atomic and molecular spectroscopy. Using non-linear frequency conversion to the infrared and visible light region, it can be easily applied for research in a wide spectrum of atomic and molecular systems. If introduced together with the comb as a light source to existing high-resolution broadband spectrometers, regardless of application, it can decrease hundred-folds the acquisition time required to obtain high-resolution spectra beyond the optical path difference limit. It also enables the use of the ultra-precise frequency scale offered by the comb and the precision in principle can reach the single-hertz level. Particularly, for gas metrology of molecules, this method has all the properties to become the workhorse of the this application, combining the advantages of continuous wave laser spectroscopy with broadband operation of conventional Fourier Transform Spectroscopy.