DESCRIPTION FOR THE GENERAL PUBLIC

The main goal of the project is to divisively examine the possibility of utilizing unique configurations of all-fiber-based 1 μm and 1,55 μm pulsed lasers in nonlinear-based frequency conversion sources to obtain radiation in the mid- and near-infrared wavelength regions.

In the last two decades a rapid process in the development of mid-infrared (2 μm - 10 μm) laser sources could be observed. According to the analysis prepared by Accuray Research LLP [1], the market growth in years 2014 – 2018 reached an outstanding 8% yearly. Moreover, as stated in the analysis, in years 2019 – 2027, the demand for novel mid-infrared (mid-IR) sources will increase exponentially. This is a direct result of the growing market for out-of-lab applications of such lasers. Statistics in [1] show, that 40% of the currently manufactured sources are utilized in laser spectroscopy apparatus, 30% in medicine (from that 5% in laser scalpels), 17% in free-space communications and 13% in remote detection apparatus. The analysis provided by Accuray Research LLP and the observable increase in out-of-lab applications, clearly states the direction in which mid-IR laser sources will develop in the following years. The current mid-IR laser market is dominated by two types of sources: semiconductor lasers (QCL and ICL) and frequency conversion sources.

Experimental work that will be conducted during this project will focus mainly on the experimental verification of the feasibility of using novel types of mode-locked fiber-based lasers as sources for nonlinear-based generation of mid-IR radiation.

The research plan will include designing, building and optimizing a set of all-fiber-based lasers working in a relatively newly discovered and yet not fully investigated regime – dissipative soliton resonance (DSR). Based on theoretical work and preliminary research, a properly designed and built laser working in the DSR regime is capable of generating pulses with energies orders of magnitude higher than in standard configurations – up to tens of microjoule per pulse. Moreover, what has been proven in preliminary research, DSR laser can be constructed in all-fiber configurations (without bulk optics) using inexpensive, widely available components, ensuring long-term, stable and reliable operation. The laser sources built during the project will be based on double-clad fibers, which enable achieving high gain without adding additional complexity to the laser.

Some of the nonlinear-optics-based frequency conversion experiments require using two independent sources of coherent radiation with severely dissimilar wavelengths, e.g. difference and sum frequency generation. In such cases, the pulses have to be both temporally and spatially overlapping in the nonlinear media. Therefore, the research plan includes pioneering experiments involving passive repetition frequency synchronization of two independent DSR mode-locked lasers – e.g. 1 μm and 1.55 μm. This will be realized by utilizing a phenomenon called cross-phase modulation.

The main part of the project will be devoted to the research, in which the newly designed configurations of DSR mode-locked lasers will be utilized as sources for frequency conversion-based experiments. This will require designing, building and optimizing a set of configurations in which an optical crystal will serve as an nonlinear medium (e.g. lithium niobate). Appropriately designed DSR lasers will enable varying several key parameters of the generated pulses, like: pulse duration, repetition frequency, optical spectrum). This feature of DSR lasers will enable an extensive investigation of the influence of pulse parameters on radiation generated via the nonlinear processes.

The proposed research plan includes experimental work on several novel configurations of DSR mode-locked fiber-lasers and on the practical utilization of the generated high-energy pulses in nonlinear-optics-based frequency conversion light sources. Although a limited number of publications documenting DSR lasers can be found in research journals, the idea of utilizing such sources to generate new optical frequencies via nonlinear processes has not been investigated yet. The realization of the research task will significantly increase our understanding of the unique process of formation of DSR pulses in all-fiber configurations and the process of optimization of such sources for applications in nonlinear optics. Moreover, the novelty of the proposed research will surely be of interest for the scientific community not only focusing on DSR ML lasers, but also working on nonlinear-optics-based sources, with particular applications, e.g. in laser spectroscopy.

Moreover, we believe, that appropriately designed DSR ML laser sources and their subsequent utilization in nonlinear-optics-based sources could find particular out-of-lab applications, serving as an alternative for currently used solutions.

[1] "Global Mid-infrared Lasers Market Analysis & Trends - Industry Forecast to 2027", Accuray Research LLP, 2018.