Research Project Objectives

The main subject of this project is theoretical and experimental research on optical parametric oscillation phenomena in the mid infrared spectral region above 3.5 μm with the use of fiber-based laser source for pumping. The most important goal we would like to achieve is to determine the optimum pumping conditions which maximize mid infrared output and the optimum resonator geometry among many available configurations (i.e. single resonant, double resonant or ring cavities). Insight in published literature and our preliminary results of theoretical analysis allow us to formulate the following hypothesis: ***The most efficient way to generate mid infrared radiation with high repetition rate is an optical parametric oscillator based on a ZGP crystal, pumped by a fiber laser system.***

Project methodology

The main subject of this project is theoretical and experimental research on parametric generation phenomena in ZGP nonlinear crystal pumping by fiber lasers with high repetition rate.

To achieve all predicated results and to verify the hypothesis, experimental and theoretical research will be divided into three tasks. Each of the tasks will provide essential knowledge about presented topic.

In the first research part, an elementary analytical model will be elaborated to determine conversion efficiency and output characteristic of optical parametric oscillator. The model will originate from differential equation system which describes mutual influence of wavelengths in a nonlinear medium. Impact of phase matching, geometrical scheme of cavity and thermal effects will be taken into account.

The second part is to build a proper pumping source based on thiulium doped fibers. Two different approaches are considered in this manner. The first is the MOPA configuration based on single-mode polarization maintaining active fiber. One to several amplification stage will be used to obtain sufficient level of output power with acceptable beam quality. Alternatively a Tm-fiber laser based on LMA (large mode area) fiber is considered to be used.

The third part contains thorough investigation of optical parametric oscillator laboratory model consisted of ZGP crystal sample. The laser developed within part 2 will be used as a pump. Research performed in this part will be a dominant part of this project. We are going to investigate influence of nonlinear crystal properties and phase matching type on efficiency of output laser beam. Moreover, thermal load of the nonlinear medium as well as its impact on the output beam parameters will be determined.

Expected impact

Middle-infrared (mid-IR) laser sources operating over the “molecular fingerprint” 3–15 μm spectral range are in great demand for a variety of applications including molecular spectroscopy, non-invasive medical diagnostics, industrial process control, environmental monitoring, atmospheric sensing and free space communication, oil prospecting, and numerous defense related applications such as infrared countermeasures, monitoring of munitions disposal, and stand-off detection of explosion hazards. The subject is especially important nowadays, where more and more often one can hear about real threat from terrorist attacks. It is important to have efficient, coherent laser source for conducting research in the field of these applications.. There is a lack of the laser sources generating in spectral range above 3.5 μm, so the optical parametric oscillators are believed to fulfill this gap.

The output parameters optimization of such a type of laser sources is a complex theoretical-experimental task. Many parameters have influence on output efficiency and power and nearly all of them are related on each other. Optimization of cavity geometry along with nonlinear crystal angle and walk off angle compensation is crucial. Moreover, analysis of thermal load of the ZGP crystal is also important to obtain efficient output in mid infrared wavelength region. **To determine the nature of these relations a comprehensive theoretical and experimental investigation is needed. This issue, to the best of our knowledge, has not been analyzed roughly enough yet.** Theoretical analyses are omitted in available scientific literature. The reports published so far describe only experimental results. Furthermore, many details are not revealed – probably due to sensitivity of the topic (military applications).

We believe that the results of this project will be very useful for future research on mid-infrared optical parametric oscillators utilizing ZGP nonlinear crystals, which are becoming more and more demanded by scientific society. The development of reliable theoretical model and understanding physical phenomena occurring during parametric generation in these crystals should increase effectiveness in various applications of such laser sources, ensuring, for example, lower production costs or increased performance.