The main goal of the project is to understand the mechanism of parasitic energy losses by studying the up-conversion process of infrared excitation in Cr-doped garnets. For the project, PI has chosen the compounds with the garnet structure of the general formula $C_3A_2D_3O_{12}$, (C -Y^{3+}, Lu^{3+}, Gd^{3+}, La^{3+}; A - Al^{3+}, Cr^{3+}, Ga^{3+}, Sc^{3+}; D - Al^{3+}, Ga^{3+}) doped with various concentrations of Cr^{3+} ions. Changing the chemical composition of the matrix allows modulating crystal field strength and phonon spectra leading to reduction of the negative impact of Cr^{3+} ions on the laser properties.

Since the development of the first ruby-based laser device in 1960, solid-state lasers revolutionized the field of optical devices. Progress was particularly noticeable after the development of lasers based on Nd^{3+}:YAG garnet crystals with a wavelength of 1 µm. However, despite the advances in the development of laser systems in continuous wave mode, potential of pulsed lasers is far from the limit. Pulsed lasers consist of an active element (usually Nd^{3+}:YAG) coupled with a Cr^{4+}:YAG saturated absorber. The main factor limiting the efficiency of such systems is related to the relatively low characteristics of the Cr^{4+}:YAG saturable absorbers. However, at the current stage there is no appropriate alternative to Cr^{4+}:YAG, as V^{3+}:YAG is more suitable for lasers operated at lower energies and LiF:F^{2-} degrades quickly. The principle of operation of the pulsed laser is based on the introduction of saturable losses (by Cr^{4+} doping) to the resonator in order to provide energy storage by an active element (Nd^{3+}:YAG). Cr^{4+} saturation is followed by generation of a giant pulse due to release of energy accumulated by the active element. The energy of this pulse is directly proportional to the difference between the saturable and unsaturable losses introduced by an absorber (Cr^{4+}:YAG). The general way to increase an efficiency of Cr^{4+}:YAG pulsed lasers is based on the introduction of Cr^{4+} ions providing saturable losses. Our recent discoveries show that Cr^{3+} is able to absorb light with energies of photon below absorption maximum and therefore is an unsaturated absorbing center reducing the output power of Cr^{4+}:YAG-based lasers. The effect of Cr^{3+} ions on the laser properties can be dominant, as their concentration is quite high (up to several percent). Sintering of garnets doped with Cr^{4+} ions only seems unreal. This is not surprising, as obtaining transparent Cr^{4+}-doped garnets is a challenge. Understanding the nature of up-conversion phenomenon will allow us to reduce the parasitic influence of Cr^{3+} ions improving the performance of lasers based on Cr-doped garnet materials.

Understanding the nature of up-conversion in chromium-doped garnets is possible through the analysis of the spectroscopic properties of the concentration series of Cr:$C_3A_2D_3O_{12}$ phosphors, where C -Y^{3+}, Lu^{3+}, Gd^{3+}, La^{3+}; A - Al^{3+}, Cr^{3+}, Ga^{3+}, Sc^{3+}; D - Al^{3+}, Ga^{3+}. The spectroscopic properties of Cr^{3+} systems depend directly on the crystal field strength (Dq/B), which determines the energies of the two lowest excited states (^2E_g doublet and $^4T_{2g}$ quartet). Modulation of the crystal field is possible by changing the chemical composition of the garnet, for example the Dq/B of the garnet crystals can be from 2.2 for LaSGG to 2.8 for LuAG. In addition, assuming that the up-conversion process in Cr^{3+} ions occurs with the participation of vibrational transitions, it can be concluded that the changes in the phonon spectrum (with a change of matrix) will affect this phenomenon. The project will be divided into two parts. The first part of the project will be devoted to the study of the influence of matrix composition and concentration of chromium ions on the efficiency of up-conversion process in Cr^{3+} ions. Cr-doped garnet powders will be synthesized using the sol-gel method. The microstructure and optical properties will be studied. On the basis of the obtained results, a series of transparent Cr-doped garnet ceramics will be prepared. Analysis of the results should provide a schematic model of up-conversion process in chromium-doped garnets finding a way to minimize its negative effects.