Laser properties of divalent iron-doped zinc-selenide crystal and its application as a mid-infrared femtosecond pulse amplifier

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High-power mid-IR ultrafast lasers are in demand in many fields of science and technology including high harmonics and attosecond pulses generation, filamentation in air, effective generation of a supercontinuum for the benefit of panoramic spectroscopy, the study of ultrafast dynamics of molecules chemical bonds in problems of femtochemistry, as well as remote sensing and special purposes related applications.

Developed in the 1990s new laser media based on chalcogenides doped with transition metal ions made it possible to develop on its basis powerful, efficient and compact broadband mid-IR sources. Zinc selenide crystal doped with divalent iron ions (Fe^{2+}:ZnSe) belongs to this type of gain media and demonstrate a broad emission band of 3.7-5 μm and high absorption and emission cross sections (~10^{-18} cm^2). This master's thesis is a part of the research project devoted to the development of the concept of a high-power all-solid-state femtosecond laser system with a Fe:ZnSe-based amplifier with optical pumping and a nonlinear optical block for the amplified pulse self-compression. Such system was not realized in any laboratory in the world to date and is able to work in 4-5 μm spectral region.

The work is devoted to the investigation of the laser properties of the Fe:ZnSe crystal and its use as an mid-IR femtosecond amplifier. In this work the spectroscopic properties of the new laser medium Fe:ZnSe were analyzed; several optical pumping sources based on Er:YAG (2.94 μm) and Cr:Yb:Ho:YSGG (2.85 μm) crystals were proposed and created; experiments on the generation and amplification of nanosecond, picosecond, and femtosecond pulses in a Fe:ZnSe crystal were carried out. The experimentally established high gain coefficient of ~ 2 cm^{-1} made it possible to achieve the amplification of the chirped mid-IR pulses with up to 1.2-mJ output energy, which is sufficient to claim the creation of a source with a high peak power for expanding the world of nonlinear optics and photonics of the mid-IR range.

The conducted research showed that the laser medium Fe:ZnSe possesses unique generation and amplifying properties and is capable to fill the lack of solid-state radiation sources in the range 3.7-5 um.