Formation and evolution of mid-IR femtosecond laser pulses (4-5 μm) in a mode-locked Fe:ZnSe laser cavity

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Annotation

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. 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.

The most practically interesting generation mode is the soliton formation mode inside the resonator. This work is devoted to computer modeling a femtosecond generator based on a Fe:ZnSe crystal with a central wavelength approximately equals 4.3 μm. This laser medium has a number of unique properties that distinguish it from other active media: high nonlinearity, long lifetime during cryogenic cooling, high gain saturation energy, low material dispersion near the generation wavelength. All these effects affect the formation of a soliton in a laser cavity.

In this work numerical simulation of the formation and propagation of ultrashort laser pulses of the mid-IR range was carried out (4-5 μm) in the laser cavity (active medium is Fe:ZnSe). The nonlinear Schrodinger equation describing the behavior of the pulse envelope was solved based on the split-step (Fourier) method. Passive mode locking was based on saturable absorption in graphene. To compensate for the dispersion, one used a dielectric plate (CaF_2) with an anomalous group velocity dispersion at the generation wavelengths. The dynamics of the generation output to the stationary mode is considered. It was found that the minimum pulse duration was achieved by overcompensating the dispersion of the resonator at -780 fs^2. It was also established that the insertion of a larger anomalous dispersion leads to a larger energy in the pulse, but also to a longer pulse, which is consistent with the soliton theorem. It was shown that it is possible to obtain a pulse with an energy of 14 nJ to 43 nJ and a duration of 90 fs to 65 fs as a result of absorber saturation intensity change in the range $5*10^5 – 5*10^8$ W/cm^2.