Direct broadband infrared generation from 12 to 35 THz with a Kerr-lens modelocked Cr:ZnS oscillator

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Broadband mid-infrared sources are demanded tools for spectroscopy in the molecular fingerprint region, potentially enabling detection of biomarkers for medical diseases via blood and breath analysis [1]. Spectroscopic methods like nano-FTIR or electro-optic sampling offer here broadband spectral coverage together with unique spatial resolution or high sensitivity and ultrafast temporal resolution [2,3]. These methods require high brightness and broadband infrared sources. Broadband pulses from Cr:ZnS lasers are an excellent choice for the relatively simple and robust process of intra-pulse difference frequency generation (IDFG) [4]. We present here mid-IR generation with a spectral coverage from 12 to 35 THz (9 – 25 µm) based on IDFG in a GaSe crystal with the pulses directly coming from a Kerr-lens modelocked (KLM) Cr:ZnS oscillator.

The developed KLM Cr:ZnS oscillator delivers pulses with a wavelength range from 2.1 to 2.5 µm (-10 dB), corresponding to a bandwidth of 23 THz. The spectrum supports a pulse duration of 37 fs (FWHM). FROG measurements of a similar oscillator configuration have confirmed pulse durations down to 36 fs. The oscillator runs at a repetition rate of 70 MHz and delivers an average power of 1.55 W, resulting in a pulse energy of 22 nJ and a peak power of 527 kW. The oscillator operates in negative dispersion regime with overall GDD and TOD compensated by dispersive mirrors. The OC mirror transmits 35 %. It is coated on a low dispersive CaF_2 substrate.

Mid-IR generation was already observable when the oscillator pulses are directly focused (f = 25 mm) into the nonlinear GaSe crystal. At wavelengths around 2 µm, GaSe exhibits an advantage of an increased damage threshold and a broader phase-matching bandwidth when compared to the standard wavelengths around 1 µm. Furthermore, GaSe shows transparency up to a wavelength of 20 µm. When employing a ca. 0.5 mm thick GaSe crystal, broadband mid-IR radiation was generated covering the range from 12 to 35 THz (9 – 25 µm) [s. Fig. 1 (a)]. The total mid-IR power lies in the range of several µW. When radiation from a similar oscillator with an average power of 1 W was amplified by a factor two and spectrally broadened in a simple single pass amplifier based on another 9 mm long Cr:ZnS crystal, the mid-IR power could be extended above 0.2 mW.

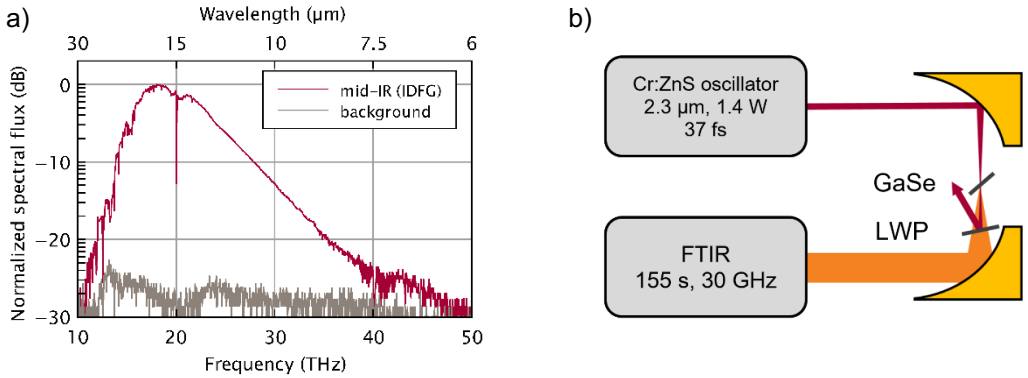

Figure 1. (a) FTIR-spectrum of the mid-IR radiation generated via intra-pulse difference frequency generation (IDFG) in GaSe directly from pulses of a Kerr-lens modelocked Cr:ZnS oscillator (red curve). The prominent absorption line of atmospheric CO_2 is appearing at 20 THz (15 µm) together with the weaker, neighboring R- and P-branches. The background was recorded after disturbing the modelocking operation (gray curve). The spectra were averaged from 50 scans recorded over a duration of 155 s. The spectral resolution of the measurements is 30 GHz. (b) Setup for direct mid-IR generation. The oscillator radiation was focused by an OAP mirror with a focal length of 25 mm into a ca. 0.5 thick GaSe crystal. Afterwards, it is separated by a longwave pass (LWP) filter with a cut-off at 3.6 µm. The generated mid-IR radiation was recorded with an FTIR spectrometer.

In summary, we have developed a KLM Cr:ZnS oscillator and generated directly broadband, coherent mid-IR radiation via IDFG in GaSe ranging from 12 to 35 THz (-20 dB). Due to the IDFG process, the radiation has an inherently stable carrier-envelope offset frequency and represents an excellent source for further spectroscopic studies based on electro-optic sampling.

References

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