Millijoule class far-infrared femtosecond laser at 10 μm

°Yuxi Fu *, Katsumi Midorikawa, Eiji J. Takahashi †

Attosecond Science Research Team, RAP, RIKEN, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan.

E-mail: *yxfu@riken.jp, †ejtak@riken.jp

Current ultrafast laser technology is experiencing a fast wavelength change from the near-infrared (NIR) to the mid-infrared (MIR) and even far-infrared (FIR) and THz. Such a trend is attributed to significant advantages of these laser wavelengths for applications in strong field laser physics [1,2]. In the FIR region, the reported energy with femtosecond pulse duration is limited to μJ level. In this paper, we employ a dual-chirped difference frequency generation (DC-DFG) [3] method to generate mJ-class MIR to FIR pulses with flexible tunability. At 10 μm wavelength, 1.16 mJ pulse energy is obtained.

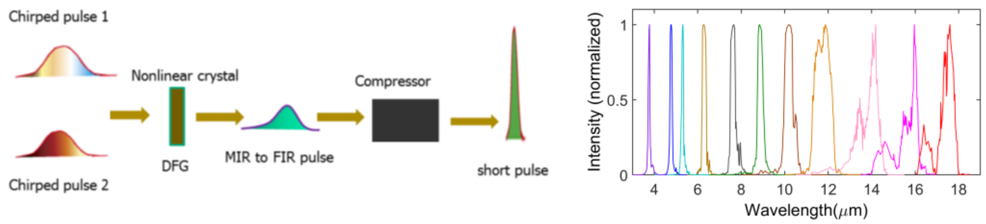

Fig. 1. (Left) Principle of DC-DFG. (Right) Output spectra by AGS (3-11 μm) and AGSe (11-18 μm).

Fig. 1(Left) shows the principle of DC-DFG. By temporally chirping two high-energy pulses, laser intensity on nonlinear crystal can be kept below the damage threshold. Thus, higher input energy pulses can be employed for DFG. In our experiment, 100-mJ-class infrared laser pulses (signal (1.2-1.6 μm) and idler (1.6-2.4 μm)) with their durations chirped to ~ 3.5 ps are generated by a collinear DC-OPA system [4-5]. These high energy IR pulses collinearly propagate to uncoated AGS (θ=33.7°) and AGSe (θ=54.3°) crystals generating 3-11 μm and 11-18 μm pulses through DC-DFG process, respectively. The spectra are free tunable as shown by Fig. 1(Right), which are characterized by a monochromator. At 10 μm, the maximum pulse energy is 1.16 mJ with a conversion efficiency of 2.3% under input energy of 49 mJ. Considering surface reflection loss from crystals, the conversion efficiency is 2.8%. The pulses will be compressed to near transform-limited (TL) duration of 130 fs (FWHM) using 76-mm-thick ZnSe bulks.

In summary, we generated 3-18 μm pulses byemploying DC-DFG method. At 10 μm (30 THz), the pulse energy reached 1.16 mJ at a conversion efficiency of 2.8 % with a TL duration of 130 fs (4 cycles). Further energy scaling is possible by increasing pumping energy. Such a laser source will be very helpful in high-order harmonics generation, attosecond pulse generation, electron acceleration and absorption spectroscopy.

[1] E. Takahashi *et al.*, Phys. Rev. Lett. **101**, 253901 (2008). **[2]** B. Wolter *et al.*, Phys. Rev. X **5**, 021034 (2015). **[3]** Y. Fu *et al.*, IEEE Photon. J. **9**, 1503108 (2017). **[4]** Y. Fu *et al.*, Opt. Lett. **40**, 5082 (2015). **[5]** Y. Fu *et al.*, Sci. Rep. **8**: 7692 (2018).