Efficient Generation of Terahertz Radiation at 800 nm Wavelength

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Abstract—**Highly efficient generation of strong-field terahertz (THz) pulses by using very short laser pulses ~30 fs has some challenges due to chromatic aberrations. Here, we demonstrate an optical-to-THz conversion efficiency of 0.2% using a 3 mJ pump pulse energy. This result paves the way for strong-field applications of THz radiation.**

Commercial Ti:sapphire laser systems delivering more than 20 mJ output pulse energy at the central wavelength of 800 nm with 150 fs pulse width is appropriate for table-top, compact terahertz (THz) sources [1]. The expected maximum THz output pulse energy can be scaled up to ~100 µJ, when employing optical rectification using tilted-pulse-fronts (TPF) and cryogenic cooling to mitigate THz absorption in the lithium niobate crystal. We have already demonstrated 0.2% optical-to-THz energy efficiency by using 150 fs Ti:sapphire laser pulses. In order to further scale up the THz output energy from the µJ to mJ-level, customized Ti:sapphire systems delivering J-level output pulse energy are promising. However, this kind of laser system has an extremely broadband infrared spectrum. When these ultrashort laser pulses (30 fs) are used for THz generation with the conventional TPF technique, there are several limitations [2]: (i) Effective interaction length for efficient THz generation will be shorter than longer pulses (150 fs). (ii) The diffracted optical beam from the grating will be expanded to an unmanageably large size due to the large bandwidth. (iii) Different spectral components will be imaged into different spatial volumes in the crystal.

We systematically investigate different imaging schemes including one concave mirror (f=-100-mm), two concave mirrors (f_1=-200 mm, f_2=-100 mm) and one bi-convex lens (f=60 mm) for THz generation using TPF in lithium niobate driven by 30 fs Ti:sapphire laser pulses. The best results of 6 µJ THz output energy, 0.2% optical-to-THz conversion efficiency with 20 MV/m electric field in lithium niobate at room temperature pumped at 3 mJ is achieved from the simplest scheme with one bi-convex lens as the imaging element, shown in Fig. 1 (a). As exhibited in Fig. 1 (b) and (c), the single-cycle THz pulse holds a peak frequency at 0.32 THz. The maintenance of 0.2% optical-to-THz efficiency from 150 fs to 30 fs is helpful for scaling up THz output energy from µJ to mJ-level when employing J-level ultrashort Ti:sapphiure laser pulses. Future work will be focused on cryogenic cooling of the generation crystal, improving out-coupling of the THz pulse at the interface of lithium niobate and air, newly designing the generation lithium niobate crystals, trying contact-grating method to make a linear generation geometry, and finally scaling up the output THz energy by impinging the generation crystal with J-level laser pulses for THz generation.

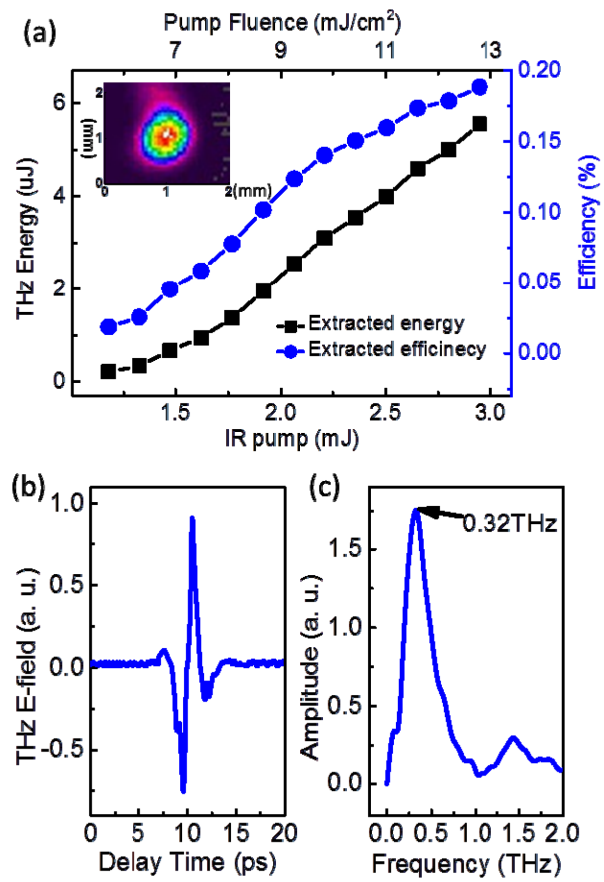

Fig.1. (a) Extracted THz output energy and corresponding conversion efficiency as a function of the pump energy. The inset shows the focused THz image. (b) THz temporal waveform and (c) its Fourier transformed spectrum.

References

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