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High efficient terahertz generation from two-color laser plasma

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Terahertz (THz) radiation from two-color laser mixing in gas has been intensively studied due to its intense broadband emission [1, 2]. In this scheme, a femtosecond laser pulse and its second harmonic pulse are co-focused to ionize a gas and create the plasma currents. Under the right phase difference between the two-color laser fields, the directional plasma current arises from non-sinusoidal electron oscillations in the laser field and it can emit THz radiation in the far field [2, 3]. In principle, THz radiation can be preferentially enhanced when driven by long wavelength pulses [4, 5].

In our studies, we experimentally demonstrate intense broadband THz generation with using mid-infrared two-color laser mixing in air. Our experiment was performed with an optical parametric chirped pulse amplification (OPCPA) laser capable of delivering 3.9 µm, 30 mJ, 80 fs pulses [6]. For the two-color laser pulse generation, we used a thin GaSe crystal to generate second harmonic pulse in our experiments. Here the energy ratio between two-color laser is measured to be 2%. In addition, a thin coverslip glass is placed after the GaSe crystal to control phase difference between the two-color laser fields.

The resulting THz pulses are characterized by a lab-built Michelson-type Fourier-transform infrared (FTIR) interferometer combined with a pyroelectric detector as shown in Fig. 1(a). The measured THz field autocorrelation (insert) and corresponding spectra obtained by the Fast Fourier Transformation (FFT) are shown with two different initial phases of 0.4π (blue line) and 0.9π (red line), which yield minimal and maximal THz geneation, respectively. Note that the absolute phase difference between two-color fields at the plasma region is different from the initial phase by -0.4π. Therefore, the minimal/maximal THz yield occurred at the absolute phase difference of 0 and 0.5π, respectively, consistent with the plasma current model [2]. We also note that the broadbnad THz radiation peaks at 12 THz with a 30 THz bandwidth as shown in Fig. 1(a).

The output THz energy rapidly increases with the laser energy as shown in Fig. 1(b). At the laser energy of 2.1 mJ, the peak THz conversion efficiency reaches ~1%, about 10~100 times larger than conventional values obtained with 800 nm lasers. Note that figure 1(b) shows THz conversion efficiency as a function of the laser energy measured just before the lens (dotted line) and estimated after the coverslip (solid line). We believe that the efficiency can be enhanced further with more efficient SHG, otherwise only 2% SHG in our experiments. With other previous measurements [4, 7], our experiments show a wavelength-dependent scaling of $\lambda^{2.6}$ for the THz conversion efficiency as shown in Fig. 1(c)

In conclusion, we experimentally observed high efficient THz generation from mid-infrared two-color mixing in air. This type of THz source can potentially produce broadband, millijoule-level THz radiation, which is useful for THz-driven nonlinear experiments.

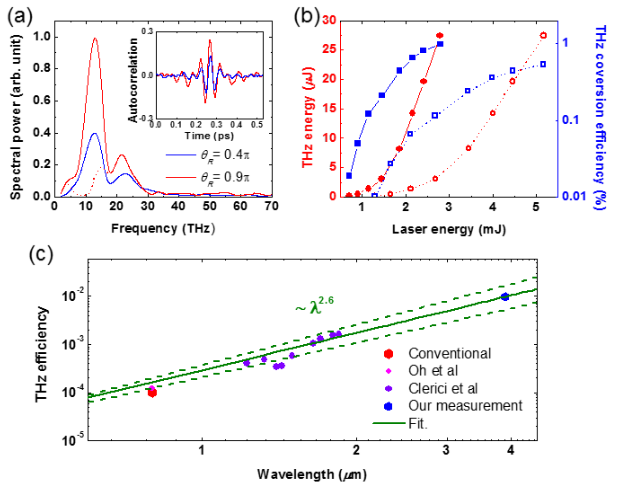

Figure 1. (a) Measured THz field autocorrelations (insert) and THz spectrum at two different initial phases of 0.4π (blue line) and 0.9π (red line). (b) THz output energy (red line) and corresponding laser-to-THz conversion efficiency (blue line) as a function of the laser energy. (c) THz generation efficiency as a function of the fundamental laser wavelength in the two-color mixing scheme.

References

[1] D. J. Cook and R. M. Hochstrasser, Opt. Lett. **25**, 1210 (2000)
[2] K. Y. Kim *et al*., Nat. Photonics **2**, 605 (2008)
[3] F. Brunel, J. Opt. Soc. Am. B. **7**, 521 (1990)
[4] M. Clerici *et al*., Phys. Rev. Lett. **110**, 253901 (2013)
[5] D. G. Jang *et al*., Optica **6**, 1338 (2019)
[6] D. Woodbury *et al*., Opt. Lett. **43**, 1131 (2018)
[7] T. I. Oh et al., Appl. Phys. Lett. **105**, 041103 (2014)