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Intense tunable terahertz bursts from picosecond laser-foil interactions

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An ever-increasing number of strong-field applications like ultrafast coherent control over matter require high-power and tunable driver light pulses. The realization of such a source in the terahertz (THz) band has long been a formidable challenge. To date none of THz sources reported, whether based upon large-scale accelerators or high-power lasers, have produced THz pulses with energies above the millijoule level. The combination of the readily available ultra-intense lasers and the damage-free plasma medium makes relativistic laser-plasma interactions be a promising approach toward producing strong THz radiation. Nevertheless, the underlying THz generation mechanisms are still not well understood, and it remains an open question whether such a powerful THz source is tunable in spectrum.

Here, we report on the highly efficient generation of THz bursts with pulse energies up to tens of millijoules, by a high-intensity ps laser pulse irradiating a metal foil. To our knowledge, this is the highest THz pulse energy and peak power reported in laboratory so far (Fig. 1). The THz spectra can be manipulated effectively over a broad band range by tuning the laser pulse duration or target size. A general theoretical framework is established that well reproduces the experimental results. Such an extreme THz source will open up new avenues for nonlinear THz field–matter interactions, compact particle accelerators, and multidimensional pump-probe experiments. The unprecedentedly high peak power could enable a fully new paradigm of relativistic optics in the THz regime. Furthermore, the THz radiation can serve as a unique laser-plasma diagnostic. The measured THz spectra have been employed in turn to quantitatively diagnose the escaping electrons and transient ion acceleration sheath, in good agreement with experimental measurements.

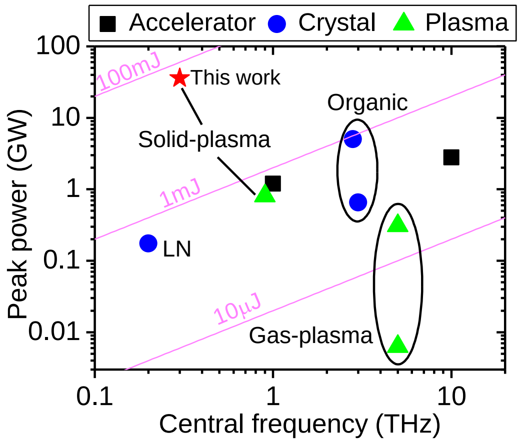

Figure 1. Comparison of currently available high-peak-power THz sources. The data are referenced from previously reported typical results of THz sources based on conventional accelerators, optical rectification from crystals like lithium niobate (LN) and organic crystals, and gas /solid-density plasmas. The red star represents the data presented in our work. Magenta curves represent different energy ranges for half-cycle THz pulses.

References

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