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Ultraintense laser-driven terahertz radiation from plasmas

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Terahertz (THz) radiation, broadly defined as the electromagnetic waves in the frequency range from 0.1 to 30 THz, has attracted considerable attention and interest over the past decades, due to its promising applications in a wide range of fields such as materials, chemistry, biomedicine, communications and security. One of the key challenges in THz science is to produce high-power THz radiation. Along with the rapid progress of ultrafast electronics and laser technology, a variety of schemes for the generation of high-peak-power THz radiation have been demonstrated, based upon whether conventional accelerators or ultrafast lasers. Due to the inherent huge Coulomb repulsion among electrons, the compromise between the electron bunch charge and bunch duration makes it difficult to enhance the THz energy in accelerators. For the nonlinear optical methods, the most direct way to enhance the THz yield is to increase the crystal size while increasing the pump laser energy, since the crystals will be damaged at a high pump laser intensity. Hurdles in the growth of large-size high-quality crystals and the inherent multiphoton absorption effect of crystals limit the potential of higher energy output in crystal-based THz sources. By contrast, laser-produced plasmas offer a damage-free medium for the generation of intense THz radiation. The THz generation from two-color laser-induced plasma filaments in air has been studied extensively, and it is found that, the THz yield tends to get saturated at the pump laser intensities exceeding ~10^{15} W/cm^2. At present, the available focused laser peak intensity in laboratories can be far above 10^{18} W/cm^2, *i.e.*, at a so-called relativistic level. Besides, solids have a much higher electron density and thereby a stronger laser absorption than gases. In this perspective, ultraintense laser interactions with solid targets (high-density plasmas) offer an alternative promising approach toward generating intense THz radiation.[1]

The THz radiation generated from ultraintense laser-irradiated solid targets has been studied systematically. In terms of THz generation mechanisms, the laser-excited plasma waves and the lase-accelerated energetic electrons have been demonstrated and clarified to be responsible for THz generation under different laser and plasma parameters.[2, 3] At the irradiation of high-intensity laser pulses on a foil target, intense THz pulses are observed to be emitted from the target rear surface. Experiments and theoretical modeling clarify that, the THz burst is originated mainly from the transient emission as a result of laser-accelerated energetic electrons crossing the target rear surface and the subsequent sheath acceleration of ions. By optimizing the laser-target configurations, the laser-to-THz energy conversion efficiency can be boosted up to ~1%, and extreme THz radiation with GW~TW peak power has been obtained experimentally.[4,5] Several techniques for single-shot ultrabroadband THz waveform and spectrum detection are developed, based upon the spectrally or spatially encoded electro-optic sampling and the autocorrelation methods. With these characterization techniques, it is found that, the THz waveform and spectrum can be manipulated effectively by tuning the laser or target parameters. Widely tunable THz radiation has been demonstrated.

The applications of such extreme THz radiation have also been explored initially. By employing single-shot THz metrology, the THz radiation enables an *in-situ*, real-time diagnostic for the ultrafast dynamics of laser-accelerated fast electrons.[6] Besides, the intense THz radiation can also be applied as a unique pump for the ultrafast control over matter, like the strong-field THz-induced ultrafast structural phase transition. GW-TW THz radiation also enables the sub-cycle, long-wavelength strong-field physics, in which distinct behaviors or features from the conventional near-infrared cases could appear.

References

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