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Extreme terahertz bursts from relativistic laser-plasma interactions

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The electromagnetic waves in the spectral coverage ranging from 100 GHz to 30 THz, routinely named terahertz (THz) waves, have been attracting a constantly increasing interest of research over last decades, due to their promising applications in a wide range of fields such as physics, chemistry, biology, communication, and security. One of the key issues for applications is to produce high-power THz radiation sources. A variety of schemes for THz generation have been demonstrated, based upon whether conventional accelerators or ultrafast lasers. For the nonlinear optical methods, high-quality large-size crystals are required to increase the THz energy output without damaging the crystal at a high pump laser intensity. High-charge ultrashort electron bunches are essential for the electron accelerators-based THz sources. By contrast, plasma as a THz generation medium circumvents the issue of optical damage, and ultraintense laser pulses can accelerate from plasmas a large amount of electrons of an ultrashort duration. In this perspective, ultraintense laser-plasma interactions offer an alternative promising approach toward generating intense THz radiation [1].

We have studied systematically the THz generation from solid targets irradiated by laser pulses at relativistic intensities (>10^{18} W/cm^2). THz generation scenarios under different laser and plasma parameters are investigated, in which the THz property is characterized and the underlying generation physics is explored [2].

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, at a laser-to-THz energy conversion efficiency of around 0.1%. The THz spectrum is tunable by varying the laser pulse duration or target size. 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 [3,4].

During laser propagation in a large-scale underdense plasma, large-amplitude plasma waves can be excited by the laser ponderomotive force, stimulated Raman scattering, or self-modulated instabilities. At an appropriate range of plasma density gradients, the plasma waves can be converted into a chirped radiation with a frequency close to the local plasma frequency through electrostatic-electromagnetic mode conversion, a reverse process of resonant absorption. For the plasma density lower than 10^{19} cm^{-3}, the mode-converted radiation falls in the THz regime below 30 THz. In the demonstrative experiment [5] where a large-scale underdense plasma is produced in front of solid targets with controlled prepulses, indeed, extremely broadband THz radiation is observed around the laser specular reflection direction, and there exists an optimal plasma density scale length for the THz generation.

By integration with other high-flux particles and radiation generated concomitantly in laser plasma interactions, the laser-plasma-based THz source enables a versatile pump-probe experimental platform. In addition, the THz radiation itself can also serve as an *in-situ* noninvasive diagnostic of laser plasmas [6].

References

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