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SP7: Laser Driven High Field Terahertz Sources for Compact Electron Acceleration

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A family of terahertz generation methods, unified by the common theme of enabling repeated (or cascaded) energy down-conversions of an infrared laser photon by nonlinear optical processes is introduced. The methods can enable laser-to-terahertz energy conversion efficiencies in the 10 % regime, which are two orders of magnitude larger than the current state of the art. Theoretical and record experimental results are highlighted. Such a class of terahertz sources holds promise to transform compact electron accelerator technology with broad implications ranging from electron diffraction to X-ray generation.

Summary

Sources of radiation in the frequency range of 0.1 to 1 Terahertz (THz) with simultaneously large acceleration gradients »100 Megavolts/meter (MV/m) and pulse energies (>10 millijoules) have attracted great interest as drivers of charged particle acceleration. Nestled between optical and radio-frequencies (RF), such sources combine the benefits of large wavelengths offered by RF sources with the large peak fields, achievable at optical frequencies. In particular, an optically driven terahertz source can help realize a low-jitter, compact, all-optical accelerator with excellent electron beam characteristics.
However, the key problem to be addressed is the relatively low energy conversion efficiency of current optically driven terahertz sources, which are in the range of 0.1 to 1% . This is due to the inherent quantum defect associated with generating a terahertz photon with only a thousandth of the energy of the infra-red pump photon. Insofar as the principle of repeated or cascaded energy down-conversion of the optical photon to create multiple terahertz photons has been proposed, no methods to actually harness this concept to surmount the quantum defect has been demonstrated or even theoretically conceived.
In the Ultrafast Optics and X-Rays Group at the Center for Free-Electron Laser Science, we have developed a family of methods which for the first time enable dramatic cascading to potentially achieve conversion efficiencies in the 10% regime for narrowband or many-cycle terahertz sources. Initial experiments are in agreement with these theoretical predictions. In addition, record experimental results in the area of broadband or single-cycle terahertz generation have been demonstrated. This body of work paves the way towards transforming instrumentation for fundamental scientific investigations, medical therapy and diagnostics.

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