Millijoule Terahertz Radiation from Laser Wakefields in Non-Uniform Plasmas

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Terahertz (THz) radiation with energy up to the millijoule level is essential for applications in THz nonlinear optics, electron acceleration and reshaping, and molecular dynamics. In 2005, it was proposed that high field THz emission could be generated from a laser wakefield in nonuniform plasma via linear mode conversion [1]. Up to now, there have been some limited efforts to test this theoretical proposal, partially due to the difficulty in collecting and detecting the radiation from backward direction. This report will give the first direct evidence of mode conversion from nonlinear electrostatic wave to electromagnetic radiation, which may open a new avenue towards tunable high-field terahertz sources for various applications. It may also provide a unique diagnosis of the laser wakfields.

In this talk, we report the experimental measurement of THz radiation emitted in the backward direction from laser wakefields driven by a femtosecond laser pulse of few joules interacting with a gas target. It is shown that the energy of the backscattered THz reaches the millijoule level, with the conversion efficiency up to 10^{-3}. The radiation is found to be radially polarized. By utilizing frequency-resolved energy measurement, it is found that the THz spectrum exhibits two peaks located at about 4.5 THz and 9.0 THz, respectively. In particular, the high frequency component emerges when the drive laser energy exceeds 1.26 J, at which electron acceleration in the forward direction is detected simultaneously. Theoretical analysis and particle-in-cell simulations indicate that the THz radiation is generated via mode conversion from the laser wakefields excited in plasma with an up-ramp profile, where radiations both at the local electron plasma frequency and its harmonics are produced. Such intense THz sources may find many applications in ultrafast science, e.g., manipulating the transient states of matter.

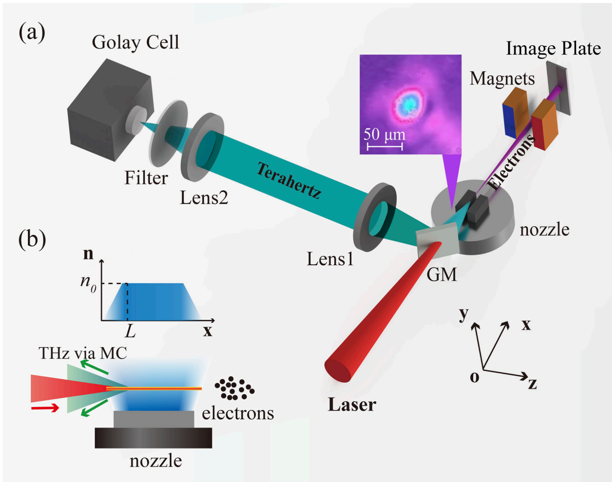

Figure 1. (a) Schematics of the experimental setup. The inset shows the image of the laser focal spot. (b) Schematic of the laser wakefield excitation and THz radiation in the nozzle, where the red arrow and green arrows show the laser injection direction and THz radiation direction, respectively. The inset shows the approximated gas density profile with an up-ramp length L. [2]

References
[1] Sheng et al., Phys. Rev. Lett. 94, 095003 (2005)
[2] Wang et al., Phys. Rev. Lett. 132, 165002 (2024)