Fs-laser-induced microplasmas as efficient broadband terahertz sources

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Terahertz (THz) sources are indispensable for various applications such as THz time-domain spectroscopy. A promising approach to generate broadband THz radiation is to employ laser-induced gas plasmas, which has already been demonstrated for various settings [1,2]. In order to miniaturize such sources, it has been proposed to exploit single-color laser-induced microplasmas [3]. Then, a conical THz emission is produced by longitudinal low-frequency currents driven by the ponderomotive force. However, the laser-to-THz conversion efficiency for this scenario has been shown to saturate for higher pulse energies to approximately 10⁻⁶ [4].



Fig. Plasma profile (blue), THz emission profile (green) from a two-color 0.17- μ J Gaussian laser pulses (20% energy in the SH, t0=50 fs) focused down to 0.8 μ m in argon at 1 bar (a) and corresponding THz spectrum (b). Conversion efficiency η THz and generated plasma charge Q when increasing the laser pulse energy Ep keeping the intensity in focus constant and thus increasing the beam width (c).

In order to increase the efficiency, we investigate the ionization current (IC) mechanism driven by two-color laser pulses [2] for microplasmas. Hereby, the temporal asymmetry of the driving pulse leads to THz emission and is achieved by admixing the second harmonic (SH) frequency to the laser pulse. Our numerical model is based on the fluid model developed in [4]. The two-color pump pulses have an energy range of $0.17 - 5.4 \mu$ J.

In the strongest focusing case presented in Fig. (a), the only 10-µm-long microplasma acts as a point-like source for THz wavelengths. The hole in its torus-shaped radiation profile is oriented as the THz generating current representing a valuable information about the THz generation process. The emitted broadband THz spectrum is presented in Fig. (b). It reaches from 1 THz to 50 THz, into the far-infrared region. The fluid model is justified by comparison with THz spectra obtained by the much more computationally costly particle-in-cell (PIC) simulations. A dramatic increase of the laser-to-THz conversion efficiency is presented in Fig. (c) when going to slightly higher laser pulse energies. Hereby, adjusting the focal beam width such that the gas is singly ionized in focus turned out to be essential for maximizing the efficiency such that unprecedented converison efficiencies of 10⁻⁴ for 10-µJ laser pulses can be predicted.

References

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