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Towards compact efficient fs-laser-induced THz sources from microplasmas

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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]. In order to increase the efficiency, we investigate theoretically [4] the ionization current mechanism driven by two-color laser pulses [2] for microplasmas.

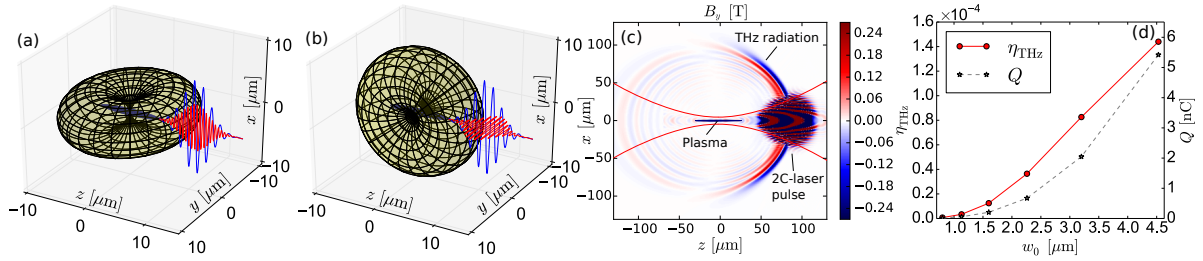


Fig. 1. Two-color μJ Gaussian laser pulses (20% energy in the SH, $t_0 = 50$ fs) are focused down to $w_0 = \lambda_{\text{FH}} = 0.8 \mu\text{m}$ in argon (1 bar). In (a) the SH electric field is parallelly polarized to the FH electric field, in (b) perpendicularly. Surfaces normal to the Poynting vector of the THz radiation (point source at $\mathbf{r} = 0$) are sketched in (a-b) (yellow surface) as well as the plasma (blue surface). In (c) an exemplary snapshot of B_y is displayed for weaker focusing and larger pulse energy leading to longer plasmas visualizing that THz waves are now mostly forward propagating. Laser pulses are propagating in positive z direction. In (d) the scaling of laser-to-THz conversion efficiency η_{THz} and final electron charge Q versus the focal beam width w_0 while keeping the peak intensity constant (increasing the laser pulse energy from $0.24 \mu\text{J}$ to $7.7 \mu\text{J}$) is presented.

In the strongest focusing case, the only $10\text{-}\mu\text{m}$ -long microplasma acts as a point-like source for THz wavelengths. Its torus-shaped radiation profile is sketched in Fig. 1 (a-b), where the fundamental harmonic (FH) and second harmonic (SH) electric fields are parallelly resp. perpendicularly polarized relative to each other. The polarization of the SH field with respect to the FH field determines the polarization of the THz radiation and the emission profile. Increasing the plasma length as illustrated in Fig. 1 (c) leads to a more forward directed THz emission, consistent with what one would expect when changing from a point to a line source. Such longer, forward emitting plasma produces an almost isotropic emission cone (not shown here). The total amount of the produced electron charge Q and thus potential THz emitters increases rapidly with w_0 , as depicted in Fig. 1 (d). This increase of the plasma volume is the main reason for the dramatic growth of the laser-to-THz conversion efficiency η_{THz} . Even for relatively low laser pulse energies below $10 \mu\text{J}$, the laser-to-THz conversion efficiency η_{THz} can exceed 10^{-4} . Thus, the two-color microplasma approach is competitive with schemes employing much larger two-color laser pulse energies. In contrast to single-color laser-induced microplasmas [3, 4], strongest focusing is not necessarily optimal and the size of the plasma volume is a key parameter that has to be optimized for a given laser pulse energy.

References

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