Terahertz radiation emission from laser-induced plasmas inside dielectrics

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Electromagnetic radiation in the terahertz ($10^{11} - 10^{13}$) frequency domain is particularly attractive for applications in remote sensing or in time-domain spectroscopy. The plasma is a promising medium to generate THz radiation. An ultrashort laser pulse can generate over-critical plasma inside dielectrics [1]. Here we show that the ponderomotive forces due to the intense resonantly driven fields at the critical surface are sufficient to create a large density difference between the ions and electrons which can lead to powerful THz radiation even at the moderate intensities that can be reached within the bulk of materials. The nonlinear current, in this case, can also lead to second-harmonic generation. In our experiments, a single 100 fs Bessel pulse at central wavelength 800 nm was focused inside transparent dielectrics at intensities of 10^{14} Wcm^{-2}, in conditions where over-critical plasma can be generated (diam. 200-500 nm). To reproduce the experiments, we performed simulations using the massively parallel EPOCH particle-in-cell (PIC) code [2].

Figure 1(a) shows the time evolution of the E_x component, parallel to the plasma density gradient, and the trajectory of a representative electron. There are intense ambipolar fields due to the induced pressure difference between the electrons and ions (dashed lines). An ejected electron from the resonance region follows an arc trajectory in the ambipolar fields with a period of around 100 fs. During this motion, it radiates in the THz frequencies. Panels 1(b-e) show the electric fields and intensity radiated by the electron during the arc between 186-219 fs. The THz radiation is polarized in the x direction as the second-harmonic in the far-field. The emission pattern corresponds with an electron having acceleration mainly in the x direction and velocity in the z direction.

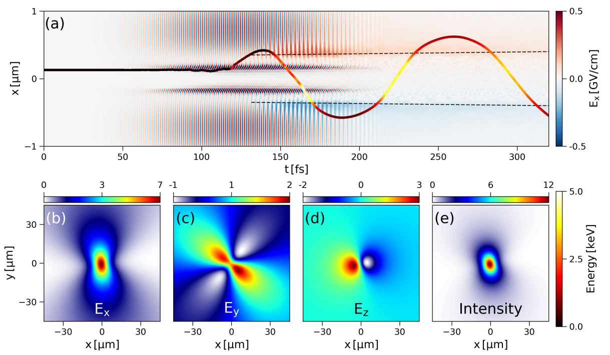

Figure 1: *Terahertz radiation from an electron trapped in the ambipolar electric fields.*

Using Bessel beams, it is possible to reach cm-scale over-critical plasmas inside solids which can be a promising candidate for generating THz radiation in the spectral range 1-30 THz.

References

[1] K. Ardaneh, R. Meyer, M. Hassan, *et al*, arXiv:2109.00803 [physics.plasm-ph], (2021)

[2] T. D. Arber, K. Bennett, C. S. Brady, *et al*, Plasma Phys. Control Fusion. **57**, 113001 (2015)