Particle-in-cell simulations of THz emission from a plasma by oblique-collision of two electron beams

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A promising way for generating a powerful electromagnetic radiation in THz range by using electron beams rather than short laser pulses, because electron beam is able to transfer more energy into the plasma oscillations, which can enhance the efficiency compared to laser-based scheme. The experimental studies on beam-plasma system were carried at GOL-3 facility[1], Russia, and obtained a significant enhancement in radiation efficiency of THz wave about ~1% of the electron beam power, when plasma transverse size comparable to the radiation wavelength. These results are explained by the theoretical model of beam-driven plasma antenna[2], according to which, the radiation at the plasma frequency is possible if plasma density has longitudinal density modulation. In another approach, the counter-propagating electron beams injection into the plasma leads to enhancement in electromagnetic emission near second-harmonic of the plasma frequency, as seen by Annenkov et al.[3-4] in their particle-in-cell (PIC) simulations. Here, we study the possibility of generating a high-power THz radiation in a plasma by oblique-collision of two electron beams propagating in opposite direction to each other, and how the radiation at second-harmonic of plasma frequency affects with different the angle of their collisions. In the previous simulation studies, people have considered only head-on-collision of electron beams, and nobody has consider their collision at angle and its effect before.

Our 2D-PIC simulations shows that for oblique-collision of low-density electron beams with different transverse profiles, show that a strong THz emission is obtained at second-harmonic of plasma frequency with a narrow spectral-width in vacuum side. Fig. 1(a) shows the snapshot of z-component of magnetic field B_z, one can see that, interaction region of obliquely-colliding-beams (d_{b1}=400μm and d_{b2}= 300μm), emits the radiation in all direction, however, the angle of strong emission appears to be higher or close to collision angle of both beams in vacuum. The Fourier transform of magnetic field gives a strong peak at the second-harmonic and a small peak at third-harmonic of plasma frequency, but does not have a fundamental peak in vacuum [Fig. 1(b)]. The radiated power increases with increasing the collision angle, at $\Theta_{collision}=20^o$, it is increased about 2.5 times compared with head-on-collision [Fig. 1(c)], and the efficiency of beams to THz power conversion is reached around ~ 0.0725. We also noted that the interaction region in the oblique-collision case begins to emit the radiation in earlier time compared to the head-on-collision case.

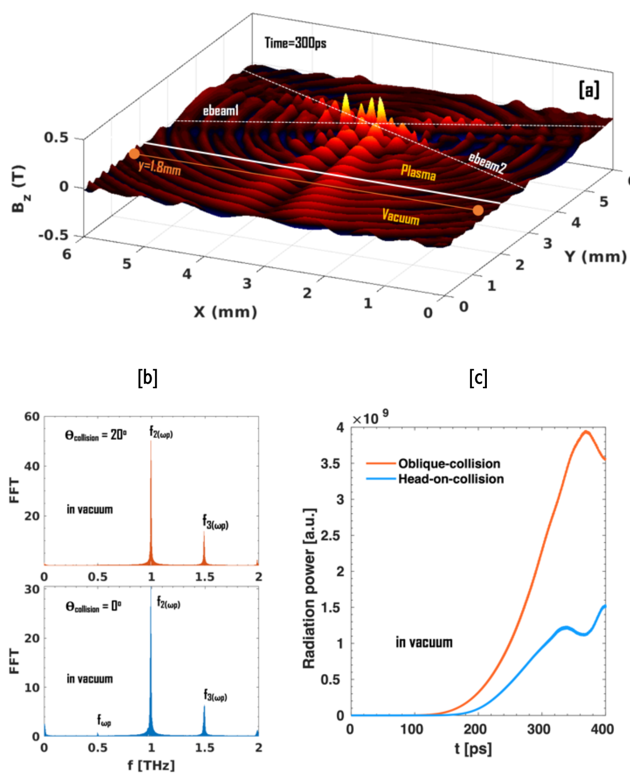

Figure 1. (a) Snapshot of z-component of magnetic field B_z (in Tesla) excited by the colliding beams in a plasma at the time t=300ps for angle $\theta_{collision}=20^0$ (oblique-collision), for both cases (b) frequency spectrum of magnetic field in vacuum (c) temporal dependence of radiated power (averaged over the radiation period) in vacuum, which is measured by a probe-line at y=1.8mm and integrating it over x_1=0.0mm and x_2=6.0mm.

References:

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