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On possibility to improve the positron acceleration at the rear surface of target irradiated by intensive short laser pulse.

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The PM2D code is used for simulation of relativistic electron-positron plasma generated at the irradiation of target by laser light with relativistic intensities. There are presented results of the PM2D code simulations performed with aims to increase a mean energy and brightness of positron jets that could be formed near rear target. The calculations have demonstrated the possibility of significant improvement of positron jet acceleration by means of target design configuring (www.vniitf.ru/events/2003/zst/files/section3.pdf).

Introduction

The relativistic positrons generation for the first time was registered in experiments [1] conducted at LLNL Petawatt laser (laser energy E_L = 200-500 J, pulse duration $\tau_L \approx 0{,}6$ ps, wavelength λ =1,06 μm). In LLNL Petawatt laser experiments up to 50 % laser energy was converted to energy of relativistic electrons with effective temperature T_-= 3-6 MeV, that agreed well with expected theoretical values at intensity above 10^{20} W/cm^2 [2]. The observed positrons yield was consistent with electron-positron pair's production by Bremsstrahlung photons in 125 μm Au targets [1,3]. However, the positron experimental spectra indicate to availability of additional accelerating processes of positrons. This additional acceleration lead to formation of positrons energy distribution with the effective positron temperature T_+ closed to the electron temperature T_-= 3-6 MeV [1].

The dynamics of relativistic electron - positron plasma arising at the backside of the foil that irradiated by picosecond laser light at super-high intensity (10^{19}-10^{20} W /cm^2) was studied with using of the PM2D code developed at RFNC-VNIITF [4]. This 2D-code based on PIC method for calculation of relativistic charged particles movement and the explicit difference scheme for solution of Maxwell equations in the cylindrical coordinate system. The PM2D code simulation [5] of the positrons acceleration and the electron-positron jet formation in self-consistent electromagnetic fields are consistent well with experimental data obtained at the LLNL Petawatt Laser [1].

The results of the PM2D code simulations performed with aims of investigation of the possibility to increase a mean energy and brightness of positron jets, which could be formed near rear target surface, are discussed below.

The simulation of electro-positron jets dynamics near the rear side of foil target varied configuration

The PM2D code simulations were performed for the last stage of the total process – escaping charged particles from the rear side of the target. The principle physics model includes 2D relativistic movement of electrons and positrons in couple with Maxwell's equations. Whereas we omit the stage of particles transport throw target matter – the region of fast particles generation is assumed as an isotropic point-like source placed at various depth in a target. While not leaving the plain of target (Z=0) electrons and positrons are move on a straight line with the constant energy received at the source. Their intersections of the plain Z=0 provide us the surface's source with the desirable angular and energy distribution. The particles returning to the target are destroyed.

In calculation there was supposed the birth of 10^{14} electrons and 10^{10} positrons per one laser pulse. The positron and electron spectra at source is assumed in form: $dn_{\mp}/d\varepsilon \propto \exp(-\varepsilon/T_{\mp})$, where $T_{\mp}$ is effective temperature of the fast electrons and positrons. The electron temperature at source defined from [2] by: $T_- = mc^2\left((1+0{,}7q_L)^{1/2}-1\right)$, where q_L — laser intensity in 10^{18} W/cm^2. The positron effective temperature is assumed equal to: $T_+ = T_-/3$. The temporal dependence of laser intensity q_L is assumed in form of isosceles triangle with the base 1 ps and maximum of $4\cdot10^{20}$ W/cm^2. The novel feature (after [5]) was the modification of model source to tight matching with experimental data [1]. The shifting their source in the target at larger depth simulated the positrons output delay in time that would be caused by real processes of the positron generation and diffusion through 125 μm Au targets [1,3]. Such effect is demonstrated here at Fig.1. At the left side there is a spectrum of the particles that reach detector plain (900 μm) for the case of coinciding points of birth ($z_e = z_p = -100\mu m$). Blue markers are electrons, red – positron, experimental data [1] are marked by stars. At the right side is the same for the shifted positron source ($z_e = -100\mu m, z_p = -300\mu m$) that modeling of positron time delay about of 1 ps.

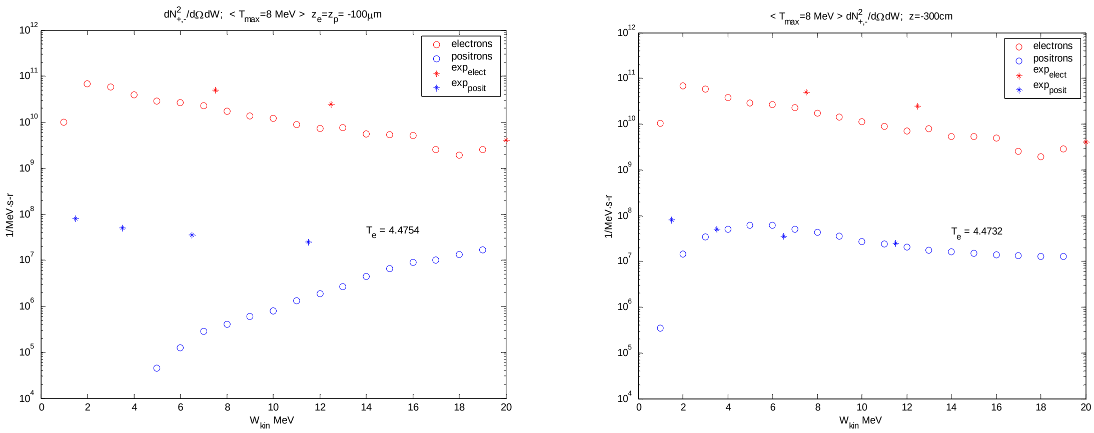

Fig.1. The experimental and calculated electron and positron spectra.

In our positron acceleration mechanism investigations we conclude that the main role has the ambipolar potential of the large amount of escaped electrons. Fig.2 demonstrates the near-spherical spray of both components with the visible fillets at the axis. At the left side there are shown isodensity of the electrons and positrons whereas at the right side are placed maps of their kinetic energy at the same moment.

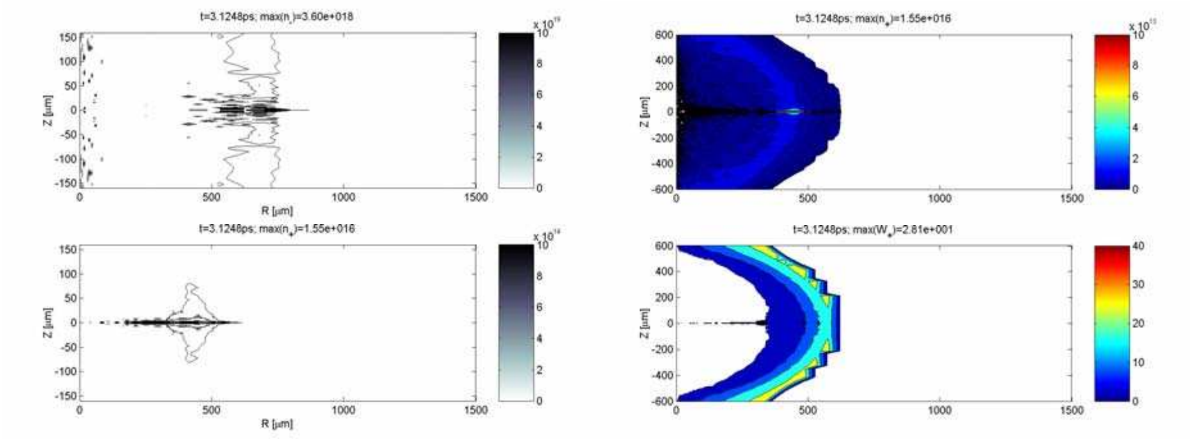

Fig.2 The PM2D simulation results for plain target.

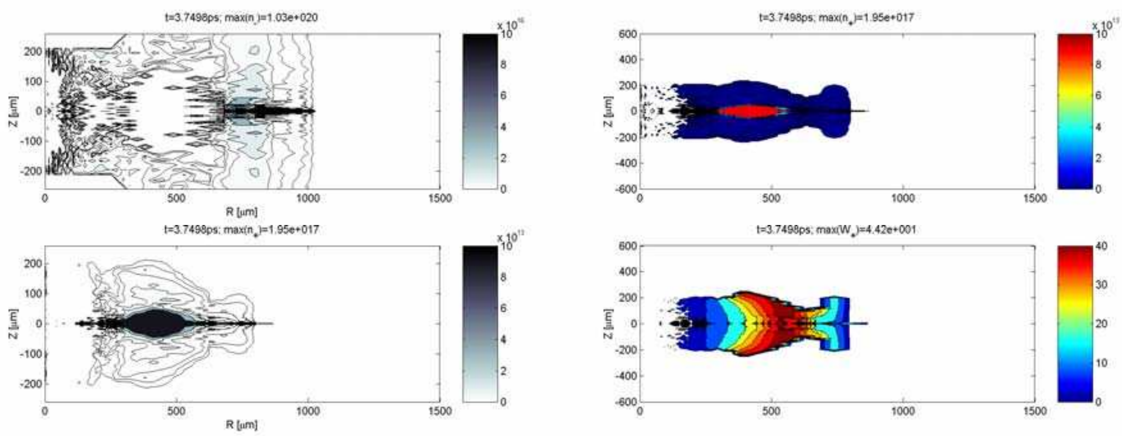

Fig.3. The PM2D simulation results for the cylindrical waveguide.

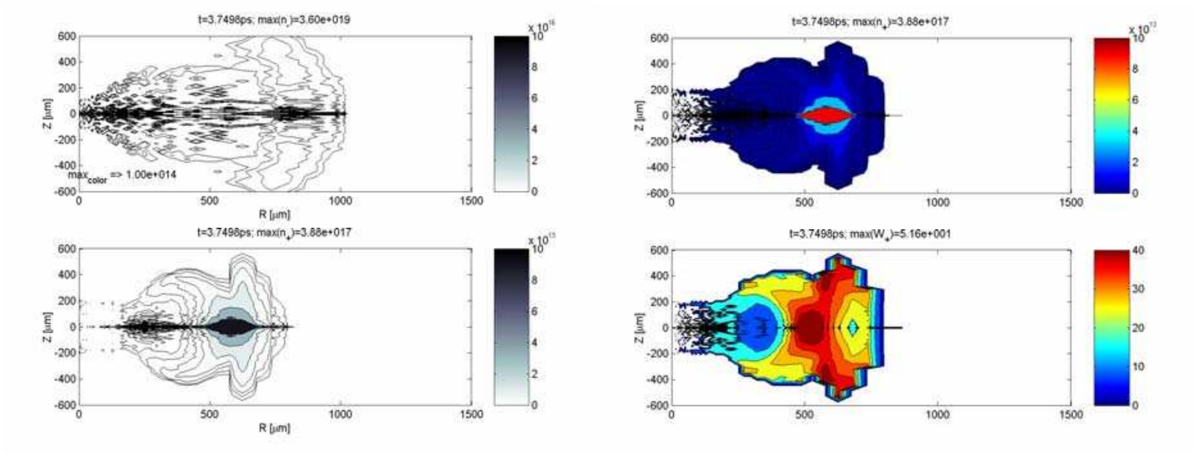

Fig.4 The PM2D simulation results for the cone waveguide.

In order to improve the positrons acceleration we examine some forms of waveguide. There are considered the cylindrical and cone waveguides with various depth and width of hole. The isodensity and isoenergy dynamic for cylindrical case (hole with r=200 mkm, h=250 mkm in ideal conductor) are presented at Fig.3. The similar pictures for the cone waveguide are presented at Fig.4 (from r=200mkm there is an expanded cone surface with the angle 45^0). The calculation demonstrated possibility to increase mean energy of the positron jet from 4 up to 19 MeV by using target shape with cylindrical hole, and up to 40 MeV – in case of cone hole in massive target.

Conclusions

The PM2D simulations have demonstrated the possibility of significant improvement of positron jet acceleration by means of target design configuring. It would be interested make theoretical and experimental investigation of the possibility to enhance the ion acceleration near rear surface of the same target design irradiated by intensive short laser pulses.

References

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