HOT ELECTRONS AND OPTICAL HARMONICS GENERATION IN THE RELATIVISTIC LASER-PLASMA INTERACTION: EXPERIMENTAL AND NUMERICAL STUDY

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The electron bunches with high energy and charge may be generated in low dense plasma via different mechanisms of laser acceleration. In this paper we present the numerical simulations of the possibility of generation MeV electrons at an intensity around 10^{18} W/cm^2 in an near-critical long pre-plasma.

In our experiments we used Ti:Sapphire laser system (wave length – 800nm, repetition rate – 10Hz, maximal pulse energy – 30mJ, minimal pulse duration – 45±5fs and maximal intensity on target – $5\cdot10^{18}$W/cm^2 , contrast on ps time scale - 10^{-8}.). The laser radiation was focused obliquely by the off-axis parabolic mirror (F~5cm) onto the metal or plastic target. To create pre-plasma layer on the target surface we use Nd:YAG laser (wavelength –1064nm, repetition rate – 10Hz, maximal pulse energy – 200mJ, pulse duration – about 6 ns and maximal intensity on target – 10^{12}W/cm^2). Varying delay between the main pulse and the pre-pulse in the range from -50 ns to 10 ns and type of the target we can change pre-plasma properties significantly. Bremsstrahlung from hot plasma was detected by scintillation detector based on NaI crystal (1 to 7 cm thick). To assess high energy gamma quanta flux the photonuclear g(D,p)n reaction in secondary D_2O target was used. The fiber spectrometers were used to measure the plasma emission in visible and infrared ranges at different angles.

We made interaction simulations using the fully relativistic 3D3V PIC code "Mandor," reduced to the 2D3V within most of the our calculations. The simulation box size was 31 mkm (x) × 14mkm (y), spatial resolution was $\lambda/100$ and total number of particles was 10^8. Temporal resolution was 3×10^{-3} fs. The planar foil target consisting of cold ions and electrons. A p-polarized laser pulse with duration of 50 fs (FWHM) and central wavelength of 1 mkm entered the simulation box. Varying the laser pulse intensity (10^{17}-10^{19} W/cm^2), the initial electron density scale length (0.1-100 λ) and incident angle (15^0-75^0) we found the dependences of the hot electrons and optical harmonics yield on these parameters.

Experiments with different pre-plasma parameters were conducted. In experiments with single fs pulse and metal target temperature was around 200 keV. When we introduce the ns pre-pulse we observe both increase (up to 0.9 MeV) and decrease of X-ray yield under different time delays between ns and fs pulses. Analysis of the electromagnetic fields and electron density spatial and temporal distributions from simulation revealed that hot electrons are generated due to the breaking of plasma waves. At the plasma scale length ~1-5λ (it is the most interesting for out experiments range) there are two mechanisms of plasma wave excitation in obliquely incident interaction, appropriate for hot electrons generation: two plasmon decay instability (TPD) and charge separation near the turning surface. Both processes lead to generation of the optical harmonics: $3\omega_0/2$ and $\omega_0/2$ for the scattering of the fundamental on TPD waves and $2\omega_0$ for the turning surface waves. Also it is shown that at specific preplasma parameters interaction intensity can be decreased by ionization defocusing, appreciably lowering the hot electron energy.