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DIAGNOSTICS OF LASER-INDUCED SPARK DISCHARGES IN AIR AND VACUUM

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Generation of extremely stable light bullets in a pre-formed plasma near critical density had been observed experimentally during interaction of intense picosecond laser beam (100 mJ pulse energy, 100 ps pulse duration) with a metallic target in air [1]. Optical probing measurements indicated the formation of pulsating channels, typically of about 5 μm in diameter, directed towards to a heating laser beam, as well as of disconnected massive plasma blocks moving also towards to the laser beam. The velocities of the dense plasma blocks reached the values of $4.5\mathrm{x}10^{8}$ cm/s. The blocks were stable during their acceleration and propagation in air. Also self-generated magnetic fields up to 4-7 MG were observed by means of the Faraday rotation of a probe laser beam The mechanism of magnetic field generation was concluded to be due to resonance absorption occurring near the shock wave front in the skin layer.

We produced a time integrated measurements of magnetic field values, so an exposure time for Faraday – rotation measurements consisted only 100 ps (duration of probe beam). Theory predicts the growth of dc magnetic fields due to resonance absorption by approximately rate of 6 MG/psec. Therefore, a nonstationary magnetic and electric fields in very thin layers in front of shock waves may be more higher as determinate in our experiments. Detailed numerical calculation based on 2D-magneto-hydrodynamical model have been performed for concrete experimental conditions. As well as in [2] we used the mathematical model ZEVS which has been generalized on a case of laser beam interaction with a solid targets (Al, W). This model is based on the following system of equations of magneto-hydrodynamics:

$$\partial \rho/\partial t + div\,(\rho\mathbf{u}) = 0\,;\ \rho\partial\,\mathbf{u}/\partial t = -\,grad\,P + [\mathbf{j}\times\mathbf{B}]/c\,;$$

$$\rho\partial\,\varepsilon_e/\partial t = -P_e\,div\,\mathbf{u} - div\,W_e + G_j - G_e + Q_{ei}\,;\ \rho\partial\,\varepsilon_i/\partial t = -P_i\,div\,\mathbf{u} - div\,W_i - Q_{ei}\,;$$

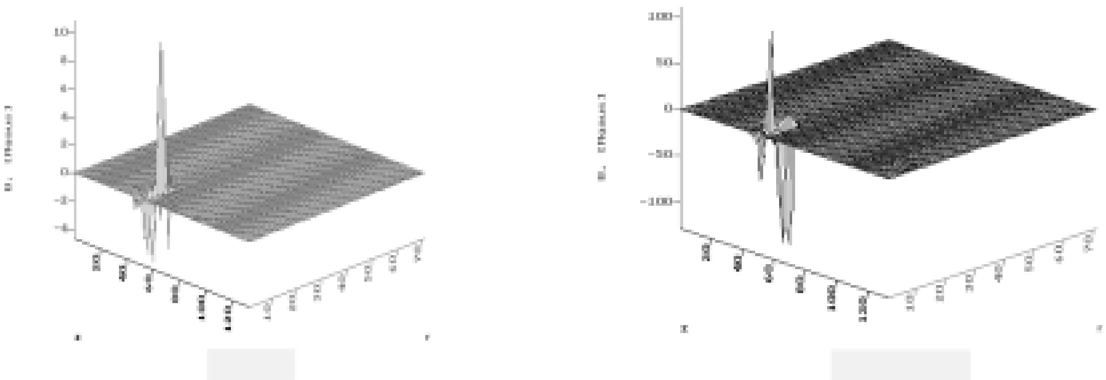
$$rot\,\mathbf{B} = (4\,\pi/c)\,\mathbf{j}\,;\ rot\,\mathbf{E} = -(1/c)\,\partial\,\mathbf{B}/\partial t\,;$$

$$div\,\mathbf{B} = 0\,;\ \mathbf{j}/\sigma = \mathbf{E}^{*} + \zeta\,\nabla T_e;\ \mathbf{E}^{*} = \mathbf{E} + [\mathbf{uB}]/c;\ P = P_e\,(\rho,T_e) + P_i\,(\rho,T_i)\,;$$

$G_e = G_{rad} + G_s(\rho, T_e, \boldsymbol{B}, t)$; $G_j = \boldsymbol{j}\, \boldsymbol{E}^*$; $\boldsymbol{W}_{e,i} = - \kappa_{e,i}\, grad\, T_{e,i}$.

Here ρ - density of matter, ε - specific internal energy, P - hydro-dynamical pressure of matter, $P_{e,i}$- electron and ion pressures, **u**- mass velocity, **B** - inductance of magnetic field, **E** - tension of electric field, **j**- density of current, $W_{e,i}$- electron and ion heat fluxes, $\kappa_{e,i}$ - coefficients of thermal conductivity, $T_{e,i}$ - electron and ion temperatures, $Q_{e,i}$ - term of exchange energy between electrons and ions, G_e- electron effluence (influx) of heat due to emission (absorption) of effluence's (sources) of heat and etc. , ζ - tensor of specific thermo-electromotive force (its determination see, for example, in [2]), σ - electrical conductivity. The term $\zeta\, \nabla T_e$ plays very principal and important role in our problem. The algorithm [3] for calculations of radiative energy exchange in pulse magnetic accelerating plasma have been used in present paper. We take into account 3 possible angels for radiation transfer with dividing of radiation spectra in a few groups (up to 20 groups, so in corresponding calculations processes of radiation transfer we solved a 5 dimensional problem: in r,z - geometry, with 3 angles, and few groups in spectra radiation). Some other details of calculation method are described in [2].

Our computer simulation shows that in laser - produced plasma (in vacuum as well as in different gas atmosphere) it is possible to obtain the conditions for soliton-like behavior of strong magnetic field. Fig.1 illustrates an examples of evolution of spatial distributions of



a) b)

Fig.1 Spatial distribution of magnetic field in laser-produced plasma for a) – pre-pulse with laser beam intensity of 2.54 10^{11} W/cm^2 and b) – for main pulse with maximum intensity I_{20} = 6.35 10^{13} W/cm^2.

Due to plasma configuration produced by pre-pulse and following heating beam it was possible to create a magnetic anvil in front of shock waves. In this case an enormous energy input in very thin plasma layer occurs. In following we tried to detect an accelerated particles from laser-produced plasma in air atmosphere and in vacuum, and used a plastic nuclear detector CR-39. We wait to register typical tracks for highly accelerated ions for comparison.

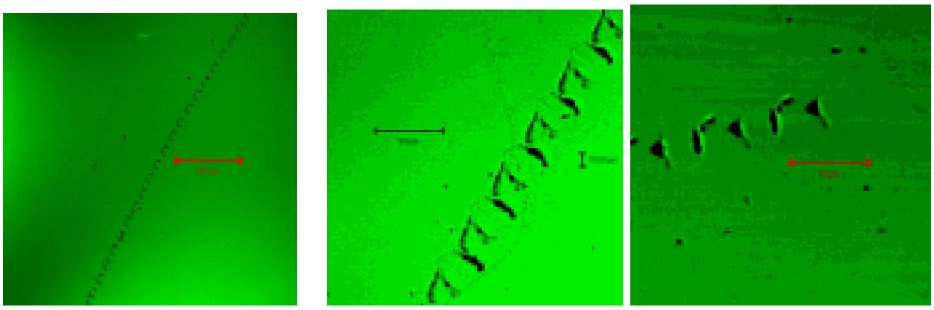
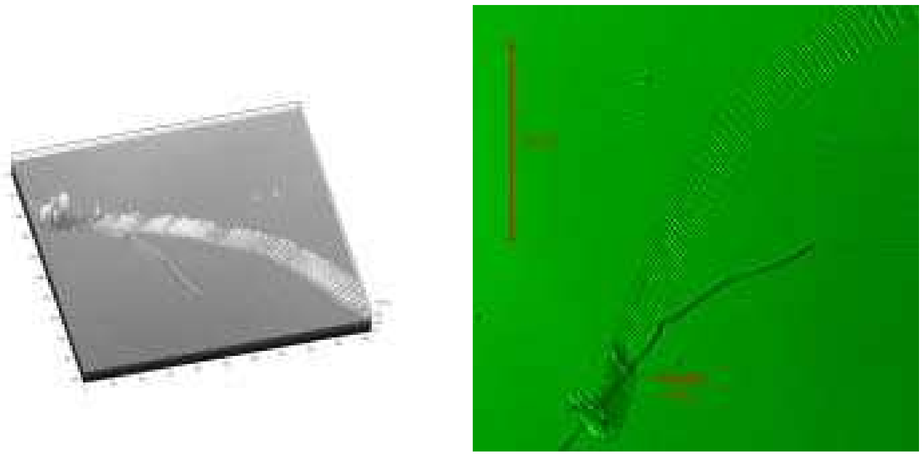


Fig. 2. Laser scanning microscope images of caterpillar track on plastic detector CR-39 without etching.

But first experiments have shown, that without etching a number of long caterpillar tracks and circle-like tracks were visible on the surface of detector. Fig.2 represents these kinds of tracks without etching. After etching in 6N NaOH solution we can detect spiral-like tracks, which are presented in Fig.3.

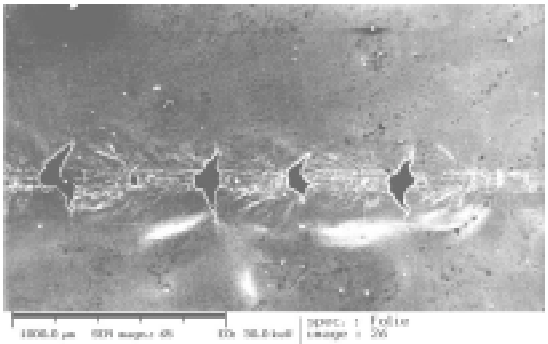


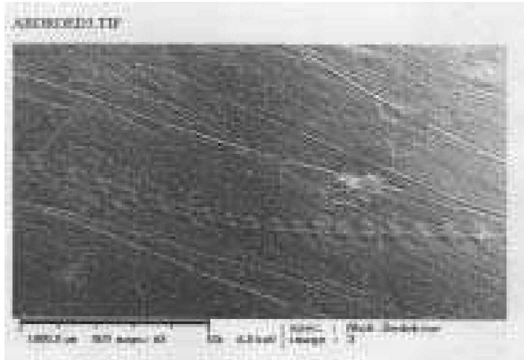
a) b)

Fig.3 . Laser scanning microscope images of tracks on CR-39 detector after etching.

Caterpillar tracks were also registered on the metallic surface. Massive blocks of foil material were removed along the tracks. Fig.4 illustrates the tracks from “quasi-particle” on the surface of semiconductor x-ray detector and 50 µm thick Al-foil.

An interaction of „quasi-particles“ with a thin layer of carbon, which was placed between two plates of plastic detector, causes a formation of long transparent and some times blue, rose-red, green-colored fibers, as well as crystals. Low energy electron diffraction measurements by means of TEM have shown an amorphous structure for fibers and diamond structure with a = 0.356 nm for crystals. Irradiation of fibers and crystals by monochromatic wave length (488nm, 543nm) shows an intensive photoluminescence in red wave length.





a) b)

Fig.4. REM images of surface of a)Al-foil and b)sputtered imprint of x-ray detector surface.

Additionally REM measurements have been performed on single fibers and crystals. They show the fine structure in fibers, which are composed of some interlaced thin filaments and a typical cubic hexagonal or simple cubic structure for crystals. The hole diameter of fibers are closed to typical diameter of tracks detected on nuclear detector and fine structure in them is similar to structure in tracks.

Together all facts: enormous concentration of magnetic field energy in small volume for short time, energy deposition in tracks, form of tracks, as well a presence of such a track on metallic surface, production of diamond and long polymer fiber, which preeminently can be created in very strong magnetic field, force us to assume, that so named "quasi-particle" must be Dirak's monopol and must have an essentially electromagnetic nature - mass $m_p \approx 2\ 10^{-36}$ g, and magnetic charge $\mu_p \leq$ 100- 200 CGSE charge .

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