Characterization of Filamented Relativistic Electron Beams from Laser-Plasma-Interaction with Cerenkov Radiation ◇

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The interaction of intense ultrashort laser pulses (ATLAS-10, 0.6 J, 160 fs, 10^{19}W/cm^2) with solids generates electron beams with relativistic energies in the MeV range. Such beams have important applications in the fast igniter concept for laser fusion. Theory and experiments have shown that in a solid or a dense plasma a return current is established which cancels the azimuthal magnetic fields accompanying the primary laser driven current and allows propagation of currents exceeding the Alfven limit ($I_{Alfven} = 17.5 \cdot \beta\gamma$ [kA]).

However, propagation of intense currents in high-density material turns out to be more complex. Due to the two-stream Weibel instability the beam decays into filaments which later-on merge into a single structure, propagation of which is inhibited by the collective fields. This 'anomalous stopping' leads to strong heating of the solid material which may be used to advantage in the fast igniter concept. This physical picture has emerged from detailed PIC simulations [1] and first measurements are presented. We investigate the propagation of laser-generated electron beams in solids by means of Cerenkov-radiation [2]. Behind the target the electron beam is passed into a transparent thin medium ($50\mu m$) and the visible emission is recorded by means of a gated detector (CCD).

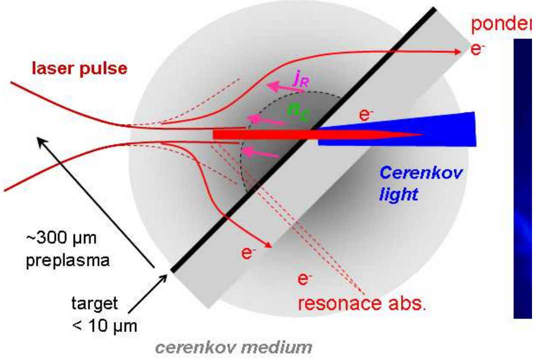

Fig. 1: Left: ATLAS-10 laser pulse focused under an angle of 45° onto the target, accelerating electrons in laser direction ponderomotively and perpendicular to the target surface due to resonance absorption. Right: Experimental result with 5 μm aluminum target and 50 μm Tesa-film as Cerenkov medium. Filamented distribution of 2 concentric rings and a dominating central peak (saturated).

Spatially resolving the Cerenkov emission we find filamented structures of beams arriving at the rear side of target foils up to a thickness of 10 μm. The filaments are arranged approximately in concentric ring structures around the beam center. The diameters of the filaments correspond to the density profile of the preplasma, beginning in an underdense condition (10^{19}cm^{-3}) increasing to the critical density $n_C \approx 10^{21}$cm^{-3} and up to solid density. The typical size of these filaments scales as $l_S \sim c/\omega_P \sim \lambda_L/(2\pi) \cdot \sqrt{n_C/n_0}$ where c is the speed of light, ω_P is the plasma-frequency, λ_L laser wavelength ≈ 800 nm and n_0 the background-density of the plasma, leading to $l_S > 10\mu m$ in the underdense preplasmas [3]. By varying the ASE-prepulse delay the influence of the preplasma size and density can be studied. With larger target thicknesses ($> 10\mu m$) filamentation phenomena disappear or cannot be resolved anymore, and two relatively broad spots are observed, reflecting the acceleration mechanism of resonance absorption and the ponderomotive potential [4].

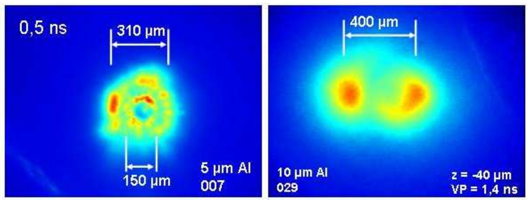

Fig. 2: Left: typical filamented ring structure with aluminum thicknesses up to $10\mu m$. Right: 2 Peak-distribution of the electron currents with Al-thicknesses of $10\mu m$ up to $200\mu m$ due to the acceleration mechanisms.

When the filamented electron beam propagates through solid targets the coalescence of the filaments leads to anomalous stopping and within $10\mu m$ of aluminum the number of detected electrons decreases by one order of magnitude. The breakdown of the corresponding current to values close to the Alfven-Limit cannot be explained by the classical Bethe-Bloch stopping.

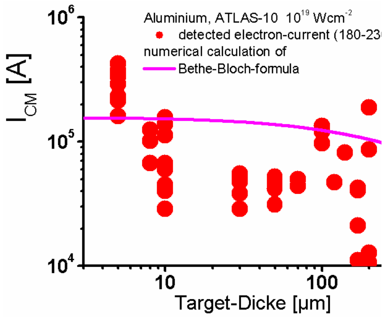

Fig. 3: The electron current detected in the energy range of 180-230 keV over the target thickness, containing 10% of all the electrons accelerated by the laser pulse.

In further studies the effect of anomalous stopping will be investigated with targets of different densities and thicknesses.

References

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