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

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In the interaction of intense ultrashort laser pulses with solids electron beams are formed and accelerated to highly relativistic energies. In a dense plasma a return current is established that allows the propagation of currents clearly exceeding the Alfven limit ($I_{Alfven} = 17.5\beta\gamma\,\mathrm{kA}$). However, owing to the two opposite currents accompanied by strong magnetic fields the situation becomes unstable leading to filamentation (Weibel instability). The temporal development of such a filamentation is shown in Fig. 1, where the result of a hybrid-code simulation is presented [1]. On a later stage, these filaments are expected to again merge into a single structure [2], propagation of which is inhibited by the pinching effect of the huge self generated magnetic fields. This "anomalous stopping" is expected to lead to strong heating of the material [3].

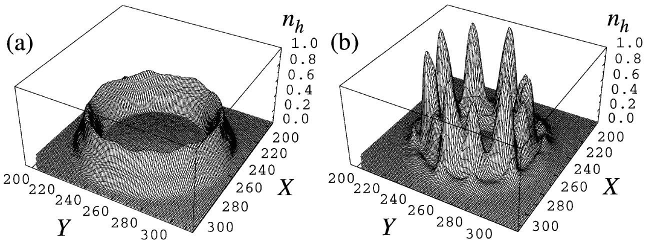


Fig. 1: The simulation [1] treats a massive cylindrical electron beam propagating into an overdense plasma. The beam first transforms into an annular beam which in the following decays into filaments along rings. The simulation uses a hybrid PIC/fluid code for the description of the hot and cold electrons, respectively.

Here, the investigation of the propagation of laser-generated electron beams in a solid is performed by means of the spatial detection of the Cerenkov-radiation emitted when the electron beam passes through a thin Cerenkov medium [4] behind the original target. The setup is sketched in Fig. 2. Targets (Al-foil and Polypropylene-foil) of varying thickness (up to 50 $\mu$m) were used.

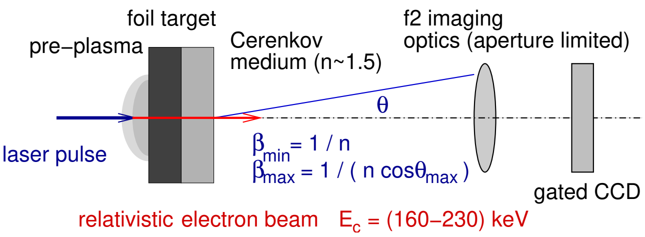


Fig. 2: Experimental setup: relativistic electrons are generated with the ATLAS laser (0.6 J, 160 fs, $10^{19}\mathrm{W/cm^2}$) irradiating thin foils. Cerenkov radiation is emitted in a second foil ($n \approx 1.5$) and imaged onto a CCD camera. The aperture of the imaging system has to be adopted to the Cerenkov angle for a energy of interest.

By the variation of the ASE-prepulse delay (and the target material) the influence of the pre-plasma size and density can be studied. Different structures have thereby been observed under different conditions similar to the ones in Fig. 1. A ring, filamentation, and rings of filaments are demonstrated in Fig. 3. As the typical size of these filaments scales as

$$l \sim \frac{c}{\omega_p} \sim \frac{\lambda_l}{2\pi}\sqrt{\frac{n_{crit}}{n_e}}\,, \qquad (1)$$

a length of $l \approx 0.1\mu$m is expected for a laser wavelength of $\lambda_l \approx 800\,\mathrm{nm}$ and a critical density of $n_{crit} \approx 10^{21}\,1/\mathrm{cm}^3$. Thus the observed structures point to a rather low density region where the filamentation occurs (possibly also some enlargement takes place), most likely to the pre-plasma region in front of the thin target.

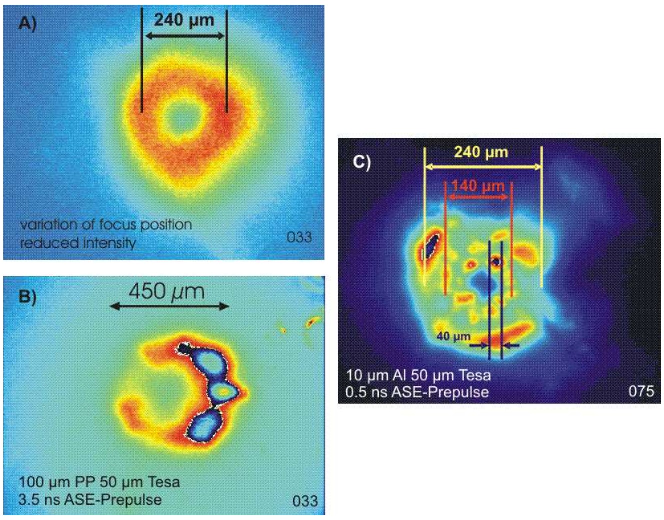


Fig. 3: Images of electron beams passing through the Cerenkov medium. From A-C the situation is further developed.

The growth rate of the process scales with $\gamma_{gr} \sim \sqrt{n_{beam}/n_e}$ and thus the stage of the process can be adjusted via the pre-plasma density and the strength of the electron current. At present, systematic variations of these parameters are performed for the quantitative understanding of the process while the images in Fig. 3 have to be regarded as samples.

In further studies propagation of electron beams in low-density foam targets will be investigated. In this material the effect of anomalous stopping should be enhanced since the growth rate of the instability is maximized.

## References

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