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Relativistic electron physics in ultrahigh intensity laser plasma interactions

G. Ravindra Kumar[1,*], Amit D. Lad[1], M. Shaikh[1], K. Jana[1], S.Tata[1], Deep Sarkar[1], J. Jha[1], G. Chatterjee[1], P. K. Singh[1], I. Dey[1], G. Birindelli[2], K. Pepitone[3], S. Sengupta[4], V.T. Tikhonchuk[2], P.P. Rajeev[5], P. K. Kaw[4,#], and Amita Das[4]

[1] Tata Institute of Fundamental Research, [2] Centre Lasers Intenses et Applications, University of Bordeaux-CNRS-CEA, [3] CERN, Beam Department (BE), [4] Institute for Plasma Research, [5] Central Laser Facility, Rutherford Appleton Laboratory, [#]Deceased

*e-mail : grk@tifr.res.in

We address one of the most important problems of high energy density science namely, the transport of relativistic, mega-ampere, femtosecond electron pulses through dense matter (solids) (G. Chatterjee, et al. 2017; S. Mondal et al. 2012; A. Das et al. 2017; M. Shaikh, et al., 2018). We review the progress made so far and present our recent experimental and theoretical studies of the instabilities that the transport experiences, the creation and turbulent evolution of giant magnetic fields (G. Chatterjee, et al. 2017; S. Mondal et al. 2012; A. Das et al. 2017) and the ultrafast mapping of the electron transport (M. Shaikh, et al., 2018) by monitoring emission created by these electrons, employing picosecond time gates.

To understand complex transport of electron currents, we measured the spatio-temporal evolution of the magnetic fields at the rear side of the thin dielectric (fused silica), plastic (mylar), and metal (aluminium) foil, targets of various thickness. A *p*-polarized high contrast (of 10^{-9}) ultra-intense laser (UIL) of 25 *fs* pulse duration at central wavelength 800 nm with 1.0 J energy is focused with an *f*/3 off axis parabolic mirror to a 10 µm spot at near normal angle of incidence (≤5˚) resulting an intensity ~ 4×10^{19} W/cm^2. We observed the magnetic field rises to 100's of mega-gauss during first few picoseconds [Fig. 1 (a)] and decreases thereby. We will also discuss the turbulence in such ultra-intense laser induced plasma and thereby their astrophysical relevance. We also present analytical and simulation results to explain the phenomena (A. Das et al. 2017).

In the UIL-solid interaction studies Cherenkov radiation provides unique imprint of energy of hot, relativistic electrons. Here we also show that, the measurement of Cherenkov radiation lifetime can provide unique signature of lifespan these electrons inside the transparent solid target. By temporally resolving the Cherenkov emission (M. Shaikh, et al., 2018), we are now able to track the lifetime of relativistic electrons inside the solid. We demonstrate that the electrons remain relativistic as long as 50 ps [Fig. 1 (b)] – more than 1000 times longer than the incident light pulse (25 fs).

We will attempt to foresee where these studies may be headed.

References

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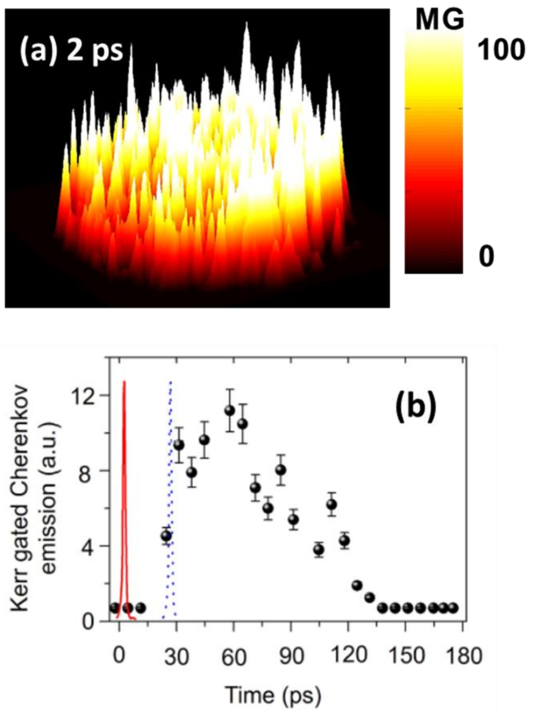

Figure 1. (a) Space and time resolved magnetic field at rear side of 5 µm thick Al-foil; (b) gated lifetime of Cherenkov emission in 5 mm thick Al-coated BK7 glass. The red curve indicates time *t* = 0. The blue curve indicates the arrival of main laser pulse at Kerr cell.