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Energy distribution of laser coupled cluster electrons in an ambient magnetic field

Kalyani Swain[1,2,*], Mrityunjay Kundu[1,2]

[1]Institute for Plasma Research, Bhat, Gandhinagar, India-382 428
[2]Homi Bhabha National Institute, Anushaktinagar, Mumbai, India-400094
[*]kalyani.swain@ipr.res.in

The study of atomic clusters (a nanometric form of matter) interacting with intense lasers has emerged as a promising research area in strong field physics. One of the important features of atomic cluster is to produce energetic charge particles and photons on effective coupling with intense laser. Studies reveal that atomic-clusters, with locally high atom densities resembling those in solids, absorb 80-90% of laser energy compared to laser-solid and laser-atomic gas interactions. Despite the fact that numerous experiments have shown energetic electrons with intensity $>10^{16}$ W/cm^2 for 780–800nm wavelength (laser absorption is mostly collision-less in this regime) and various mechanisms have been proposed through analytical models and numerical simulations to support experiments, there is limited understanding on the maximum energy that an electron can gain (on an average) for a given set of laser and cluster parameters [1]. Also the effect of the laser magnetic field (B_l), which is weaker than the laser electric field by a factor of inverse light speed, is frequently ignored in theories and simulations of laser-cluster interaction (LCI). Our recent studies [2] on LCI with an external magnetic field (B_0) in crossed orientation in addition to B_l demonstrate that for both in a rigid sphere model (RSM) and a three dimensional particle-in-cell (PIC) simulation, the collision-less laser energy absorption occurs in two stages via anharmonic resonance (AHR) and electron cyclotron resonance (ECR) or relativistic ECR (RECR) processes. Coupling of laser to cluster electron in auxiliary B_0 enhances the average absorbed energy per cluster electron (E_A) up to 30-70 times of ponderomotive energy (U_p). Fig.1 discusses a PIC simulation instance where the solid line comprises B_0 = 0.057a.u. (~13.3 kilo Tesla) and displays E_A = 38 U_p whereas the dotted line represents E_A for B_0=0 demonstrates essentially negligible absorption. Consequently, it is important to know how such a large amount of energy is transferred. In the current study, we report the dispersion of this significant amount of energy by examining the angular distribution of the cluster electrons. The energy histograms provided in Figs.2(a) and 2(b) correspond to the cases of Fig.1 (B_0 = 0 and B_0 = 0.057a.u., respectively). Also note that a significant portion of electrons radiate at a restricted polar angle as shown in Fig.3(a) and Fig.3(b). The electron emission becomes more directed [as in 3(b)] and contains a greater number of energetic electrons as the cluster size grows (not presented here), resulting a collimated electron beam. This study is significant because an intense, collimated electron beam has wide applications, including ion acceleration, the fast ignition technique for inertial confinement fusion, and ultra-short x-ray sources.

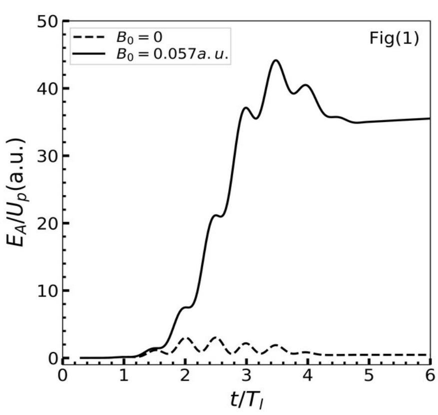
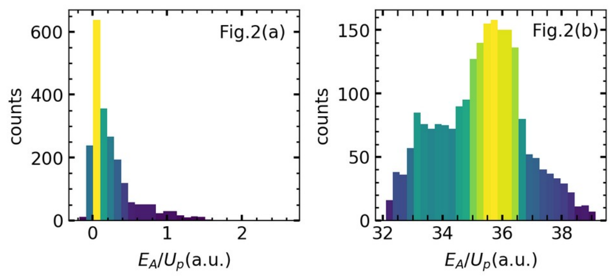
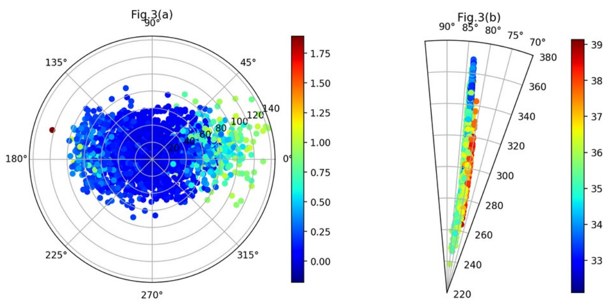


Fig.1: E_A in case of PIC simulation for a deuterium cluster with laser intensity =7.13×10^{16} W/cm^2, wavelength = 800 nm.





References:

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