§6. Attosecond Photon and Electron Beams from Relativistic Laser Plasma Interactions

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Advancing optical and electron beam technology toward the attosecond regime has opened the avenues of a novel ultra-fast science, in particular, as sub-disciplines of atomic, molecular and solid-state physics and real-time chemistry [1-3]. Here, first, we focus on attosecond photon pulse generation based on a reflection of a femtosecond optical pulse from a relativistic electron beam plasma. While most of the proposed schemes for attosecond light pulses require nonlinear high harmonics generation in ultra-relativistic intensity laser-plasmas, our model is based on a linear reflection, which allows a low energy laser. Moreover, we are able to perform analytics of a linear time-dependent transient EM wave problem. Using Lorentz transformations, covariance of Maxwell's equations and the principle of phase invariance we transform between the laboratory (rest) frame and the relativistic moving electron frame, to readily calculate before transforming results back to the laboratory frame [2, 4]. Analytical formulae for obliquely reflected pulse, predict temporal compression and reflected intensity amplification, by the parameters of 2γ and $4\gamma^2$, respectively; where γ- is the relativistic Lorentz factor of the electron plasma. Further, we can test the feasibility by relativistic particle-in-cell (PIC) simulations. As in many applications single attosecond pulse is preferred, we take a half-cycle cosine laser pump. Good agreement between PIC data and analytical results is found [4], which predicts, e.g., for NIR laser light reflected from 5 MeV ($\gamma \sim 10$) electron beam at a critical density, pulse compression to 50 attosecond (Figs 1-2). Further, some ideas for proposing a proof-of principle experiments have been considered.

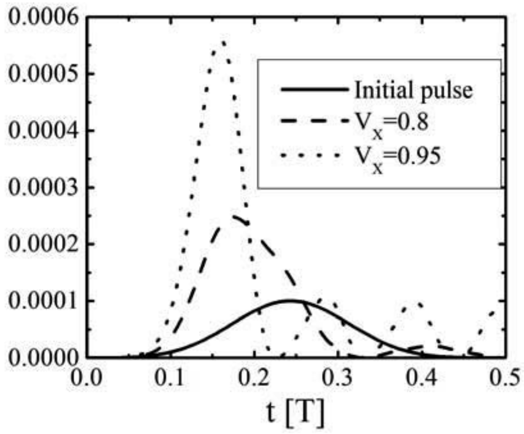

Fig.1. Intensity of the laser pulse reflected from a relativistic electrons from 2D PIC data [4], shows temporal compression (T-laser period) and pulse amplification [2].

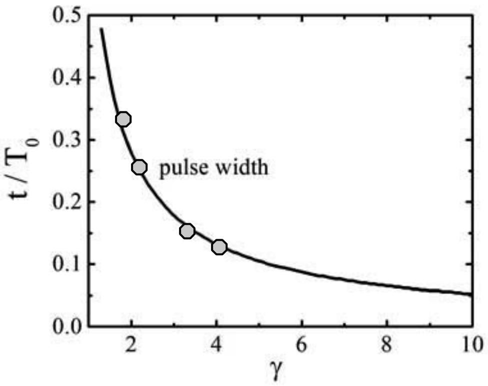

Fig. 2. Agreement between analytics and PIC (circles) for pulse compression as a function of relativistic γ-factor [2,4].

Second, we turn to 2D particle simulations of relativistic-intensity laser interaction with hollow cone-shaped overdense plasma targets, typically designed for fast ignition schemes in laser fusion. We focus on generation and transport of energetic electrons [3] by examining different targets configurations. It is found that relativistic laser interaction with an open cone target apart from high harmonic generation of reflected light can efficiently generate a train of attosecond relativistic electron bunches (> 10 MeV) in the direction of laser propagation (Fig. 3), separated in space by λ/2. The beam angular spread and collimation properties are discussed for target parameters.

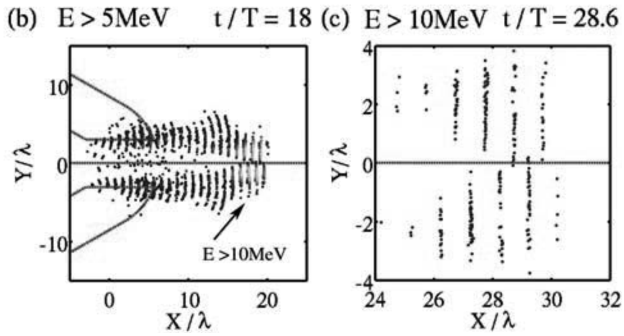

Fig.3. Relativistic attosecond electron bunches in space for b) E > 5MeV at t/T=18 and c) close view of a train of electron sheaths (E.10 Mev) at t/T=28.6, from PIC data [4].

1. P.B. Corkum and F. Krausz, Nature Physics 3, 381-387 (2007).
2. M.M. Škorić, B. Stanić, Lj. Hadzievski and Lj. Nikolić, J. Plasma Phys. 75, 111-115 (2009).
3. Lj. Nikolić, M.M. Škorić, S. Ishiguro, F. Vidal and T. Johnston, J. of Phys. Conf. Ser. 112 022086 (2009).
4. M.M. Škorić, Lj. Nikolić, S. Ishiguro, invited talk at the ITCPS 2011, Lisboa (Portugal)