DPP13-2013-000212

Abstract for an Invited Paper
for the DPP13 Meeting of
the American Physical Society

Relativistically Induced Transparency Acceleration (RITA) - laser-plasma accelerated quasi-monoenergetic GeV ion-beams with existing lasers?[1]

AAKASH A. SAHAI, Department of Electrical Engineering, Duke University, Durham, NC 27708 USA

Laser-plasma ion accelerators have the potential to produce beams with unprecedented characteristics of ultra-short bunch lengths (100s of fs) and high bunch-charge (10^{10} particles) over acceleration length of about 100 microns. However, creating and controlling mono-energetic bunches while accelerating to high-energies has been a challenge. If high-energy mono-energetic beams can be demonstrated with minimal post-processing, laser (ω_0)-plasma (ω_{pe}) ion accelerators may be used in a wide-range of applications such as cancer hadron-therapy, medical isotope production, neutron generation, radiography and high-energy density science. Here we demonstrate using analysis and simulations that using relativistic intensity laser-pulses and heavy-ion ($M_i \times m_e$) targets doped with a proton (or light-ion) species ($m_p \times m_e$) of trace density (at least an order of magnitude below the cold critical density) we can scale up the energy of quasi-mono-energetically accelerated proton (or light-ion) beams while controlling their energy, charge and energy spectrum. This is achieved by controlling the laser propagation into an overdense ($\omega_0 < \omega_{pe}^{\gamma\simeq 1}$) increasing plasma density gradient by incrementally inducing relativistic electron quiver and thereby rendering them transparent to the laser while the heavy-ions are immobile. Ions do not directly interact with ultra-short laser that is much shorter in duration than their characteristic time-scale ($\tau_p \ll \sqrt{m_p}/\omega_0 \ll \sqrt{M_i}/\omega_0$). For a rising laser intensity envelope, increasing relativistic quiver controls laser propagation beyond the cold critical density. For increasing plasma density ($\omega_{pe}^2(x)$), laser penetrates into higher density and is shielded, stopped and reflected where $\omega_{pe}^2(x)/\gamma(x,t) = \omega_0^2$. In addition to the laser quivering the electrons, it also ponderomotively drives ($F_p \propto \frac{1}{\gamma}\nabla_z a^2$) them forward longitudinally, creating a constriction of snowplowed e^-s. The resulting longitudinal e^--displacement from laser's push is controlled by the electrostatic space-charge pull by the immobile background ions. In the rest-frame of the laser, the electrostatic-potential that the ions create to balance the ponderomotive force on e^-s, scales as the effective vector potential, a_{plasma}. This potential hill, due to snowplowed e^-s, co-propagating with the rising laser can reflect protons and light-ions (Relativistically Induced Transparency Acceleration, RITA). Desired proton or light-ion energies can be achieved by controlling the velocity of the snowplow, which is shown to scale inversely with the rise-time of the laser (higher energies for shorter pulses) and directly with the scale-length of the plasma density gradient. Similar acceleration can be produced by controlling the increase of the laser frequency (Chirp Induced Transparency Acceleration, ChITA). References - ChITA - A. A. Sahai, T. C. Katsouleas, et. al., Proton acceleration by a relativistic laser frequency-chirp driven plasma snowplow, WEPPD059, Proceedings of IPAC 2012, May 2012, New Orleans, Louisiana, USA. RITA - A. A. Sahai, T. C. Katsouleas, et. al., Proton acceleration by trapping in a relativistic laser driven uphill plasma snowplow, MOP081, Proceedings of 2011 Particle Accelerator Conference, March 2011, New York, NY, USA.

[1]Work supported by the National Science Foundation under NSF- PHY-0936278. Also, NSF-PHY-0936266 and NSF-PHY-