Direct Electron Acceleration by Radially Polarized Ultra-Intense Laser Focus During Ionization of High Charge States of Neon

Nour El Houda Hissi[1]*, Gregory K. Ngirmang[2] and Enam A. Chowdhury[1]

[1] *Department of Material Sciences and Engineering, The Ohio State University, Columbus, Ohio, 43210, USA*
[2] *National Academies of Sciences, Engineering, and Medicine Fellow Extreme Light Group, Air Force Research Laboratory, Dayton, Ohio, 45433, USA*

**hissi.1@osu.edu*

Abstract: We investigate direct acceleration of electrons produced during ionization of Neon gas using a tightly focused and radially polarized Petawatt-class short pulse lasers. Gigaelectron volt (GeV) energies are reached at specific laser wavelengths and spot sizes.

1. Introduction

In the past 50 years, research demonstrated that accelerating particles using laser beams is potentially achievable [1] and different schemes representing and explaining the laser matter interaction were proposed. The most successful so far is plasma wakefield acceleration: production of collimated multi-MeV electron beams was proven [2] and reaching multi-GeV energies was reported [3]. Direct electron acceleration by tightly focused ultra-intense laser pulses also opens new horizons and offers promising avenue [4, 5]. It takes advantage of the strong longitudinal component of the electric field at the beam center. This unique property leads to a considerable improvement in trapping and accelerating electrons to relativistic energies [6]. A Matlab code based on 5th order Runga-Kutta method with adaptive time step control is used to solve the relativistic invariant differential equations describing the electron dynamics and obtain the electron's trajectory and momentum.

2. Approach, results and discussion

In the paraxial limit, the lowest-order of a radially polarized laser beam RPLB (TM01) is characterized by its central dark intensity region that turns into a bright spot of sub-wavelength diameter under tight focusing conditions [5]. This particular behaviour is due to the beam symmetry that favors a strong longitudinal electric field component making it well-suited for the task of accelerating electrons to relativistic energies. The paraxial ap-

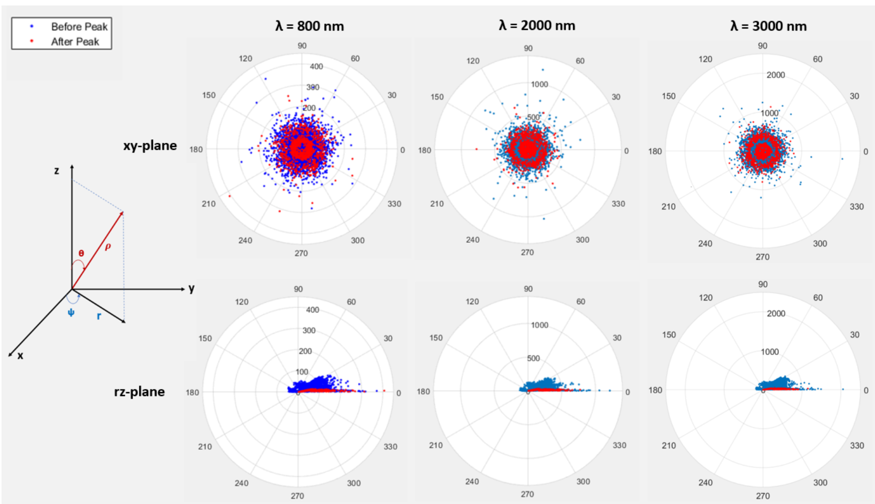

Fig. 1. Polar plot representing the final energy (gamma factor) of Ne10+ electrons at different wavelengths in xy-plane and rz-plane while z-direction is the propagation direction.The f/2 setup resulting in peak laser intensity of $5e22$ W/cm^2

proximation may fail at small spot sizes and high laser intensities, a 5th order correction of electromagnetic fields of the laser is therefore considered to correctly describe electron dynamics and avoid erroneous results in electron trajectories and energies [6].Electron generation during ionization of low density gases -here we considered Ne10+ - occurs in the quasiclassical regime where electrons are tunneled from a bound to a free state. One of the accurate tunneling models in this regime is the semiclassical model [7]. Initially, 100,000 neutral Ne atoms were randomly distributed within a cylinder with length equal to the Rayleigh range and radius equal to the considered wavelength.All particles are positioned symmetrically around the focal spot. The significant enhancement in electron energy is due to the fact that the radial field vanishes at axis and the strong longitudinal field accelerates the electrons axially. Due to the ponderomotive scattering, the electrons will leave the interaction region before being decelerated and therefore retain significant energy. All particles born right before or after the peak of the pulse get accelerated by an intensity close to the peak intensity. High energy peaks are reached for longer wavelength (fig. 1.), a gamma factor of about 2000 (1GeV) is seen at 3 microns wavelength. At a larger focal spot (fig. 2.) particles accelerate more and reach very high energies, up to 1.5GeV.

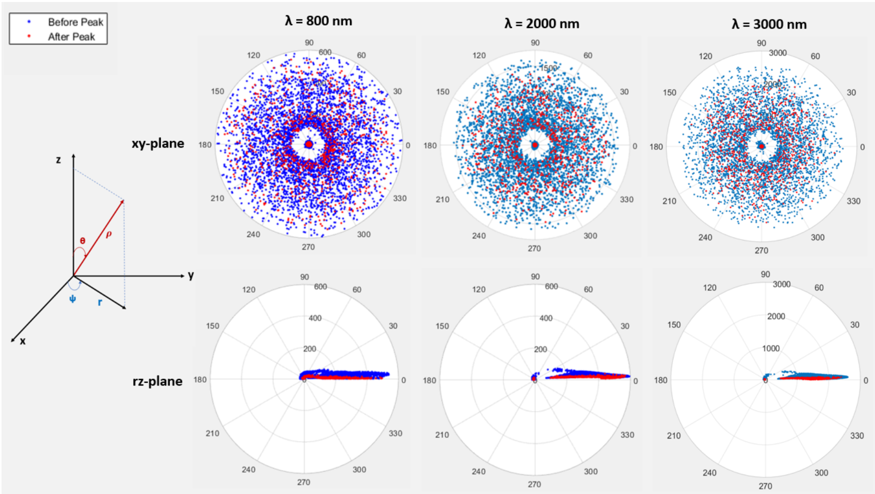

Fig. 2. Polar plot representing the final energy (gamma factor) of Ne10+ electrons at different wavelengths in xy-plane and rz-plane while z-direction is the propagation direction.The F number is 10 and the laser intensity is considered to be $5e22$ W/cm^2

Acknowledgement: This work was supported by AFOSR MURI Award no. FA9550-16-1-0013 and US DOE award no. DE-SC0020242.

3. References

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