Seminar

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Institute for Plasma Research

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Title: High Quality Electron Beam Generation through Laser Wakefield Acceleration in Bubble Regime with Its Application to Fusion

Speaker: Dr. Sonu Kumar

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Date: 25th August 2023 (Friday)

Time: 03.30 PM

Venue: Seminar Hall, IPR

Abstract

The concept of Laser Wakefield Acceleration (LWFA) was first developed by Tajima and Dawson in 1979[1]. In a Laser Wakefield Acceleration setup, a high-intensity and short duration laser pulse is focused onto an under-dense plasma target. The intense laser pulse creates a strong enough electric field within the plasma to push the plasma electrons away from the pulse axis, leaving behind a region of positively charged ions and a region of relatively low-density electrons. This separation of charges creates a cavity or bubble in the plasma. Electrons injected in the bubbles get accelerated in the Wakefield behind the laser pulse. The advantage of this type of acceleration is that there is no need of external bunch of electrons as the electrons are self-injected in the ion cavities or bubbles[2,3].

We have analysed the Wakefield acceleration in bubble regime using various approaches. We have studied various Gauge conditions and corresponding wake potentials for analysing different shapes of the bubble such as spherical bubble, longitudinal ellipsoid bubble and transverse ellipsoid bubble and their effect on accelerating field and maximum energy gain[4]. We have used a numerical method known as ode45 MATLAB code for solving a coupled differential equation obtained by Hamiltonian analysis in relativistic mode and Hamiltonian equation of motion of trapped plasma electrons in bubble regime and analysed the self-Injection of trapped plasma electrons in the said different shaped bubbles [5]. We have also performed numerical modelling of LWFA bubble regime using Particle in cell (PIC) simulation method[6]. Using the PIC code named Smilei [7] which is a high-performance open-source code for the simulation of relativistic laser-plasma interaction, we have investigated the scheme of multi-pulse laser wakefield acceleration (MP-LWFA). To benchmark the experimental conditions of LWFA, a comparison has been made for various temporal and spatial profiles of laser and plasmas such as temporal trapezoidal laser pulse, trapezoidal density profile and polygonal plasma density profile. The scheme of Wakefield acceleration in bubble regime using colliding laser beams has also been studied, where electrons were observed to get accelerated on a longer longitudinal accelerating length[8–10].

In my future program, I would like to investigate the Wakefield acceleration in pre-formed laser channel with externally injected electrons. Other shapes such as triangular and rectangular will be considered for plasma density for MP-LWFA and for colliding laser pulse LWFA. In Trapezoidal laser pulse, up ramp, down ramp and plateau region can also be modified for better results. In MP-LWFA, we can increase in the number of pulses in the pulse train by optimising the synchronization. In Colliding laser pulse scheme, a Gaussian and a super-Gaussian pulse can be used for pump and injection pulse system. I would like to develop a 3D model for LWFA for better analysing the acceleration process of electrons. I would like to extend my work into Inertial Confinement Fusion

(ICF) as ICF has been realised by a highly energetic laser pulse into a highly dense plasma. I would like to develop the simulation codes for ICF for multi-pulse laser system, and colliding laser pulse scheme with changing the structure of plasma [11]. I plan to investigate the generation of high quality electron beam by using D-T plasma during ICF process by multi-pulse laser system and by colliding laser pulse system[12].

References

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