Seminar

==

Institute for Plasma Research

==

Title:	Fast electron transport in the laser-plasma interaction: Studies of the ion acceleration and X-rays
Speaker:	Dr. Kousik Makur Indian Institute of Technology, Hyderabad
Date:	29th November 2024 (Friday)
Time:	10.30 AM
Venue:	Seminar Hall, IPR

Abstract

The invention of Chirped Pulse Amplification (CPA) has transformed laser technology by enabling the creation of short-pulse, high-intensity lasers. This innovation has unlocked new possibilities in physics, allowing scientists to simulate extreme conditions such as high pressures, temperatures, and strong electric and magnetic fields by generating relativistic plasmas. The interaction between these powerful laser pulses and matter offers exciting prospects for producing particles and radiation, creating astrophysical scenarios, and advancing various fields, including fundamental physics research, as well as social and medical applications. My presentation will focus on my research in optimizing the production of relativistic particles and laser-driven radiation.

The interaction between ultra-intense lasers and matter creates a strong electric field, reaching magnitudes of Tera-volts per meter, which accelerates ions, particularly protons, into the MeV range. Laser-based accelerators offer notable advantages over conventional ones due to their lower cost, smaller size, higher beam densities, and shorter pulse durations, typically in the picosecond range. This has sparked considerable interest in ion (proton) acceleration in the MeV range through laser-plasma interactions, given its potential applications in proton therapy, proton radiography, and fast ignition in inertial confinement fusion. For successful implementation in various applications, it's crucial to optimize both the energy and beam divergence of accelerated protons. My research focuses on optimizing the proton beam profile in terms of both energy and collimation from a single set-up. Our simulation research using PIC simulation has designed a novel scheme using three lasers and three targets, enabling significant improvements in beam quality for both energy and collimation. This new configuration provides enhancements in proton energy by 40% and yields a more collimated beam (approximately 4 degrees) compared to traditional single laser-foil target setups. To our knowledge, this is the first setup that effectively addresses both collimations. and energy optimization of accelerated proton beams. Another approach to optimizing the proton beam involves understanding the mechanisms behind its acceleration. Protons are accelerated by the immense sheath electric field formed at the rear side of the target material. The characteristics of the proton beam profile are influenced by this sheath field, which, in turn, is affected by the rapid propagation of electrons within the plasma. My research explores smoothing out this sheath field to precisely control the proton beam profile. We've successfully implemented a unique sandwich target composed of various resistive materials, showing promising results for sheath field smoothing and beam optimization.

The second part of my presentation will focus on laser-driven X-ray radiation via inner-shell transitions and bremsstrahlung processes. These X-rays have wide-ranging applications, from biomedical imaging to ultrafast atomic-scale studies and astrophysical investigations. I will share experimental results that analyze X-ray spectra from copper targets under varying laser parameters and polarizations. Using X-ray spectroscopy, we correlate plasma conditions with observed spectra to deduce temperature and ionization states, advancing our understanding of astrophysical plasma behavior. Additionally, Particle-In-Cell (PIC) simulations complement the experimental

findings by providing deeper insights into the generation mechanisms of hot electrons, their propagation within the plasma, and their role in shaping the X-ray spectra.

Lastly, I will present ongoing work on improving bremsstrahlung radiation's energy and collimation using a core-cladding target structure. PIC simulations reveal that guiding hot electrons within the core channel enhances both the energy and directional properties of the radiation, promising advancements in high-energy applications.

Through these studies, my research contributes to a deeper understanding of laser-plasma interaction physics, offering valuable insights that drive advancements in high-intensity laser applications and their potential technologies.