# Seminar

# Institute for Plasma Research

**Title:** Ultra-intense Laser-Matter Interaction: Enhanced Gamma-Photon Generation and Pair Production via Quantum Electrodynamics Effects

**Speaker:** Dr. Kousik Makur
Institute for Plasma Research, Gandhinagar

**Date:** 20th January 2026 (Tuesday)

**Time:** 10:30 AM

**Venue:** Seminar Hall, IPR

## Abstract

Recent advancements in high-power laser technology have enabled petawatt-class laser systems achieving peak intensity near $10^{22}$–$10^{24}$ W/cm² [1]. At such ultra-high intensity, laser–plasma interactions generate energetic electrons of relativistic energy and heavy ions; and subsequently fast electrons emit gamma-photons via bremsstrahlung during their acceleration/deceleration. Nonlinear Compton scattering also contributes gamma-photons through interactions of laser photons with relativistic electrons, which can further produce electron–positron pairs via the well-known Breit–Wheeler process [2]. Thus, quantum electrodynamics (QED) effects may begin. These secondary photons (gamma-photons) and energetic electrons have promising applications in medical physics, industry, and fundamental sciences, demanding effective control of their energy and the beam quality.

In this work, by performing numerical simulations, we report enhanced gamma-photon and high-energy particle generation due to the interaction of a 1 μm intense laser of intensity $5\times10^{23}$ W/cm² with uniquely structured targets, using the 2D-3V Particle-In-Cell (PIC) code EPOCH [3]. Compared with the conventional flat-foil targets, our structured targets exhibit nearly a three-fold energy enhancement across all processes. This enhancement arises primarily from improved collimation of energetic electrons driven by the intensified electric field within the target and the self-generated Giga-Gauss magnetic fields. Compared with earlier studies, our results also show higher energy gain for both structured and foil targets, attributed to the more energetic electron population at the current intensity scale [4].

Additionally, we also numerically investigate laser-driven optimized proton beams via the interaction of hydrocarbon targets with laser of intensity $\sim5\times10^{19}$ W/cm² for the future Proton–Boron (p–B) fusion [5]. Unlike conventional D–T fusion, p–B fusion yields no neutrons, minimizing radiation shielding and material damage issues, making it a promising route for clean energy generation.

[1] J. W. Yoon et al, Proceedings of the 2022 Conference on Lasers and Electro-Optics Pacific Rim, Technical Digest Series (Optica Publishing Group, 2022)
https://doi.org/10.1364/CLEOPR.2022.CMP4B_01
[2] L. L. Ji et al, Phys. Plasmas 21, 023109 (2014).
[3] T D Arber et al, Plasma Phys. Control. Fusion 57 113001 (2015).
[4] S. Chintalwad et al, Phys. Rev. E 105, 025205 (2022).
[5] V.S. Belyaev et al., Phys. Rev. E 72 (2005) 026406