Seminar

Institute for Plasma Research

Title: Adaptive Plasma Optics for High-Power Short Laser Pulses

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Date: 20th May 2026 (Wednesday)

Time: 10:30 AM

Venue: Seminar Hall, IPR

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(Conference ID: 5992138016; Password: 232142)

Abstract

Phase front distortion is one of the major challenges in petawatt-class laser systems. Efficient correction of wavefront aberrations is crucial for achieving optimal focal spot quality and minimizing instabilities in laser–plasma interaction experiments [1]. In the present study, a comprehensive plasma-based framework for real-time wavefront correction of high-power, short-pulse lasers is presented, which is inherently immune to the damage-threshold limitations associated with conventional deformable mirrors [2]. In this regard, a theoretical framework for wavefront correction based on plasma-density-tailored optical path length control has been proposed, which preserves the pulse duration and ensures uniform wavefront correction throughout the pulse. The analysis identifies the regime in which nonlinear plasma effects remain negligible, such that the correction is governed primarily by the prescribed plasma density profile [3]. The model is validated through a series of two-dimensional Particle-In-Cell simulations. The results show that wavefront distortions can be reduced from the micron scale to the tens-of-nanometer scale while preserving the pulse duration and maintaining invariant plasma-induced aberrations throughout the pulse. Furthermore, the simulations show that, as the laser intensity approaches ~10^{18} W/cm², nonlinear effects such as density modulation begin to degrade the correction efficiency, thereby setting the practical limit of the linear regime. Thus, this study establishes a rigorous framework in which plasma emerges as a robust, damage-resistant, and dynamically reconfigurable optical medium for wavefront control in next-generation multi-petawatt laser systems.

[1] A. Jeandet *et al*., Survey of spatio-temporal couplings throughout high-power ultrashort lasers, *Optics Express* **30**, 3262 (2022).

[2] B. W. Neisswander et al., Plasma lens for optical path difference control,AIAA Journal 50, 123 (2012).

[3] E. Esarey, et al., Physics of laser-driven plasma-based electron accelerators, Reviews of Modern Physics 81, 1229 (2009)