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基于级联激光尾波加速器的新型自由电子激光方案

摘要

激光尾波加速（LWFA）具有超高加速梯度，具备实现紧凑型自由电子激光器 (FEL) 的重要潜力。当前 FEL 应用面临 X 射线、极紫外（EUV）及大带宽等多样化需求，但现有基于 LWFA 的 FEL 方案尚难以在单一系统中实现上述多模式兼容。在本报告中，我们提出一种新型基于级联 LWFA 的 FEL 方案解决这一问题，通过两级 LWFA 加速并配合磁压缩器（chicane）的综合调控，本方案可产生带宽与能量可调的高品质束团，满足不同的 FEL 应用需求。模拟表明，基于一个 35J 的激光器，可在一个总长 115m 的装置中通过不同的参数设置实现 X 射线、EUV 以及谱宽达 10% 的宽谱 FEL 三种模式的饱和出光。本研究为实现基于 LWFA 的紧凑型 FEL 的发展提供了可行的新途径。

关键词

激光尾波加速，自由电子激光，级联加速，相空间操控

Abstract

Laser wakefield acceleration (LWFA) possesses ultra-high acceleration gradients, demonstrating significant potential for realizing compact free-electron lasers (FELs). Current FEL applications face diverse requirements including X-ray generation, extreme ultraviolet (EUV) radiation, and broad bandwidth operation. However, existing LWFA-based FEL schemes struggle to achieve multi-mode compatibility within a single system. In this study, we propose a novel cascaded LWFA-based FEL scheme to address this challenge. By combining two-stage LWFA acceleration with comprehensive control through magnetic chicanes, this solution can generate high-quality electron beams with tunable bandwidth and energy to meet various FEL application needs. Simulation results demonstrate that using a 35J laser system, saturated FEL outputs can be achieved in three operational modes (X-ray, EUV, and broad-spectrum with 10% bandwidth) within a compact facility of 115 meters total length through different parameter configurations. This research provides a viable new pathway for developing compact LWFA-based FEL systems.

Keywords

laser wakefield acceleration, free electron lasers, cascaded acceleration,phasespace manipulation

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