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Free electron lasing based on a laser wakefield accelerator in EUV regime

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Laser wakefield accelerators (LWFAs) are capable of generating ultra-high accelerating gradient up to 100 GV/m, and hold a great potential as a candidate for driving compact free electron lasers (FELs) [1]. However, the stability and insufficient beam quality, in terms of energy spread, large initial divergence, present a substantial obstacle to the realization of high-gain FELs. Improving electron beam quality and stability is of curial importance for LWFA-based applications, which is an active field of research.

With the in-house developed 200-TW laser system with a repetition rate of 1-5 Hz [2] and a well-designed gas target, a stable and high quality LWFA has been experimentally obtained [3]. The accelerated electron beam typically has a peak energy of ~490 MeV, with the energy spread of approximate 0.5%, an average integrated charge of around 30 pC, r.m.s. divergence of approximately 0.2 mrad and a reproducibility of approximately 100% [4].

Here, we present an experimental demonstration of undulator radiation amplification in the exponential-gain regime [4]. The beamline has the total length of approximate 12 m from the gas target to the X-ray spectrometer, as shown in Figure 1. The present beamline consists two permanent and three electromagnetic quadrupoles to ensure the minimum transverse electron beam sizes throughout the three-segment undulators.

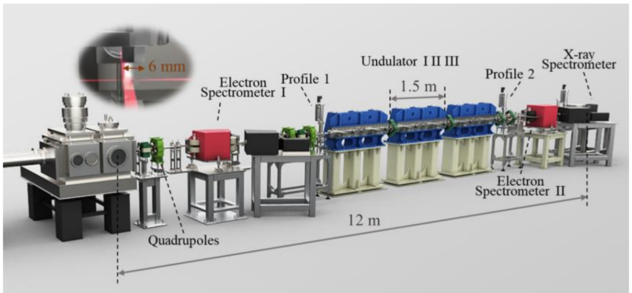

Figure 1. Schematic layout of the table-top FELs based on a LWFA at SIOM.

Figure 2 shows the typical transverse pattern of the amplified undulator radiation and the spectra of the amplified radiation and the spontaneous emission. The amplified undulator radiation, typically centered at the 27 nanometers, has a maximum radiation energy of approximate 150 nJ. The maximum gain was estimated to be 100-fold in the third of the three undulators with the orbit kick method, indicating an undoubtable exponential gain. The exponential gain was also demonstrated through the spontaneous emission calibration method. The fluctuations of the radiation energy mainly come from two aspects, the shots noises and the intrinsic fluctuations of LWFA-based electron beams.

Recent experimental demonstration on the free electron lasing have also been realized in the beam-driven plasma wakefield accelerators (PWFAs) in the visible regimes [5]. Such proof-of-principle experiments will expedite the development of future compact facilities with broad applications.

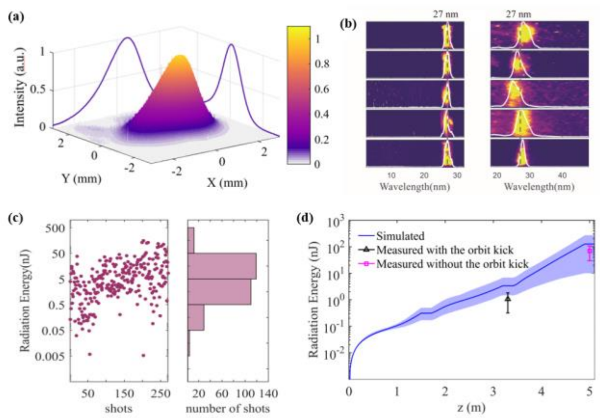

Figure 2. (a) Measured typical transverse pattern of the amplified undulator radiation and (b) the spectra of the undulator radiation with the amplified and the spontaneous emission cases. (c) Measured shot-to-shot radiation energy over 270 pulses. (d) Measured radiation energy with (magenta triangle) and without (magenta square) the orbit kick and the simulated energy along the undulator.

References

[1] Nakajima, K. Nat. Phys. **4**, 92–93 (2008).
[2] F. X. Wu, *et al.*, Opt. Laser Technol. **131**, 106453 (2020).
[3] L. T. Ke, K. Feng, *et al.*, Phys. Rev. Lett. **126**, 214801 (2021).
[4] W. W. Wang, K. Feng, et al., Nature **595**, 516 -520 (2021).
[5] R. Pompili, *et al.*, Nature **605**, 659-662 (2022).

Note: Abstract should be in (full) double-columned one page.