Scientists propose novel self-modulation scheme in seeded free-electron lasers

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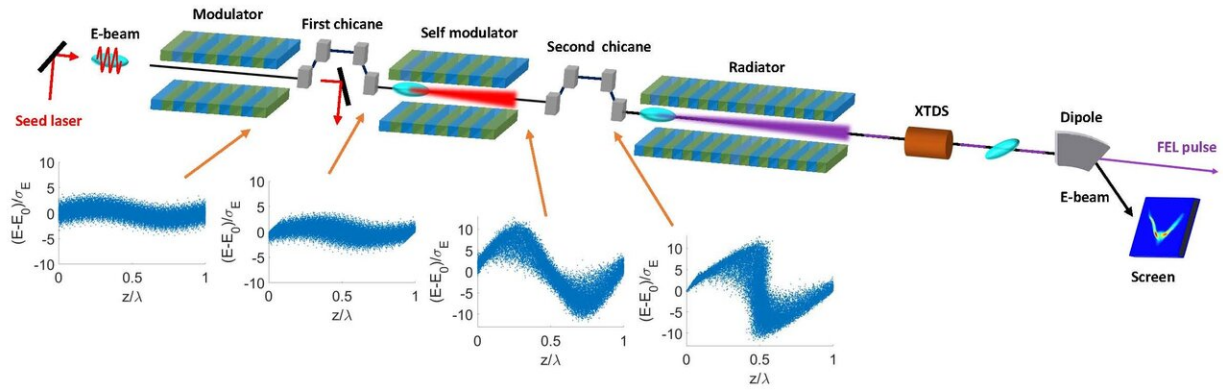

The self-modulation scheme together with the electron-beam longitudinal phase spaces at various positions. Credit: SARI

Seeded free-electron lasers (FELs), which use frequency up-conversion of an external seed laser to improve temporal coherence, are considered ideal for supplying stable, fully coherent, soft X-ray pulses. However, the requirement for an external seed laser with sufficient peak power to modulate the electron beam can hardly be met by the present state-of-the-art laser systems, it remains challenging for seeded FELs to operate at high repetition rate, e.g., MHz repetition rate.

Motivated by such a challenge, researchers at the Shanghai Advanced Research Institute and the Shanghai Institute of Applied Physics of the

Chinese Academy of Sciences reported a novel self-modulation method to enhance laser-induced energy modulation, thereby significantly reducing the requirement of an external laser system.

Based on the Shanghai soft X-ray FEL test facility, the self-amplification of coherent energy modulation in a seeded FEL is experimentally verified. The peak power requirement of an external seed laser is demonstrated to be relaxed by a factor of 10 to 25 when utilizing the proposed scheme.

Moreover, the high harmonic generation in a seeded FEL is realized by using an unprecedentedly small energy modulation. A 795 MeV electron beam with a laser-induced energy modulation amplitude as small as 1.8 times the slice energy spread is used for lasing at the 7th harmonic of a 266-nm seed laser in a single-stage high-gain harmonic generation (HGHG) and the 30th harmonic of the seed laser in a two-stage HGHG.

The results pave a way for a high-repetition-rate seeded FEL, which is expected to show great promise for multidimensional coherent spectroscopies, far beyond what has been demonstrated to date.

Furthermore, the self-modulation scheme proposed in this work is also promising to solve other critical problems of seeded FELs such as reaching shorter wavelengths and improving stability.

More information: Jiawei Yan et al. Self-Amplification of Coherent Energy Modulation in Seeded Free-Electron Lasers, *Physical Review Letters* (2021). DOI: 10.1103/PhysRevLett.126.084801

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