Novel approach for generating coherent and ultrashort soft X-ray pulses

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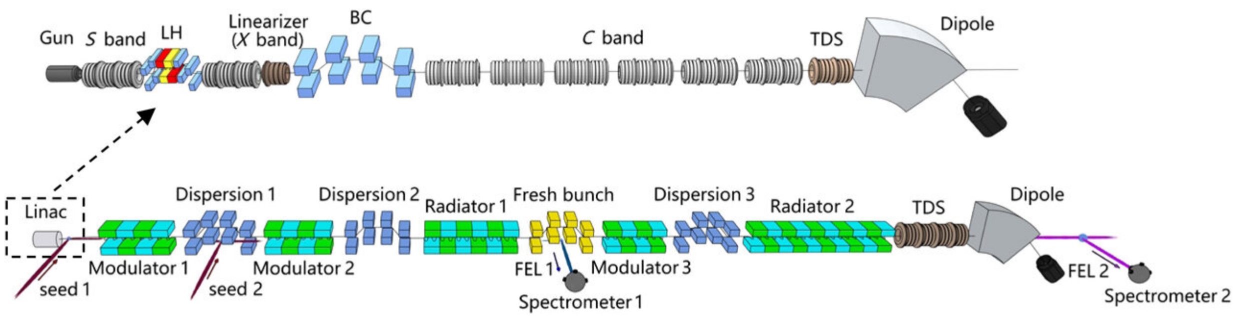

Schematic of the EEHC experiment. The upper beamline shows the linac which consists of a photocathode rf gun, a laser heater (LH) system, an ?X-band linearizer, a bunch compressor (BC), ?S-band and ?C-band accelerating structures, a ?C-band transverse deflecting structure (TDS), and a dipole for beam dump. The under beamline shows the undulator system. The first stage is an EEHG consisting of two seed lasers (seed 1 and seed 2), two modulator undulators, two dispersion sections, and a radiator. The second stage is a typical HGHG with one modulator, one dispersion section, and a radiator. These two stages are connected with a fresh bunch chicane. The FEL pulses from two stages can be detected separately by diagnostic stations located downstream of each stage. The longitudinal phase space of the electron beam can be measured by using the TDS and the dipole magnet. Credit: *Optica* (2022). DOI: 10.1364/OPTICA.466064

A research team from Shanghai Advanced Research Institute of the Chinese Academy of Sciences has proposed an external seeding mechanism, termed echo-enabled harmonic cascade (EEHC), for generating coherent and ultrashort soft X-ray pulses.

The results were published in *Optica*.

The generation of intense, tunable, and fully coherent pulses in the X-ray regime has been a long-standing challenge for laser technologies. The urgent need for intense X-ray light sources has prompted the development of X-ray free-electron lasers (FELs). However, most of the presently existing X-ray FEL facilities are faced with limited temporal coherence and large shot-to-shot fluctuations.

An efficient way to generate "laser-like" FEL is to employ an external laser source as the "seed" to dominate the gain process and control the output properties. Current limitations on seeded FELs are the low harmonic up-conversion efficiency and long output pulse duration.

The proposed EEHC mechanism uses echo-enabled harmonic generation as the first stage, producing intense extreme ultraviolet pulses that seed the second stage X-ray free-electron laser (FEL) with the high-gain harmonic generation setup.

The mechanism shows that 100 MW-level peak power, transform-limited soft X-ray pulses with tunable pulse duration from 25 fs to 55 fs can be generated. Comparing with previous demonstrated seeded FEL mechanisms, EEHC holds the superiorities of much higher harmonic up-conversion efficiency and tunable pulse durations.

Besides the temporal coherence, researchers have also demonstrated a unique feature of EEHC on generating isolated ultrashort pulses. The supreme up-frequency conversion efficiency and flexible pulse length control of this EEHC mechanism allows it to exceed the current limitations of seeded FELs while preserving the coherence of the seed.

More information: Chao Feng et al, Coherent and ultrashort soft x-ray pulses from echo-enabled harmonic cascade free-electron lasers, *Optica* (2022). DOI: 10.1364/OPTICA.466064

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