Scientists develop new approach for single-shot characterization of ultrashort free-electron laser pulses

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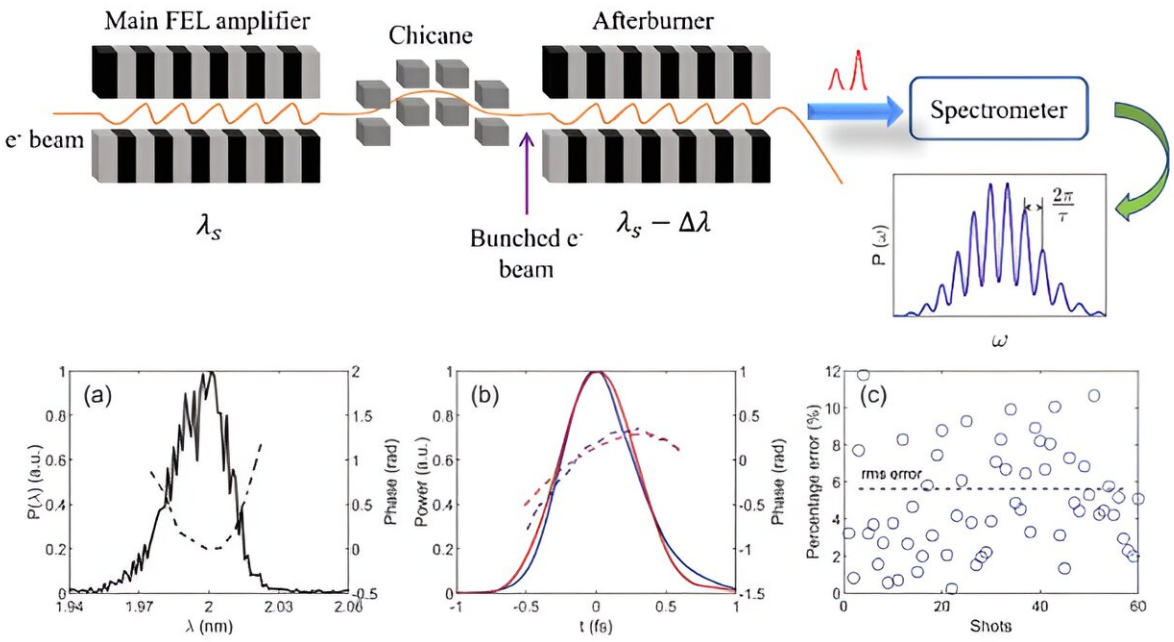

Schematic layout of the proposed method and spectrotemporal reconstructions of attosecond X-ray free-electron laser pulses. Credit: SARI

Scientists at the Shanghai Advanced Research Institute (SARI) of the Chinese Academy of Sciences have proposed and validated a novel approach for single-shot characterization of ultrashort free-electron laser pulses based on self-referenced spectral interferometry. Their innovative

approach, published in *Physical Review Letters*, offers a promising solution to the challenges of ultrafast scientific experiments.

Attosecond light pulses can be used to observe and manipulate the electronic motion in atoms and molecules, thus helping scientists gain a deeper understanding of chemical reactions, electronic structures, and molecular dynamics. The complete spectrotemporal characterization of attosecond X-ray free-electron lasers is of great significance to ultrafast scientific experiments. However, the precise single-shot characterization of these pulses has been a major bottleneck in the application of attosecond X-ray free-electron lasers.

Led by Prof. Feng Chao, the researchers have proposed an approach using the frequency-pulling effect as a way to induce the spectral shear. This approach allows the generation of both the ultrafast radiation pulse and the reference pulse from the same electron beam, enabling self-referenced spectral interferometry of the radiation pulse.

With the help of the parameters of the Shanghai soft X-ray free-electron laser facility, the researchers demonstrated that this approach can accurately reconstruct the complete spectrotemporal information of attosecond X-ray pulses, with a reconstruction error rate of less than 6%.

Compared to traditional ultrafast pulse characterization methods in free-electron laser facilities, this approach has several advantages. It employs simple equipment, yet achieves high diagnostic efficiency in real-time and single-shot measurements,

Simultaneously, it provides complete spectrotemporal information and higher diagnostic precision for shorter radiation pulses. These advantages present a unique diagnostic approach for optimizing and fine-tuning ultrafast X-ray free-electron lasers and future attosecond scientific experiments based on X-ray free-electron lasers.

This study marks a significant breakthrough in high-precision real-time diagnostics for attosecond free-electron laser pulses.

More information: Yaozong Xiao et al, Self-Referenced Spectral Interferometry for Single-Shot Characterization of Ultrashort Free-Electron Laser Pulses, *Physical Review Letters* (2023). DOI: 10.1103/PhysRevLett.131.205002