

# Physics and Applications of High Brightness Beams



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## Terawatt-Scale Attosecond X-ray Pulses from a Free Electron Laser Cascade

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High intensity, sub-femtosecond XFEL pulses are key to taking full advantage of nonlinear x-ray spectroscopies and advanced imaging methods. The X-ray Laser-Enhanced Attosecond Pulses (XLEAP) collaboration is an ongoing project for the development of attosecond x-ray modes at the Linac Coherent Light Source (LCLS). Here we report development of a high power attosecond mode via cascaded amplification in two undulator stages. In the first stage, a sub-femtosecond x-ray pulse is produced by enhanced self-amplified spontaneous emission (ESASE) by a femtosecond, high-current spike within the electron beam. A magnetic chicane delays the electron beam, allowing the x-ray pulse to slip onto a fresh slice of the bunch in the second undulator stage, where it undergoes further amplification. We experimentally demonstrate generation of sub-femtosecond duration soft x-ray free electron laser pulses with hundreds of microjoules of energy, and use angular streaking to characterize the pulse durations.

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