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Three-dimensional theory of soliton-like superradiant free-electron lasers

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The soliton-like superradiant regime of free-electron lasers (FEL) offers a promising path towards ultrashort pulses, beyond the natural limit dictated by the bandwidth of the high-gain FEL instability. In this work we present a three-dimensional theory of the superradiant regime. Our work takes advantage of recent developments in non-linear FEL theory to provide a fully analytical description of soliton-like superradiance. Our theory proves the existence of a diffraction-dominated steady-state regime in which the superradiant peak power grows indefinitely while leaving the pulse duration and on-axis intensity almost unchanged. These results are in excellent agreement with three-dimensional simulations and are supported by recent experimental results at the Linac Coherent Light Source. This work advances non-linear FEL theory and provides a theoretical framework for the next generation of attosecond x-ray FELs.

Footnotes

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