Stimulated coherent spontaneous emission in an FEL with `quiet' bunches

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For a planar FEL configuration we study stimulated coherent spontaneous emission driven by a gradient of the bunch current in the presence of different levels of noise in bunches. To perform a vast amount of simulations required for obtaining statistically valid results, we developed a memory and time efficient one-dimensional simulation code based on the integral solution to a Klein-Gordon equation describing the field evolution. The longitudinal granularity of the electron bunch density originating from shot noise is maintained throughout the analysis. Three-dimensional effects like transverse emittance and diffraction are taken into account in simulations via an effective FEL parameter calculated from Xie's fitting formula. Calculations are performed for an FEL model with the SwissFEL injector bunch parameters. It turns out that a reduction of noise by several orders of magnitude below the level of shot noise is required to mitigate the noise effect. We propose a novel scheme that allows for formation of electron bunches with a reduced level of noise and a high gradient of the current at the bunch tail to enhance coherent spontaneous emission. The presented scheme uses effects of noise reduction and controlled microbunching instability and consists of a laser heater, a shot noise suppression section as well as a bunch compressor. The noise factor and microbunching gain with and without laser heater are estimated. We found that shot noise reduction by three orders of magnitude can be achieved for a finite transverse size electron bunch.

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