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Ponderomotive Prebunching for Spontaneous Superradiant and Stimulated Thomson Scattering

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Compact sources offering high-brightness radiation in the EUV to X-ray regime are highly desired. Thomson scattering, in which an electron beam colliding with a laser pulse produces radiation, is a source of X-rays of increasing prevalence in modern labs, complementing large scale facilities like synchrotrons and X-ray free electron lasers. By imposing a density modulation on the electron beam the brilliance of a Thomson source can be enhanced by orders of magnitude via superradiant emission. However, microbunching at the beam energy relevant to Thomson sources is a challenge that has yet to be met. Here, we analytically and numerically analyze electron beam modulation via the ponderomotive force from the copropagating beat wave formed by two laser pulses at different frequencies. First, we find that energy modulation favorably scales with electron beam energy, but is limited by the interaction length imposed by the finite size of the laser pulses. Next, we quantify the brightness of a Thomson source including a ponderomotive buncher that is optimized for superradiant emission. Last, we investigate under which conditions the spontaneous superradiant Thomson regime transitions into a stimulated Thomson (FEL-)regime, potentially allowing for even further increase of source brightness.

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