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Laser-Driven Plasma-Based Sources of Intense, Ultrafast, and Coherent Radiation[1]

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Extreme light sources - providing attosecond pulse durations, ultra-relativistic intensities, or x-ray wavelengths - allow us to probe the boundaries of modern physics with exquisite precision and unrivaled power. Future source development requires plasmas, which support high-intensity fields, offer useful non-linear and ultrafast responses, and scale with wavelength. We focus on two plasma-based mechanisms suitable for the near-infrared to soft-x-ray spectral window: relativistic high-order harmonic generation for high-power frequency conversion and parametric plasma amplification using stimulated Raman or Brillouin scattering. For both mechanisms efficiency is crucial, and, drawing on similar analytic and computational tools, we show how simple models lead to efficiency limits. For high-order harmonic generation, paths to the highest efficiencies can be found by manipulating the laser waveform or plasma parameters [Edwards et al. Opt. Lett. 39 (2014); Edwards and Mikhailova, PRA 93 (2016); Edwards and Mikhailova, PRL 117 (2016)]. For plasma amplification, efficiency can be improved via use of an appropriate scattering mechanism for the specific wavelength and conditions [Edwards et al. PoP 23 (2016); Edwards et al. PRE 96 (2017); Edwards et al. PRL (2019)], tuning of plasma properties [Edwards et al. PoP 22 (2015)], and the suppression of competing instabilities [Edwards et al. PoP 24 (2017)]. We explore physics-based and engineering solutions for improving performance - informed by applications [Edwards et al. PRL 116 (2016)] and alternative mechanisms [Edwards et al. PoP 25 (2018)] - and relate these processes to the broader ecosystem of plasma and non-plasma sources of extreme radiation.

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