Synchrotron emission from nanowire-array targets irradiated by
ultraintense laser pulses

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Forthcoming multi-petawatt lasers will enable scientists to access a new regime of laser-plasma interactions where collective plasma processes are intertwined with radiative and quantum electrodynamics effects, offering exciting prospects for fundamental and applied research [1, 2, 3, 4]. One underlying mechanism common to all these applications is the copious generation of hard x-ray or $\gamma$-ray photons through synchrotron emission—equivalent to nonlinear inverse Compton scattering in the strong-field regime.

Here we present the results of two-dimensional particle-in-cell simulations of the synchrotron emission from carbon nanowire arrays irradiated by femtosecond laser pulses of intensities $I = 10^{21} – 10^{23}$ W cm$^{-2}$. The realization of intense laser-driven synchrotron sources is but the latest application of nanowire arrays, whose capability in strongly enhancing the laser energy absorption and hot-electron generation is now well established and exploited [5, 6]. Through an extensive parametric scan on the laser-target parameters, we identify and characterize several dominant radiation mechanisms, mainly depending on the transparency or opacity of the plasma produced by the laser-driven wire expansion, and on the quasistatic fields self-induced around the wires. At $I = 10^{22}$ W cm$^{-2}$, the emission of high-energy ($> 10$ keV) photons attains a maximum energy conversion efficiency of $\sim 10\%$ for $\sim 30 – 50$ nm wire widths and 1 $\mu$m inter-spacing. While this maximum radiation yield does not exceed that achieved in uniform plasma of same average (sub-solid) density, we show that nanowire arrays provide efficient radiation sources over a broader parameter range. Finally, we demonstrate that the radiation efficiency can be further boosted by adding a plasma mirror at the backside of the nanowire array.

References