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Short-pulse, high-energy radiation generation from laser-wakefield accelerated electron beams[1]

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Recent experimental results of laser wakefield acceleration (LWFA) of $\sim GeV$ electrons driven by the 200TW HERCULES and the 400TW ASTRA-GEMINI laser systems and their subsequent generation of photons, positrons, and neutrons are presented. In LWFA, high-intensity ($I > 10^{19}\ W/cm^2$), ultra-short ($\tau_L < 1/(2\pi\omega_{pe})$) laser pulses drive highly nonlinear plasma waves which can trap $\sim nC$ of electrons and accelerate them to $\sim GeV$ energies over $\sim cm$ lengths. These electron beams can then be converted by a high-Z target via bremsstrahlung into low-divergence ($< 20\ mrad$) beams of high-energy ($< 600\ MeV$) photons and subsequently into positrons via the Bethe-Heitler process. By increasing the material thickness and Z, the resulting N_{e+}/N_{e-} ratio can approach unity, resulting in a near neutral density plasma jet. These quasi-neutral beams are presumed to retain the short-pulse ($\tau_L < 40\ fs$) characteristic of the electron beam, resulting in a high peak density of $n_{e^-/e^+} \sim 10^{16}\ cm^{-3}$, making the source an excellent candidate for laboratory study of astrophysical leptonic jets. Alternatively, the electron beam can be interacted with a counter-propagating, ultra-high intensity ($I > 10^{21}\ W/cm^2$) laser pulse to undergo inverse Compton scattering and emit a high-peak brightness beam of high-energy photons. Preliminary results and experimental sensitivities of the electron-laser beam overlap are presented. The high-energy photon beams can be spectrally resolved using a forward Compton scattering spectrometer. Moreover, the photon flux can be characterized by a pixelated scintillator array and by nuclear activation and (γ,n) neutron measurements from the photons interacting with a secondary solid target. Monte-Carlo simulations were performed using FLUKA to support the yield estimates.

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