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Laboratory-based intense gamma-ray and lepton beams for strong-field QED and laboratory astrophysics

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Sources of high-energy, dense and collimated photon and lepton beams enable new avenues for research in strong-field QED and relativistic laboratory astrophysics 1-2.

Here we show that a high-current ultrarelativistic electron beam interacting with multiple thin conducting foils can undergo strong self-focusing accompanied by efficient emission of gamma-ray synchrotron photons. Physically, self-focusing and high-energy photon emission originate from the beam interaction with the near-field transition radiation accompanying the beam-foil collision. This near field radiation is of strength comparable with the beam self-field, and can be strong enough that a single emitted photon can carry away a significant fraction of the emitting electron energy. After beam collision with multiple foils, collimated electron and photon beams with number density exceeding that of a solid are obtained 3.

The relative simplicity, unique properties, and high efficiency of this gamma-ray source open up new opportunities for both applied and fundamental research including laserless investigations of strong-field QED processes with a single electron beam 3 and the generation of dense electron-positron jets that are essential for laboratory astrophysics investigations of electron-positron plasma 1-2.

Based on these findings, the E-332 experiment on solid-density gamma-ray pulse generation in electron beam-multifoil interaction has been developed and approved with maximal ranking, and will be carried out at the FACET-II facility at SLAC.

Finally, we show that high-energy and dense lepton beams enable precision studies of fundamental quantum processes in the supercritical QED regime, where the beam particles experience rest-frame electromagnetic fields which greatly exceed the QED critical one 4.

References

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