Improving Experimental Parameters to Observe Two-Photon Processes

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Light-by-light scattering is a fundamental prediction of quantum electrodynamics (QED), which is precluded in classical theory due to the linearity of Maxwell's equations. Elastic two-photon processes present a real challenge to observe in an experimental environment directly; linear Breit-Wheeler production [1] has a large energy threshold in the zero momentum frame (ZMF), $E_{ZMF} \geq 2m_e c^2$, and photon-photon scattering via virtual electron-positron pairs [2] is an α^4-order process with an extremely small cross section (approximately 10^{16} times smaller than the Thomson cross section).

Previous campaigns aimed at detecting scattering events using optical and X-ray beams were unsuccessful in direct observation, instead bounding the magnitude of the cross section [3-6]. One recent campaign at the Gemini facility at RAL, UK, was able to place the tightest bound to date, at 10^{11} times the theoretical value [7]. The interacting photons were comprised of two distinct sources – LWFA electrons striking a high-Z target to generate 100's MeV-scale bremsstrahlung, and keV-scale X-rays generated from an exploding foil.

Here, we consider the same setup of [7] with the capabilities of a multi-PW laser acting as the source for LWFA electrons and a kJ-class laser as the X-ray generator. With this upgraded configuration, we show the results of extensive simulations which indicate that it will be possible to not only directly detect Breit-Wheeler pairs on a single-shot basis, but also to potentially observe photon-photon scattering within a realistic time frame or otherwise bounding it within $10^4 - 10^6$ times the theoretical value; up to seven orders of magnitude tighter than the current best.

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