Creating observable QED collective plasma effects

Kenan Qu[1], Sebastian Meuren[2], Nathaniel J. Fisch[1]

[1] *Department of Astrophysical Sciences, Princeton University, Princeton, New Jersey 08544, USA*

[2] *Stanford PULSE Institute, SLAC National Accelerator Laboratory, Menlo Park, California 94025, USA*

To observe in laboratory plasmas the QED plasma regime, it is crucial not just to create a pair plasma – but to create a pair plasma such that collective effects can be observed. Colliding intense laser beams produces pairs, but collective plasma effects are then notoriously hard to observe. The small pair plasma has only micron-scale widths. It is moving at relativistic speeds, making the pairs heavy, which diminishes the plasma frequency and the associated collective effects [1]. However, colliding a relativistic electron beam with a less intense laser creates pairs that have larger plasma frequency, made even larger as they slow down by reversing direction due to the laser pressure [2]. Signatures of collective pair plasma effects in the QED cascades then appear in exquisite detail through plasma-induced frequency upshifts in the laser spectrum. The distinctive features of this signature include a chirp to the frequency upshift as well as parametric dependencies. Recent optimizations will also be discussed [3-4]. Because the electron beam and laser technologies are available, this solution to the coupled production-observation problem means that strong-field quantum and collective pair plasma effects can now be explored with existing technology, provided that ultra-dense electron beams are co-located with multi-PW lasers [5-6].

1. 1. A. R. Bell and J. G. Kirk, *Possibility of Prolific Pair Production with High-Power Lasers*, PRL 101, 200403 (2008).
2. 2. K. Qu, S. Meuren, N. J. Fisch, *Signature of Collective Plasma Effects in Beam-Driven QED Cascades*, **127**, 095001 (2021).
3. 3. K. Qu, S. Meuren, N. J. Fisch, Collective plasma effects of electron-positron pairs in beam-driven QED cascades, arXiv:2110.12592 (2021).
4. 4. A. Griffith, K. Qu, N. J. Fisch, *Structured Laser Pulses to Accentuate Signatures of Collective QED-Plasma Effects*, BP11.00063, Bull. 63rd Ann. Meet. APS DPP (2021).
5. 5. S. Meuren et al., *On Seminal HEDP Research Opportunities Enabled by Colocating Multi-Petawatt Laser with High-Density Electron Beams*, arXiv:2002.10051 (2020).
6. 6. S. Meuren et al., *Research Opportunities Enabled by Co-locating Multi-Petawatt Lasers with Dense Ultra-Relativistic Electron Beams*, arXiv:2105.11607 (2021).