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Resonant Emittance Mixing of Flat Beams in Plasma Accelerators

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Plasma accelerators can sustain extremely high field gradients, making them strong candidates for future X-ray sources and compact linear colliders. Achieving the high luminosity required for collider applications necessitates the use of flat beams to minimize harmful beamstrahlung effects. However, we show that flat beams in plasma accelerators are susceptible to beam quality degradation due to emittance mixing, driven by transverse coupling in the wakefields. When a resonance arises between the horizontal and vertical betatron oscillations of beam particles within a coupled wakefield, the transverse emittances can fully exchange—resulting in a round beam. The impact of this resonance depends on its underlying mechanism and can be mitigated by appropriate design choices. In particular, using laser drivers or flat particle beam drivers can help suppress the resonance and preserve beam quality. These investigations are made possible by recent advances in high-performance, open-source simulation tools, which enable detailed studies of high-quality, high-energy electron beam acceleration in plasma wakefields. This study was published in [S. Diederichs et al., Phys. Rev. Lett. 133, 2024].

Authors: THÉVENET, Maxence (DESY); DIEDERICHS, Severin (CERN)

Co-authors: Mr SINN, Alexander (DESY); FERRAN POUSA, Angel; SCHROEDER, Carl (Lawrence Berkeley National Laboratory); BENEDETTI, Carlo (LBNL); OSTERHOFF, Jens (Lawrence Berkeley National Laboratory)

Presenter: THÉVENET, Maxence (DESY)

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