Contribution ID: **110** Type: **Student Poster**

Enhanced Spectral Flux of Synchrotron X-ray Beams from Laser Wakefield Accelerators

Tuesday, 8 November 2022 17:00 (2h 30m)

Due to the oscillation and subsequent emission of synchrotron radiation of electrons accelerated to GeV-order energies over centimetre scales, laser wakefield accelerators (LWFAs) have produced x-ray beams with a peak spectral flux up to 104 photons/pulse/mrad^2/0.1% BW. In a recent experiment performed by Wood, J. et al., an f/40 parabolic mirror was used to focus a 100 TW laser pulse into a plasma. A particle-in-cell simulation of the LWFA was performed, the accelerated electron trajectories and mometa were tracked and the spectral characteristics of the synchrotron radiation were modelled by calculating the Liènard-Wiechert fields from each tracked electron. Peak flux values over 10^4 photons/pulse/mrad^2/0.1% BW were both measured and simulated, which have not been observed in previous, similar experiments using smaller f-numbers.

From measurements and simulations of different plasma lengths up to 40 mm, the increased x-ray flux is shown to be produced by a sub-GeV electron bunch with a higher number of electrons and a larger oscillation amplitude. These electrons get accelerated to energies below 1 GeV in the laser wakefield after the first electron bunch behind the laser pulse reaches over 2 GeV, before dephasing. The increase in bubble length due to the wakefield of the multi-GeV bunch means that the sub-GeV bunch then gets accelerated at the back of this elongated bubble. The growth in oscillation amplitude of the sub-GeV bunch is studied using existing hose instability models. A hose instability model derived by Mehring, T. et al. [1] best describes the RMS amplitude growth in the simulation to 2 µm before this growth gets damped.

[1] T. Mehrling, R. Fonseca, A. Martinez de la Ossa and J. Vieira, "Mitigation of the Hose Instability in Plasma-Wakefield Accelerators," Physical Review Letters, pp. 1-5, 2017.

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Session Classification: Poster Session and Reception

Track Classification: Poster Session: WG1 Poster: Laser-Plasma Wakefield Acceleration