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Characterisation and optimisation of laser-wakefield betatron emission for imaging applications - Part I

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A unique aspect of high intensity laser plasma interactions (LPI) is the ability to generate broad ranges of energetic radiation by tuning the target and laser conditions. The different radiation types share a common set of characteristics, they are short pulse (sub-ps), emanate from a small source (100nm-100um), and can be tuned by altering the laser parameters or target conditions. For laser-wakefield betatron emission we expect the x-ray energies to be ~10-100 keV and emanate from a sub-micron source size with narrow collimation. This bright, directional, and energetic source of x-rays is highly applicable to radiography and has been demonstrated to be capable of both X-ray CT and phase contrast imaging. New facilities, such as the Extreme Photonics Applications Centre (EPAC) at the CLF, are looking to utilise these sources for industrial applications, combining the increased repetition rate of the new laser facilities with the penetrative imaging of laser-driven sources.

With laser-wakefield interactions we are able to tune the x-ray energies and flux by altering the gas channel (length and density) [1], or the laser conditions (focus and temporal profile) [2]. Recent work has also demonstrated the ability to maximise the emission using a Bayesian optimisation processes on all parameters simultaneously [3]. We can apply this flexibility to secondary applications instead and determine the optimum spectra required for different samples and detectors, and therefore look to tune the source as required.

[1] J. Wood. Betatron radiation from laser wakefield accelerators and its applications. Diss. Imperial College London, 2016.
[2] SJD. Dann, et al. Physical Review Accelerators and Beams 22, 041303 (2019)
[3] RJ. Shalloo, et al. Nat Commun 11, 6355 (2020).

Summary

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