Shock-front injection and laser-driven polarized X-ray

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Laser-driven betatron radiation has essentially reproduced the principle of conventional synchrotron at the millimeter scale. Similar to undulator radiation, electron bunch inside laser wakefield accelerator (LWFA) undergoes transverse betatron oscillations due to the ultra-high focusing field in the laser wakefield and thus emits bright x-ray beams with a synchrotron-like spectrum[1]. However, despite its success in phase contrast imaging of bio-sample, the usability of the laser-driven betatron source has been constrained by its poor control and stability over photon energy and polarization. Unlike undulator radiation, betatron radiation from LWFA is naturally non-polarized because electrons are injected along propagation axis and quiver in all radial direction. Polarization is crucial for applications relying on magneto-optical phenomena such as diagnostic of ferromagnetic materials. The only two experiments that have been proposed so far to manipulate the X-ray polarization are done by either rotating the polarization of laser pulses during ionization injection[2], or introducing laser pulse front tilt to wiggle wakefield transversely[3]. Although both methods claim the tunability of X-ray polarization, they are not ideal due to the requirement of complicated manipulation of high-power laser systems. To overcome these issues, we propose to use a tilted shock-front injection to achieve a comprehensive control of both polarization and energy of the betatron source. Shock front is a sharp density transition, which serves as a highly localized electron source[4]. The measured characteristic length of the transition is below 5 micron compared to the size of bubble of 25 micron. Particle-in-cell simulations show the tilted shock front breaks radial symmetry of injection and creates an in-plane oscillation of electrons which leads to a linear polarized betatron radiation. The resulting X-ray is collimated by a polycapillary lens, then sent to an ADP crystal for polarization analysis.

References

[1] E.Esarey, B. A.Shadwick, P.Catravas, andW. P.Leemans, "Synchrotron radiation from electron beams in plasma-focusing channels," *Phys. Rev. E - Stat. Physics, Plasmas, Fluids, Relat. Interdiscip. Top.*, vol. 65, no. 5, p. 15, May2002, doi: 10.1103/PhysRevE.65.056505.

[2] A.Döpp *et al.*, "Stable femtosecond X-rays with tunable polarization from a laser-driven accelerator," *Light Sci. Appl.*, vol. 6, no. 11, p. e17086, 2017, doi: 10.1038/lsa.2017.86.

[3] M.Schnell *et al.*, "Optical control of hard X-ray polarization by electron injection in a laser wakefield accelerator," *Nat. Commun.*, vol. 4, no. May, pp. 8–13, 2013, doi: 10.1038/ncomms3421.

[4] A.Buck *et al.*, "Shock-Front Injector for High-Quality Laser-Plasma Acceleration," *Phys. Rev. Lett.*, vol. 110, no. 18, p. 185006, May2013, doi: 10.1103/PhysRevLett.110.185006.