Enhancement of Laser-Driven Betatron Radiation

L Chen$^1$, Z M Sheng$^{2,3}$, and J Zhang$^3$

1Laboratory of Optical Physics, Institute of Physics, Beijing, China
2Department of Physics, University of Strathclyde, Glasgow, UK
3Key Laboratory for Laser Plasmas and Department of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai, China

Contact Email: lmchen@iphy.ac.cn

Hard x-ray emission from fs laser produced plasmas have a number of interesting applications in the dynamic probing of matter and in medical/biological imaging. Betatron radiation is a highly collimated laser-driven hard X-ray source with fs duration which generated by electron transversely oscillation during acceleration in underdense plasmas. However, yield of this source is always limited by competitive between parameters during electron acceleration. we will present our recent progress in enhancing acceleration to enrich the X-ray photon yield.

A new method is demonstrated for generating intense betatron x-rays using a clustering gas target irradiated with an ultra-high contrast laser of 3 TW only [1]. The yield of the Ar x-ray betatron emission has been measured to be $2 \times 10^8$ photons/pulse, which is over ten-fold enhancement compared to the emission yield produced by using a normal gas target. Simulations point to the existence of clustering as a contributor to the DLA mechanism, leading to higher accelerated electron charge (x40) and much larger electron wiggling ($\sim 8 \mu$m) amplitudes in the plasma channel, thereby finally enhancing the betatron X-ray photons and improving conversion efficiency over 40 times.

Another concept of generation of bright betatron radiation during electron acceleration was newly studied in experiment and simulation [2]. Two electron bunches with different qualities were injected sequentially into the wakefield driven by a super-intense laser pulse. The first one is a mono-energetic electron bunch with peak energy of GeV level, and the second one is injected continuously with large charge and performs transverse oscillation with large amplitude during the subsequent acceleration. When propagates in plasma, laser pulse undergoes periodic self-focusing and defocusing. The moderate self-focusing and defocusing at beginning causes longitudinal stretch and contraction of the plasma bubble generated. The first mono-energetic electron bunch, then the significant pulse hosing leads to a significant bubble stretch triggering the second electron bunch injected continuously with large charge. Various acceleration procedures were demonstrated by experimental results of betatron emission profiles using Callisto laser facility [3,4]. The enhancement of transverse resonant oscillation of the ionization injected electron bunch which results in the betatron radiation would lead to gamma-ray photon energy and peak brilliance beyond that of 3rd generation synchrotron facilities [5].

References