Extreme betatron x-rays from relativistic self-trapping of a short laser pulse

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On a short distance, laser-plasma accelerator can produce high-energy and high-current electron bunches emitting bright synchrotron x-ray radiation. A small size (down to 1μm), ultrashort duration and relative low divergence make such betatron sources attractive for applications in biology, chemistry, medicine, and material science. At the same time in dense gas plasma a short laser pulse can propagate in relativistic self-trapping mode that provides effective conversion of laser energy to the accelerated electrons maximizing the total charge of the accelerating electrons, which emits a large amount of betatron radiation.

The 3D particle-in-cell simulations have revealed how such regime triggers x-ray generation with 0.1-1 MeV photon energies, low divergence, and high brightness. It have been shown that a 135 TW laser can produce up to 3×10^{10} photons of > 10 keV energy and a 1.2 PW laser makes it possible generating about 10^{12} photons in the same energy range. Based on the test particle simulation for different configurations of laser and plasma-cavity fields, we have analyzed the role of the laser field in the betatron radiation. It has been shown that a laser pulse filling the plasma cavity enables effective loading high number of electrons and triggers soliton-like acceleration structure with strong accelerating plasma field and rather long propagation distance. We predict extrabright x-ray beams, which can be produced with few J, tens of fs laser system working at 10Hz and might have order of magnitude larger (than already achieved) laser-to-photons conversion efficiency. We suppose that experiments encouraged by such scheme are very attractive and timely.

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