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Particle-in-Cell Simulation of X-ray Wakefield Acceleration and Betatron Radiation in Nanotubes

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Laser wakefield theory shows that for a given laser, the energy gain and accelerating length are both inversely proportional to the plasma density [1]. This means that the lower the gas density, the longer the acceleration distance, which is undesirable in reaching ultra-high energies. The recent proposed generation of the X-ray laser pulse provides an attractive way to achieve ultrahigh energy [2]. Benefitting from the much higher critical density which is inversely proportional to the square of the laser wavelength, solid density materials can be chosen for the X-ray laser pulse driven case [3]. On the other hand, functional nanomaterials such as carbon-nanotubes have a large degree of dimensional flexibility and higher than 10 TV/m wakefield is possible, Accordingly, compact structures to obtain ultrahigh energy gain can in principle be realized through the state-of-the-art nanotube technology. Motivated by these, we explored the X-ray wakefield accelerator in a nanotube. We investigate the acceleration due to a wakefield induced by a coherent, ultrashort X-ray pulse guided by a nano-scale channel inside a solid material. By two-dimensional particle-in-cell computer simulations, we show that an acceleration gradient of TeV/cm is attainable. This is about three orders of magnitude stronger than that of the conventional plasma-based wakefield accelerations, which implies the possibility of an extremely compact scheme to attain ultrahigh energies. In addition to particle acceleration, this scheme can also induce the emission of high energy photons at ˜O(10-100) MeV. Our simulations confirm such high energy photon emissions, which is in contrast with that induced by optical laser driven wakefield scheme. In addition to this, the significantly improved emittance of the energetic electrons has been discussed.

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