Nonthermal relativistic electron acceleration due to laser-induced incoherent wakefields with external static magnetic fields

Yao-Li Liu[1,*], Yasuhiro Kuramitsu[2], Nima Bolouki[3] and Shih-Hung Chen[3]

[1] Institute of Atomic and Molecular Sciences, Academia Sinica, P. O. Box 23-166, Taipei, Taiwan
[2] Graduate School of Engineering, Osaka University, 2-1 Yamadaoka, Suita, Osaka 565-0871, Japan
[3] Department of Physics, National Central University, Jhongli 32001, Taiwan

The diffusive shock acceleration is a standard model to explain acceleration of cosmic rays or energetic particles within our galaxy, however, extra galaxic origins are not ascertained. Recently, wakefield acceleration has been considered as a candidate for origins of cosmic rays. Lyubarsky demonstrated that the synchrotron maser instability due to the interaction between the incoming plasma flow and shock front could radiate the large-amplitude light waves [1]; Hoshino reported that the large-amplitude precursor light waves in the upstream region of relativistic perpendicular shock waves excite wakefields to accelerate particles efficiently [2]. Kuramitsu numerically found that the power-law spectra of accelerated particles are independent of laser amplitude, plasma density and focal spot size of laser as long as the laser intensity is relativistic [3]. To demonstrate the power-law energy spectrum by wakefield acceleration, Kuramitsu et al. experimentally showed the evidence of nonthermal acceleration of relativistic electrons [4]. Further, Kuramitsu compared the mono-energetic spectra and the power-law energy spectra in wakefield acceleration [5], and Liu discussed the transitions of wakefields from coherent to inherent as the plasma density increasing [6]. The incoherent wakefields yielding the power-law spectra imply the stochastic accelerating of electrons. Chen indicated that the random accelerations and decelerations by turbulent wakefields result in a power-law energy spectrum with an index of -2 [7].

Since magnetic fields are everywhere in the universe, we are motived to investigate the nonthermal acceleration of relativistic electrons due to the wakefield acceleration induced by an intense laser pulse with static external magnetic fields [8]. The 2D-PIC simulation results indicate that the power-law spectrum with a factor -2 still remains under the condition of magnetic field B = 1000 T (ω_c/ω_p~0.3).

[1] Y. Lyubarsky, Astrophys. J. 652, 1297 (2006);
[2] M. Hoshino, Astrophys. J. 672, 940 (2008)
[3] Y. Kuramitsu, et. al., Astrophys. J. Lett. 682, 113 (2008)
[4] Y. Kuramitsu, et. al., Phys. Plasmas18, 010701 (2011)
[5] Y. Kuramitsu, et. al., HighEnergyDensityPhys. 8, 266 (2012)
[6] Y. L. Liu, et. al., HighEnergyDensityPhys. 22, 46 (2017)
[7] P. Chen, et. al., Phys. Rev. Lett. 89, 161101(2002)
[8] M. Iwamoto, et. al, Astrophys. J. Lett. 840, 52 (2017)