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Model experiments of cosmic ray acceleration using intense lasers

Yasuhiro Kuramitsu[1, 2, 3], Yao Li Liu[4], Masanori Iwamoto[5], Shogo Isayama[6], Toseo Moritaka[7], Tzu-Yao Huang[8], Nur Khasanah[8,9], Shih-Hung Chen[8], Hsu-Hsin Chu[8], Jyhpyng Wang[8, 10], Chih-Hao Pai[8], Che-Men Chu[4], Po-Yu Chang[4], Wei-Yen Woon[8], Chun-Sung Jao[11], Naoya Tamaki[1], Yuki Abe[1], Hayato Kusano[1], Rikimaru Kitamura[1], Fuka Nikaido[1], Kensei Iwasa[1], Shutaro Kurochi[1], Keita Yamanaka[1], Yoshiki Naito[1], Kaichi Iida[1], Ryusuke Yamamoto[1], Yoshiki Arakawa[1], Masaki Nagao[1], Tsuyoshi Takami[1], Yamato Esaki[1], Yutaka Nakamura[1], Shuta J. Tanaka[12], Kentaro Sakai[7], Takumi Minami[13], Hideyuki Suzuki[13], Youichi Sakawa[2], Kohei Yamanoi[2], Yuji Fukuda[3], Kotaro Kondo[3], Hiromitsu Kiriyama[3], Shuichi Matsukiyo[6], Michel Koenig[14], Tatiana Pikz[15], Hideki Kori[16], Masato Kanasaki[17], Masahiro Hoshino[18]

[1] Graduate School of Engineering, Osaka University, [2] Institute of Laser Engineering, Osaka University, [3] Kansai Institute for Photon Science, National Institutes for Quantum Science and Technology, [4] Institute of Space and Plasma Sciences, National Cheng Kung University, [5] Yukawa Institute for Theoretical Physics Program-Specific Researcher, Kyoto University, [6] Faculty of Engineering Sciences, Kyushu University, [7] National Institute for Fusion Science, [8] Department of Physics, National Central University, [9] Department of Physics Education, Faculty of Education and Teacher Training, Universitas Islam Negeri Mataram, [10] Institute of Atomic and Molecular Science, Academia Sinica, [11] National Center for High-performance Computing, [12] Department of Physical Sciences, Aoyama Gakuin University, [13] Graduate School of Information Science and Technology, Osaka University, [14] Laboratoire pour l'Utilisation des Lasers Intenses, Ecole Polytechnique, [15] Institute for Open and Transdisciplinary Research Initiative, Osaka University, [16] Research Center for Nuclear Physics, Osaka University, [17] Graduate School of Maritime Sciences, Kobe University, [18] Department of Earth and Planetary Science, University of Tokyo

e-mail (speaker): kuramitsu@eei.eng.osaka-u.ac.jp

Energetic particles in the universe, or cosmic rays, are ubiquitous in a variety of phenomena with their energies of orders of magnitude different. The origins of cosmic rays in our galaxy are considered to be the first-order Fermi acceleration relevant to collisionless shocks or the so-called diffusive shock acceleration. However, the origins of ultra-high-energy cosmic rays from extragalactic sources are not well understood. One of the candidates is wakefield acceleration in relativistic collisionless shocks, where the synchrotron maser instability emits intense electromagnetic waves. The intense electromagnetic waves propagate in the upstream of the relativistic collisionless shocks and excite wakefields. Then, the wakefields nonthermally accelerate particles in the upstream of the relativistic collisionless shocks [1-5]. However, there is no way to access such extreme astrophysical plasmas to verify this.

We have been working on space and astrophysical phenomena in laboratories using high-power lasers and exploring the relativistic regime with intense, short-pulse lasers [6]. By replacing the intense electromagnetic waves with intense lasers, we have demonstrated relativistic electron acceleration with the power-law components in high-energy tails of the energy distribution functions [7, 8]. Recently, we have been investigating the ion wakefield acceleration with controlled injection of pre-accelerated ions into the relativistic wakefield [9]. We introduce model experiments of cosmic ray acceleration in laboratories using intense lasers. We address the universality of the power-law spectra of energetic particles in laboratories and in the universe.

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