Achieving Laser Wakefield Accelerated Electron Beams of Low Enough Energy Spread for an X-FEL

J. K. Koga[1], S. V. Bulanov[1], T. Zh. Esirkepov[1] and M. Kando[1]

[1]*Quantum Beam Science Center, Japan Atomic Energy Agency, Kizugawa, Kyoto, Japan*
**E-mail: koga.james@jaea.go.jp*

Abstracts: *We describe a method to obtain sufficiently low energy spread laser-wakefield accelerated electron beams for injection into a conventional undulator to obtain free electron lasing. This is done by the combination of two laser pulses and a tailored gas density profile. A moderate power laser is used to inject electrons into the wakefield which are then accelerated to sufficient energies for injection and further acceleration in a wakefield generated by a second more powerful laser pulse. If the electron bunch is accelerated to 1 GeV, an energy spread of ~0.1% is possible. The realization of such a bunch would make possible the construction of a compact x-ray free electron laser.*

Since the proposal for the laser wakefield acceleration of electrons [1], great progress has been made towards achieving such compact accelerators (see [2] and references cited therein). However, such beams do not yet have small enough energy spread and transverse emittance for efficient lasing in an x-ray free electron laser (X-FEL). In this paper we will address the issue of achieving such a sufficiently small energy spread. The concept involves the use of staging. In the first stage electrons are injected into the wakefield behind a moderate power laser pulse with a steep density gradient [3-5]. The density gradient allows us to control into which bucket the electrons are injected. After the injection the electrons are accelerated in a lower density plasma. The possibility to obtain high quality beams using such a combination has been shown previously [4]. By controlling the length of the acceleration we can obtain a minimal energy spread. We show this using 2D particle-in-cell simulations (PIC) [6]. After achieving electron bunches with energies of 26 MeV and energy spreads of ~5%, we propose further accelerating the bunches in a lower density plasma with a second more powerful laser. The key to achieving GeV level energy bunches with small energy spreads near 0.1% is the proper phase matching of the electron bunch into the wakefield. We show this using 1D theory [7]. Such beams would be a step closer towards achieving the goal of a compact X-FEL.

[1] T. Tajima and J. M. Dawson, Phys. Rev. Lett. 43, 267 (1979).
[2] E. Esarey, C. B. Schroeder, and W. P. Leemans, Rev. Mod. Phys. 81, 1229 (2009).
[3] S. Bulanov, N. Naumova, F. Pegoraro, and J. Sakai, Phys. Rev. E 58, R5257 (1998).
[4] P. Tomassini, M. Galimberti, A. Giulietti, D. Giulietti, L. A. Gizzi, L. Labate, and F. Pegoraro, Phys. Rev. ST Accel. Beams 6, 121301 (2003).
[5] A. V. Brantov, T. Z. Esirkepov, M. Kando, H. Kotaki, V. Y. Bychenkov, and S. V. Bulanov, Physics of Plasmas 15, 073111 (2008).
[6] T. Esirkepov, Computer Physics Communications **135**, 144 (2001).
[7] T. Esirkepov et al., Phys. Rev. Lett. 96, 014803 (2006).