A robust method to generate brilliant electrons through laser interaction with NCD plasma converted from hohlraum radiation of foam target

Jieru Ren[1], Zhigang Deng[2], Ziyao Wang[1], Mingzhe Yang[1], Wenqing Wei[1], Lirong Liu[1], Dieter H. H. Hoffmann[1], Benzheng Chen[1], Shisheng Zhang[1], Bubo Ma[1], Fangfang Li[1], Yun Liu[1], Zhongfeng Xu[1], Wei Qi[2], Shaoyi Wang[2], Quanping Fan[2], Zongqing Zhao[2], Zhurong Cao[2], Yuqiu Gu[2], Yong Chen[2], Bo Cui[2], Shukai He[2], Shaoping Zhu[2,3,4], Leifeng Cao[5], Rui Cheng[6], Guoqing Xiao[6], Hongwei Zhao[6],Weimin Zhou[2], Yongtao Zhao[1*]

[1] School of Physics, Xi'an Jiaotong University, Xi'an 710049, China

[2] Laser Fusion Research Center, China Academy of Engineering Physics, Mianyang 621900, China

[3]Institute of Applied Physics and Computational Mathematics, Beijing 100094, China.

[4]Graduate School, China Academy of Engineering, Physics, Beijing 100088, China.

[5]Shenzhen University of Technology, Shenzhen, 518118, China

[6] Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730070, China

e-mail (speaker):renjieru@xjtu.edu.cn

The laser-driven relativistic electron beam is characteristic of short pulse, high energy and large charge quantity. It has significant applications in suprathermal electron transportations, fast ignitions, particle beam radiography, and the generation of ultra-short X/γ radiation sources as well as neutron sources. Generally, there are three ways to generate electron beams with lasers, including laser-foil interaction through pondermotive force acceleration, laser-low-density-plasma interaction through wake-field acceleration as well as laser-NCD plasma interaction through direct laser acceleration (DLA) mechanism. Comparatively, The DLA electrons have advantage of both high energy and high brilliance, hence attracted a lot of attentions these years. However, the experimental realization of stable and controllable NCD plasma remains highly challenging. For example, NCD plasmas generated via solid target ablation evolve rapidly with unstable parameter gradients, while those produced by hypersonic gas jets suffer from long rising edges and limited maximum density.

We experimentally generate uniform and stable NCD plasma sample (T~17 eV, $n_e \sim 4 \cdot 10^{20}$ cm^{-3}) through heating a foam target with nanosecond-laser-induced hohlraum radiation in the soft x-ray regime. When a high-power ps laser was focused in the plasma, the DLA mechanism was effectively triggered and a brilliant relativistic electron beam was generated. Previous studies[1] have shown that nanosecond-laser-heated foam evolves into plasmas with specific density gradient profiles depending on the delay. Measurement with different delays between the ps laser and ns laser were investigated to study the characteristics of the resulting electron beams.

In cases of 6 to 15 ns delay, the electron beam spectra can be relatively well-repeated, which demonstrated the robust property of this method. The electron beam has a Maxwellian distribution with temperature of about 12 MeV and cutoff energy near 90 MeV. The charge quantity is about 90 nC for electrons with energy larger than 1 MeV. The half-divergence angle is about 11°. By adding a high-Z converter, brilliant γ-ray sources with brightness up to 10^{10} /sr (reference energy: 16 MeV) were further produced.

References

[1] O.N. Rosmej et al., Plasma Phys. Control. Fusion 57, 094001 (2015)