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Generation of laser-driven proton beams from nanostructured film targets
薄膜上にナノ構造を付したターゲットからのレーザー駆動陽子線発生

Yuto Nakashima[1,2], Shunsuke Inoue[1,2], Kensuke Teramoto[1,2], Masayasu Hata[1], Yoshihide Nakamiya[2], Masaki Hashida[1,2], Shuji Sakabe[1,2]
中島裕人[1,2], 井上峻介[1,2], 寺本研介[1,2], 畑昌育[1], 中宮義英[2], 橋田昌樹[1,2], 阪部周二[1,2]

[1]*Department of Physics, Graduate School of Science, Kyoto University*
Kitashirakawa, Sakyo Kyoto 606-8502, Japan
[2]*Advanced Research Center for Beam Science, Institute for Chemical Research, Kyoto University*
Gokasho, Uji Kyoto 611-0011, Japan
[1]京都大学大学院理学研究科 〒606-8502 京都市左京区北白川
[2]京都大学化学研究所 〒611-0011 京都府宇治市五ヶ庄

We have demonstrated the usefulness of a nano structure target to improve the maximum energy of laser-accelerated proton beam. A moth-eye filem is irradiated by 10TW femotosecond laser pulses. The maximum energy of proton beam is much enhanced to up to 9MeV at most, while lesss than 3MeV for a polethylene foil target. This result would be a motivation to drive much more development of the targets for future proton laser acceleration.

1. Introduction

Proton beams generated and accelerated by the interaction of intense laser pulses with foils have unique characteristics such as temporal shortness (pulse), low emittance, and high brightness. These are promissing for the applications such as a proton beam cancer therapy[1], proton radiography[2], and radioisotope production for PET (Positron Emission Tomography) [3]. Many studies have been performed to reduce beam divergence angle (emittance), and energy spectra width to get higher beam quality. It is rather important issue in particular to generate higher energy with a compact laser system. It is of importance to develop ways to improve the quality of proton beam, without depending on the intensity of laser pulse emitted from rather huge facilities, that is, to develop targets. There have been some reports that high energy proton beams are generated from nanostructured targets[4],[5],[6]. In this study, we have studied the performances for the target of a moth-eye film. This nanostructured film is made of polymer and promising for reduce the cost of target supply [7]. On the surface of the film, small pillars (their height and radius are few hundred nm) line up in a honey-comb-like structure. Irradiating 10 TW short (40fs) laser pulses on this film, then we have succeeded in generating much higher energy protons than for the plastic film without nanostructure.

2. Experiments

The experiment was conducted using the T^6 laser system at the Institute for Chemical Research, Kyoto University. Laser pulses are generated from Ti:sapphire chirped pulse amplifiers, the pulse duration is 40 fs, and the central wave length is 800nm. The laser pulse is focused on the foil target to a spot size of 3μm × 5μm (FWHM) by F/3.2 off-axis parabolic mirror to have the intensity of 2×10^{19} W/cm^2. Schematic of experimental setup is shown in Fig. 1. The angle of laser incidence is 45°. The targets are a moth-eye film and a polyethylene film. To detect proton beam, we have used stacked CR-39 plastic track detectors (CR-39 stack) . The "CR-39 stack" consists of five-layered CR-39 and is covered with an aluminum filter (11μm thickness). The first CR-39 layer of the CR-39 stack is in 100μm thickness and the stack from the second through fifth CR-39 layers have 900μm thickness. Table I shows how much energy of protons are detected in each layer. We have estimated the maximum energy of the proton beam by observing the tracks on the CR-39.

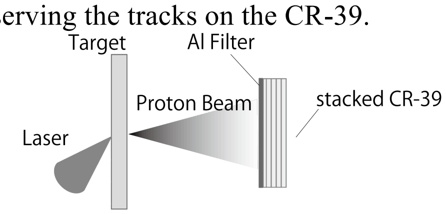

Fig.1. Schematic top view of the experimental setup. The "CR-39 stack" is set in the direction of the target normal.

Table I. Energy of protons detected in each CR-39 layer.

CR-39 layer	Energy of protons E (MeV)
1st	$0.9 < E$
2nd	$2.8 < E$
3rd	$9.2 < E$
4th	$13 < E$
5th	$16 < E$

3. Results

When laser pulses are irradiated to the nanostructured side of a moth-eye film target, proton tracks can be seen on the second CR-39 layer. On the other hand, for a polyethylene target, no proton tracks can bee seen as all (Fig. 2). From this observation, we confirm that the maximum energy of proton beam from moth-eye film target is much higher than that from a polyethylene target, and its energy is estimated from 2.8 to 9.2MeV.

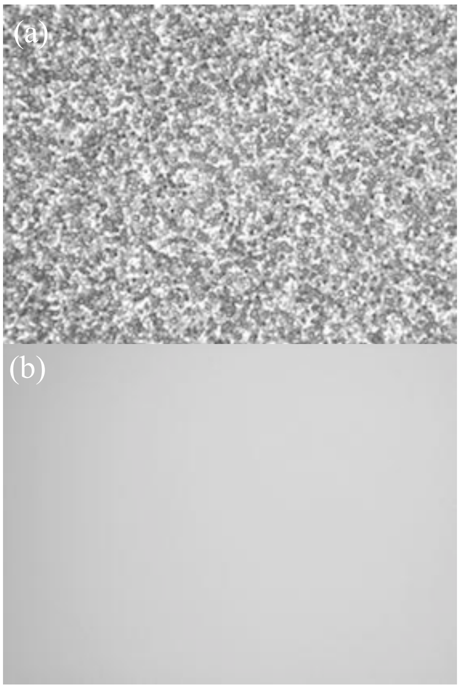

Fig.2. Processed the second CR-39 layer for the targets of a moth-eye film target (a) and a polyethylene film target (b).

4. Summary

We have succeeded in generating higher energy proton beam by using a moth-eye film target than using a polyethylene target. This shows that this nanostructured film is useful to enhance the maximum energy of laser-driven proton beams.

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References

[1] A. J. Mackinnon, P. K. Patel, M. Borghesi, R. C. Clarke, R. R. Freeman, H. Habara, S. P. Hatchett, D. Hey, D. G. Hicks, S. Kar, M. H. Key, J. A. King, K. Lancaster, D. Neely, A. Nikkro, P. A. Norreys, M. M. Notley, T. W. Phillips, L. Romagnani, R. A. Snavely, R. B. Stephens, and R. P. J. Town, Phys. Rev. Lett. **97** (2006), 045001.

[2] S. V. Bulanov, and V. S. Khoroshkov, Plasma Phys. Rep., **28** (2002), 453.

[3] K. W. D. Ledingham, P. McKenna, T. McCanny, S. Shimizu, J. M. Yang, L. Robson, J. Zweit, J. M. Gillies, J. Bailey, G. N. Chimon, R. J. Clarke, D. Neely, P. A. Norreys, J. L. Collier, R. P. Singhal, M. S. Wei, S. P. D. Mangles, P. Nilson., K. Krushelnick, and M. Zepf, J. Phys. D: Appl. Phys. **37** (2004), 2341.

[4] D. Margarone, O. Klimo, I. J. Kim, J. Prokůpek, J. Limpouch, T. M. Jeong, T. Mocek, J.Pšikal, H.T. Kim, J. Proška, K. H. Nam, L. Štolcová, I. W. Choi, S. K. Lee, J. H. Sung, T. J. Yu, and G. Korn, Phys. Rev. Lett. **109** (2012), 234801.

[5] T. Ceccotti, V. Floquet, A. Sgattoni, A. Bigongiari,4 O. Klimo, M. Raynaud, C. Riconda, A. Heron, F. Baffigi, L. Labate, L. A. Gizzi, L. Vassura, J. Fuchs, M. Passoni, M. Květon, F. Novotny, M. Possolt, J. Prokůpek, J. Proška, J. Pšikal, L. Štolcová, A. Velyhan, M. Bougeard, P. D'Oliveira, O. Tcherbakoff, F. Réau, P. Martin, and A. Macchi, Phys. Rev. Lett. **111** (2013), 185001.

[6] A. Zigler, S. Eisenman, M. Botton, E. Nhum, E. Schleifer, A. Baspaly, I.Pomerantz, F. Abicht, J. Branzel, G. Priebe, S. Steinke, A. Andreev, M. Schnuerer, W. Sandner, D. Gordon, P. Sprangle, and K. W. D. Ledingham, Phys. Rev. Lett. **110** (2013), 215004.

[7] C. J. Ting, F. Y. Chang, C. F. Chen and C. P. Chou, J. Micromech. Microeng. **18** (2008), 075001.