Developments of Laser-driven Ion Sources using T-cubed Laser

Background

Our laboratory raised laser and optical technology in enrichment of uranium, and now is developing optical measurement technologies such as high-precision laser radar and researching laser-driven energetic particle sources. In particular, it might be possible to apply a special laser called T-cubed laser (T^3:Table Top Tera Watt Laser) to material evaluation and diagnoses of facilities and equipments. In addition, since ion sources generated by this laser can produce positron emission isomer, application to positron emission tomography (PET), which is promising for early detection of cancer, is also expected. In order to turn this new type of ion source to practical use, we need grasp the conditions for more efficient acceleration.

Objectives

To seize the characteristic of laser-driven ion sources, to find the most suitable condition for ion acceleration, and further clarify the possibility of new ion sources to apply to diagnoses of plants and to the medical field.

Principal Results

1. Production of protons with high energy level for fluorine 18 generation

Using our T-cubed laser and a very thin tape target, which is made of a low density compound of hydrogen and carbon, we obtained hydrogen ion (proton) with maximum energy of 3 MeV (Fig.2). This value is equivalent to three million volts in acceleration voltage and is beyond the threshold of generation of fluorine 18(^{18}F), which is most frequently used as a positron emission isomer in PET. Although, usually protons with energy more than 10 MeV are used for the isomer generation, we have prospects for increasing proton energy by improvement of laser focusing in the near future.

2. Clarification of proton acceleration mechanism

Dependence of proton generation on laser pulse duration was investigated and the result was that the difference was small when pulse duration was longer than 1 ps. Maximum proton energy was found to be estimated by a isothermal plasma expanding model. From these results, we derived the feasibility of effective ion acceleration by Yb-YAG Laser, which is expected to be more efficient and more compact, and showed the direction of future developments in this field.

Future Developments

From results as described above, we obtained prospects for generation of positron emission isomer in PET using T-cubed laser. As the next step, other parameters such as laser focus diameter will be investigated for the purpose of developing more efficient ion source. We will also try to generate positrons through X-ray conversion because positron analysis is a powerful tool for estimation of material damage.

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Reference

T. Nayuki, et al., 2003, “Thin tape target driver for laser ion accelerator”, Rev. Sci. Instrum. vol.74, 3293.

Fig.1 T-cubed Laser

In spite of small energy of 1J, ultra short pulse can lead ultra high peak power of 20 TW (1 TW=10^{12} W). Using this laser, we are studying high-energy particle generation and developing new diagnoses of plants and equipments.

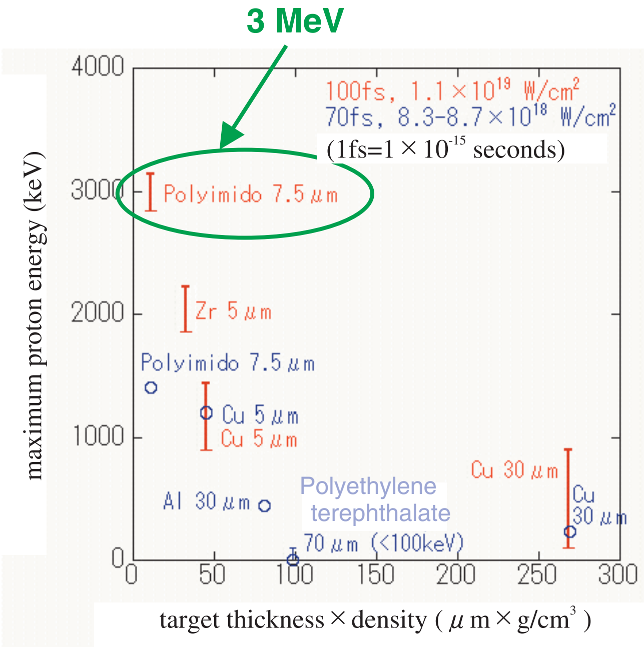

Fig.2 Dependence of proton energy on target hickness and density

As a target, thinner and lower density material is better for generation of higher energy protons. Thus far, our laboratory obtained maximum energy of 3 MeV, which is equivalent to three million volts in acceleration voltage.

Fig.3 Cross Section for Positron Emission Isomer Generation

It is possible of our protons with energy of 3 MeV to generate fluorine 18, which is most frequently used in medical diagnosis.

^{18}O(p,n)^{18}F means production of a fluorine 18 and a neutron by a interaction between a energetic proton and a oxygen 18 in a target.