High repetition-rate laser-driven carbon ion generation for the injector of a heavy ion beam cancer therapy system

Sadaoki Kojima, Kotaro Kondo, Thanh Hung Dinh, Tatsuhiko Miyatake, Noboru Hasegawa, Masahiko Ishino, Michiaki Mori, Hironao Sakaki, Mamiko Nishiuchi, Akira Kon, Nicholas Peter Dover, [A]Shunsuke Inoue, [A]Masaki Hashida , [A]Shuji Sakabe, Masaharu Nishikino, Masaki Kando, [B]Toshiyuki Shirai, and Kiminori Kondo

Kansai Photon Science Institute, QST, Kizugawa, Kyoto, Japan
[A] Advanced Research Center for Beam Science, ICR, Kyoto Univ., Gokasho, Uji, Kyoto, Japan
[B] National Institute of Radiological Sciences, QST, Chiba, Japan
kojima.sadaoki@qst.go.jp

Laser-driven carbon ion acceleration is being investigated as a potential injector into a compact accelerator for carbon ion radiotherapy. However, the stability and repetition rate of these ion sources is still under development and currently insufficient for practical medical applications. In many experiments, a thin film of high-purity carbon such as diamond-like carbon or graphite has been used as the target. [1] However, these thin carbon films are too fragile to be replenished with a high repetition rate. Graphite synthesized by chemical vapor deposition on transition metal substrates such as nickel can be a potential candidate target for laser-driven carbon ion acceleration. The metal substrate is flexible, even at micrometer-scale thicknesses, and this property allows target supply with high repetition-rate. In addition, the number of graphene layers that grow on the substrate can be controlled on the thickness of the substrate. This allows for the fabrication of many targets with the same quality. [2] In this study, 300 layers of graphene (100 nm thickness) grown on a 10 um-thick nickel substrate was used as the target. The laser pulse（330 mJ, 80 fs） was focused on the target by an f/2.7 off-axis parabola with a 45° incident angle at an intensity of 2×10^{19} W/cm^2. The maximum energy of accelerated carbon ions (C^{4+}) is 0.5 MeV/u, comparable to the extraction energy of a radio frequency quadrupole (RFQ) accelerator which acts as the first stage of the ion injector of current accelerators for carbon ion radiotherapy. [4]

[1] A. Henig et al., Phys. Rev. Lett. **2009**, 103, 245003.
[2] R. Kato and M. Hasegawa, Carbon N. Y. **2019**, 141, 768-773.
[3] Y. Iwata et al., Nucl. Instruments Methods Phys. Res. Sect. A Accel. Spectrometers, Detect. Assoc. Equip. **2007**, 572, 1007-1021.