

Proton Beam Generation by Nanotube Accelerator

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Carbon nanotubes (CNTs) are hardy and versatile, with remarkable material and electronic properties. And they could be useful in some extreme conditions as well. We here propose a novel ion acceleration scheme using CNTs [1, 2], where embedded hydrogen-rich fragments - which could be water ice, paraffin, or some other low-Z material but were modeled as hydrogen nanotubes - are irradiated by an intense laser to eject substantial numbers of electrons. Due to the resultant unique electrostatic field, the nanotube and the embedded materials play the roles of the barrel and bullets of a gun, respectively, to produce highly collimated and quasimonoenergetic proton beams. Such beams are of great interest in fields as diverse as medicine, fusion energy, and materials engineering.

Figure 1 shows the schematic view of a nanotube accelerator. The double-nested nanotubes are irradiated by an ultrashort ultraintense laser pulse. The outer carbon nanotube is assumed to be chemically adsorbed with heavy atoms such as gold, while the inner nanotube is made of light materials such as hydrogen and carbon to form the projectiles. After blowing off the electrons, the remaining nanotubes composed of positive ions generate a unique electrostatic Coulomb field so that the inner ions are accelerated along the axis symmetrically toward both ends of the outer nanotube.

Figure 2 shows temporal evolution of the proton energy spectrum in the axial (solid curves) and radial (dashed curve at $T=5$) directions obtained by three-dimensional molecular-dynamic simulations, where T denotes time normalized by the laser cycle. The size of CNT is only 30 nm. As a result quasimonoenergetic protons with an energy of about 1.5 MeV are produced. If the hydrogen atoms are replaced by carbon atoms, the maximum ion energy increases to 10 MeV for the same target structure.

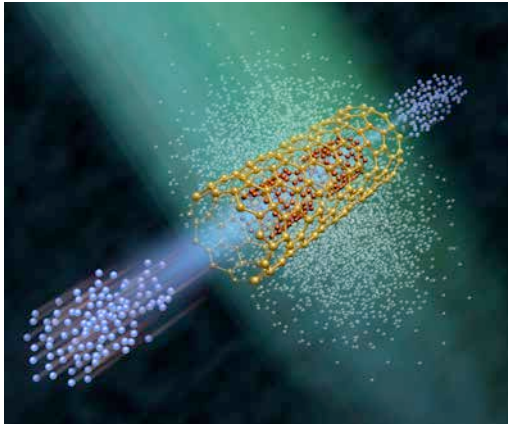


Fig. 1: Schematic of a nanotube accelerator

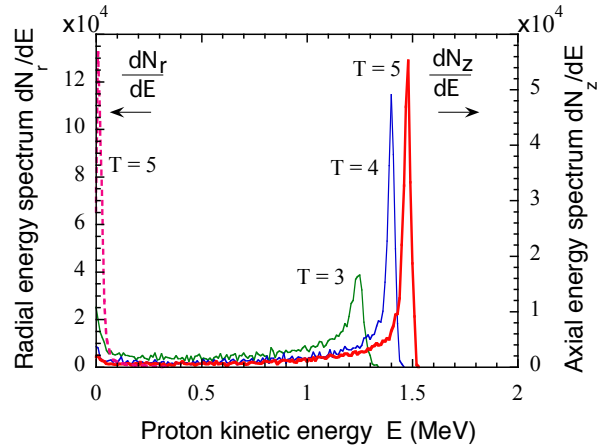


Fig. 2: Temporal evolution of energy spectrum

[1] M. Murakami, M. Tanaka, *Appl. Phys. Lett.* **102**, 163101 (2013).

[2] S.G. Benka, *Physics Today* **66**, 17 (2013).

