5-1 Demonstration of a New Method for Ion Acceleration Aiming at a Development of a Compact Laser-Driven Hadron Therapy System

—Ion Acceleration Using Subcritical-Density Plasma Created Using a Nanoparticle Target—

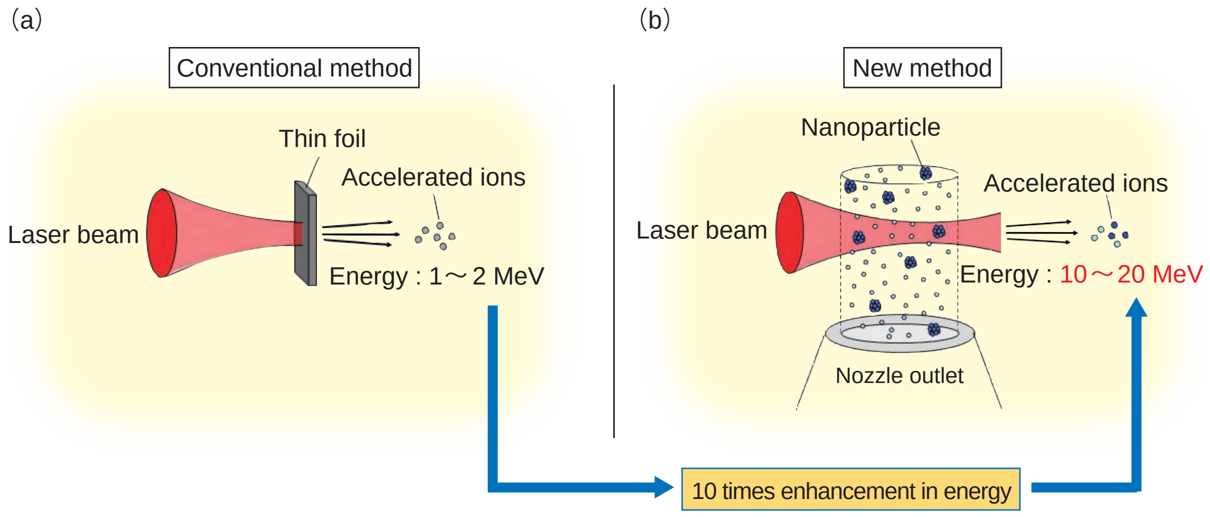

Fig.5-3 Schematic of laser-driven ion acceleration
In a conventional method (a), high energy ions are generated by irradiation of a focused laser beam onto a micron-thick foil target. In the new method (b), instead of using thin foil targets, the laser beam is focused onto a nanoparticle target. In the case of the nanoparticle target, it is easy to create a state of matter that effectively absorbs laser energy, called subcritical-density plasma. As a result, we demonstrated efficient generation of high energy ions whose energies are ten times higher than those in previous experiments with thin foil.

Extremely strong electromagnetic fields at micron scale are created by irradiation of a strong focused laser beam onto matter. Laser-driven ion acceleration, which utilizes such strong electromagnetic fields, has attracted much attention in terms of hadron therapy system downscaling and cost reduction. A laser-driven ion beam with energies of 80~250 MeV is required for the purpose of a medical application. However, if we used the conventional ion acceleration method using a thin foil target (Fig.5-3(a)), it would require an enormous amount of laser energy from a newly-developed large-scale laser system. Therefore, in order to downscale the whole treatment unit including the laser system, we have to discover a new method for ion acceleration using the compact laser systems which are widely used around the world.

In the Photo-Medical Research Center (PMRC), instead of using a thin foil target but by irradiating a laser beam onto a nanoparticle target, we successfully created a state of matter (called "subcritical-density plasma") which can effectively absorb laser energy (Fig.5-3(b)). As a result, we demonstrated efficient generation of high energy ions with energies up to 10~20 MeV. This corresponds to an approximately tenfold improvement in accelerated ion energy compared to previous experiments (1~2 MeV) with thin foil targets.

The experimental results and computer simulations estimate that ions greater than 200 MeV could be generated at a laser intensity of 10^{20} W/cm^2 with the nanoparticle target, which is one of the milestones of the PRMC's research program. The laser intensity of 10^{20} W/cm^2 could be attainable using the compact laser system at the PMRC, if its beam quality can be further improved. Moreover, the new method is replenishable and has a small divergence angle, which makes it possible to shorten the treatment time with an increase in the dose rate, and to construct a compact beam transport system.

In summary, the method we demonstrated has the potential to enhance development of a compact laser-driven hadron therapy system.

Reference
Fukuda, Y. et al., Energy Increase in Multi-MeV Ion Acceleration in the Interaction of a Short Pulse Laser with a Cluster-Gas Target, Physical Review Letters, vol.103, issue 16, 2009, p.165002-1—165002-4.