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Development of laser driven carbon ion injector for the next generation heavy ion cancer therapy machine

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One of the most important advantage of laser driven acceleration is that the size of the energetic accelerator could be much smaller than the conventional accelerator. Then the researcher of laser driven ion acceleration mentions that the possibility of the compact and the low-cost particle cancer therapy machine, which will enable to bring the innovation in the radiation cancer therapy. However, a few decades have passed from the start of the real experimental laser driven ion acceleration study. Not only laser driven ion acceleration, but also electron acceleration is not used as the real accelerator for some application. Moreover, recently, proton cancer therapy machine has been developed to be compact and low-cost with a conventional accelerator technology. For example, the size of the advanced proton therapy machine became is very compact, then the diameter of the cyclotron for generating 230 MeV proton beam is 5 m in diameter and the site area of the accelerator is roughly 30 m square in commercial base. Although the one of the important goals of laser driven ion acceleration is the development of laser driven proton cancer therapy machine mainly in EU. Actually, still no one succeeded in generating over 200 MeV proton beam even with a large CPA (Chirped Pulse Amplification) laser system. In this back ground, National Institutes for Quantum and Radiological Science and Technology (QST) has been started from 2016. QST is the band new society in Japan, which has been made with combining the part of Quantum Beam Science Directorate (QuBS), Japan Atomic Energy Agency, and National Institute for Radiological Science (NIRS). NISRS was the pioneer of the heavy ion (carbon) cancer therapy, they were trying to develop a compact heavy ion cancer therapy machine for generalizing this excellent cancer treatment. Actually, by using heavy ion beam, we can expect much more excellent treatment than proton beam in particle cancer therapy. For example, unresectable pancreatic cancer can be treated by heavy ion cancer therapy with a chemical treatment depending on the better stopping property in the body. At the beginning of QST, the development of the next generation heavy ion cancer therapy during coming ten years has been shown by the president. This therapy will be held with the next generation heavy ion cancer therapy machine called “Quantum Scalpel”. The main accelerator of this Quantum Scalpel is the super conducting synchrotron accelerator of which diameter is 8 m. The laser driven accelerator is to be used for the injector to this main accelerator. The laser driven injector is expected to be placed inside the ring of the 8 m super conducting synchrotron. By making compact this injector, the accelerator part of Quantum Scalpel could be placed on the site area of 10 m square. Then a comparatively large hospital is thought to be able to set Quantum Scalpel without making the additional building for the next generation heavy ion cancer therapy. Then the price of Quantum Scalpel could be suppressed so much. Therefore, one of the important key components is the laser driven carbon injector in Quantum Scalpel. The required specification of the laser driven injector is based on that of present injector of a linac with ECR ion source. It is required to inject 10^9 4 MeV/u carbons during 2 seconds. Here the number of injecting carbons is in the 1 % band width. Moreover, pure carbon beam has to be generated with over 99 % purity, although protons in a contamination on the target are mainly generated in laser driven ion acceleration in an usual laser driven ion acceleration in experiments. 4 MeV/u carbons has been already observed even in KPSI, then an enough number of 4 MeV/u pure-carbon beam generation is challenging goal. JST-MIRAI large scale project, which is a national project of MEXT in Japan, has started from Nov. 2017, which is total ten years project. This project includes the development of not only electron accelerator for the compact XFEL but heavy ion injector for the heavy ion cancer therapy machine.

In this study, the development of Quantum Scalpel will be introduced, and a present condition of the development of the laser driven carbon beam injector will be also shown.

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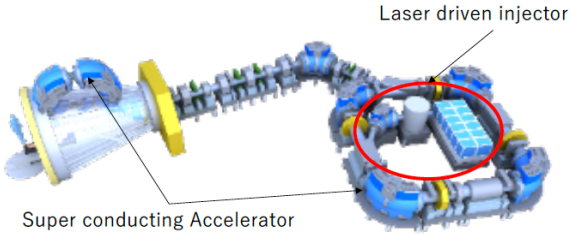

Figure 1 Schematic of Quantum Scalpel