Heavy-ion beams are very suitable for deeply-seated cancer treatment not only owing to their high dose localization around the Bragg peak, but also owing to the high biological effect there. NIRS, therefore, constructed HIMAC as the world’s first heavy-ion accelerator facility dedicated to medical use. NIRS has conducted the cancer treatment with a carbon-ion beam of HIMAC since 1994, which results in the treated patient number of more than 9000 during 20 years operation.

Since the carbon-ion radiotherapy with HIMAC was approved as an advanced medical technology in Japan in 2003, NIRS developed a compact carbon-ion radiotherapy facility in order to boost applications of the carbon-ion radiotherapy in Japan. As the fruits of this work, its pilot facility was constructed in the Gunma University, which has been successfully conducted since 2010.

Since 2006, further, NIRS has been engaged in a “new treatment research project” toward a new next generation research. One of the most important purposes is to realize the “adaptive cancer radiotherapy” to accurately treat tumor even with changing both the tumor size and shapes during a treatment period. Since both the static and moving tumors should be treated in HIMAC, the phase-controlled rescanning (PCR) method, based on a fast 3D scanning technology with a pencil-beam scanning, has been developed to move toward the goal of adaptive cancer radiotherapy. As one of the experimental studies for the fast 3D scanning technology, the survival curve of HSG cell line is shown in Fig. 1, which is obtained using the fast 3D scanning. In this figure, the red line indicates the survival curve designed by Microdosimetric Kinetic Model (MKM), and the symbols are the measured ones. It is obviously found that the measured data are in good agreement with the designed survival curve. In order to verify the developed technology through the clinical study, the new treatment research facility was constructed. As the first stage, one of three treatment rooms has been opened since May 2011, utilizing an energy degrader for slice change for depth scanning in the 3D scanning. As the second stage since September 2012, both the first and second rooms have been being operated with the hybrid depth scanning with eleven energy steps of the HIMAC synchrotron toward more accurately treatment. Since September 2015, further, the NIRS scanning has adapted a full depth scanning with 201 energy steps of the HIMAC synchrotron. The moving-target treatment has been carried out since March 2015. As the third stage, a compact carbon-ion rotating gantry with superconducting technology has been developed in order to realize the intensity modulated carbon-ion RT (IMCT) combined with the 3D scanning, which will bring the more accurate and shorter-course treatments owing to the higher dose concentration. As shown in Fig. 2, the rotating gantry was already installed in the new treatment research facility, and has been in a beam commissioning stage since October 2015.

We report the development of HIMAC for the heavy-ion cancer radiotherapy in Japan.

References: