RECENT PROGRESS OF NEW CANCER THERAPY FACILITY AT HIMAC

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Abstract

The new cancer therapy facility has been constructed at HIMAC. In order to realize the adaptive charged particle therapy, the 3D scanning irradiation system is installed in the new facility. In March, 2011, the treatment room E was completed and the commissioning was finished. We started the heavy ion radiotherapy to the first patient as a clinical study on May 17, 2011. We have continued the clinical studies for a more than a dozen patients in this year. Some improvements and developments such as the superconducting rotating gantry are continued in parallel.

INTRODUCTION

Since 1994, the carbon beam treatment has been continued at Heavy Ion Medical Accelerator in Chiba (HIMAC) [1]. The total number of patients is more than 6,000 in 2011. Based on more than ten years of experience, we have constructed new treatment system at New Particle Therapy Research Facility in NIRS. The project design was started in 2006 and the facility building was completed in May, 2010 (Table 1). There are three treatment rooms in the facility. Two of them are equipped with fixed beam delivery systems in both the horizontal and vertical directions (Room E & F), and the other will be equipped with a rotating gantry (Room G). The heavy ion beam is provided from the HIMAC upper synchrotron (Fig. 1(a)).

The aim at the new facility is the establishment of the following subjects ,

1. Adaptive charged particle therapy,
2. Compact rotating gantry for carbon beam.

The size and shape of the tumours vary during the treatment period. The adaptive therapy is a method to meets the change of the targets. To achieve it, a 3D scanning method with a pencil beam is employed in the new facility [2]. The maximum ion energy is designed to be ^{12}C, 430 MeV/n in both the horizontal and vertical beam-delivery systems, in order to obtain more than the residual range of 30 cm. The Fig. 1(b) shows the horizontal and vertical irradiation lines for the treatment room E.

The rotating gantry improves the dose conformity and less sensitivity to range uncertainties. It also reduces the patient's load. The challenges of the carbon gantry are a cost and size, including the building. In the initial design of the rotating gantry using normal conducting magnets in NIRS, the weight was about 400 tons. We have preceded the development of the superconducting gantry to reduce the size and the weight.

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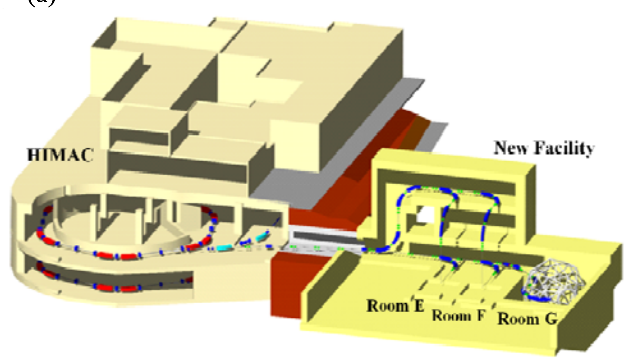
Table 1: Progress of the new facility project

Year	Events
2006 ~	Project started.
2009/2	Building construction started.
2010/3	Building construction completed.
2010/6	Machine installation started.
2010/9	First carbon beam to Room E.
2010/10	Commissioning at Room E started.
2011/5	Clinical trial at Room E started.

(a)



(b)

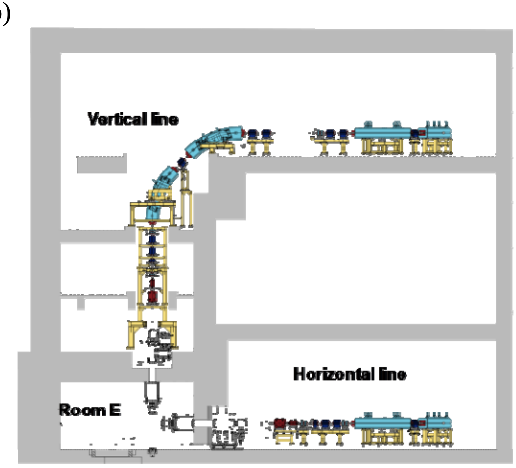


Figure 1: Schematic view of the HIMAC and New Particle Therapy Research Facilities (a), and the horizontal and vertical irradiation lines for the treatment room E (b).

OPERATIONAL STATUS

The first beam test of the high energy transport line was carried out in September, 2010 after the installation of the magnets (Fig. 2). Figure 3 shows the beam profiles of the carbon beam with 430 MeV/n and the beam envelope in the transport line. The β-function is 3m at the isocenter. In parallel with the transport line commissioning, the commissioning of the 3D scanning system was carried out from November, 2010 to March, 2011 [3].

Table 2 shows the major parameters of the 3D scanning system. The range of the carbon beam is controlled by the range shifter in our scheme and the beam energy is chosen according to the maximum range of each irradiation. The 4 kinds of the beam energy are available for the clinical trial. The commissioning of other energy continues and it will become 11 steps in this year. The beam intensity is constant now and it will be increase to 256 steps [4].

The carbon beam is provided from the existing HIMAC synchrotron but the synchrotron operation has been also improved for the 3D scanning. Figure 4 shows the typical operation pattern of the synchrotron and the 3D scanning system. When the scanning irradiation starts, the synchrotron change to the storage mode at the top energy until the stored beam becomes empty or the irradiation finishes. It can reduce the waiting time of the synchrotron and the treatment time.

Figure 2: High energy beam transport line (horizontal).

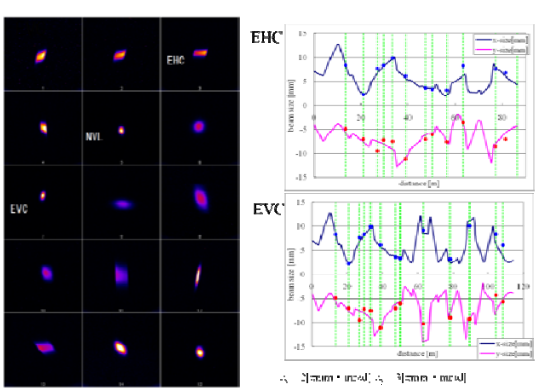


Figure 3: 2D beam profiles measured by florescence screens along the transport line (left) and the calculated and measured beam envelope (right). The horizontal and vertical emittance is assumed to be 2 and 4 π·mm·mrad, respectively.

We started the heavy ion radiotherapy at Room E to the first patient as a clinical study on May 17, 2011 and it was finished on June 10. We have continued the clinical studies for a more than a dozen patients in this year. The inside of Room E is shown in Fig. 5. The horizontal and vertical irradiation equipments such as range shifters, ridge filters, dose and position monitors are covered by the boxes. Patients are fixed on the treatment table with robotic arms.

Before the summer shutdown in August, 2011, the number of the patients treated by the 3D scanning irradiation is 8 and their targets are in pelvic and head regions. The total irradiation number is 124 and the irradiation time is 1–3 min. The average treatment time is 19 min per one patient, which includes the patient positioning. The beam operation period is 52 days (13 weeks) and 2-3 hours per day, which includes the beam QA time. There is no severe trouble in this period and the worst one was a three hours delay of the treatment due to the lightning damage.

Table 2: Major operating parameters of the irradiation

Ion species	Carbon
Beam energy	4 steps (290, 350, 400, 430 MeV) ⇒ 11 steps (140 ~ 430 MeV)
Beam intensity	1 step (~2 x 10^8 pps) ⇒ 256 steps (1x10^7 ~ 1x10^9 pps)
Irrad. method	Scanning + range shifter
Max. irrad. Area	220 mm x 220 mm
Max. SOBP	150 mm
Max. scan speed	X : 100mm/ms, Y : 50mm/ms

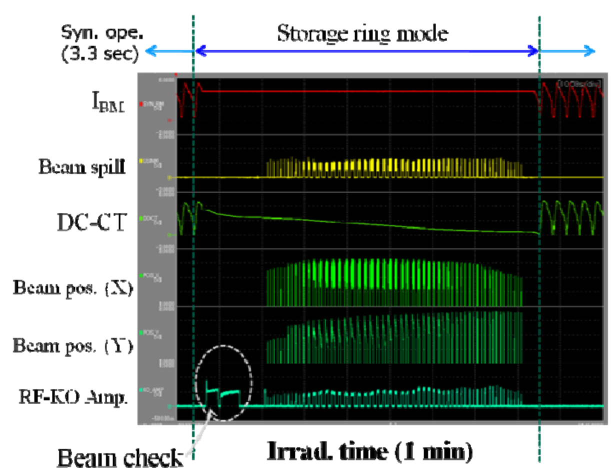


Figure 4: Typical operation pattern of the 3D scanning system. I_{BM} is the current of the bending magnets in the synchrotron. Beam positions are the measured values by the beam position monitors near the isocenter.

Figure 5: View of the treatment room E.

FUTURE PROMRAMS

The clinical studies at Room E continue until November, 2011 and the treatment will restart in 2012 at Room E and Room F. In parallel, some improvements and developments are planned in the new facility,

1. Combination scanning [5],
2. Scanning irradiation for the moving target [6],
3. Superconducting rotating gantry for carbon beam [7].

Because we use the thick range shifters, the multiple scattering in the range shifter becomes large in some cases and it worsens the dose distribution. Therefore, we plan to introduce the combination scanning scheme, which uses both the energy change of the synchrotron and the range shifters [5]. The thickness of the range shifter is limited within 20 mm. The existing 11 energy profiles are used in the new scheme and it can be omitted the new parameter adjustments and the beam measurements. It is expected to be the short commissioning time.

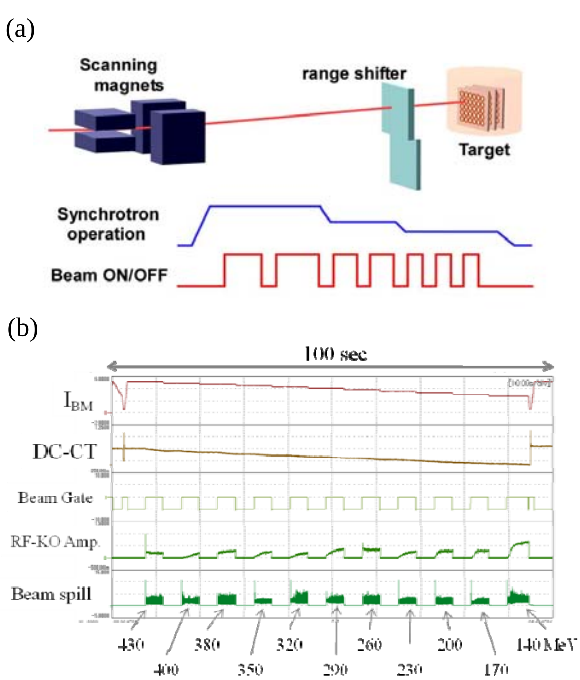


Figure 6: Scheme of the combination scanning (a) and the demonstration of the continuous change of the extracted beam energy (b).

The irradiation system in the new facility is the 3D scanning method not only for a fixed target but also for a moving target. The phase-controlled rescanning (PCR) method is implemented [6]. It can complete the several times rescanning of one slice during a single gated period of the respiration. This scheme is realized by the very fast scanning system and the intensity control system in the beam extraction from synchrotron in order to provide the optimum beam rate [4], because the period of the respiration is almost constant but the required dose is different slice by slice. The commissioning of the PCR method will start soon and the clinical trial is schedule in 2012-2013.

The development of the compact rotating gantry system using the superconducting magnet technology is also important subject in the new facility [7]. In the preliminary design, the gantry radius is 5.5 m and the total length is 13 m. We expect that the size and weight of the carbon gantry become those of the proton gantry (Fig. 7). The maximum beam energy is 430 MeV/n and the maximum bending magnetic field is 2.88 T. The 3D scanning system is identical with those of the fixed port.

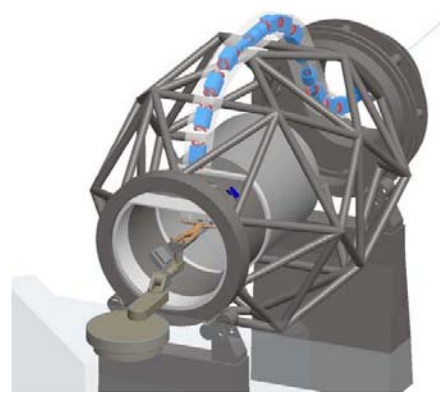


Figure 7: Schematic view of the superconducting rotation gantry for carbon beam.

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