Present Status of the Proton Therapy Project at the Wakasa Wan Energy Research Center

Kyo Kume, Shigekazu Fukuda, Sadayoshi.Fukumoto, Hisakazu Hamachi, Takashi.Hasegawa, Satoshi Hatori, Yutaka Hayashi, Go Kagiya, Shuji Kakiuchi, Shinobu Kimura, Michiya Kondo, Tetsuro Kurita, Ichiro Maruyama, Jun-ichi Mori, Hiroaki Yamada, Masahiro Yamada, Kazutaka Yamamoto and Noriya Yokohama

The Wakasa Wan Energy Research Center, Tsuruga 914-0192, Japan
e-mail: kkume@werc.or.jp

ABSTRACT

Present status of the proton therapy project at the Wakasa Wan Energy Research Center , Japan, is reported. Construction of the accelerator system was finished in 2001, followed by some trials of the production of the flat clinical irradiation field for the clinical usage. After the patient positioning system with X-ray CT was verified, the first clinical trial was started for two patients with prostate cancer.

Keywords: Particle therapy

1. INTRODUCTION

The proton therapy project at WERC (the Wakasa Wan Energy Research Center) was proposed before the construction of an accelerator system with a 5 MV tandem and a 200 MeV proton synchrotron. Beam tests were performed after the construction was finished last year. After the patient positioning system with X-ray CT were checked, the first clinical trial was started for two patients with prostate cancer, to get the governmental approval. The overview of this facility, beam and positioning tests, and the present status of the clinical trial will be reported below.

2. FACILITY

The medical facility in WERC consists of the accelerator system, the medical beam line, and the information part, all of which were constructed by Hitachi Ltd. In this section, each part is described briefly.

2.1. Accelerator system

The accelerator system is composed of a tandem accelerator and a proton synchrotron as mentioned above (See Fig.1). The tandem is used as an injector when this system delivers high energy ion beams on the occasion of the medical purpose. There are two ion sources in this accelerator system; a plasma sputtering type source for hydrogen and solid elements and a bucket type gas source. The former source is used for accelerating proton in the synchrotron use in the pulse mode, when maximum of 18 mA proton beam is injected to the tandem accelerator. The maximum terminal voltage of the tandem accelerator is 5 MV, which is generated by a Schenkel rectifier. The Schenkel type generator allow to accelerate high intense beam (at pulse operation: 18 mA x 250 μs x 0.5 Hz). By using large capacitance for the terminal condenser, the energy dispersion is 4×10^{-4} lower than RFQ-DTL system. The tandem beam is injected to the synchrotron by the multi-turn injection method and then accelerated up to 200 MeV in the case of proton, of which energy is almost high enough to be for the cancer therapy for many of Japanese people. The circumference of the synchrotron is 33.2 m. The superperiodicity is four. Each lattice has QF-D-OD-D-QF and it is operated in separate function style. Horizontal and vertical tunes are 1.75 and 0.85, respectively. The beam remains captured for about ten turns. The acceleration is done by an asyncronous RF cavity. After the acceleration, the beam is slow-extracted during the 0.5 sec flat top period by a RF-knockout method. Accelerated proton beam energies are 80, 90, 100, 120, 140, 160, 180 and 200 MeV by now. The construction of the accelerator system was finished in summer, 2000. The maximum proton beam intensity of 8 nA was measured at the beam shutter in the beam extraction course from the synchrotron at 200 MeV. The accelerator system is dedicated not only to medical purpose, but also to wide range of academic and industrial fields, such as biology, ion implantation, radiation damage, material science, and so on, with other beam lines. Details of this accelerator system are described in elsewhere.[1]

2.2. Medical beam line

The construction and commission of the medical beam line was finished in summer, 2001. This beam line consists of two medical irradiation ports and patient positioning system with X-ray CT. Two ports of "horizontal" and vertical courses were constructed. Here the "horizontal" course is not physically really horizontal but has a finite angle of 9.5 degrees to horizontal direction so that iso-center positions for both ports are united to one. The flat irradiation field of ϕ100mm x SOBP (Spread Out Bragg Peak) 100mm is produced, using tangsten scatters and a couple of wobbler magnets for lateral direction and alminium ridge filters for distal direction in each port. Beam passes a patient collimator made of brass with thickness of 60 mm and a patient bolus made of chemical wood in the air adjusted for the shape of tumor in a patient body. This shape is determined by a treatment planning system briefly described below. The observed irradiation field is shown in Fig.2. Absorbed dose is controlled by a pair of ion chambers in each port in air, signals of which are collected and analyzed by a PC of Windows NT connected to both of the accelerator control and the interlock system. Beam is finally delivered to the patient with dose rate of approximately 1 Gy/min/nA. Beam intensity for medical use is at present achieved up to 3 nA with certain quality in time structure of beam itself. Patient positioning system consists of an X-ray CT, a common bed with rails between the X-ray CT and the irradiation port, and a pair of a DR system with an image intensifier and a laser marking system both of which are located at each irradiation course. The X-ray CT, W-3000AD of Hitachi Medical Ltd., is set with a CT simulator system, to fix the iso-center position in the patient tumor from the CT image, to achieve a positioning precision of 1 mm. This X-ray CT is also used to take images used at treatment planning. After the iso-center is fixed, the patient is left on the common bed which is carried by technicians on the rail to the irradiation port. Before the irradiation starts, the iso-center is checked again with the DR system and the laser markers.

2.3. Information part

The information part consists of a treatment planning system, a database system, and a DICOM server. Once images of a patient are taken at the X-ray CT, the DICOM server saves data, which are used at the treatment planning system. Details of the treatment planning system, which was developed and customized by Hitachi Ltd. just for WERC, will be presented by one of the authors in this meeting.[2] It outputs the shape of a bolus and a collimator, beam parameters and snout conditions to the database system, and modified images with the dose distribution to the DICOM server.

3. CLINICAL TRIAL

Before starting clinical trials, some tests were carried out. Major subjects were (1) verification of irradiation field flatness, (2) measurement of RBE (Relative Biological Effect) value, (3) stability check of the accelerator performance and (4) interlock tests. As shown in Fig.2, the irradiation field flatness was shown to be within 2.5 % in the proton energy region of 100 – 200 MeV, which is flat enough for therapeutic purpose. The RBE value was determined with both of HSG cell and C3H/He mice to be 1.1. The stability check was carried out since radiation damages on some sequencers, which were finally moved outside of accelerator rooms, occurred during previous operation period of the synchrotron. The result of this check was good enough to keep operation for medical purpose. The interlock tests were carried out to check the whole system including the dose monitor system, the accelerator control system, and so on, and they were shown to be good enough for medical operation. The first treatment was started in June 2002, as the trial to get the Japanese governmental approval with six patients scheduled until August 2003. The first two patients with prostate cancer were treated in two months. A total dose of 67.5 GyE was delivered in 27 fractions to each patient. Though the accelerator system failed in some severe conditions, such as unstability in the ion source and an insulation breakdown at a deflector in the synchrotron, these first two treatments were finished already. In the meantime, the accuracy of the patient positioning system was verified within 1 mm as a daily check. The next clinical trial is planned between January and March, 2003, to treat four patients. Since there remains a big problem in the accelerator and beam transport system , it would take around a couple of hours to change both of the energy accelerated in the synchrotron and the irradiation port. This problem results in a small number of patients to be treated in one day, supposed to be limited up to around ten. This number should be increased with some improvements in the accelerator system.

4. CONCLUSION

The accelerator system and medical beam line were constructed at WERC. After some check of proper operation of the whole system, the clinical trial has started. In future, the number of daily patients shall be increased with improvement of the accelerator system.

REFERENCES

1. S.Hatori *et.al.*, Proceeding of the 13th Symposium on Accelerator Science and Technology (SAST2001), Suita, Osaka, Japan , 2001, pp. 25-27(2001).
2. S.Fukuda *et.al.*, presented in this meeting.

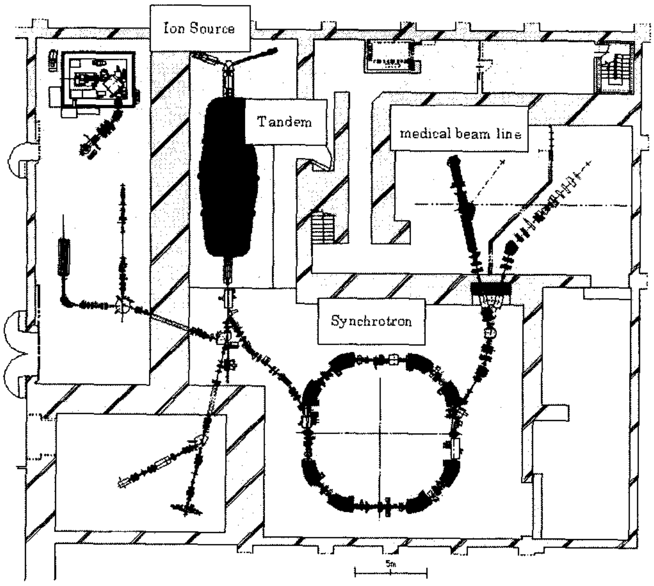

Fig. 1 Accelerator system at WERC.

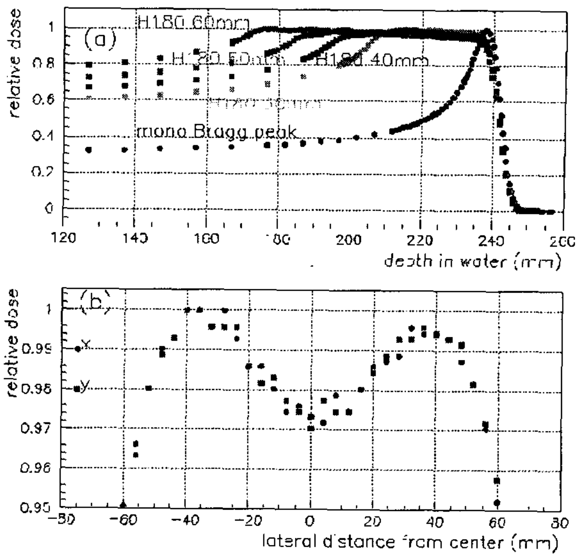

Fig. 2 Dose distribution measured in a water phantom for 200 MeV proton at the horizontal port. Irradiation field desired for clinical use is produced. (a) Depth distribution, (b) lateral distribution.