The present status of medical application of particle accelerator
- Started construction of a new medically dedicated proton accelerator facility in Tsukuba -

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A new facility of PMRC starts the construction in the neighborhood of Tsukuba university hospital, in order to establish technical skill for practical use in the cancer treatment and to grope for new skill. The facility has a linac injection system, a compact synchrotron, two rotating gantry rooms and two fixed horizontal beam lines. The outline of the design arranged for the facility is reviewed. As one of the important technique for the treatment, investigation into target adjusting accuracy in respiration-gated proton irradiation is presented.

1. Introduction

Medical application of particle accelerators is in progress recently owing to the rapid advance of accelerator technology and computer performance. Cancer treatment by heavy charged particles (proton, heavy ion) has advantage in its sharply controllable dose distribution without surrounding irradiation. As the next step following the proton radiotherapy (about 600 patients) at PMRC which has begun at 1983 in KEK , a new facility for proton therapy starts the construction in the neighborhood of Tsukuba university hospital. The purpose of the facility is to establish technical skill for practical use in the treatment and to grope for new skill such as scanning beam irradiation. In this report, the outline of the design for the facility is reviewed. The respiration-gated irradiation system was developed for the treatment of moving organ [1,2,3,4] with relation to the respiration. The technique is one of the importance for the cancer treatment in the new facility.

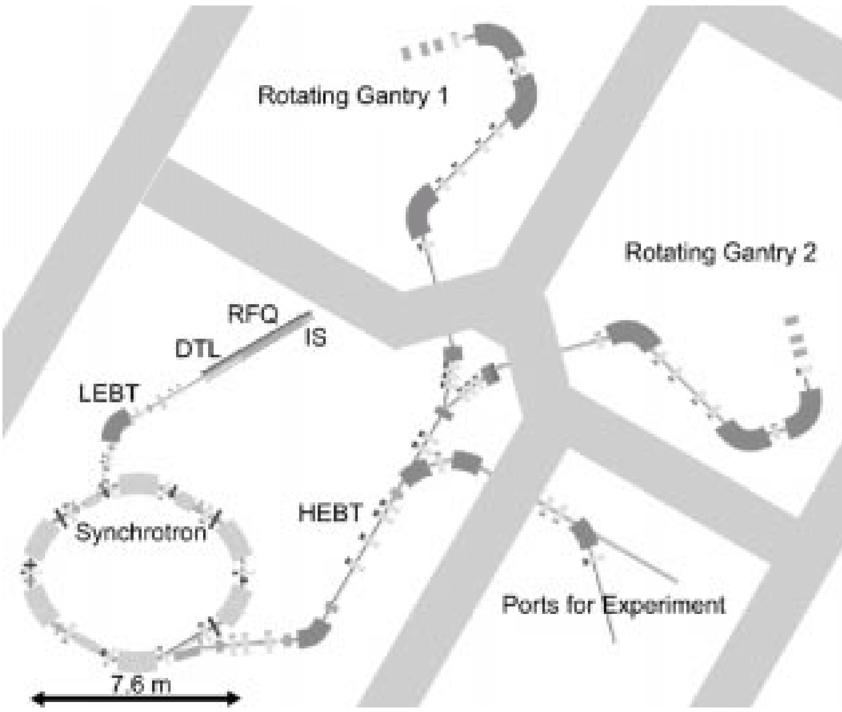

Fig. 1 Layout of the new facility in PMRC, Tsukuba.

Accuracy of the target adjustment in the irradiation synchronized with the respiration is investigated.

2. Outline of the facility.

The facility has a linac injection system (7MeV), a compact synchrotron (70-270 MeV) with separated functional lattice, two rotating gantry rooms and two fixed horizontal beam lines. The layout of the facility is shown in figure 1. Table 1 is the list of principal parameters of the accelerator proposed for the facility. In the accelerator, a broad band RF cavity using FINEMET is adopted because of its compactness and simple operation. The accelerated beam is extracted through the diffusion resonant extraction scheme developed by Hiramoto et al [5,6]. The diffusion is achieved by RF perturbation with nominal cycle time of 2 sec. This extraction scheme can make the current stable in the spill of beam emission and useful flexibility for the respiration-gated irradiation. Radiation dose rate of 2 Gy/min on the average can be obtained by the system even though intermittent irradiation for the respiration synchronized treatment. By using the rotating gantry, optimized irradiation angles are selectable in order to avoid damaging critical organs. In the nozzle of the gantry, scattering method is adopted to make beam spreading. To get sufficient beam spreading by the distance (3.2m) from the scatterer to the target position, new methods are developed for the facility. Dual-ring double scattering method [7] and hybrid filtering method are shown schematically in figure 2 with filtering apparatus in comparison with single scattering method.

Table 1 Principal parameters of the accelerator proposed for the new facility.

Injector (Duo-plasmatron+RFQ+ Alvarez -DTL)		
	Beam energy	7 MeV
	Peak current	15 mA
	Pulse	5 - 100 micro sec
	Momentum spread	+-0.3%
	Emittance(90%)	<1 pi mmmrad
	RF	425MHz
Synchrotron (Multiturn injection, Separated functional lattice)		
	Extraction energy	70-270 MeV
	Size	7.6 x 6.7 m
	Circumference	23 m
	Extracted Particle Number	1.8×10^{11} ppp
	Typical operation cycle	2 sec
RF Cavity (8 FINEMET cores)		
	Operation frequency	1.6 – 8.2 MHz
	Gap voltage	1.3kV
	Accelerating gap	40 mm

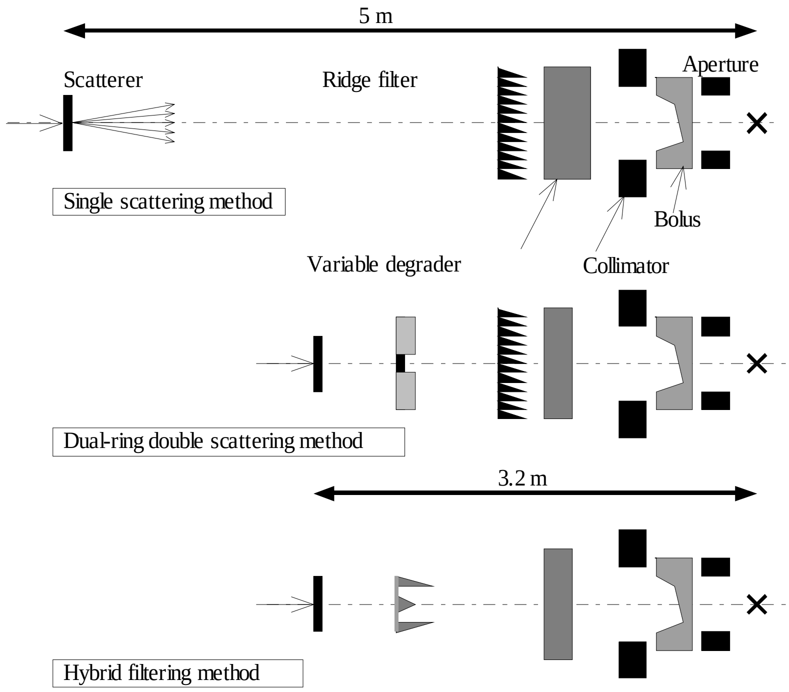

Fig. 2 Scattering methods for beam spreading.

3. Accuracy of target adjustment in the proton irradiation.

Precise measurement of target position on proton radiotherapy are performed in present facility of

PMRC to estimate the accuracy of the target adjustment in the irradiation synchronized with respiration. In order to estimate the target position in X-ray projected images, pattern matching of the moving region of interest is calculated for a frame of pictures one by one. The organ motion calculated by the pattern matching is shown in figure 3(b). The respiration signal given by measuring tension of body surface and the gate for irradiation are shown in figure 3(a). The correspondence between the respiration signal given by the tension measurement and the motion of the target organ is investigated [8]. By using the data, position deviation of the target during the irradiation period can be estimated as a function of discrimination level making the irradiation gate. On condition of usual treatment in which fraction of the irradiation gate is 0.2-0.3, the position deviation is clarified to be about 1mm in mean value and about 3-4mm in maximum value [8].

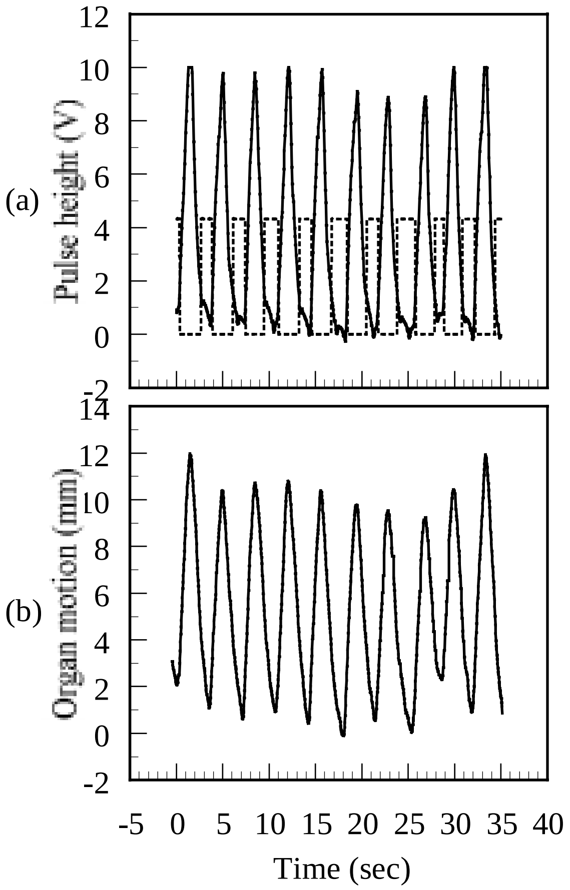

Fig. 3 Respiration signal with gate for irradiation(a), and organ motion (b).

4. Summary

Outline of the design proposed for the medically dedicated proton accelerator facility in Tsukuba is presented. By the new facility, not only reliable technique for practical cancer treatment but also challenging technique such as beam scanning can be investigated.

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