STATUS REPORT OF HIMAC ACCELERATOR FACILITY

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Abstract

Heavy Ion Medical Accelerator in Chiba, HIMAC, has been in operation for the last two and a half years. Treatments of more than 100 patients were completed by using carbon beams. Physics and biology experiments have also been carried out with various ions ranging from He to Ar. New improvement now under way is also described.

1 INTRODUCTION

HIMAC was designed and constructed as an ion accelerator complex (injector linac and two synchrotron rings) that can deliver 100 to 800 MeV/u beam of q/A=1/2, with an intensity of typically 10^8 - 10^9 particles per second, to three therapy rooms where horizontal and vertical ports are equipped with beam field devices such as wobbler magnets, ridge filter, collimators, etc.[1] After the commissioning as described in the report to previous conference[2], clinical trial of cancer treatment started in June '94. Since then more than 100 patients were treated with 290 - 400 MeV/u carbon beam. Carbon ion was selected for the initial clinical trial because it has one of the best biological depth-dose distribution and similar RBE value to that of fast neutron which had been practiced at NIRS. The result of tumor control and patient's life should be examined in more than 5 years range, but preliminary evaluation of therapeutical effect is encouraging. Sites of tumor that have been treated include head & neck, central nerves system, lung, liver, prostate, and uterine cervix, each of which numbers about 15 - 20 patients. Treatment usually spans 4 -6 weeks, depending on "protocol" by medical doctors. It means that beam must be supplied more than six consecutive weeks with stable and reproducible manner. It should be noted that each treatment irradiation is done in about 3-5 minutes but patient-positioning to set target tumor volume at the beam field usually takes 15-30 minutes and that beam must come at the same position and direction before and after this interval.

Although the priority goes to clinical usage, physical and biological research experiments can be done during night shifts and weekends. Experiments are carried out by researchers both within and from outside of NIRS. The programme advisory committee has been organized and beam time for proposed experiments are allocated according to PAC's recommendation. To meet needs of various experiments, we have accelerated, other than carbon ions, such ions as ^{4}He, ^{20}Ne, ^{22}Ne, ^{28}Si, and ^{40}Ar. In case of ^{28}Si, Si^{13+} acceleration was also achieved in synchrotron.

2 OPERATION OF HIMAC

2.1 Operations overview

Since October '94, operation was extended from a scheme of 8 a.m. - 8 p.m. daily to weekly 24 hours operation.[3] Machine operation is now continuous from Monday through Saturday evening or Sunday morning. It saved the time for beam tuning and enabled physical and biological experiments at night. For the initial years, almost 1500 hours per year were used for clinical trial, while nearly 2500 hours per year were open for physical and biological research. Biological research used about 700 hours.

Operation and maintenance of the machine are carried out by the engineers and operators of AEC (Accelerator Engineering Corporation) under supervision of NIRS accelerator operation section. Semi-annual shutdown for major maintenance work and for installation of new/improved equipments are scheduled in August and March, when manufacturers of the facility are called.

C^{4+} ion is extracted from ECR source and RFQ and DTL linacs can operate as low as 3 kV acceleration, which contribute to achieve reliable beam supply for treatment use. Dual ring scheme of HIMAC also proved useful both in exploratory phase and in operational phase. When one faces a problematic phenomenon, one can look into both rings and searches for relevant difference and possible clue on the problem. In case of trouble during operation, one can switch to the other ring for continuation. It was a fortunate case of this scheme when a coil of septum magnet broke down in the upper ring last October. Although the treatment schedule of the day had to be cancelled, it was managed to re-schedule treatment in such a way that the beam from lower ring is delivered to vertical ports and used as if it were the beam from upper ring.

2.2 Requirements on operation

At present, treatment is carried out at two or three different energy to cover wide variation of depth of tumor in patients. Therefore, requirement is that tuning for different energy be short and reproducible. Because we limit ourselves to carbon beam during Tuesday - Friday portion of the week, tuning of ion source and linacs, which are relatively time-consuming, can be done in Monday evening for the rest of the week. Standardization in tuning of beam transport between linac and synchrotron and of injection is ongoing by utilizing NMR value of analyzer magnet. It is also the case with transport of extracted beam, where 'initialize' procedure is applied to obtain well reproducible result for daily switching of beam energy.

It is also required to switch the beam port after each treatment, in order to utilize beam efficiently while patient positioning needs longer time than irradiation. On the other hand it must be assured that beam is switched back with better reproducibility than positioning error. This latter requirement is met with 'initialization' of switching magnet, again.

3 IMPROVEMENTS

In the injector system, control system computer was upgraded from a microVAX3500 to a VAX4000/705A, which improved the system response to operator manipulations and enabled application of the resource to recognize long-term maintenance needs. The beam course for use of linac beam, Medium Energy eXPeriment course as we call it, was constructed and has been operated for experiments.

Synchrotron is now operated at 3.3 sec interval or 0.3 Hz repetition cycle, where flat top period is elongated from 400 ms of original 0.5 Hz operation to 1700 ms. The change has been made to realize the irradiation gated by patient's breathing motion, together with application of RFKO extraction.[4]

In the case of supplying beams of different energy or with $q/A < 1/2$ to research experiment, it is important to set the working point of the synchrotron properly. This became possible by improving RFKO system.

Recently, vertical steering system has been installed to the synchrotron ring and it was shown to be effective in reducing the COD.[5]

Improvement was also made to avoid unwanted activation by unextracted high energy beam in the ring. By using B^- clock and modified memory board, Beam deceleration was achieved.[6]

As mentioned earlier, not-fully-stripped ion of Si^{13+} has been accelerated by same timings of injection capture, and acceleration as for fully stripped one. This suggests that argon and heavier ion can be accelerated by the present machine in the same manner.

Beam extraction efficiency and ripple content of the beam are major objective of the beam performance improvement. With installation of DCCT to both the rings, we can now measure the circulating beam intensity without help of rf bunching. As for ripple content, efforts are continually made to reduce it further.[7]

HEBT (High Energy Beam Transport) system is described in Ref.[8]. The system can switch the beam to various beam ports in a short time with sufficient reproducibility. Air-operated MWPCs were installed at each therapy port and biology experiment port in order to monitor the profile, position and intensity of the beam continuously.

4 DEVELOPMENTS

In order to meet demands for heavier ions, the third ion source (18 GHz, ECR) is now being installed. With three ion sources available, a system that can accelerate ions of different q/A by pulse-to-pulse mode is under development. This will enhance the versatility of the machine tremendously, because one can use different ions like carbon and argon , in respective synchrotron ring and MEXP course at the same time independently.

Beam lines for radioactive beam is now under construction for the investigation of applying positron emitter beam , such as ^{11}C, to on-line confirmation of irradiation volume and dose in therapy.

Further sophistication,such as gantry that must rotate beam port more than 90 degrees, and radio-surgery where beam of more than an order of magnitude higher intensity is necessary, is also now under study. Feasibility of a gantry with superconducting magnet is being discussed, for example.

In yet wider perspective, a design study of sychrotron ring for bio-medical use of synchrotron radiation has been approved for budget request by the government, which aims at angiography.

Plans for new facility to advance particle therapy is discussed in numerous prefectures.[9]

5 SUMMARY

The HIMAC facility has been delivering beam to medical and research users since 1994. Preliminary result of cancer treatment by carbon ion beam is encouraging. Various improvements to deliver beams for treatment even more reliably were made in the last two years and, among others, beam delivering system where electronic gate signal controls beam extraction according to breathing motion of patient has been put into operation. Major modification in injector transport line is under way to provide the means of supplying three different beams.to respective users of synchrotrons and MEXP course. Radioactive beam from projectile fragmentation is now under construction.

ACKNOWLEDGMENTS

The authors would like to express their sincere gratitude to Dr. Y. Hirao for his continuous encouragement. They are grateful to other members of Division of Accelerator Physics and Engineering, and Section of Accelerator Operations (both of NIRS) for their warm supports and cooperations. They thank crew from AEC (Accelerator Engineering Corp.) for skillful operations and assistance at various phase of studies. They would also like to acknowledge Profs. K. Sato and T. Kohno, and guest researchers for their valuable discussions.

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