Development of Visual Beam Adjustment Method for the Beam Transport

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Abstract

We have developed a computer-based visual beam adjustment method for the beam transport system at the JAERI AVF cyclotron. This system provides CRT display of the beam trajectories and beam envelope in real-time.

1 Introduction

A cyclotron design requires a large number of physical theories, calculation codes and analysis of the beam trajectory. These codes and analyzed results have not been used in actual operation. For a new cyclotron control technique, we have developed a computer-based visual beam adjustment system[1] for JAERI AVF cyclotron operation by using the above codes. This system provides CRT display of the cyclotron beam trajectories, feasible setting regions, and search traces which were designed to improve beam parameter adjustment.

A new computer-based operation system which assists inexperienced operators has been implemented for the beam transport system at the JAERI AVF cyclotron. To examine the reliability of this system, the simulation result was compared with that of the actual operations.

2 Visual Interfaces

Ion beams extracted from the cyclotron are transported to a target point without any beam loss in the beam ducts. The beam transport system consists of bending and focusing magnets, beam monitors, beam shutters, etc. There are 9 bending magnets, 85 quadrupole magnets and 10 beam steering magnets in 10 horizontal and 4 vertical beam courses which transport ion beam to 17 target ports on the ways or at the ends of the beam courses located in 8 ion rooms. An achromatic and telescopic beam transport system was designed for high transmission efficiency of ion beams and good adjustability of the magnet parameters using the beam optics calculation program TRANSPORT[2].

The ion beams extracted from an AVF cyclotron have large emittance and energy variations. Beam transport system start-up operations require dozens of adjustable parameters to be finely tuned to maximize beam transmission efficiency. Generally, the transportation of accelerated ion beam is efficiently realized by setting quadrupole magnets at parameter for a magnetic field gradient designed by TRANSPORT-code. However inexperienced operators have a difficult time because operator consoles displaying measured beam parameters, alarm information, component status, etc. do not provide enough information to guide these new operators. There are two ways of describing the ion transfer properties. One is the ray tracing that is used to study the behavior of individual ion trajectories. The other is the phase space ellipsoid method that treats the beam envelopes characterized by the boundaries of the phase space volume.

The new computer-based operation system provides two kinds of visual human interfaces to support the beam adjustment of the beam transport system as follow: i) beam envelope and trajectory are rapidly simulated and graphically displayed on a CRT whenever the operators change the excitation current of the magnet, ii) historical display of simulating beam envelope and trajectory are superimposed on CRT. For simulation the beam envelope/trajectory, these interfaces have special four functions as follow; i) the magnetic field of each magnets are calculated from exciting current, which are operator adjustable parameter, considering the effect of the field saturation, ii) initial setting parameters (energy, ellipse, etc.) for calculating the beam envelope/trajectory can be changed at will, iii) all narrow channels which are obstacles to pass through the beam in the beam transport line are displayed, iv) beam ellipses can be displayed whenever the operator changes the exciting current of the magnets.

The simulation method of beam envelope is a simplified transfer matrix method based on the phase space ellipse. The beam trajectories are calculated at five positions on the ellipse including a center point as shown in Fig. 1. In order to reflect operators' action to the simulation immediately, each elements of transfer matrix are linked directly to a parameter database and the calculation is invoked whenever change value event occurs. And for reduction of simulation and display time, historical envelope/trajectory are saved as bitmap data.
As the data which are necessary for simulation and display, such as layout data, initial beam conditions, magnet characteristics, data base entry and so on, are described in editable definition files, it is easy to modify these data for accurate simulation.

3 Examination of the System

In case of the ion which do not move close to the beam axis, namely, the ion beam is not paraxial, the beam trajectories were simulated. We examined the beam trajectories by the real beam operations of 45MeV H^+. In real beam operation, the beam axis was changed by changing the field of steering magnet which is located at the cyclotron exit. The beam changes not only the position but also the profile on the target as shown in Fig. 2. The typical simulated beam trajectories for 45MeV H^+ are shown in Fig. 3. Fig. 3 (a) shows the simulated beam trajectories in case of the ion move close to the beam axis. Fig. 3 (b) shows the simulated beam trajectories by setting excitation current to +10A of a CSTE (horizontal steering magnet).

4. Conclusion

The beam adjustment interface calculates the beam trajectories/envelopes using actual parameters and displays them on a CRT. This display shows a historic summary of simulated beam trajectories/envelopes after any parameter "setting" adjustment by an operator. Operators can refer to either display, correct the differences between them, and search for the optimum set point which provides desirable beam envelope/trajectories.

Since, operators are able to quickly gain valuable operation experience which ultimately leads to a reduction of the time to reach the planned beam transport condition.

References

[1] T.Agematsu, K.Arakawa, and S.Okumura, *Proc. 14th Int. Conf. on Cyclotron and Their Applications, Cape Town, South Africa*, pp.284-287(1995).
[2] K.L.Brown et al. , *SLAC Report*, No.91(1974).

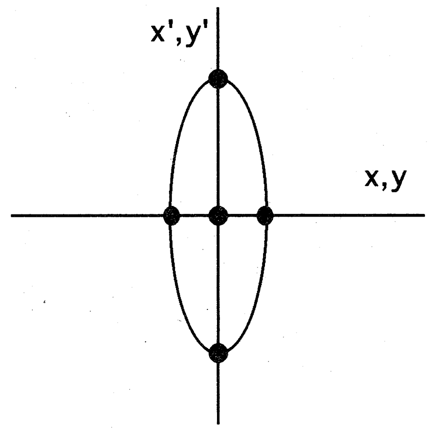


Fig. 1 The elliptical phase space and the representative five ion particles at the first waist point of the cyclotron exit.

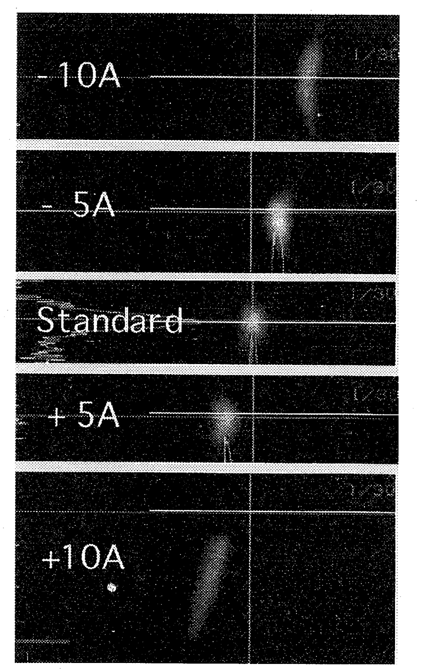
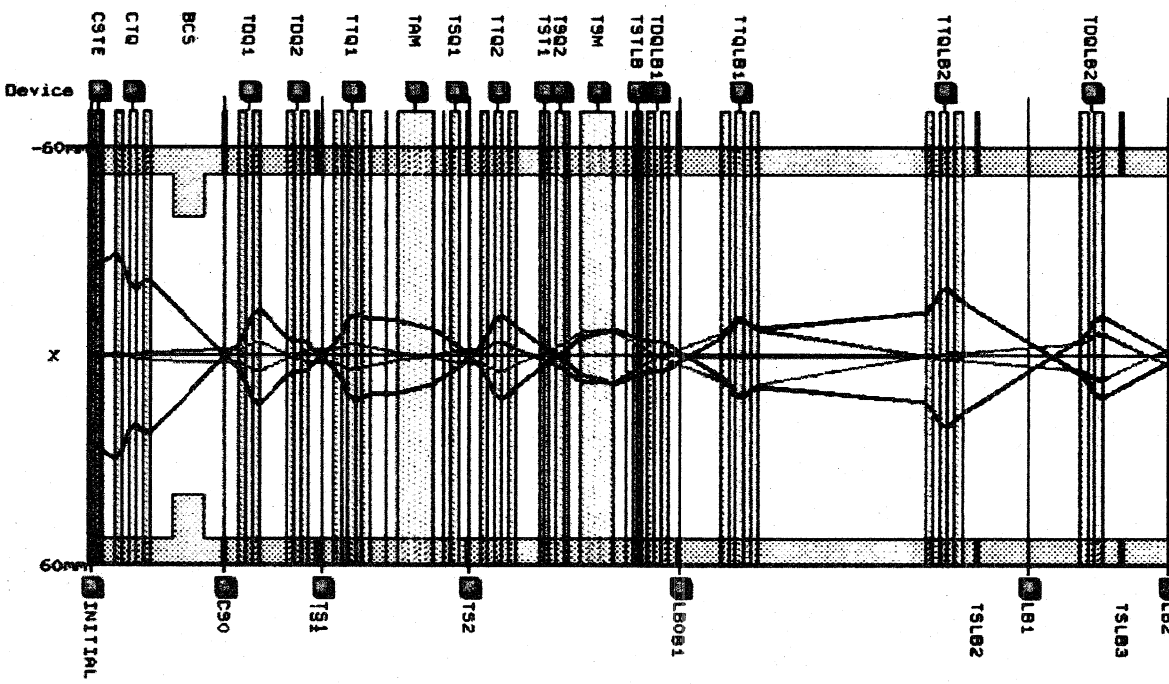
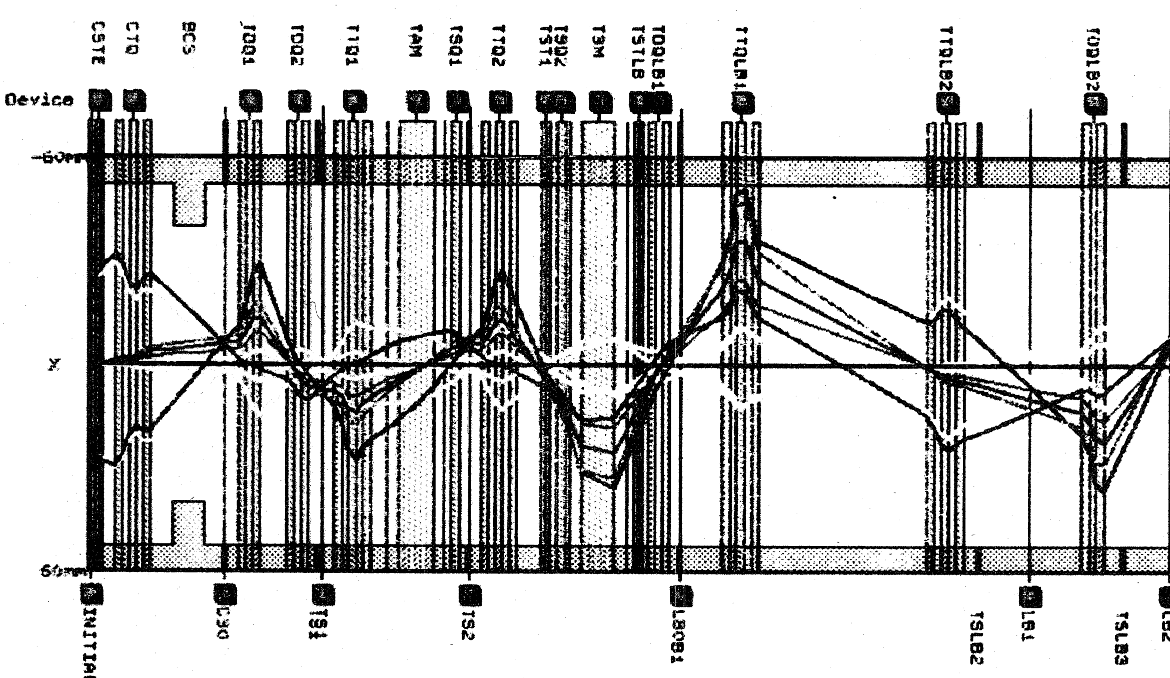


Fig. 2 The change of beam profile on the almina monitor at the target point LB2.
In actual operation, by changing field strength of horizontal steering magnet located at the cyclotron, the change of profiles is measured with 45MeV H^+.



(a) Beam trajectories by standard condition, namely the ion beam move close to the beam axis.



(b) Beam trajectories by setting excitation current to +10A of CSTE (the ion beam is not paraxial).

Fig. 3 Beam trajectory simulation for 45MeV H^+ in the beam transport system of the cyclotron.