Development of Visual Beam Adjustment Method for Cyclotron

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Abstract

We have developed a computer-based visual assistance system for JAERI AVF-cyclotron operation. This system provides a CRT display about the cyclotron beam trajectories, feasible setting regions (FSR's), and search traces designed to enhance beam parameter adjustment. As a result of the test in actual operation, it was realized that simulated beam trajectories and FSR's were nearly agreeable with actual beam condition in the axial injection block and the extraction block.

I. INTRODUCTION

A cyclotron design requires a large number of physical theories, calculation codes and analysis of the beam trajectory. These codes and results are helpful but haven't been used in actual operation. Cyclotron operators must adjust the parameters with monitoring beam properties such as position, size, shape, divergence etc. However, obtainable information on the beam properties are so limited that operators often have to infer them. Further, operators should pay attention not only to the information from beam probes but to spatial limits from devices. We have developed a computer-based visual assistance system[1] for JAERI AVF cyclotron[2] by using above codes and data.

II. HUMAN INTERFACES

This system provides three kinds of visual human interfaces for beam parameter adjustment: (a) Beam trajectory is rapidly calculated and graphically displayed whenever the operators change the cyclotron parameters. (b) Feasible setting regions (FSR's) of the parameters which satisfy beam acceptance criteria of the cyclotron's are indicated. (c) Search traces, being a historical visual map of beam current values represented by various colored dots, are superimposed on the FSR's.

The system treats three blocks divided for the cyclotron control: the axial injection, the central region, the extraction. This system is constructed by language of C and works on workstation of VAX-3100 connected through Ethernet with computers controlling[3] the cyclotron, as shown in Fig.1.

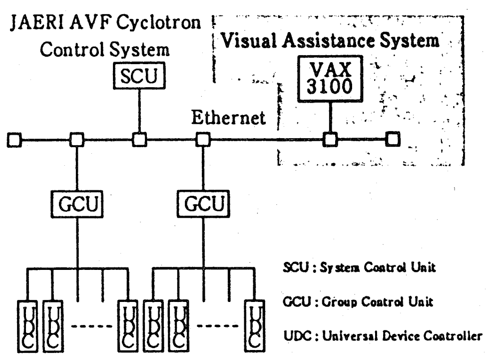

Fig.1 Architecture of the control system.

III. EVALUATION OF SIMULATION

A. *Axial Injection Block*

The axial injection block treats a region between the bottom of the cyclotron yoke and the inflector as shown in Fig.2. There are four Glaser lenses (GL1,2,3,4) with adjustable focal lengths. The beam is led into the cyclotron through a small gap of the inflector entrance by adjusting these lenses. A typical simulated beam envelope is shown in Fig.3. The FSR's are limited mainly by the geometry of the inflector entrance.

We have compared the human interfaces with the results of actual operation in the cyclotron condition of H^{+}10MeV etc. It is realized that there are discrepancy between of the simulated FSR's and the search traces obtained in actual operation. To identify the main reason of the discrepancy, we have searched condition for good agreement between the FSR's and the result of actual operation. The simulated beam trajectories have deviated from just after GL4. By correcting the estimated leakage magnetic field from main magnet, the FSR's can agree

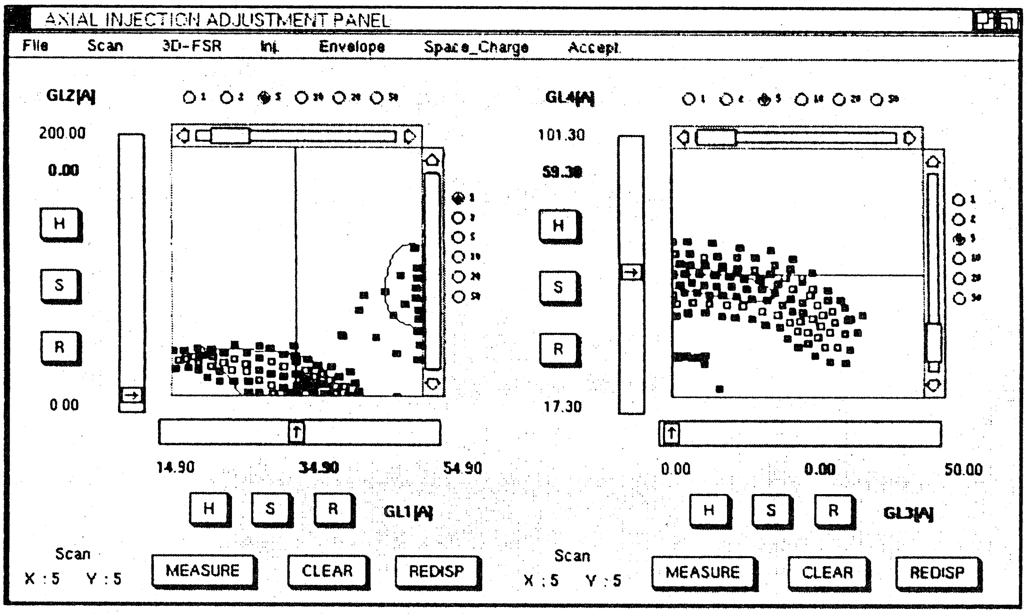

Fig.4 The Feasible setting regions (FSR's) and measuring data at the injection block. Search trace display showing colored dots of the measured beam current values. Ion beam of H^+ is 3.10kV, 1μA at the injection line.

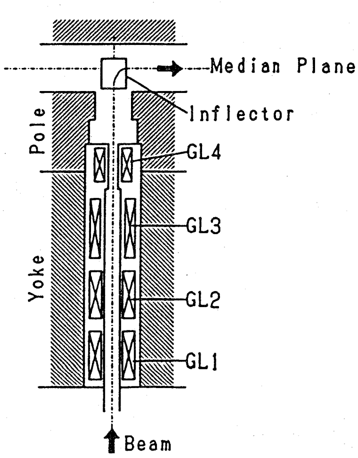

Fig.2 Cross section of the axial injection block.

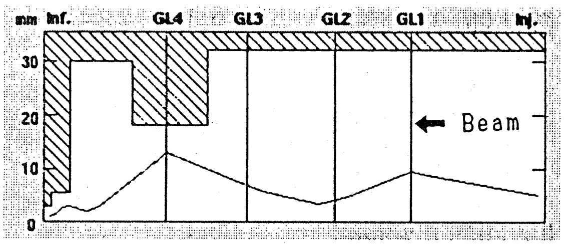

Fig.3 Typical beam envelope of the axial injection.

with the search trace, as shown in Fig.4. It's clear that the more precise measurement of the leakage magnetic field from main magnet is required.

B. Central Region Block

The central region block, which follows the axial injection block, determines the first turn of the beam trajectory after the inflector. This initial trajectory is important for beam adjustment because it influences the characteristics of the later beam behavior, such as the precession of the trajectory, the spread of the beam, and the turn separation. Figure 5 shows a top view of a cross section of this block, which is defined as a section between the exit of the inflector and the second phase slit. The adjustable parameters are adjusted so that the beam passes through the two phase slits. The parameters in this region are dee voltages, trim coil currents and the phase of beam buncher voltage. The beam trajectory is calculated from these parameters and magnetic and electric field data. The FSR's are determined by geometrical condition of two phase slits. The primary purpose, which makes the beam pass through to narrow channels of the phase slits, has been already achieved in the system. We will test about the central region block in next experiment.

C. Extraction Block

The beam in the final turn is led into the deflector and the magnetic channel, deflected from the circular orbit, and is finally extracted from the cyclotron. In this block, the system simulates the deflected beam trajectory. At the first step, the beam trajectory entering the deflector

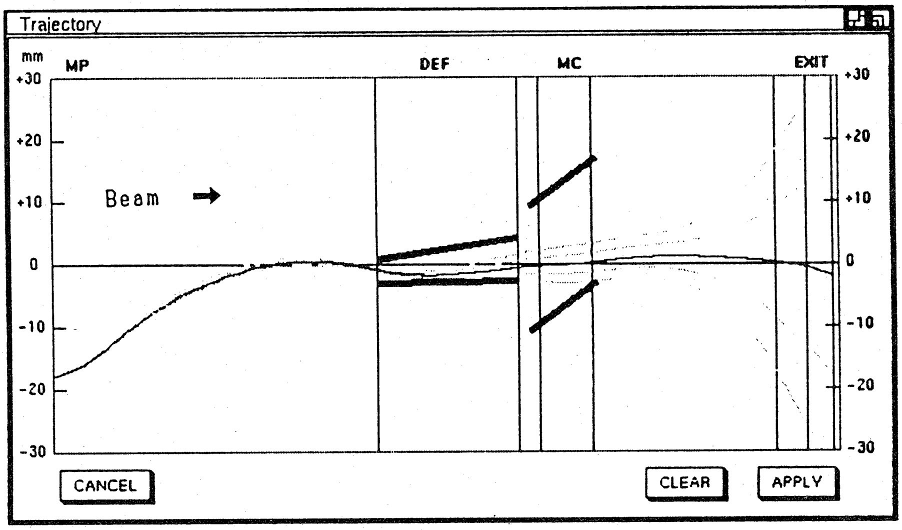

Fig.6 Beam trajectory simulation at the extraction block.
In this diagram, the spiral beam trajectory is shown as a form of a stretched line.

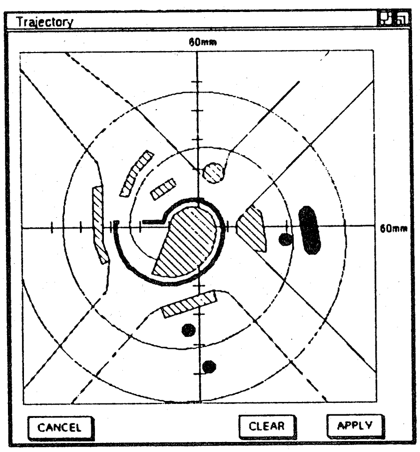

Fig.5 Beam Trajectory at the Central Region Block.

is calculated on the basis of the magnetic field data and two beam positions measured by the main probe and the deflector probe. At the second step, the beam trajectory in the deflector and the magnetic channel are simulated from the deflector position, the deflecting field and the magnetic channel field. The FSR's are calculated from the above parameters, and clearance in the deflector and the magnetic channel.

H^+45MeV beam trajectory is simulated as shown in Fig.6. We have executed beam trajectory simulation in changing beam energy. The most suitable energy for simulated beam extraction is 43.5 to 43.7MeV. We have estimated the actual beam energy to be 43.3MeV using the magnetic field of analyzing magnet at downstream the cyclotron. It seems that the system can simulate the actual beam trajectory at the extraction block.

IV. FUTURE ACTIVITY

Precise comparison of the simulated beam trajectory and the actual beam trajectory is planned for the three blocks of the cyclotron under various conditions. For the extraction block, the extracted beam energy will be measured precisely by the method based on scattering kinematics. It is expected that the result will be fed back to the system improvement.

V. REFERENCES

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