AUTOMATED CONTROL OF JAERI TANDEM ACCELERATOR

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ABSTRACT

An automated control of JAERI tandem accelerator is discussed. Some results of feasibility tests for the tandem are presented.

INTRODUCTION

Much manpower is needed for operation and maintenance for an accelerator of large scale. Thus an automated control for an accelerator is desired. The automated control enables us to save manpower and to extend the time of beam service effective with faster setting up than human tuning. Through precise calculation, it also make beam transportation difficult with human handlings easier. JAERI tandem is one of the largest electro-static accelerators in Japan and there will be many merits in such an automation. We are going on with works to develop technic for automated accelerator control of the tandem and we want to discuss it.

STRATEGY

It is natural to use an computer for automating a equipment, today. In the tandem we already have a computer system through which all operating parameters of the accelerator can be controlled or read. This is the first step to develop automated control.

We considered it difficult to automate beam transportation. Thus, hereafter we want to focus our discussion on the problem. First of all, we can consider that phenomena about beam transportation can be analyzed with electro-magnetism. If we have enough knowledge about physical quantity about beam optics, we can predict precisely what will be happened. Thus the first method we can consider is the method where all setting values of the beam optical elements are calculated with beam-optics from known parameters of the devices. These calculations have been done to verify a specific configuration of optical devices to give enough transportation, in a design process of any accelerator. But if we intend to transport some beam, only through the method in an actual accelerator system, we need much accurate information about dimensions, position, etc. of each optical element and very precise calculations.

In the second method, some beam is transported by a human operator and the parameter set of that time is stored as a reference. Desired beam of specific particle is obtained by setting a parameter set with extrapolation using the previously stored parameter set as a reference. In this method, many of optical parameters are reduced to small set of parameters among instances of beam transportations having same qualitative characteristics. Construction of a computer program for the method is straightforward and resultant computational time is rather short. Problems are as follows. One of the problem about the method is that we need several reference parameter sets according to different patterns of beam transportations(corresponding to different configuration of shorting rods and different particles). Another problem is stability of parameters of optical elements set by the computer system. This problem is less severe than in the first method previously mentioned. Poor stability and poor reliability narrow an available range of a reference set. It is, therefore, important to keep absolute accuracy of parameters. The other problem is that the second method doesn't have enough capability to be adapted for control of ion sources which have natural ambiguity.

The third method is a negative feedback control using appropriate beam monitors as sensors. An instance of realization in this method severely depends on performance of the adaptable monitors. Without monitors of enough performance, tuning process of parameters can not be straightforward and programing of the computer is very difficult. But with good monitors, the programing is easy and straightforward and this method can be the most powerful means, because it adapts itself for instability of upstream devices.

The above three methods can be adapted to complement each other in an actual automation of the transportation. In the tandem, we intend to use the second method as a main principle and to adapt the third method for tuning of extraction part of ion sources. For the first method, there has not been enough care in the design of the accelerator and we have devices with poor accuracy. Thus, the first method can not be used to transport actual beam. We intend to adapt the method to get guide line for the beam transportation and to evaluate a set of parameters for actual transportation.

TESTS OF FEASIBILITY

According to the policy mentioned above, we had experiments to examine the feasibility of the second method.

We tested reproducibility of the beam-optical conditions of the tandem, at first. In the test, some ion beam was extracted from a negative ion source of the tandem and manually transported through the accelerator to a Faraday cup behind an analyzer of the final energy. All the setting values for control of the tandem were stored into a disc file for later use. After the parameters of the tandem were changed to accelerate other beams, the stored parameter set was recalled to reproduce the previous beam condition. Current settings for three bending magnets in the system were manually tuned to reproduce the previous readings of the magnetic fields. Current in the Faraday cup was compared with the previous current reading and over all reproducibility was tested. In this way, ^{12}C, ^{16}O, ^{19}F and ^{35}Cl ion beams were accelerated and their current readings in the Faraday cup showed no degradation in the beam transportation in a day or even after a few months.

The second experiment was performed to examine an algolithm to set parameters for a specific beam. A set of parameters that provided enough transportation for some beam was used as a reference. The new set of parameters for different condition was calculated to give the same optical effect to the beam as the reference. The extrapolation gives voltage (V) for a electro-static device as

$$V = (V_0 \, q_0 \, / \, E_0) \, E \, / q \qquad (1)$$

and it gives current(I) for an electro magnetic devices as

$$I = (I_0 \, q_0 \, / \sqrt{2m_0 \, E_0} \,) \sqrt{2m \, E} \, / \, q, \qquad (2)$$

where m, q and E denotes mass, charge state and energy of the particle at the location, respectively, and suffix 0 and no suffix correspond to the reference beam and the new beam, respectively. A computer program is used to set the parameters, about 40 parameters including steerers. In the program, ratio between pre-acceleration voltage and the terminal voltage of the tandem is selected to be same as in the reference. Parameter setting for the ion source is omitted in it. In the way, $^{12}C^{5+}$ at Vt=15.0 MV, $^{12}C^{5+}$ at Vt=14.1 MV, $^{19}F^{6+}$ at Vt=15.0 MV, $^{19}F^{8+}$ at Vt=14.1 MV ,$^{35}Cl^{9+}$ at Vt=14.1 MV, $^{80}Se^{10+}$ at Vt=15.0 MV, $^{76}Se^{10+}$ at Vt=15.0 MV and $^{74}Se^{10+}$ at Vt=15.0 MV were successfully transported using a single set of parameters for $^{12}C^{6+}$ at Vt=15.0 MV as the reference. Especially in the case of ^{74}Se, beam current from the ion source was very small and even after the transportation, current on many Faraday cups was less than limit of detection. However the computer program transported such beam, which human handling could not transport.

CONCLUSION

In the present work, the automated control of JAERI tandem was tried. Feasibility of the technic of setting parameters with extrapolation was confirmed. On the other hand, problems have been appeared. One of them is how to keep reference data stable before and after maintenances or through months. We will improve accuracy of the devices, high voltage power supplies, current power supplies, etc., to remove the problem. For parameter setting for ion sources, which is omitted in the present experiments, we must develop a feed back control system with beam monitors.