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（博士課程）
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	Energy Sciences 専攻	申請学位（専攻分野）： Academic Degree Requested	博士 (Science) Doctor of
学生氏名： Student's Name	Xingguang Liu	指導教員（主）： Academic Advisor(main)	Prof. Ken Takayama
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The primary objective of the KEK-Digital Accelerator (KEK-DA) is to demonstrate a compact fast cycling induction synchrotron. Since the KEK-DA was started in 2006 by utilizing the formal Booster of the KEK Proton Synchrotron, many key devices had been developed and preliminary experimental and theoretical studies had been conducted. However, a comprehensive study from the ion source to the ring as a whole has not been done. By describing the experimental studies of the beam commissioning from the ion source to the ring and focused on the simulation code that was originally developed to understand the beam loss and the beam physics in the KEK-DA ring, this thesis is such a study that considers the whole facility in a single frame. The experimental techniques and simulation tools developed in present works are of great practical importance for present project and future induction synchrotron accelerators.

In Chapter 1, the brief history of the induction synchrotron is introduced. The KEK-DA of a fast cycling induction synchrotron, was realized by renovating the former KEK-PS Booster Ring. All the thesis work were done at this facility.

In Chapter 2, the beam dynamics of the induction synchrotron is reviewed. The equations of single particle motion are self-consistently derived from the Hamiltonian. The transfer matrices for lattice elements such as drift section, combined function type magnet and quadrupole magnet are derived in the 6D phase space. The transfer matrices have been implemented as essential components in the simulation code that is described in Chapter 6.

In Chapter 3, the outline of the KEK-DA including the most recent development related to the thesis work is given. The ion source, LEBT line, electrostatic injection kicker, the KEK-DA ring, induction acceleration system, trigger system and diagnostic system are introduced. Description of these subsystems is necessary to get a complete image of this facility. In addition, the sources of some phenomenon observed at downstream are found to be from the upstream.

In Chapter 4, the KEK-DA ECRIS is described. In order to suppress the discharge problem in the extraction region of the original KEK-DA ECRIS, redesign of the extraction electrode and orifice have been initiated by the present author. In addition, the replacement of the plasma chamber, gas support system, and vacuum pump have been conducted. With the present status of instruments, the optimization work for the operational parameters employing the

IGUN simulation are described and the experimental results are analyzed.

In Chapter 5, two experimental studies using the profile monitors on the LEBT line are discussed. In the first experimental study, the Courant-Snyder parameters and the transverse beam emittance are measured. The results in the vertical direction are fairly good, while the horizontal ones are with some ambiguity because of the momentum dispersion effects. In the second experimental study, a quasi-3D profile monitor has been developed by modifying the original wire-grid based profile monitors. With the quasi-3D profiles observed at the PR2, the 4 ms long beam is found to have a bending part while the 4 μs beam is found to have a shifted beam head and tail. It turns out from careful experiments and circuit analysis that the beam loading effects take place in the extraction region of the ECRIS and the post-acceleration column of the HVT, resulting in the momentum modulation in the 4 ms long beam. The momentum modulation had been known to be induced as a result of chopping of the beam pulse in a short time period of 4 μs beam by the Einzel Lens Chopper. This fact was confirmed in the present experiment in the LEBT line for the first time.

In Chapter 6, the simulation code developed for the induction synchrotron is discussed. The structure of the simulation code is described with two flow charts. The core calculation includes the momentum kicks due to space charge effects and the orbital evolution of the particle distribution is obtained from macro-particle tracking using the transfer matrices, which are derived in Chapter 2. The sub-3D space charge solver is discussed in details with the justification of its validity.

In Chapter 7, the simulation code has been applied to the KEK-DA. At first, the lattice functions is calculated assuming the lattice elements of the KEK-DA ring. The beam emittance blow-up in terms of total charge in a beam bunch in the KEK-DA ring is discussed where coupled motion makes the horizontal emittance continue to increase while the vertical emittance blow-up slows down very quickly. In the simulation aiming to identify the beam loss in the KEK-DA ring, space charge effects are found less dominant than the injection error at the early stage after injection. There are still unknown factors causing the beam loss which cannot be explained by present simulation code.

In Chapter 8, a summary of the thesis work is given. Based on these studies, some perspective views are given for present KEK-DA and the near future induction synchrotron accelerators. The major contributions of present works on the accelerator communities are also emphasized.

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