# Present status of the beam test of the deflection element for dispersion control

Mikio Tanabe [A)], Masahiro Ikegami [A)], Toshiyuki Shirai [A)],
Hiromu Tongu [A)], Akira Noda [A)]Koji Noda [B)]

[A)]Institute for Chemical Research, Kyoto University, Gokanosyo, Uji-City, 611-0011, Kyoto, Japan
[B)]National Institute of Radiological Science, 4-9-1, Inage-Ku, Chiba-City 263-8555, Chiba, Japan

*Abstract*

A deflection electrostatic deflector has been designed for an ion storage ring. This electrostatic deflector, together with a dipole magnet makes a condition where a dispersion function of ion beams is controlled at a bending section. For this purpose, the electrostatic deflectors are designed, and the deviation of the calculated field from the ideal value is less than 0.1%, within 2.5mm from the beam axis. The effect of a hole for laser injection is also considered. After modification of the structure of the electrodes, the deviation near the hole is improved. We planned the experiment to verify the effect of dispersion control by using the first constructed deflection element. An ion beam will be produced from an ion source and injected into the deflection element directly. Adjustment of an ion source and the setup of the experiment are also considered.

## 1 INTRODUCTION

An ion storage ring, S-LSR, is now under construction at Institute for Chemical Research, Kyoto University [1]. S-LSR, whose circumference is 22.557m and superperiodicity is 6, is planned to use for the experiment of beam cooling. For this purpose, this ring is equipped with an electron cooler and a laser cooling system. The final goal of this experiment is realization of three-dimensional crystalline beam. Three types of the beams, proton, $^{12}C^{6+}$, and $^{24}Mg^{+}$ are prepared for storage in this ring.

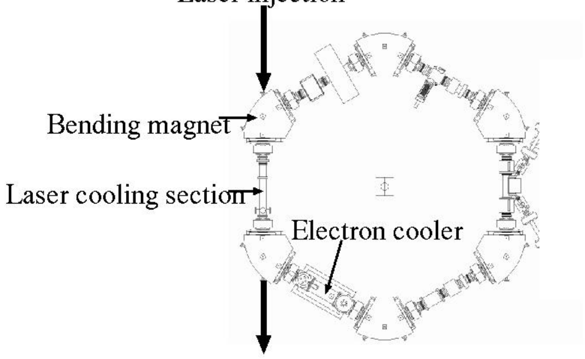


Figure 1: Ion storage ring, "S-LSR".

This ring has its peculiarity in its bending sections .It includes an electrostatic deflector, as well as a dipole magnet. These electrostatic deflectors make the electric field perpendicular to both the beam path and the magnetic field. The beams passing through the bending sections are bent by both Rorentz force and Coulomb force. A dispersion function of the beams is adjustable, because of these two forces.[2] In particular, a dispersion function is completely canceled, if the magnetic field and the electric field satisfy the following equation,

$$\vec{B} \times \vec{v} = \left(1 + \frac{1}{\gamma_0^2}\right)\vec{E}$$

where $\gamma_0^2$ is gamma factor of a particle of the beam. This effect is thought to be useful for stable storage of the 3-dimensional crystalline beam. [2]

For this effect to be experimentally verified, we have designed the electrostatic deflectors installed in the vacuum vessels at the bending sections. The dipole magnets used here have already constructed, and vacuum vessels installed between the gaps of the dipole magnets are under construction. The height of the vacuum vessels is limited because of the limited gap of the dipole magnets. The electrostatic deflectors must be equipped with a mechanism to move them inside, when the ring is used for a normal storage ring. This mechanism is set at the bottom of the electrostatic deflectors. So, these electrostatic deflectors are required to be installed into rather small gap of the vacuum vessels. The width between the main electrodes is determined to be 30mm because of two reasons; the aperture at the bending sections must be kept wider, and the higher the ratio of the height of the electrode to the width between the electrodes is, the less the deviation of the electric field is.

For more precise electric field, we have changed the structure of the electrodes, and added small intermediate electrodes. We determined the structure of the electrostatic deflectors with use of 3-dimensional calculation code, in order for as precise electric fields as possible.

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## 2 DESIGN OF THE ELECTRODES

### *2.1 Three-dimensional structure*

The cross sectional view of the electrodes is shown in Fig 2.

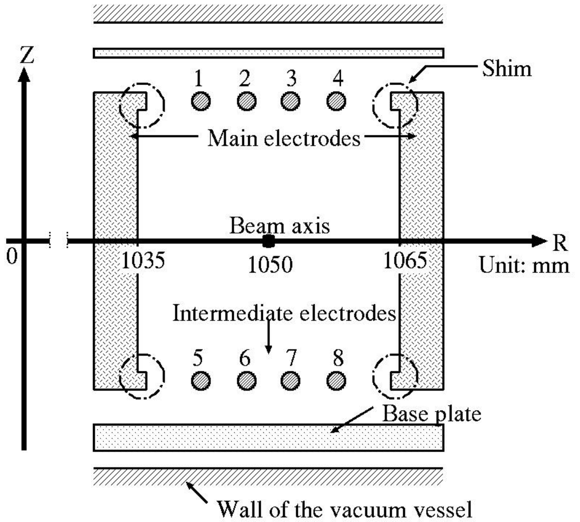


Figure 2: Cross sectional view of the electrostatic deflector.

The electrostatic deflector consists of two cylindrical main electrodes and eight wires. The top and bottom part of the main electrodes are thicker than the others. These parts are called ‘shims’. The shims extend the effective electric fields area above and below the median plane. The eight wires, called ‘intermediate electrodes’, also improve the quality of electric fields in the aperture of electrodes. The sizes and positions of them are optimized with use of the 3-dimensional calculation code, TOSCA (TOSCA is known as a calculation code for magnetic fields. It is also used for electrostatic fields.). The voltages to be given on each electrode are also optimized and determined as table 1.

| Name of the electrode | Voltages for 3-dimensional calculation(V) |
|---|---|
| Inner main electrode | 1007 |
| Intermediate electrode 1 and 5 | 562 |
| Intermediate electrode 2 and 6 | 180 |
| Intermediate electrode 3 and 7 | -180 |
| Intermediate electrode 4 and 8 | -558 |
| Outer main electrode | -993 |

Table 1: The optimized voltages to be given one the electrode.

Then the error of the electric field on and 2.5mm above the median plane are shown in Fig. 3. This shows that the deviation of the electric field is less than 0.1%, in the range of surroundings 2.5mm of the reference orbit.

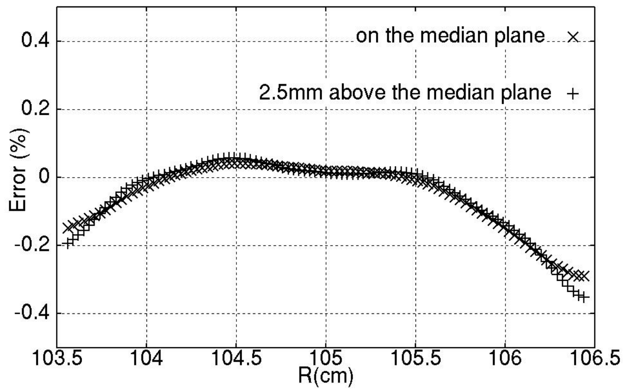


Figure 3: The deviation of the electric field near the median plane.

### *2.2 Modification for laser injection*

As is shown in Fig 1, a laser has to be injected thorough the bending section in order for the experiment of laser cooling at the straight section of this ring. Therefore, we have to make a hole on the main electrode. This hole will naturally be thought to reduce the strength of the electric field near the hole. In order to compensate field vacancy, we changed the structure of the electrode as Fig. 4.

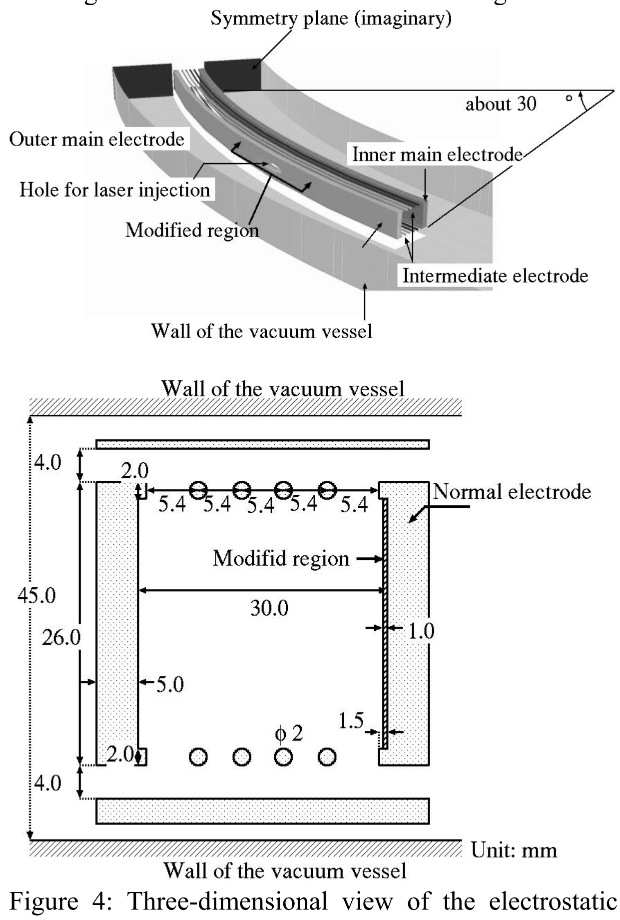


Figure 4: Three-dimensional view of the electrostatic deflector is shown above. The cross section of the modified electrostatic deflector near the hole is shown below.

The thickness of the electrode near the hole is modified. It is changed to be 1mm thicker than the other parts of the electrode. This modified region is from 157mm to 197mm measured from the end of the dipole magnet. By the modification of the structure of the electrode near the laser injection hole, the deviation of the electric field is improved as shown in Fig. 5. This figure shows that the deviation of the electric field is less than 0.2% within ± 2.5mm from the beam axis.

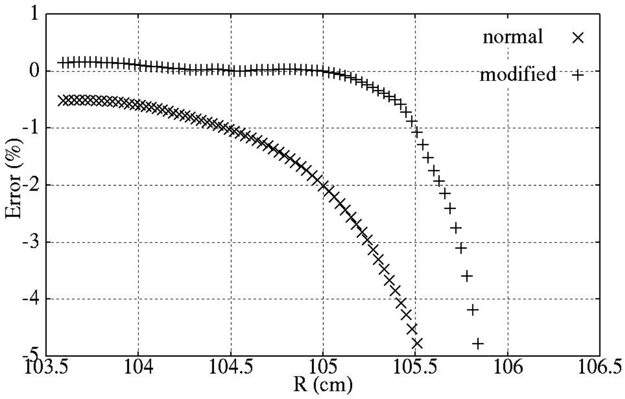


Figure 5: The deviation of the electric field near the laser injection hole.

## 3 SET UP OF THE EXPERIMENT

The electrostatic deflectors designed here are now assembled. The deflectors installed in the vacuum chamber first are estimated to be completely made by the end of July, in 2004. We are going to confirm the efficiency of the electrostatic deflectors for the dispersion control experimentally, with use of the single set of the deflection element, before construction of all electrostatic deflectors is finished. And the closed orbit distortion induced by the electric field error will be estimated by this experiment.

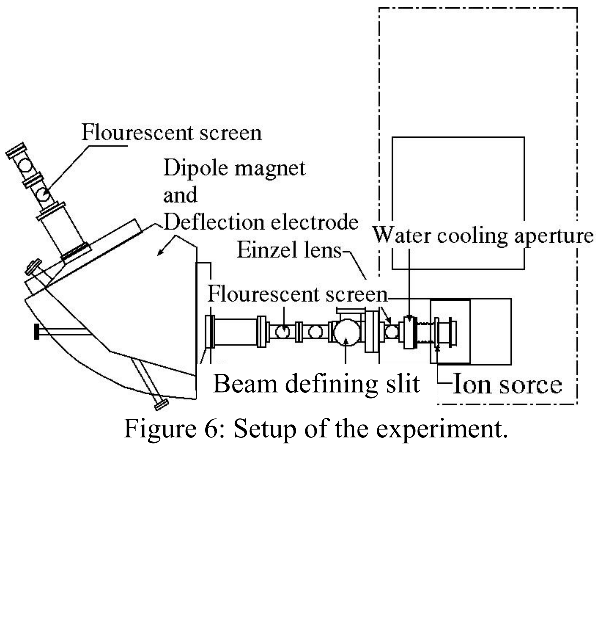


Figure 6: Setup of the experiment.

The setup of this experiment is shown in Fig.6 .The ion beam used here is $^{14}N^{+}$. First, the beam is generated in an ion source. Next, this beam passes through the water cooling aperture, whose bore radius is 16mm, and is transferred to the Einzel lens. This beam is made to be a parallel beam during passing through the lens. The positions and the sizes of the beams are determined by the beam defining slit placed after the Einzel lens. The positions of the beams before and after passing through the bending section are measured with use of the fluorescent screens.

The kinetic energy of $^{14}N^{+}$ is planned to be 35keV, and radius of the curvature of this ring is 1050mm. In order to satisfy this condition, the strength of the magnetic field is 0.192T. This strength of the magnetic field is able to be made with the dipole magnets, the magnetic field strength of which has already measured.

## 4 SUMMARY AND PROSPECT

The experiment to control a dispersion function of beams is planned. This effect is thought to be useful for stable storage of three-dimensionally crystalline beams, which could be realized by the experiment of beam cooling also planned utilizing a storage ring, S-LSR. For this experiment, an electrostatic deflection element is designed. The result of three-dimensional electrostatic calculation shows that the deviation of the electric field is less than 0.1% within ±2.5mm from the beam axis.

The deflection element designed here is now under construction. The experiment to verify the effect of the electrostatic electrode is also planned. An ion source for this experiment is prepared. The experiment to make ion beams directly pass through the bending section will begin from September, in 2004.

## REFERENCES

[1] A. Noda et al., in this proceedings.
[2] M. Ikegami et al., submitted to Phys. Rev. ST-AB as a title "Heavy Ion storage ring without dispersion"