SURVEY AND ALIGNMENT OF HIRFL-CSR AT IMP

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1. INTRODUCTION

HIRFL-CSR, a new ion Cooler-Storage-Ring project, is under construction in Institute of Modern Physics (IMP), Chinese Academy of Sciences, and will be completed in 2004. It is the post-acceleration system of the Heavy Ion Research Facility in Lanzhou (HIRFL) and consists of main ring (CSRm), an experimental ring (CSRe) and radioactive beam line (RIBLL2) to connect the two rings. The two existing cyclotrons SFC (K=69) and SSC (K=450) of the HIRFL will be used as its injector system, see Fig. 1. The heavy ion beams with the energy range of 8~30 MeV/u from the HIRFL will be accumulated, cooled and accelerated to the high energy range of 100~400 MeV/u in the main ring (CSRm), and then extracted fast to produce radioactive ion beams (RIB) or highly-charged heavy ions. The secondary beams (RIB or highly charged heavy ions) can be accepted and stored by the experimental ring (CSRe) for many internal-target experiments or high precision spectroscopy with beam cooling. On the other hand the beams with the energy range of 100~900MeV/u will also be extracted from CSRm by using slow extraction or fast extraction for many external-target experiments.

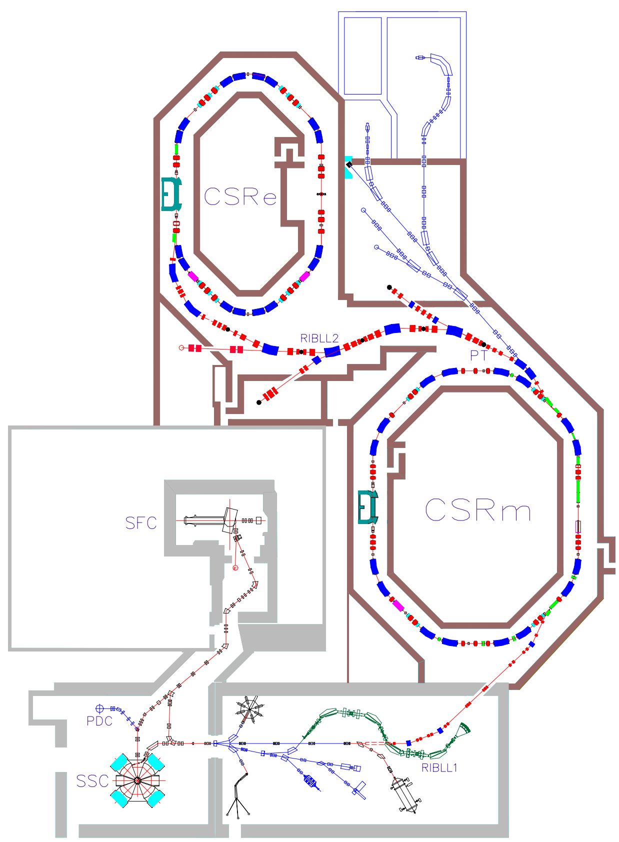

Fig. 1. Overall layout of HIRFL-CSR

CSR intends to provide internal and external target beams for many physics experiments. One internal target in the long straight section of CSRe will be used for nuclear physics and highly-charged-state atomic physics. Many external targets of CSRm will be used for nuclear physics, cancer therapy study and other researches [1].

HIRFL had been constructed in 1988. At that time, the traditional optical instruments were used for survey and alignment. They are K&E 71-10 jig transit, J2 theotolite, Dini 005 optical lever, alignment telescope, etc. The SSC (separate sector cyclotron) consists of four sectors magnets, each one is 500 ton (see Fig.2). The height of magnet gap is 100mm, and the radius of magnet is 4 meters. The gap tolerance is ±0.08 millimeter. Using the traditional optical instruments, we successfully mounted and measured the SSC and the SSC has operated for 14 years successfully. But for the new project, CSR, the traditional method can not meet the more stringent requirements on alignment, the new concept and stratagem should be studied.

2. ALIGNMENT TOLERANCES OF MAGNETS

The circumference of CSRm and CSRe is 161.21m and 128.96m respectively. The desired installation tolerances are showing in Table 1.

Table 1. The position tolerance of CSR magnets:

MAGNET TYPE	HORIZONTAL	VERTICAL	BEAM DIRECTION	ROLL ANGLE
Dipole	±0.5mm	±0.5mm	±2.0mm	±0.5mrad
Quadruple	±0.15mm	±0.15mm	±0.5mm	±0.5mrad
Sextuple	±0.15mm	±0.15mm	±0.15mm	±0.5mrad
Corrector	±1.0mm	±1.0mm	±1.0mm	±2.0mrad

The Tolerance is based on the 1σ Gaussian distribution and the number in the table 1 is total tolerance and includes three parts, for quadruple they are:

1. The position error of fiducials to the theoretical centre of component, 0.05mm.
2. The position error of control network, 0.05mm.
3. The error of position adjusting and measuring of components, 0.13mm.

3. ESTABLISHING CONTROL NETWORK

In order to meet the stringent requirement, tow stages control network was established. One is global control network or primary network, the other is local control network or secondary network. The global control network is for all HIRFL-CSR system, it is used to define the correct location and orientation of accelerator subsystems (i.e. SSC, SFC, CSRm, CSRe and Inject line) to each other. Each subsystem has its own control network, the local control network. According to the local control network, the components of each subsystem can be mounted to an ideal position. Because the relative position of each component is more stringent at the CSRm and CSRe than that at beam line, the CSRm and CSRe control networks are more precise than global network, and the floating control network is used in CSRm and CSRe that means we concern more for the relative position of each component in CSRm and CSRe system than for the absolute position in the global control system.

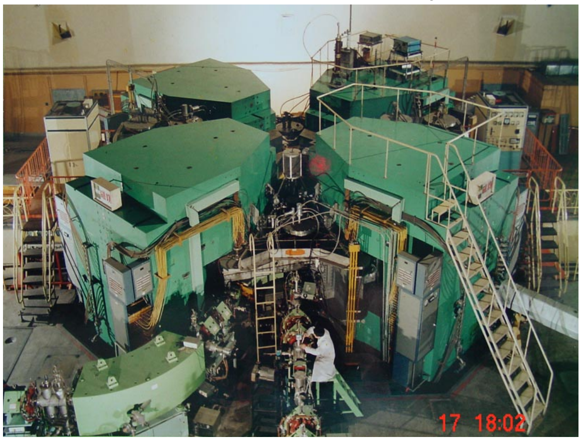

Fig. 2. Separate Sector Cyclotron (SSC)

The original point of HIRFL-CSR global control network is on the mechanical center of SSC (Separate Sector Cyclotron), which had been constructed in the 1988 (See Fig.2). Because the center of SSC is invisible after it was constructed, two reference points were built on the wall along the axis of SSC at that time, which were used to define the center of SSC (see Fig. 3). After thirty years later, we should know if the two reference points can be used to define the center of SSC accurately. Fortunately there are tow fiducial points on the top of each sector of magnet, which are machined in plant and accurately on the axes of each sector of magnet. These fiducial points can be used to determine the center of SSC. In summer of 2001, we used Laser Tracker 4500 (SMX company produced) to measure all fiducial points on the magnet. After calculation using the SMXIsight that is a program for Laser Tracker 4500, a measurement coordinates system was set up, which original point is on the center of SSC.

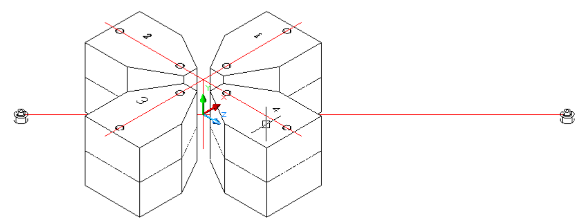

Fig. 3. SSC coordinates system

According to the coordinate system, the new reference points were built on the wall and floor to construct the control network and the old reference points on the wall also measured. The maxim position deviation of old reference point is 0.4mm along 27meters axis. The results are encouraging and prove the foundation of SSC is very solid and stable.

According to the global control network, the CSRm and CSRe control networks are established. Because of the high-required alignment tolerances of magnetic components, two very stable floor monuments were constructed at the center of each ring as the original points of measurement coordinate system. The construction of the monument is shown as Fig.4. The pipe is about 25 meters long and inserts into the bedrock. The anchor is fixed into the bedrock. There is a long stainless steel wire in the pipe that one end is fixed to the anchor, another end is fixed to the floater. The floater is immersed into oil and gets a float force to keep the stainless steel wire vertical and upright. The plumb mirror that puts on the button of floater is as the measuring target. This special construction of floor monument keeps the measuring target from the influence of floor movement, so the tiny movement of floor can be monitored.

The designed CSRm control network is shown in Fig. 5. It is special designed for laser tracker. There are 36 monuments and 18 tracker stations as the network points for calculating the network precision . Some of monuments are fixed on floor and some of them fixed on the wall.

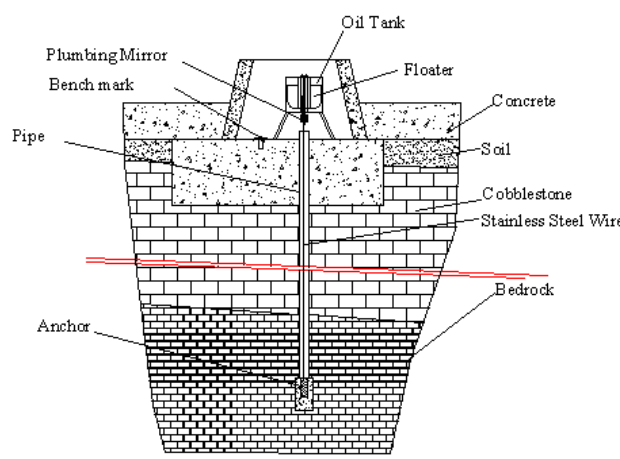

Fig. 4. CSRm center monument

The survey of network will be done by the Laser Tracker 4500, which is given precision as 18μ+4μ/m for distance measure. The optimization design of control network has been done using the NASEW95 geodesic adjustment software and the maxim error of point position is 0.046mm.

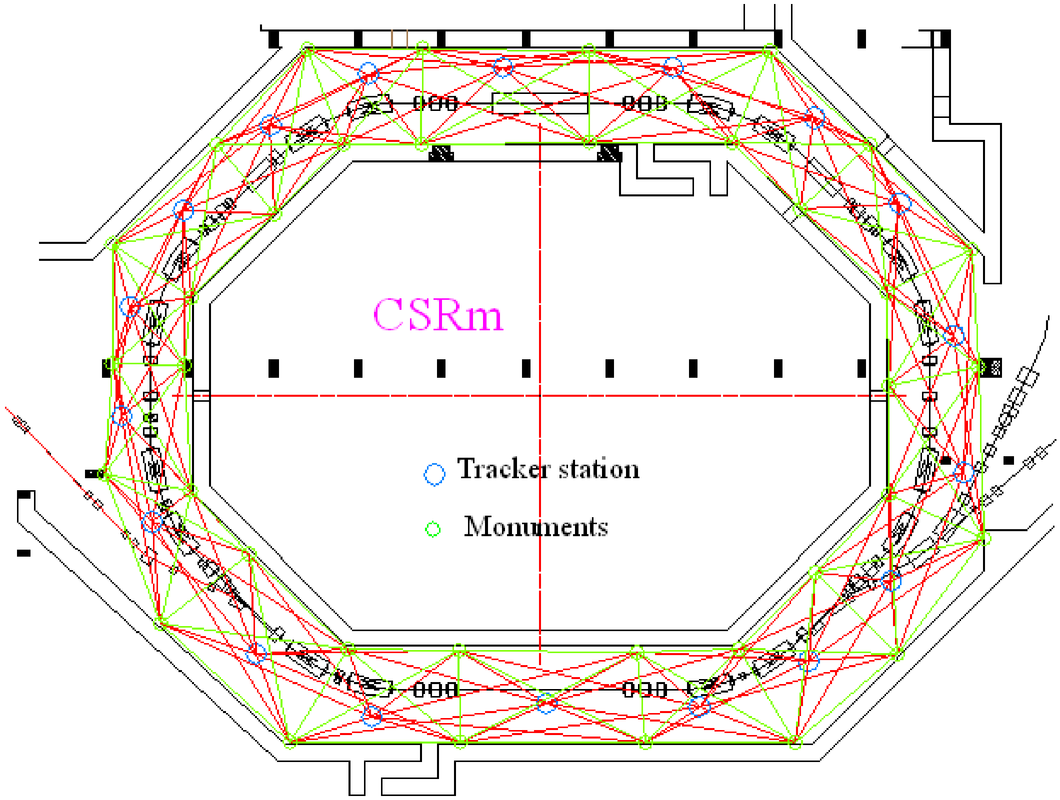

Fig. 5. CSRm control network

4. COMPONENT FIDUCIALIZATION

Eight SMR nests were welded onto the magnet, four on the top and four on the ails side, as the fiducials. Before measure the fiducials, the geometry of component should be measured first to find the center of component and establish the component coordinates system.

The origin of magnet component coordinate system is on its geometric center. In order to easy measure the geometric center, the lamination of magnet has been machined 5 slots, one on the top and two on each side, and they are good symmetric. The special designed mandrels have been machined also for measuring the symmetric center of the four pole tips of quadruple. Using the laser tracker, first the slots and pole tips are measured, after dada processing by Insight, the geometric center and the axis are calculated and the component coordinate system will be established. According to the coordinate system, the fiducials are measured and the data will be saved in the database of survey. This method is similar to that using in SLAC [2].

Fig. 6 Fiducials of magnet

5. THE APPLICATION SORTWARE

An application software, DSCS (Database System for CSR Survey), has been developed. It is a program used for survey and alignment of CSR. It bases on the SQL SERVER relational database system. This program has three functions:

1. Accept input from the Insight, the laser tracker software, to the database or vice versa.
2. Convert the data from one coordinate system to another.
3. Exchange the file format of AutoCAD to the file that NASEW95 can read.

Using the DSCS, the data of fiducials of each magnet will be saved in the database and convert the data of component coordinate system into the data of local coordinate system according to the theoretical position of this component in the local coordinate system. When mounting and measuring the component, the DSCD can calculate the center position of component according to the data of fiducials measured by laser tracker and give the position error comparing the measured data with the theoretical data saved in the database. This software can also give the advice for adjusting the component position when it is out of the position tolerance.

When designing the network, we usually draw the network shape and decide the position of network points by AutoCAD then input the data of network points into the NASAW95 to do the adjustment calculation. Because the NASAW95 software unable to read the CAD file, the data used to be input manually. Using the DBCS not only the data are able to be input from CAD file to NASAW95 but also able to output the adjusted results to Insight as the nominal data for installing the magnets. It is very convenient for us to optimize the control network.

6. THE INSTRUMENTS

The instruments we use in CSR system mainly are SMX Laser Tracker 4500, LEICA TCA2003 total station and NA3003 digital level. The distance precision of TCA2003 is 1mm+1ppm that manufactory given. In order to use it with higher precision, calibration has been done with the dual-frequency interferometer. The distance measured is 25m with 1m interval. Fig. 7 shows the deviation of TCA2003 measured.

The laser tracker uses the SMR as reflector and the TCA2003 uses prism as reflector. If TCA2003 can uses the SMR as reflector, it will bring us more convenient. For this purpose, two works have been done: first is measuring the constant of the SMR by the comparing method, second is input the constant number to TCA2003 and measuring the same distance using the SMR with TCA2003 and Tracker 4500 separately, and contrast the two data. Fig. 8 shows the results. The measured distance is 35 meters and standard deviation is 0.139mm. Because the TCA2003 and Laser Tracker 4500 can use the same target (SMR), we do the pre-alignment using TCA2003 total station and do the final alignment using Laser Tracker 4500.

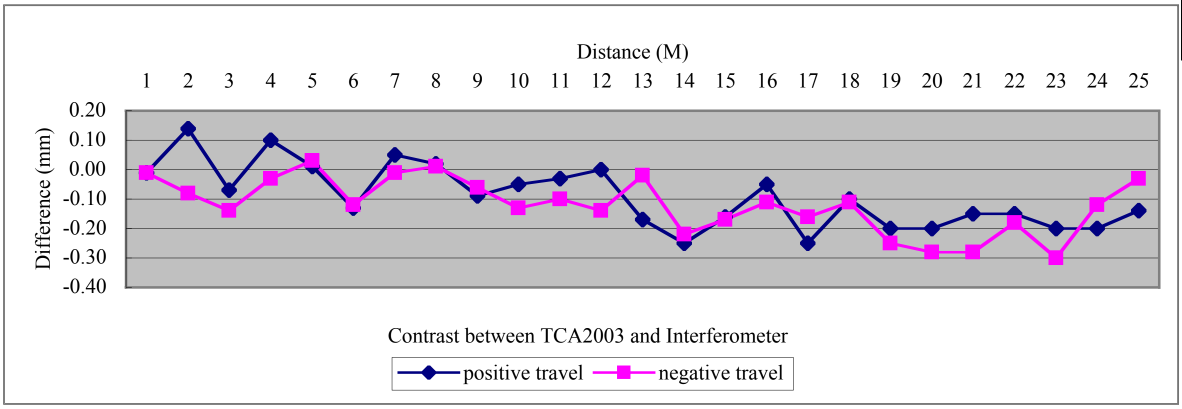

Fig. 7 Calibration TCS2003 with Interferometer

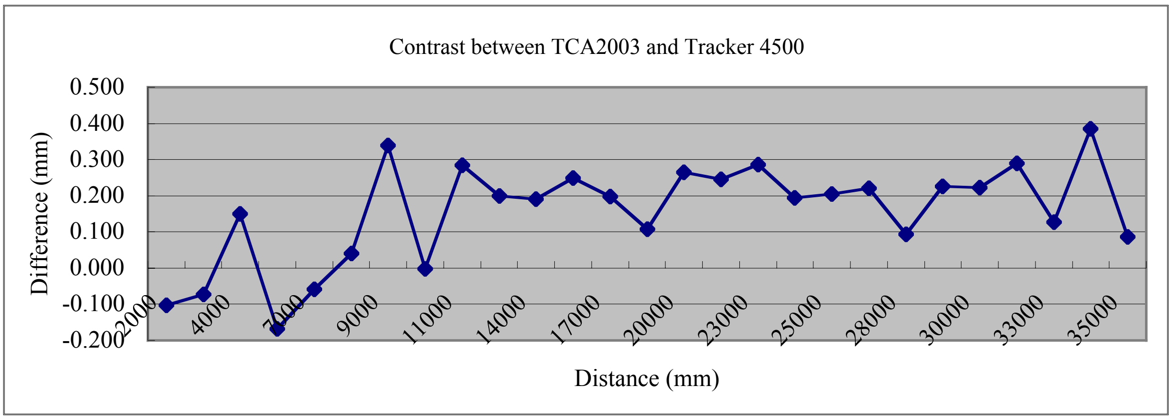

Fig. 8 Contrast between TCA2003 and Laser Tracker 4500

7. ACKNOWLEDGENMENT

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8. REFERENCES

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