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PROTOTYPE GIRDER SYSTEMS FOR KOREA 4GSR*

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Abstract

A 4th generation storage ring based light source is being developed in Korea since 2021. The storage ring based on the multi-bend achromat lattice concept may be able to surpass the brightness and coherence. It features about 800 m circumference with 28 cells, 4 GeV e-beam energy. The storage ring girders consist of 140 girders and each cell of girder is composed of five pieces. We have designed prototype girder using new schemes to achieve long-term mechanical stability, vibration suppression and precision adjusting system. Each girder have vertical, transverse and longitudinal adjusting mechanism with ball screw jack. The alignment error between girders should be less than 50 μm. In this report, the conceptual design of the 4GSR girder and support systems are reported.

INTRODUCTION

Third generation storage ring based light sources have been used as a bright light source for many years. Recently multi-bend achromat (MBA) lattice presents a further decrease in the electron beam emittances and becoming a new standard for next generation light source like MAX-IV in Swden, ESRF-EBS in France, SIRIUS in Brazil. Many other laboratories are also preparing their own version of 4th generation light sources. In this context, Korea is trying to build a 4th generation light source (Korea-4GSR) based on modified hybrid multi-bend achromat lattice [1].

The beam stability is determined by the stability of the magnets as provided by the girder system supporting the magnets and vacuum chamber. For a 4th generation light source, a very stable girder system with eigen-frequencies greater than 50 Hz is required. The supports of the storage ring magnets and vacuum chambers rely on 140 girders without injection straight section. Girder system consist of five girders for each of the 28 storage ring cells. Each girder has to support several magnets. The girders are all identical with a difference length of 3.4 m, 3.8m and 4.8 m (see Fig. 1). Each girder assembly has three parts, the girder body, the adjusting mechanism with screw jack and stepping motor and the support. These girders have adequate transverse and torsional stiffness to satisfy deflection and vibration requirement in addition to the stability requirements due to thermal distortion. As all girders must be aligned to a designed position, an adequate adjusting mechanism should be implemented.

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GIRSER SYSTEM DESIGN

The E-beam center is designed to be at a height of 1.4 m to accommodate some components. The eigen-frequencies of the girder loaded with all magnets and equipped with the movers and eventual further support structure should be above 50 Hz. Maximum vertical deformation under full load should be below 80 μm. The individual elements on the girder should be aligned to better than 30 μm. The precision fixation of the magnets on the girder is to be realized by precision alignment mechanism on the girder and in the supports of the individual elements. This would also allow for the fiducialization of the girder body. The girder will be equipped with a measuring device above each mover for the vertical plane. Each magnet on the girders must be separable in order to allow the installation. Main parameters of the girder systems are shown in Table 1.

Table 1: Main Parameters of the Girder System

Parameters	Value
Cell/Circumference of SR	28 cell / 799 m
Beam Height	1.4 m
Girder Dimension	4.8 mm x 1000 mm x 850 mm
Leveling Range(vertical)	± 10 mm
Lowest Natural Frequency	50 Hz
Girder to Girder Alignment	± 50 μm
Adjusting Method(vertical)	Motorized
Position Accuracy(vertical)	± 50 μm

Girders are designed based on experience with the PLSII girder systems. It is consisting of four supports with each vertical degrees of motorized adjustment and considering the length of the girder. We would like to make some modifications to reduce the higher gravitation deflection of the girder body and increase the adjusting range with screw jack. Girders are used to support and to position with high precision for the storage ring magnets. The girder is a welded box structure of rectangular cross section with inner ribs and side supports. The upper girder plate serves as a reference surface and contains a high precision alignment mechanism for magnets [2]. The girder has three types 3.4 m, 3.8 m and 4.8 m long girder. Relative positioning of the assemblies is achieved with the help of the girder movers that form the part of the girder supports. Seven movers are used to compose a four vertical support with stepping motor, two horizontal adjustment support and one beam direction adjustment support.

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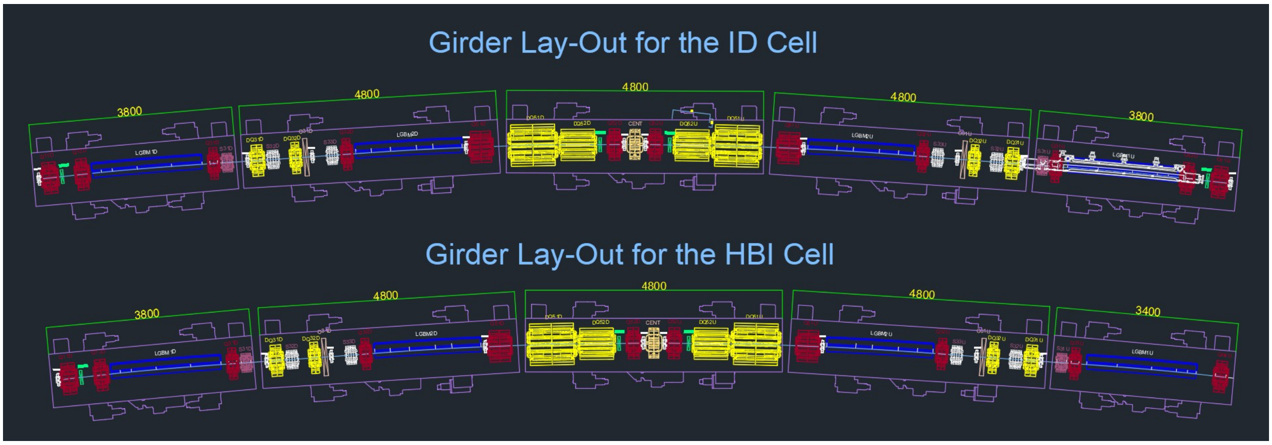

Figure 1: Girder lay-out. Upper is normal for insertion device cell and Lower is long straight section for injection cell.

A girder mover for vertical consists of base support, stepping motor, Digital Prove and screw jacks. The girder movers are placed on supports which have a hollow box with base and top plates. Figure 2 shows girder system with adjusting mechanism.

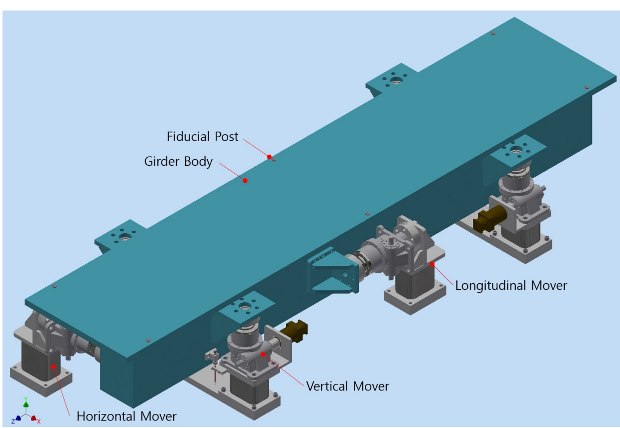

Figure 2: Girder system with adjusting mechanism.

Girder Body Design

The girder body is a hollow box structure with internal ribs and side brackets that are placed onto the movers. The three types of girders differ mainly in their length. The structure has rectangular cross section. In the preliminary design included here, the top plate thickness is 50 mm, the rest of the walls, ribs and side supports have the same thickness of 30 mm.

The axial locations of the inner ribs and side support surfaces are defined to maximize the girder transverse and torsional stiffness and at the same time minimizing the amount of material and simplifying the construction. The vertical placement of the side supports is designed to minimize the lever arm of the applied torsion. The finish of the side brackets bottom surfaces has tight tolerances to enable high precision alignment and positioning of the girders. Each magnet, equipped with vertical, horizontal and beam direction adjustment supports, will isolated from the girder by its own supports. These supports will reference to the high precision surface on the girders. This mechanism is adjusted by bolt. The range of adjustment for the magnet is ±5 mm. Before the final machining of the reference surfaces, the girder should be exposed to high temperature annealing in order to reduce inner stresses remaining after welding and preliminary machining and to prevent possible long term deformations.

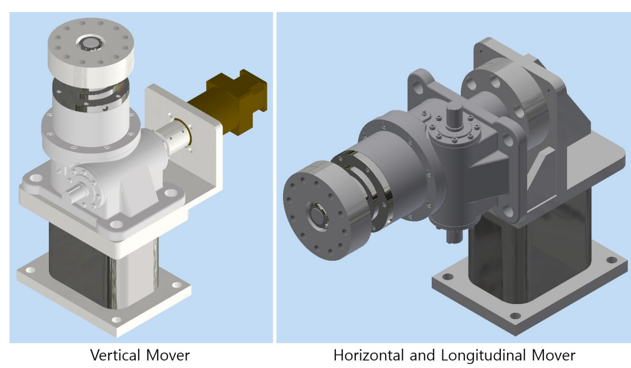

Figure 3: Base support and moving mechanism

Girder Mover and Support

Each vertical girder mover consists of screw jack and base support. The screw jack was adjusted by stepping motor to adjust height and manually to adjust horizontal and longitudinal direction. Screw jack is composed of screw jack, gear box, stepping motor, and digital prove. The girder is mounted on the screw shafts via spherical plain bearings. Spherical plain bearings are self-aligning and enable multi-directional alignment movement to be made. It should be possible to exchange the individual movers with the whole girder assembly in place. The base support is designed to be a strong foundation for the screw jack to firmly support and precisely adjust the girder. The base supports have a hollow box with base and top plates which is made of steel plate. Figure 3 shows base support

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and moving mechanism including screw jack and stepping motor.

ANALYSIS OF GIRDER

The structural deformation of the girder depends on the upper magnet. There are four vertical support, two transverse and one longitudinal support. The girder support is analyzed using ANSYS, including the complicated geometry structure. A solid geometry is adopted for the girder and screw systems including magnets loads about 10tons, which is fixed on the girder top plate. The support girder material is structural steel. ANSYS result for the girder system in the vertical direction is shown in Fig. 4. The minimum deformation on the girder top plate is 33.7 μm, and the maximum deformation is 60.9 μm in the vertical direction with magnet loads. The 1st mode and 2nd mode frequencies are 60.08 Hz and 72.92 Hz without magnet as a result of modal analysis.

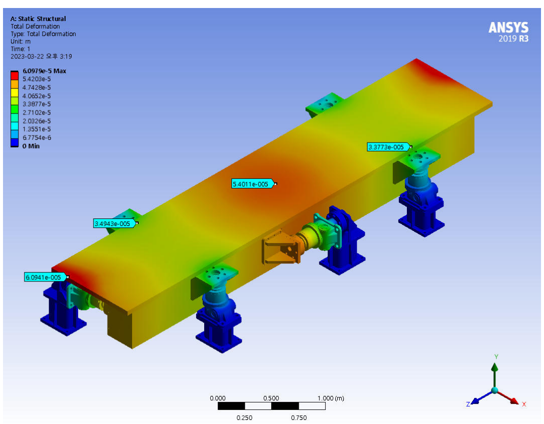

Figure 4: Displacement of girder with magnet loads.

CONTROL SYSTEM

The controller will be manufactured using Beckhoff PLC [3]. A total of 28 cells, 5 girders per cell, and a total of 140 girders are entered. Prototype only one needs to be manufactured, but this product needs to control 140 girders, so the design of the controller is very important. The length of the cable between the motor and the motor drive must also be considered, and how fast the LVDT is read is also important. So PLC(Beckhoff) was used, and each Sub(slave) PLC is bound together as Main(master) PLC. Figure 5 shows the Girder Control System Overview, the PLC's I-PC(Industrial PC) is loaded with Window OS, and the PLC program and EPICS ioc will be installed. Figure 6 shows the girder control system detail overview. The instrument is connected to the slave unit via a dedicated cable, and the slave and master are connected by an optical cable. We tried to install the Encoder to read the exact position of the motor but due to the structure of the instrument I installed a Digital Probe (LVDT). The operation screen will create with CSS (Control System Studio) [4], and the EPICS IOC use Asyn motor. EPICS and beckhoff used TCP / IP and EPICS will connect to the channel access network.

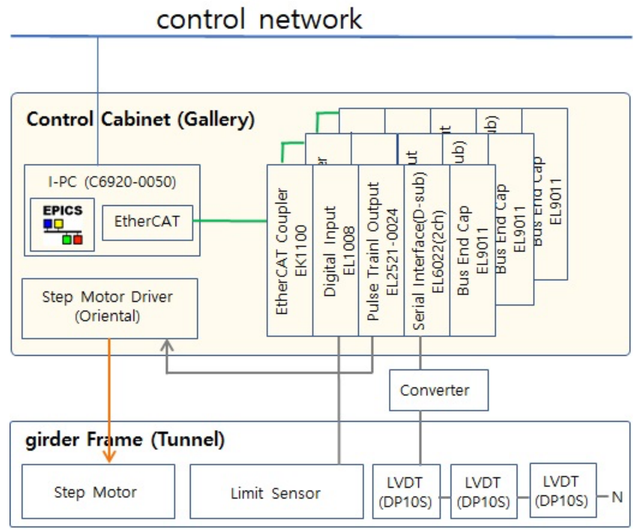

Figure 5: PLC control system

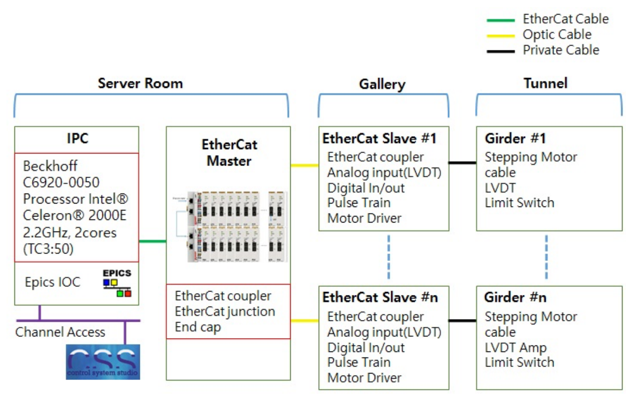

Figure 6: Girder control system detail overview

SUMMARY

The status of the Korea 4GSR girder system is briefly summarized. The new girder system will be adopted active moving system for the vertical adjustment with screw jack and stepping motors.

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