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The construction of an auto-tuning girder system for TPS storage ring

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Outline

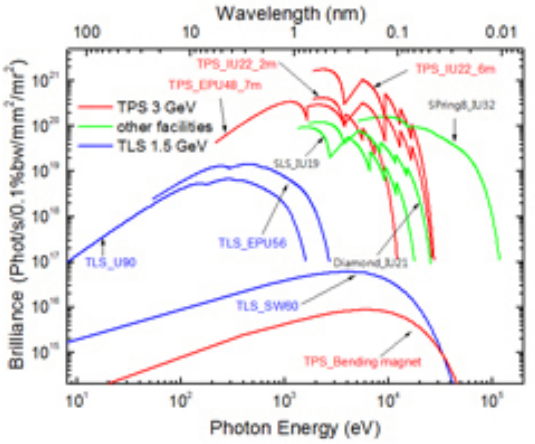
1. Storage ring girder system design
2. Manufacturing and inspection
3. 1/24 ring section mockup girder system installation, measurements and testing
4. System assembling processes
5. Summary

Taiwan Photon Source

Parameters of TPS Synchrotron Facility

Energy	3 GeV
Beam Current	500 mA at 3 GeV
C of the Storage Ring	518.4 m (h = 864)
C of the Booster	496.8 m (h = 828)
Cells	24-cell DBA
Straight Sections	12 m x 6 (σ_v = 9.8 μm, σ_h = 165.1 μm) 7 m x 18 (σ_v = 5.1 μm, σ_h = 120.8 μm)
Emittance	1.6 nm·rad at 3 GeV (Distributed dispersion)
RF frequency	499.654 MHz
Critical Energy	7.13 keV (dipole)
Energy Loss/turn	853 keV (dipole)

Brightness of Synchrotron Light Sources



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Design goals of the girder system for TPS

- Firm support and precise positioning of magnets (30μm relative to the girder)
- High nature frequency above 30 Hz
- Alignment accuracy within 0.1mm

Traditional alignment network simulation reveals an accuracy of 0.15mm typically. It needs to be iterated several times to reduce to 0.1mm and is also time consuming

- Precise resolution (um)

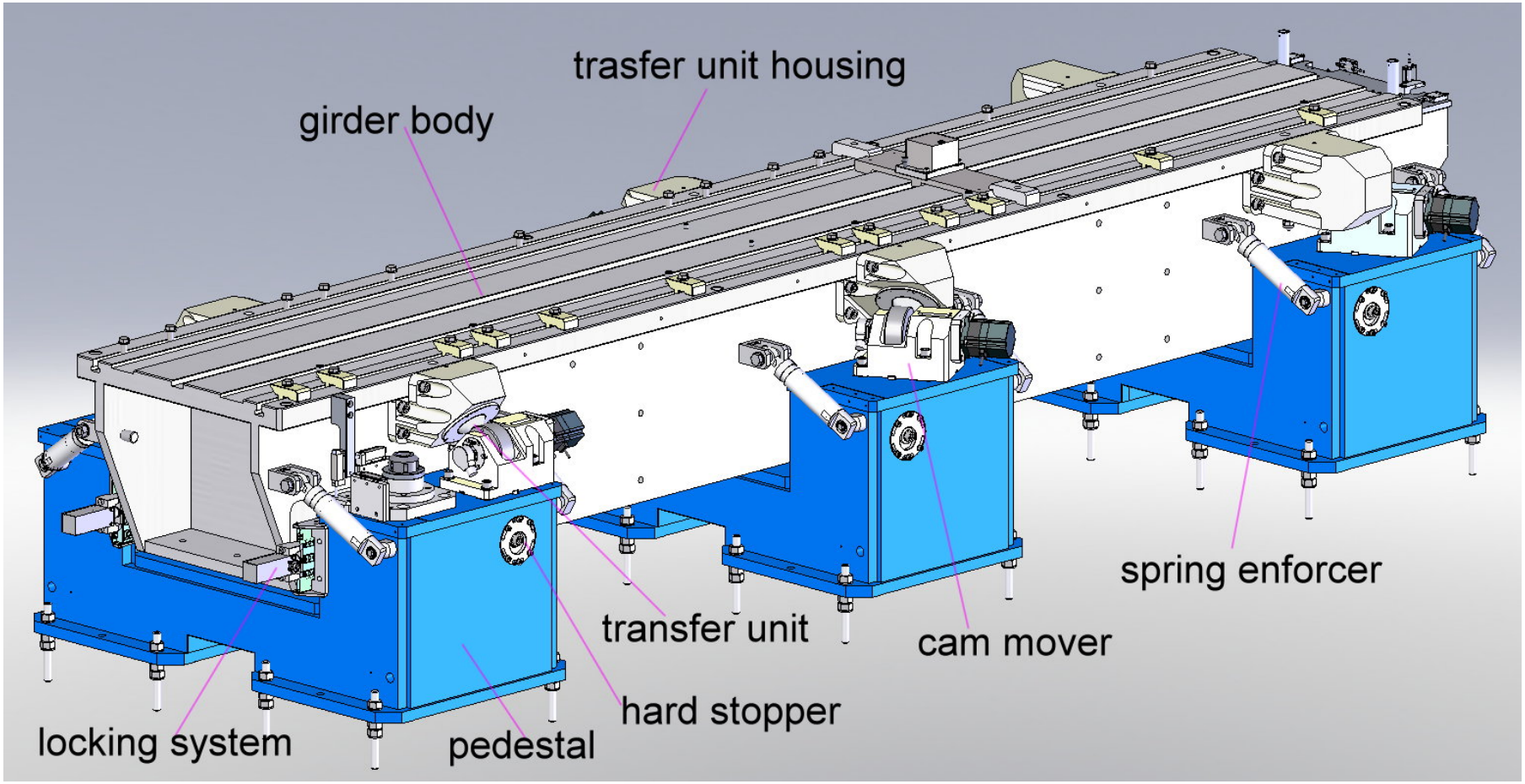
Manual adjustment mechanism is of poor resolution and time consuming

- Toward whole ring automatic alignment (optional)

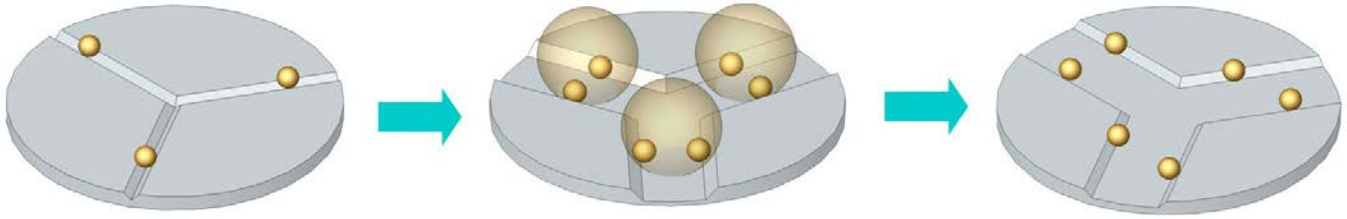
How to align the girders precisely and quickly with less manpower? Considering the deformation of the floor and limited space in the tunnel also frequent earthquakes in Taiwan .

A 6-axis motorized adjusting mechanism is proposed!

One girder system configuration

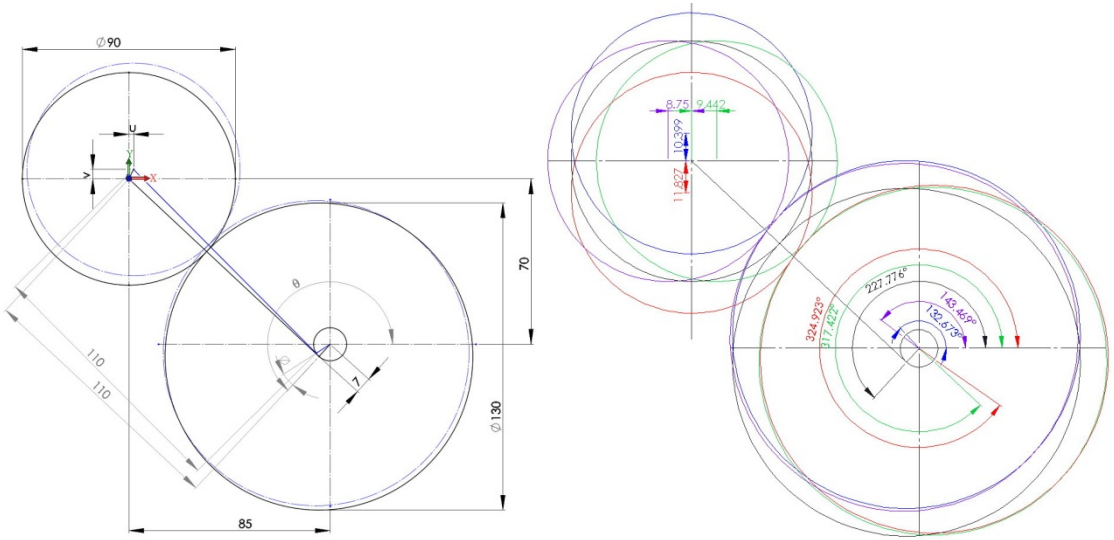


Cam mover type mechanism modification and adjusting algorithm

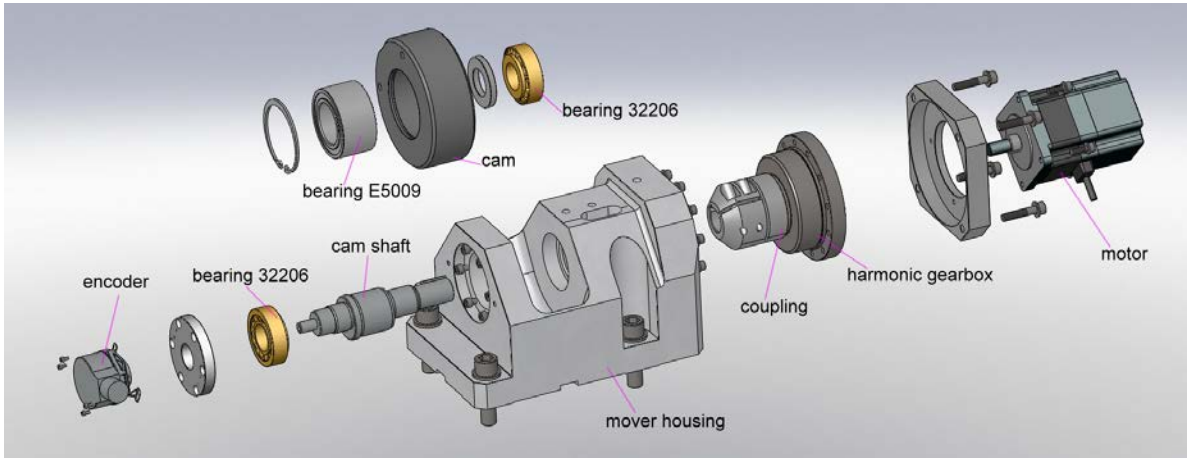


A 3 grooves type kinematic mounting modification to 6 stands girder design

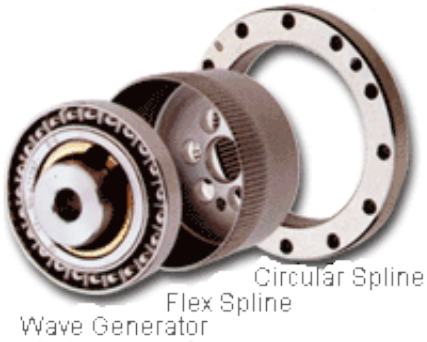
- To determine how to adjusting the girder in each direction by movers directly is not easy.
- An algorithm had been established to transfer the directional adjusting magnitude to the motor's steps.
- Two coordinate systems are to be established at girders and movers separately, from the rigid body assumption, the adjustment of center position of each ball can be calculated.



Modification of point contact type cam to line contact to reduce stress

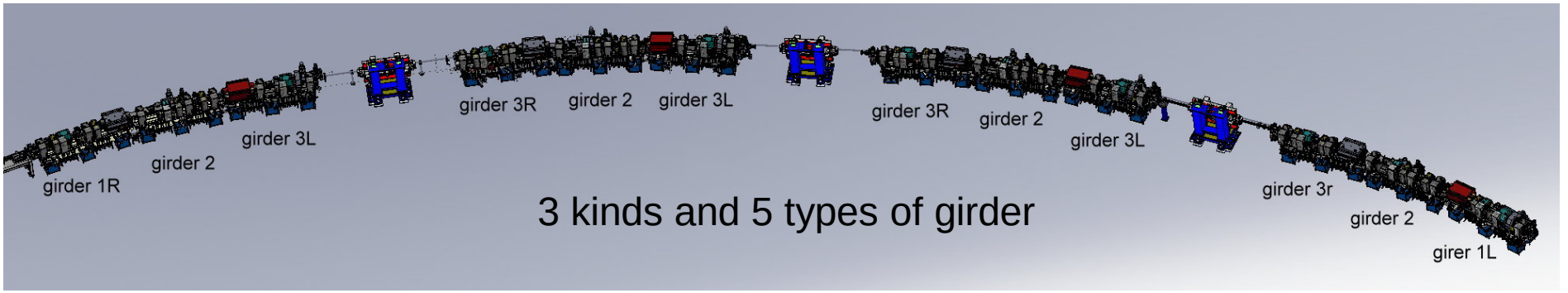


- Kinematic mounting situation preserved.
- The contact position of the ball and the cam remains the same for adjusting algorithm.
- the contact situation changes from point contact to line contact.
- the stress is reduced drastically to 12.4% and far beyond the elastic limitation of the cam.



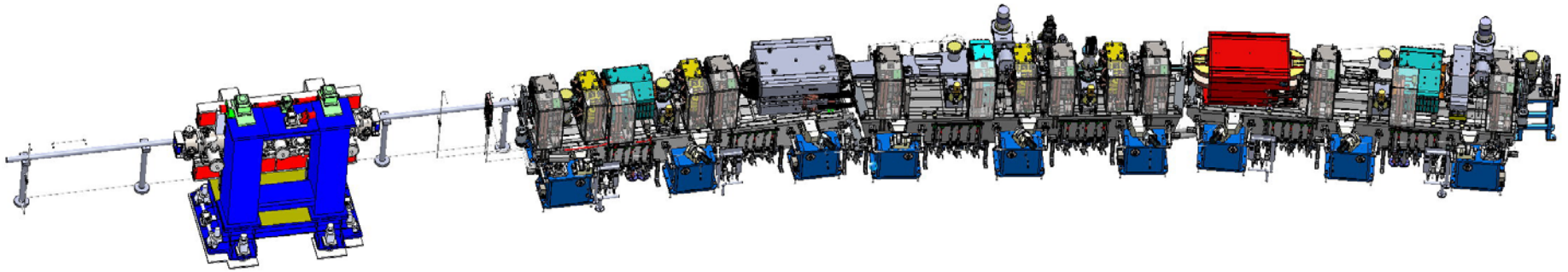
harmonic drive
constant torque : 35 kg.m

Storage Ring Girder System Design

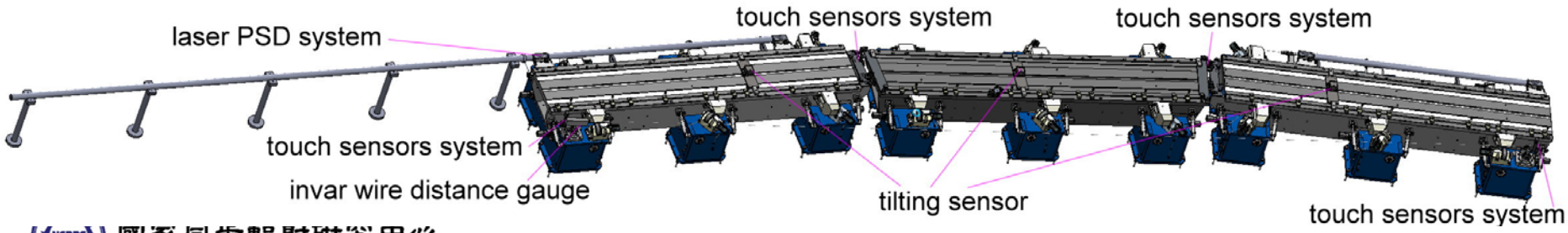


3 kinds and 5 types of girder

1/6 ring symmetry super-period configuration



One girder section(1/24) with magnets and vacuum system



One girder section

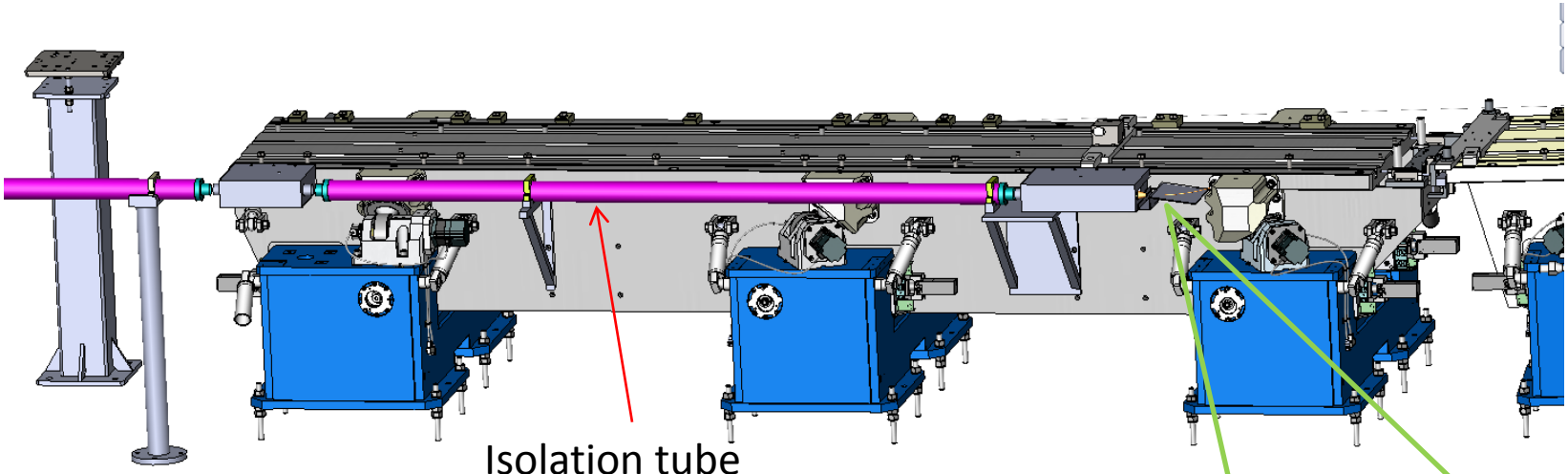
Sensors System

72 Leica Nevil220 tilting sensors

440 Heidenhain ECN425 rotary encoder

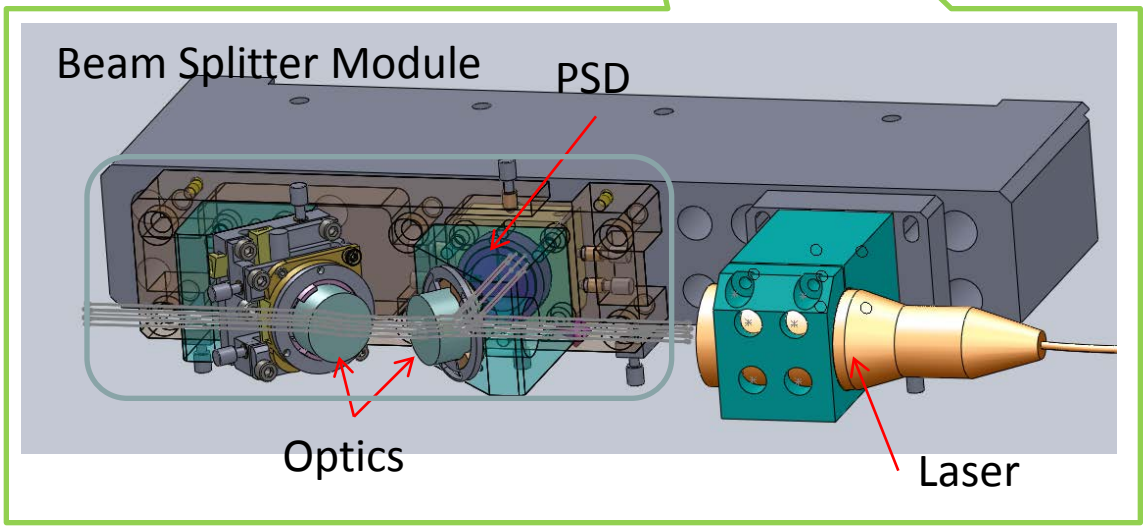
400 Heidenhain Acanto AT1218 absolute length gauge

Laser positioning system



Architecture

- Fiber Laser
- PSD
- Beam Splitter Module
  - Optics
  - Mechanism
- Isolation tubes and relative parts



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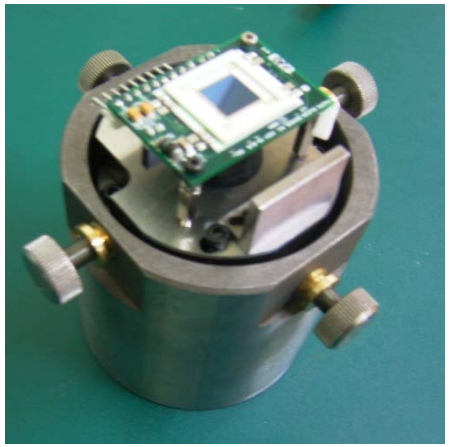
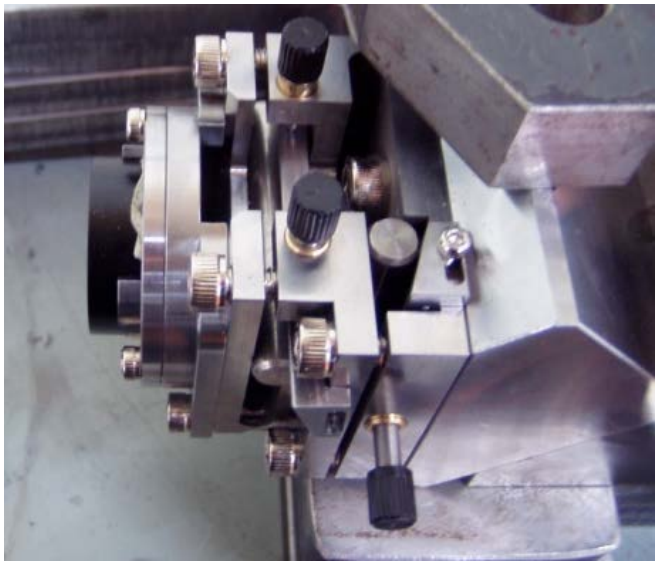
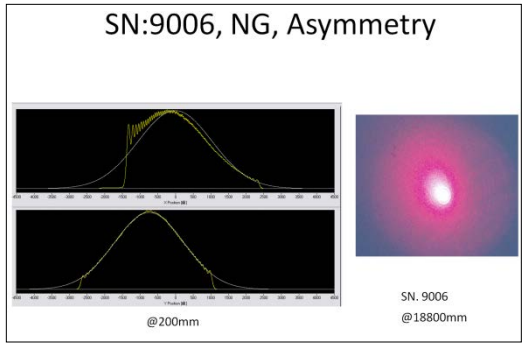
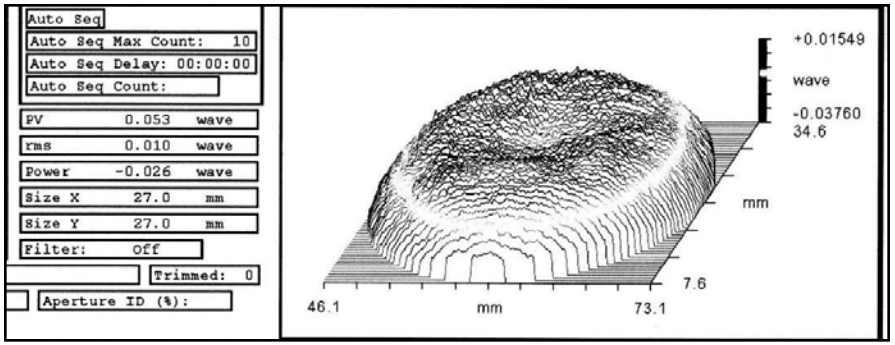
Laser Positioning System

- PSD and Fiber Laser
  - Purchased, received& inspected
- Beam Splitter (PV(rms)<1/20λ, parallelism <0.5s)
  - Purchased ,received & inspecting
- Beam Splitter Module
  - Delivering and inspecting









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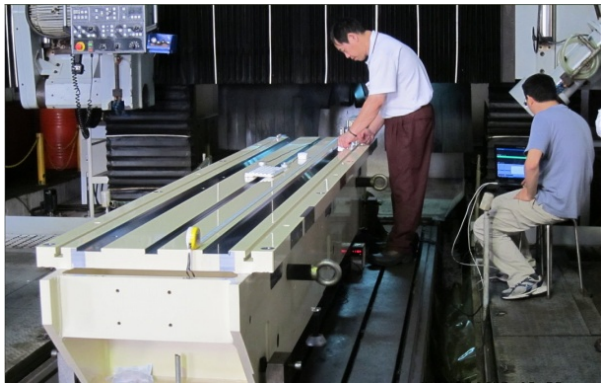
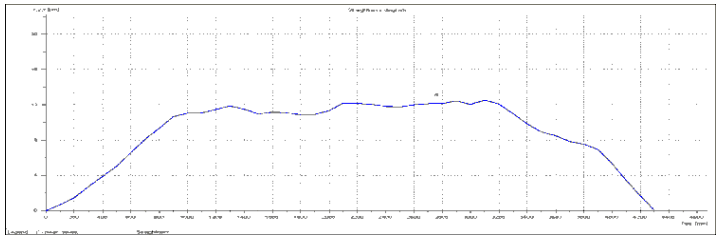
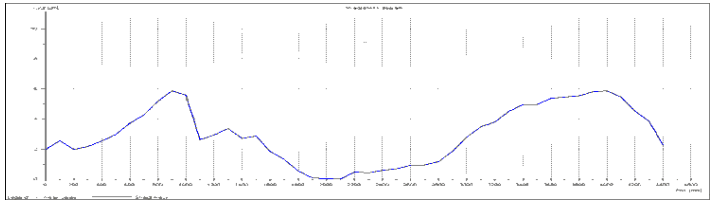
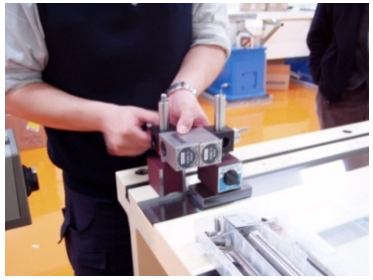
Girder Measurement and Assembly







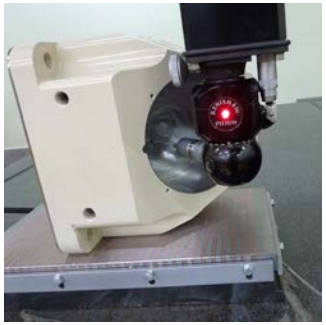


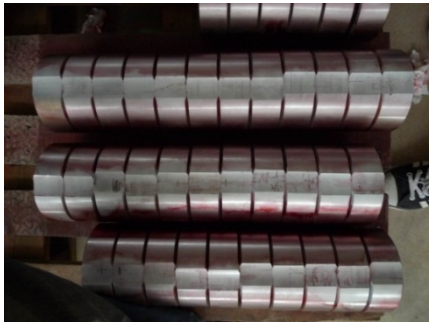
- All the girders are examined by using laser interferometer, autocollimator and laser tracker
- Straightness measurement of assembling reference channel on each girder is around 8~12um
- The deviation of the ball center of transfer unit is less than 0.3mm

Pedestal and manufacturing parts measurement and assembly



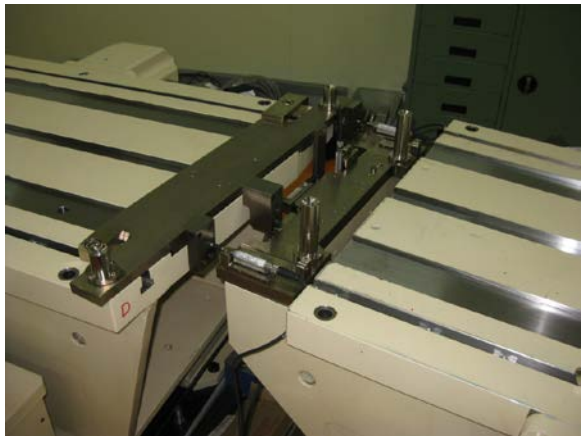


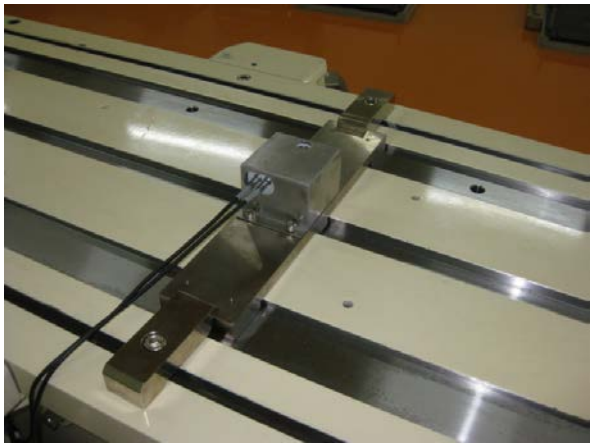





- All components were measured with CMM stage and arms, laser tracker and precision gages to make sure within spec before assembling.
- The movers also being performed with life cycling test

Sensor Module Assembly



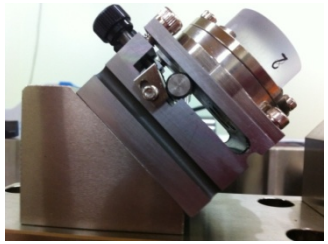


Touch sensor module

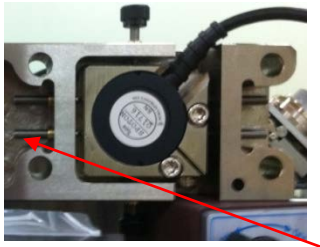
Tilting sensor module

Lens adjusting with a toolkit

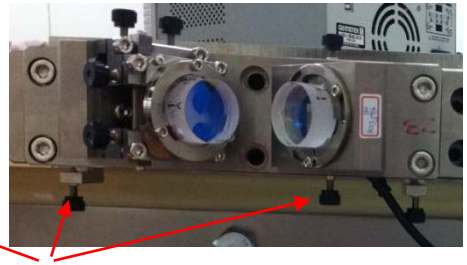
Lens fine_tune



PSD alignment



Lens module adjustment



Adjusting Screw(pitch: 0.2mm)

PSD module

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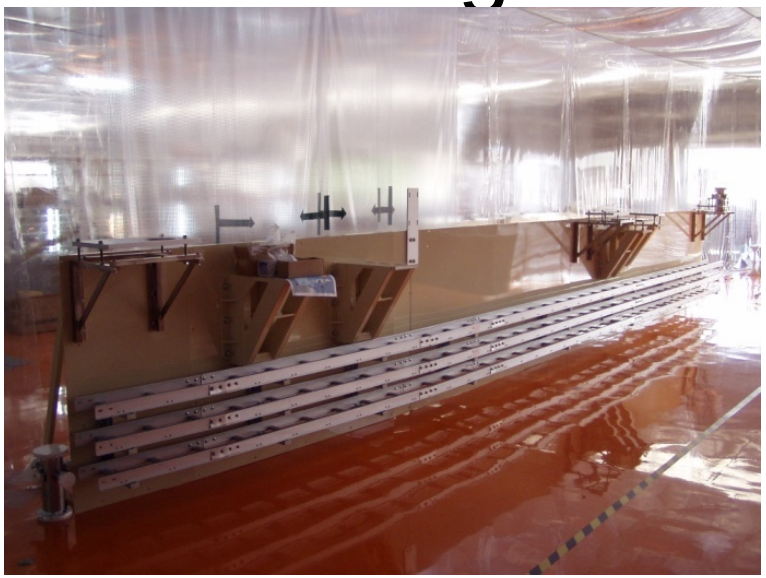
Control system

Delivered and assembled into the Racks

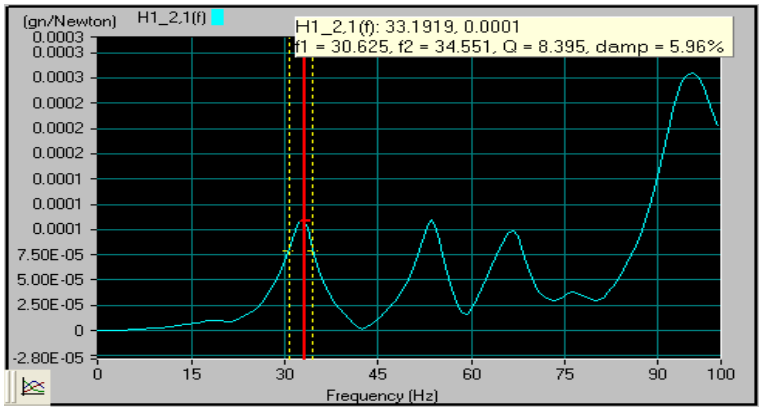
Mockup System Installation Measurements and Testing



3 mockup system had been installed at the rental fab. for interface and assemblage testing

Natural Frequency and damping testing

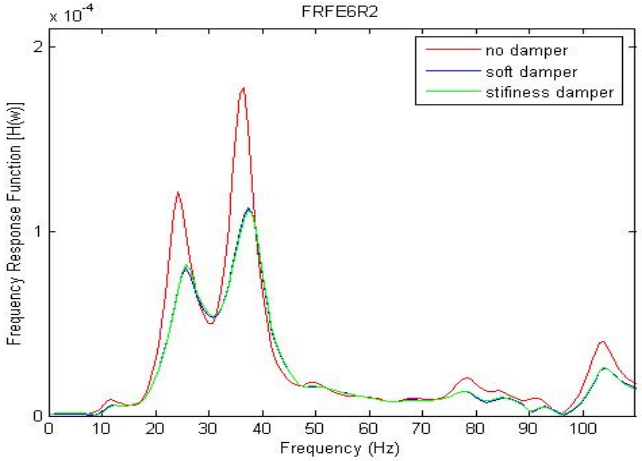
One girder section was installed with dampers and locking system for testing



The 1st NF can be raised to 33 with locking mechanisms

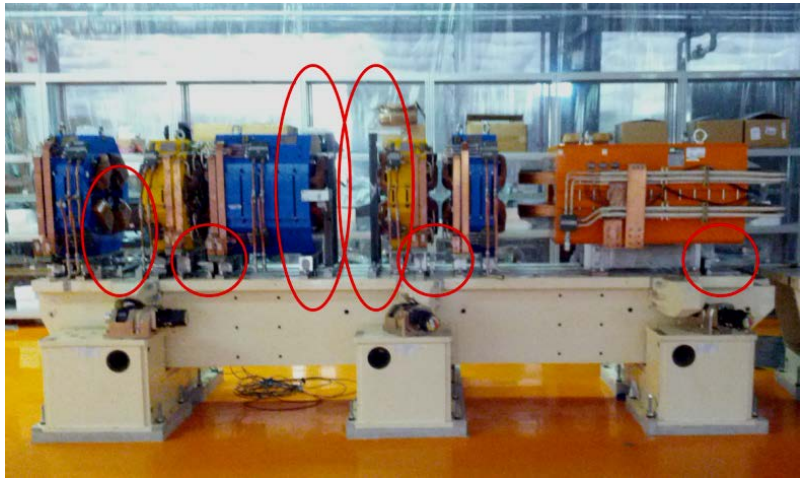
	pedestal (x 10^{-5} mm)	ground (x 10-5 mm)	
	4~100Hz	4~100Hz	AMP
w/o damping X	5.85	5.52	1.060
Soft damping X	7.86	8.67	0.907
stiff damping X	6.78	6.78	1.000
w/o damping Y	6.71	6.68	1.004
stiff damping Y	6.95	7.64	0.910
Soft damping Y	8.23	8.26	0.996

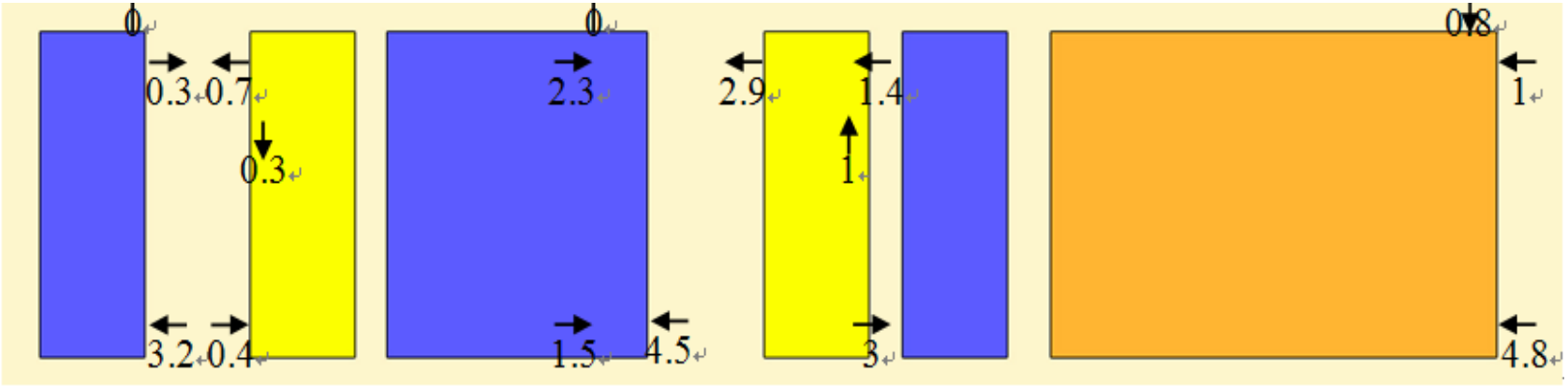
Amplification with damper



The Peak amplitude is reduced with dampers

Girder assembled with magnets transportation test



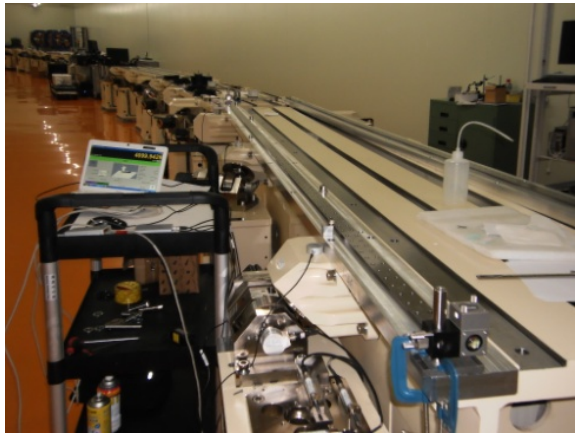


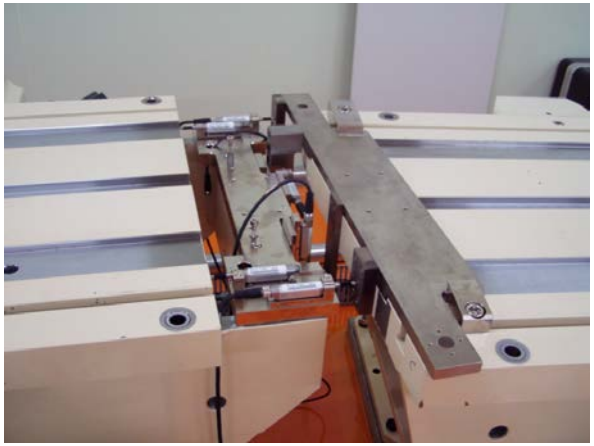
Since the girder and magnets will be assembled in the rental fab., a transportation test was performed. With a air-cushion truck and speed less than 20 km/hr, the deviation at the magnet button is less than 5um

Girder System Assembling Processes

- **Almost all components have been delivered and sub-assembled then the girder with sensors system assemblage start.**
- **The procedures include:**

1. Measure distances between reference holes on one girder with a laser interferometer
2. Measure distances between reference holes on adjacent girders with a encoder rule
3. Touch sensor module assemblage
4. PSD module assembling, partially auto-alignment processing and sensor's data acquisition





8 girder sections (24 girders) were finished till now (2012/10)

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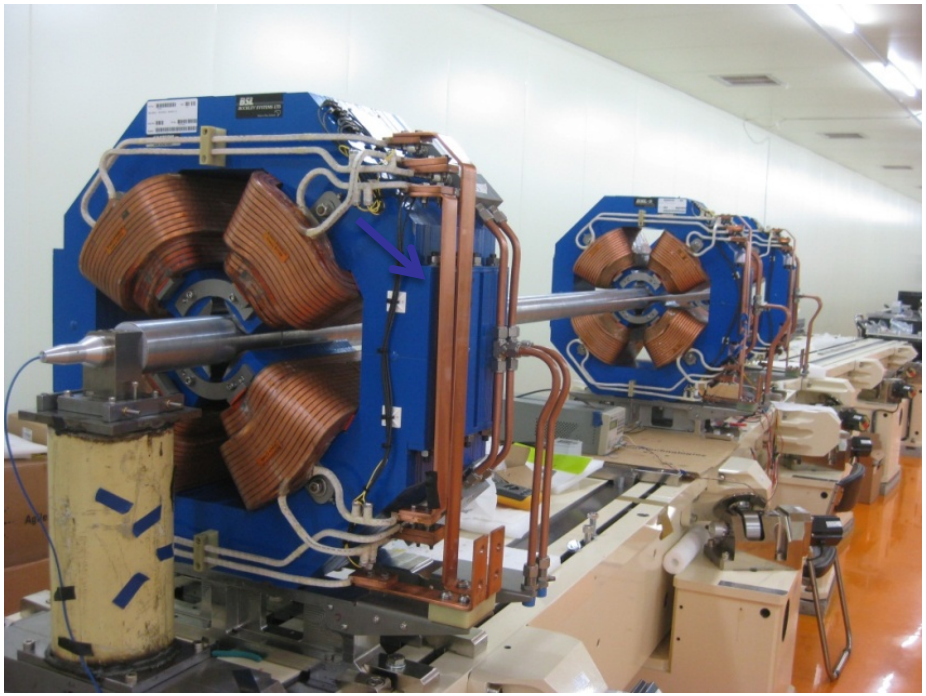
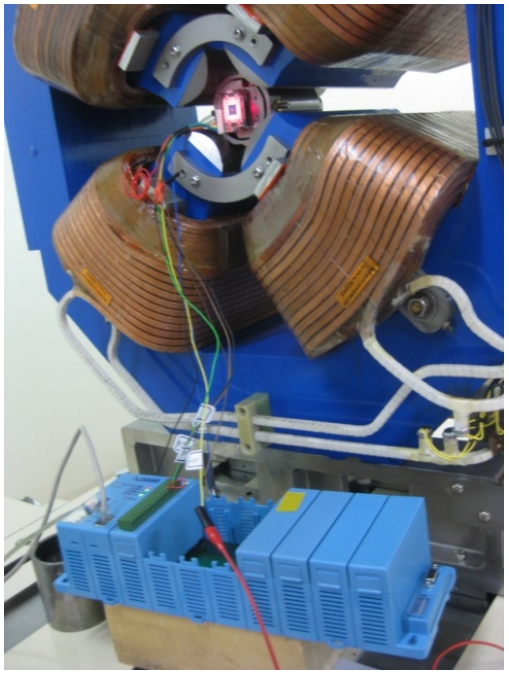
Assembled Magnet Center Deviation Measurement PSD system

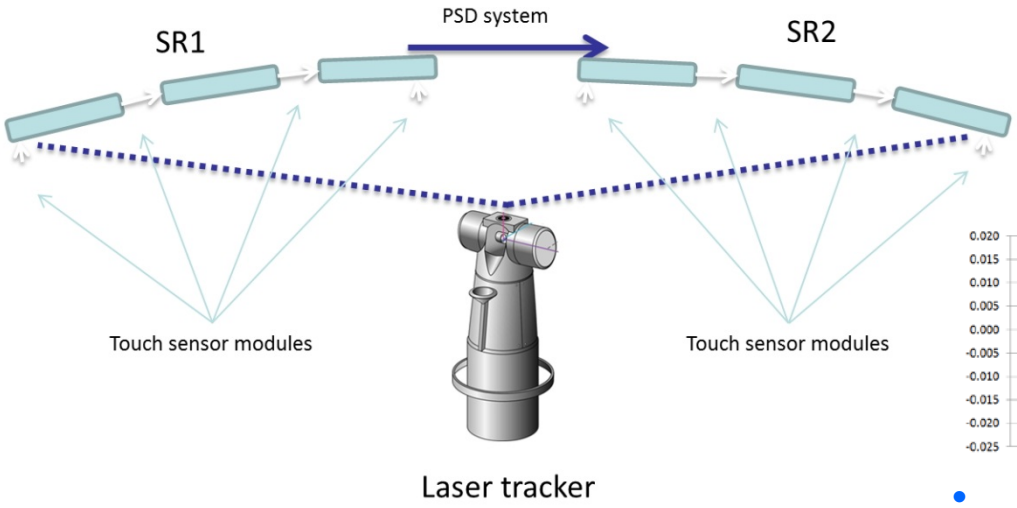


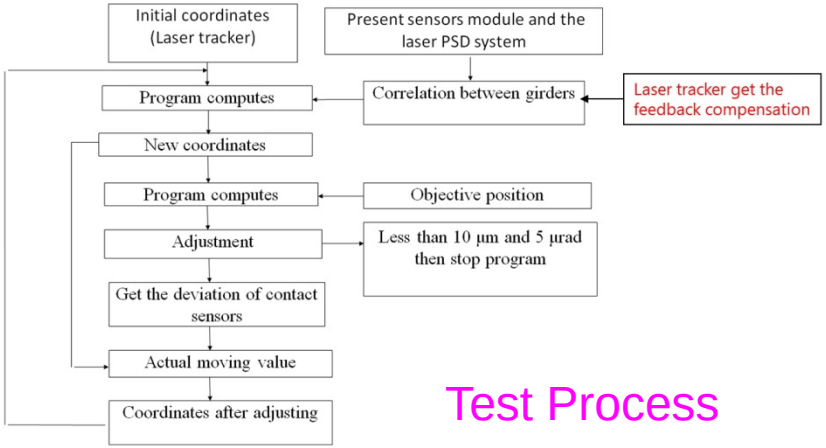


In order to measure the center deviations of the magnets on one girder, a laser PSD system were set up and under testing now

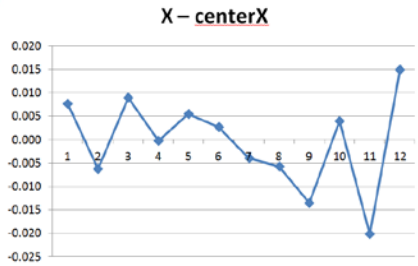
Auto-Alignment Experiment

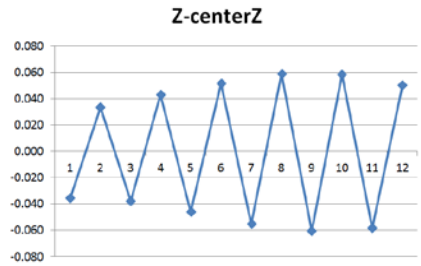
With the 1/12 ring assemblage (2 bending sections with one straight section) configuration, An auto-alignment Experiment was carried out





Test Process





- The laser tracker is utilized to be the feedback in the system.
- It is connected to control system by network.

- **Sensor measurement errors：Laser tracker 21 um，Touch sensor 1.6 um，PSD 3.85 um，Nivel 2 urad**
- **Convergence: X(19 um), Z(60 um)**
- **Repeatability: X(16 um), Z(4 um)**
- **Systematic error (1mins) : 27um (max)**

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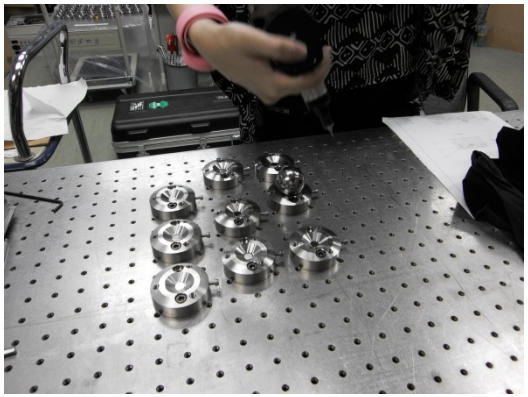
The laser tracker control fiducial points network

- Survey targets are installing on the wall and floor of the tunnel and the distance between two survey targets of the storage ring is about 10 m.
- 48 survey holes on the shielding wall , top of the frontend outlet window, and the survey targets are installed on the two side of the wall.
- The survey network connects the survey of the storage ring and the experimental area by the view holes.



Survey target of TPS

The storage ring and survey holes

Pedestals transportation into tunnel

Pedestals were transported into tunnel and scheduled to be half-ring installed at November 2012

Summary

1. Most components of the TPS girder system were delivered and fully checked to meet the specification.
2. Sub-system assemblage were finished and function tested.
3. System assemblage with sensors calibration data accumulation is under going and 1/3 ring were finished.
4. A Laser PSD system to measure the center deviations for magnets assembled on a girder was setup and under testing.
5. A preliminary auto-alignment testing had been carried out and the results shows good conservation and repeatability.
6. A thorough survey network has been established and used to monitor the building construction and the set out for the pedestals installation is underway.
7. A half ring girder installation without magnets is scheduled in 2012.

Thanks for Attention!