HLS Used at *BEPCII*, *SSRF* and *NSRL*

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HLS Used at *BEPCII*, *SSRF* and *NSRL*

★Sensors of HLS used at BEPCII,SSRF and NSRL

★Calibration of the sensors

★HLS at SSRF, the most complicated in China so far

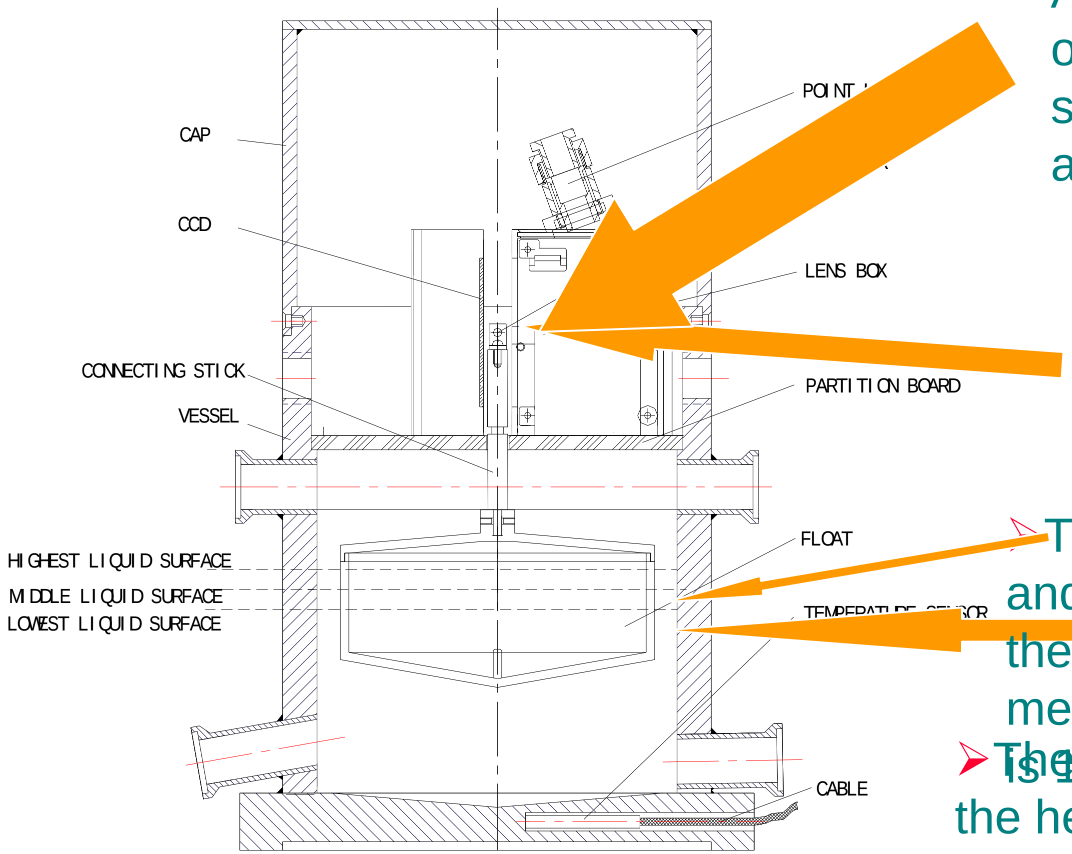
★Some questions followed with interest

★Data of HLS at SSRF from Sep. to Dec.,2008

1. Sensors of HLS used at BEPCII,SSRF and NSRL

- They are all based on the same technology--Charged Coupled Device (CCD)
- Their structures have been changed
- Water is chosen as the working liquid.
- The influent factor of the temperature difference between vessels must be adjusted in the altimetry measurement

1.1 sensor used at BEPCII (Intruduced at IWAA2004)



A bundle of parallel light shines on the bar and it will produce a shadow band on the acceptance widows of CCD.

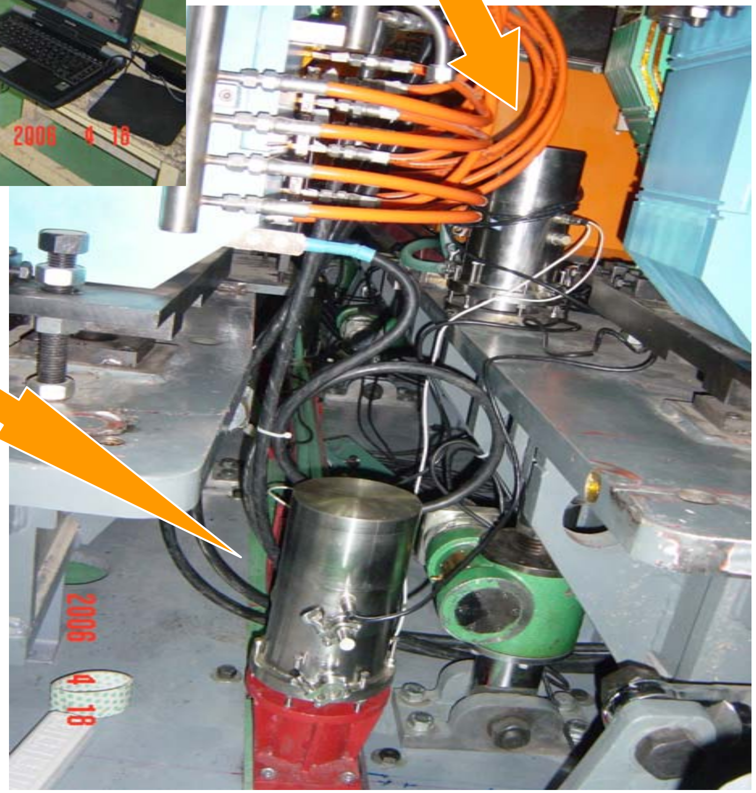
- The mark bar moves up and down along with the float connected through connecting stick.
- The distance between the highest and lowest liquid surface determines the measurement range. The measurement rang of this type of HLS is 10 mm.
- The float moves up and down with the height of the surface of liquid.


2004 6 3


2004 6 15

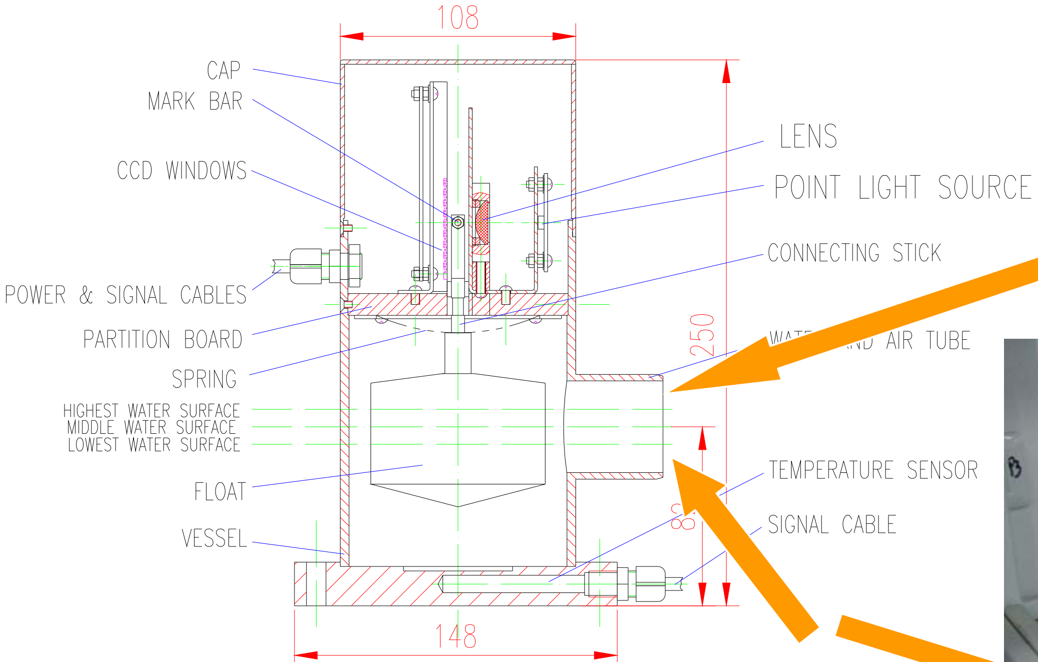
HLS

HLS



Because the ring is crowded and have no place to install a large set of HLS. The nine sensors were used in two set of system, one with 4 sensors and the other with 5 ones, to monitor one gird upper plane and the ground around it in the ring.

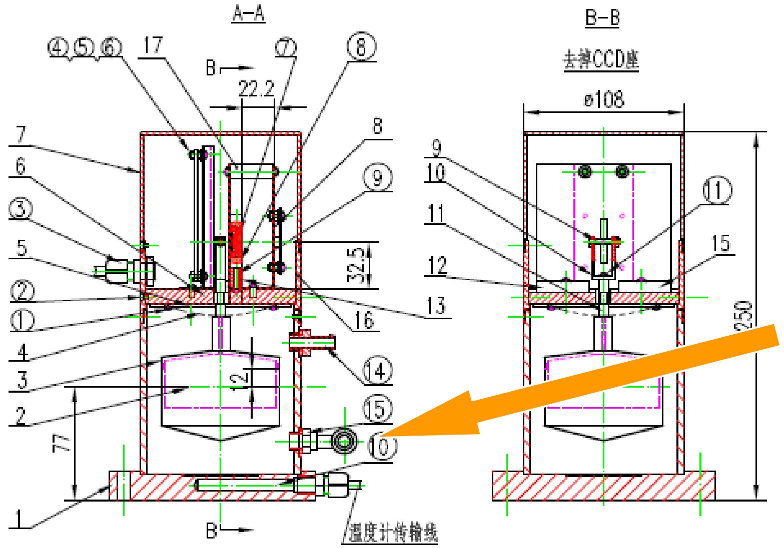
1.2 sensor used at SSRF (Intruduced at IWAA2008)



The sensor developed for BEPCII was the kind of full-filled one, but the one for SSRF is a half-filled one. The basic principle is the same.

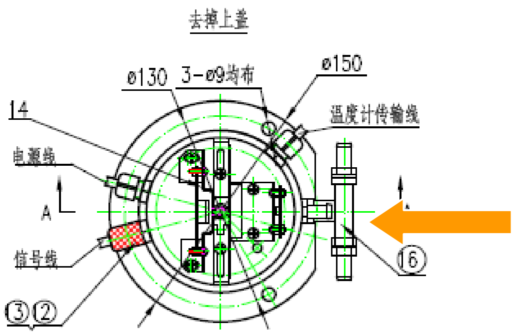
Because the geological condition of the SSRF site is more unstable than the BEPCII site, the HLS must have larger measuring range. Meanwhile, in order to get shorter time for HLS to stabilizing, the system uses circuit through stainless steel pipe with inner diameter 40 mm.

1.3 sensor used at NSRL



The air tube and the water tube are seperated again.But different from the one used at BEPCII, there are only one air tube and one water tube.

For the sensor, it is the full-filled type,but for the system, it is a half-filled one.



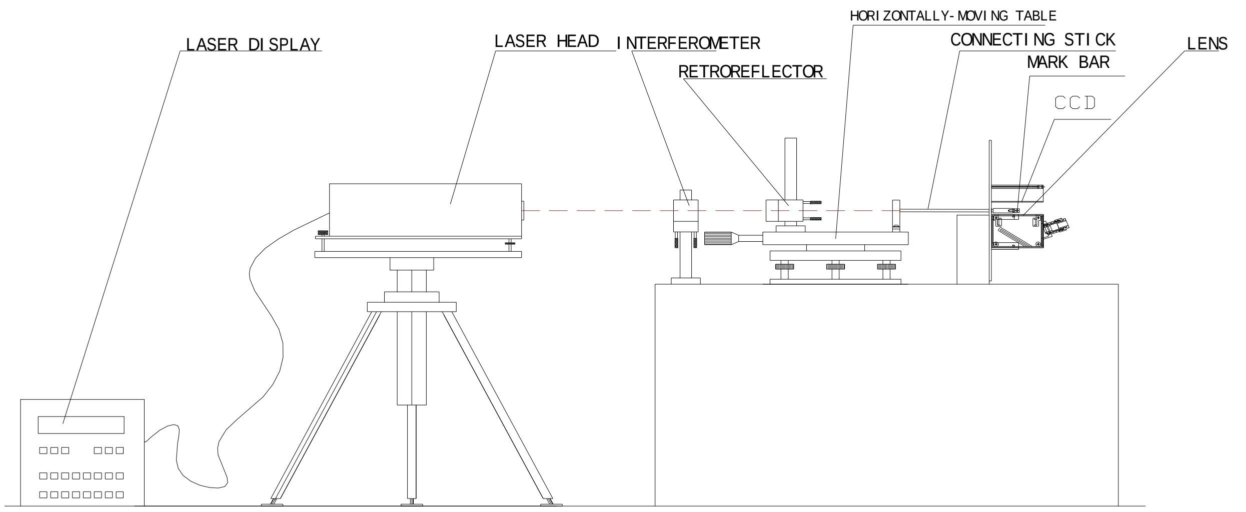
The new structure of the water tube joint make it easier for the vessel sensors to be seriatim connected in the system

2 Calibration of the sensors

Calibration includes the CCD ,vessel sensor and system test before used on-the spot.

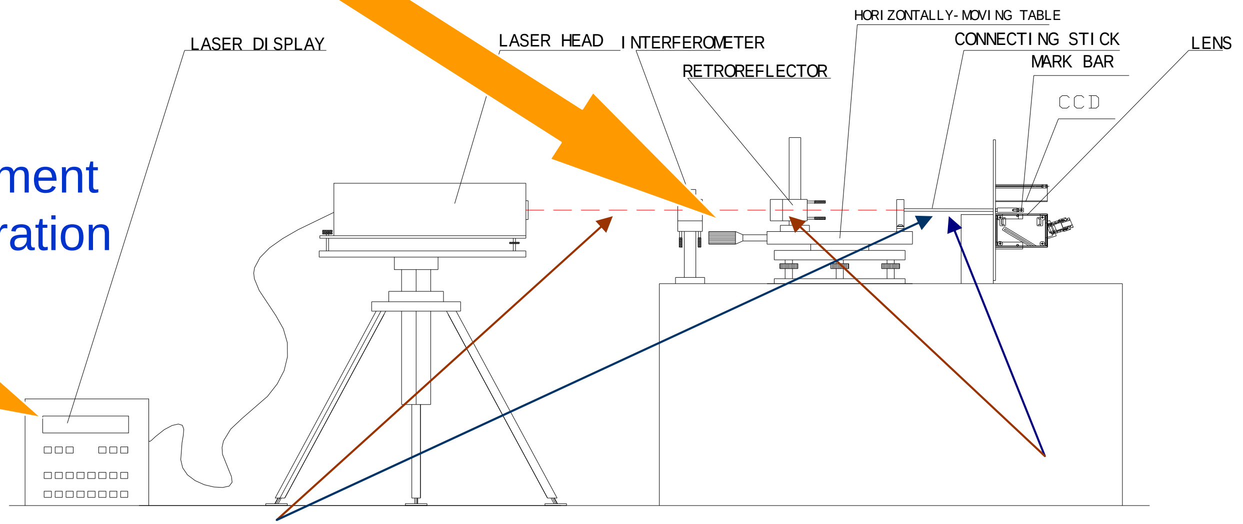
2.1. Calibration of CCD (introduced at IWAA2004)

Measurement Laser System is used to calibrate the CCD



Moving the table forth and back, we get the readings of the laser system and the signs from the CCD.

The laser measurement reading is the calibration datum.



The axle of the connecting stick and the laser beam are on the same line so as to eliminate the Abbe error during measuring.

The connecting stick and retroflector are fixed on the horizontally moving table by screws and connecting spare parts.

Laser head

Horinzontally-moving table

Connecting stick

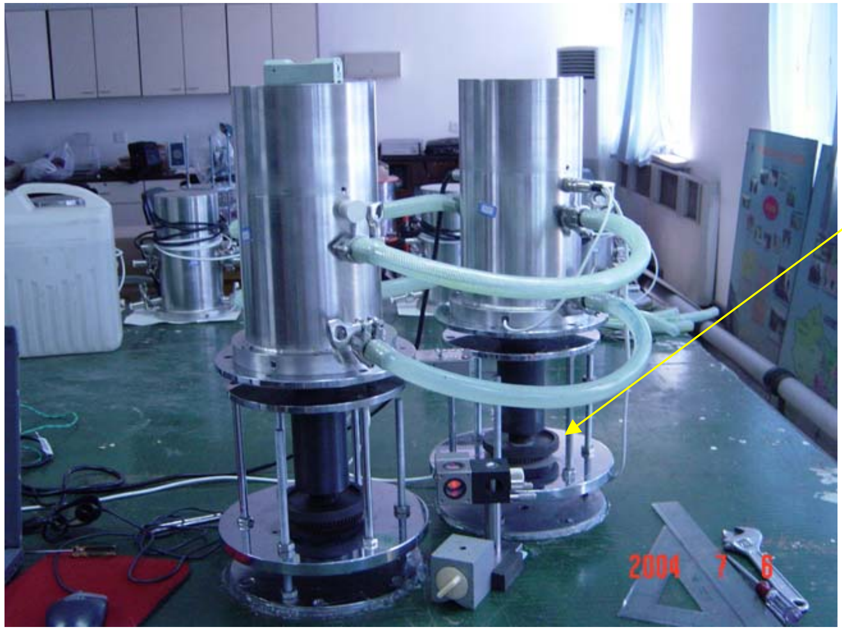
Interferometer

Retroreflector

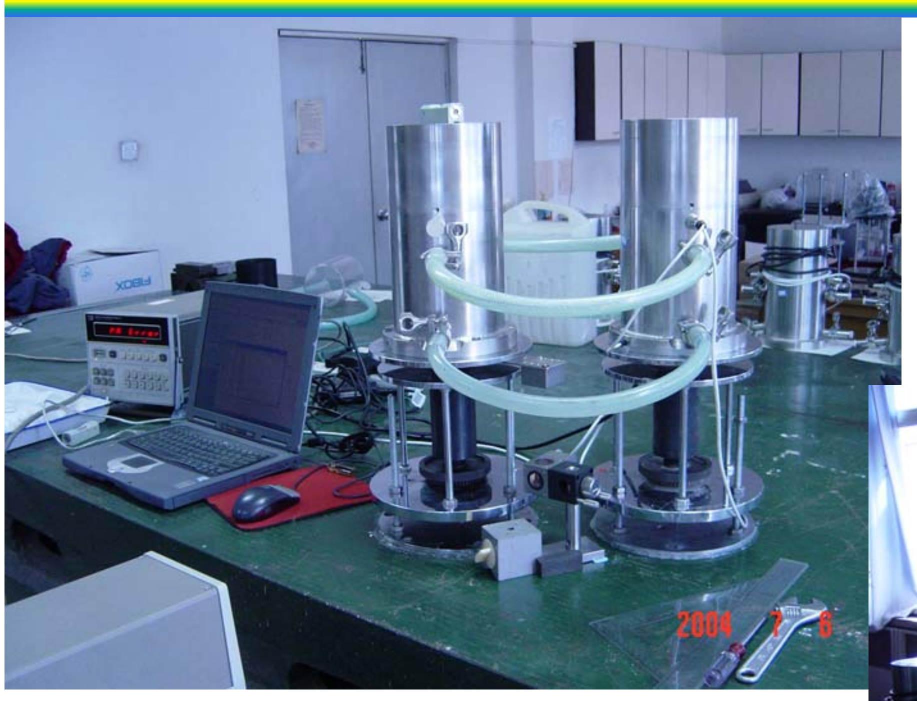
2.2 Calibration of vessel sensor

2.2.1 Calibration of vessel sensor for the BEPCII (introduced at IWAA2004)

✓First method: by controlling the elevation of one vessel in a system of two vessels. HP 5528A Laser Measurement System is used to measure the change of the elevation, which is changed by turning the large central screw.



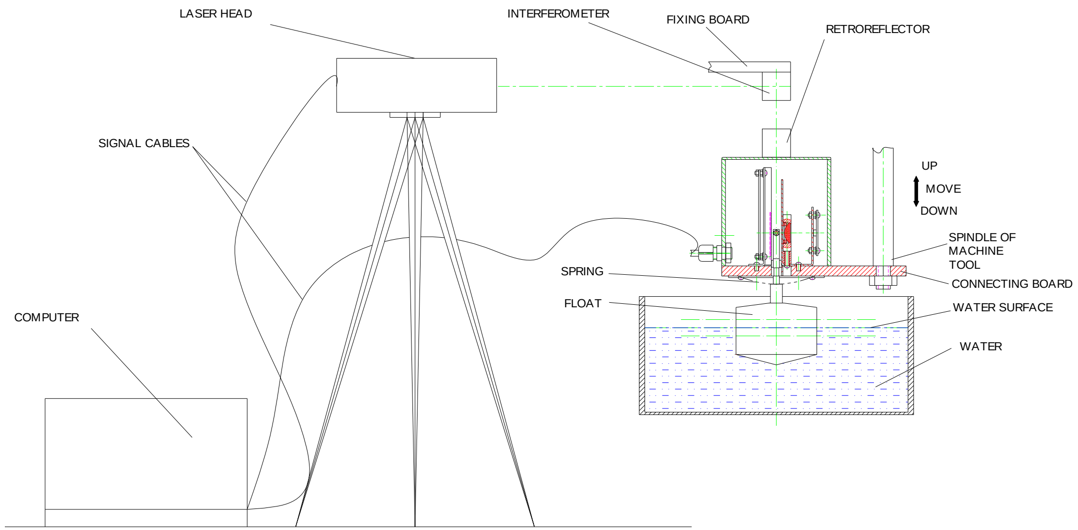
- The uneven screw pitch made the HP readings do not reflect the true change of the elevation of the vessel.
- So we use the second method instead of the first one, which is by adding a known volume steel lump.
- The steel lump is a cylinder of $\Phi 21mm \times 10mm$. And the inner diameter of the vessel is 126mm.So in a system of two vessels, one of the steel lump is added in the water of a vessel will make the water level raise about 138.89 μm.We added five lumps one time and the water level would raise 694.445 μm in each vessel.
- After linear fitting of the data we got standard deviation of the fit is 27.28 μm. In order to correct the non-linearity of the sensor output over the range of 10mm(the readings of output of the sensor from 17 mm to 28 mm), we used a third degree polynomial curve to fit the measurement curve. And the result of SD is better then 0.02 mm.



steel lump

2.2.2 Calibration of vessel sensor for the SSRF (introduced at IWAA2008)

✓But the above methods always using two or more vessel sensors to establish a system, and the system factors often influence the calibration result.
✓Here we designed a system which can calibrate just one vessel sensor by comparing the read of laser measurement system and the output of the sensor.

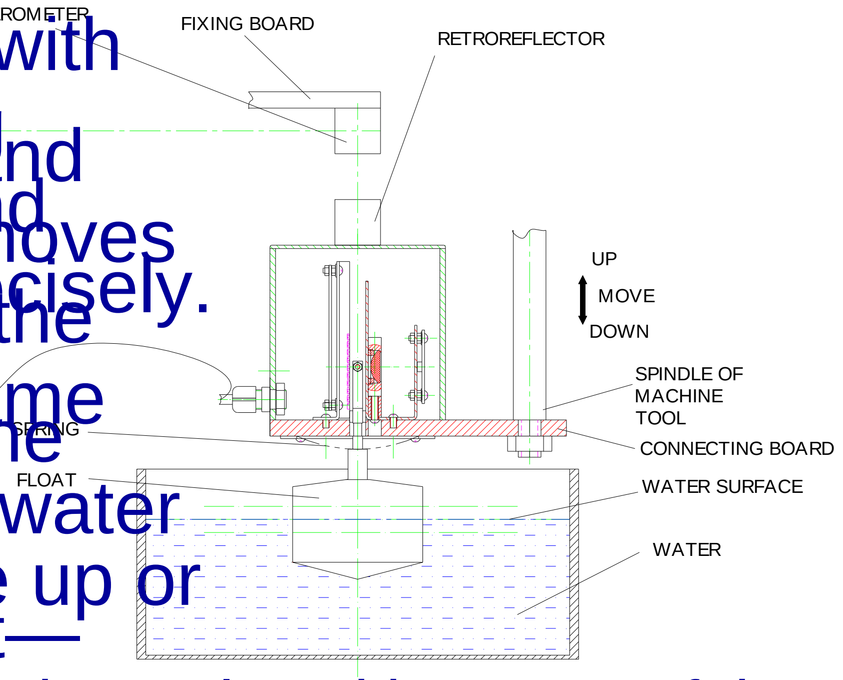


The upper part of the vessel sensor is fixed on a connecting board, and the connecting board is fixed with the spindle of CNC Machining Centre which can move up and down with a pace of 2 μm precisely.

When the spindle moves up and down, the connecting board moves up and down meanwhile and the fixed upper part moves the same distance simultaneously.

When the distance between the upper part and the surface of water changed the float would move up or down accordingly.

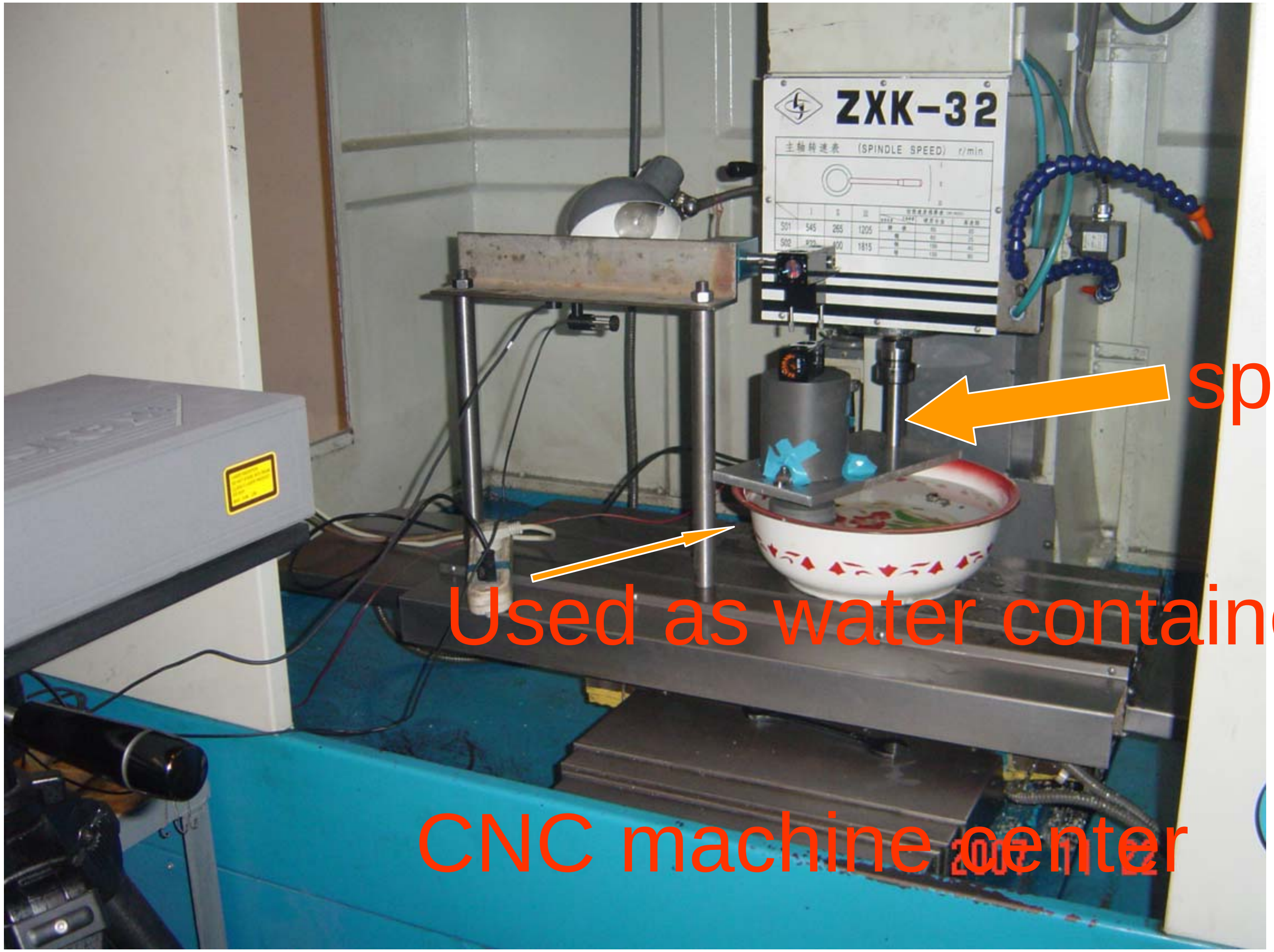
The lower part-- the float— freely float upon the surface of water with a fair depth in a container.



The method can actually reflect the real working state of the vessel sensor. On the top of the vessel a retroreflector of the laser measurement system is fixed. The interferometer is fixed on a fixing board, and use the laser measurement system to measure the moving distance of the vessel.

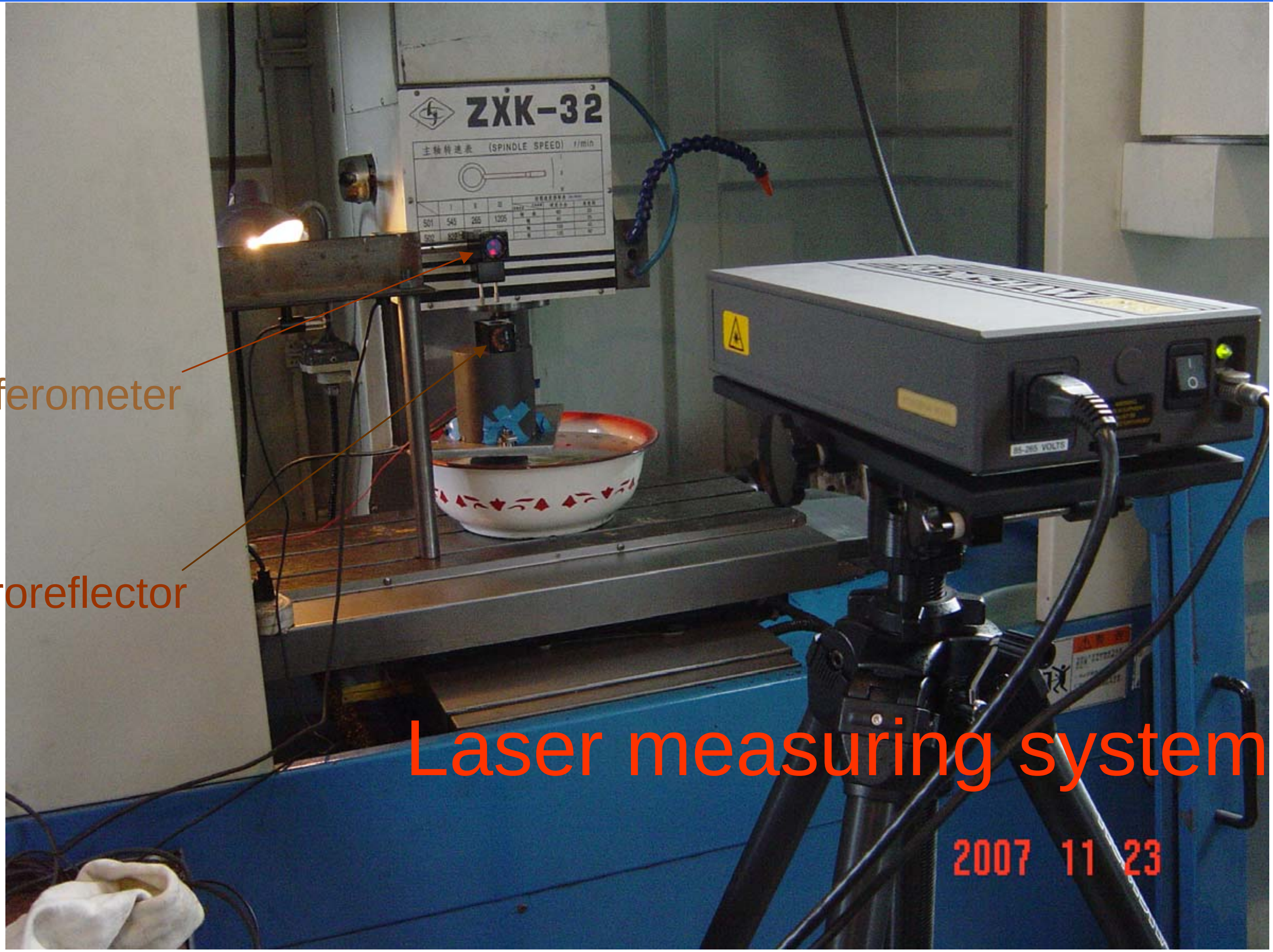
Calibration system for one vessel

★Using the laser system as the reference and by comparing the readings the laser system and the outputs of the vessel sensor, the vessel sensor is calibrated.


ZXK-32
(SPINDLE SPEED) r/min
spindle
Used as water container
CNC machine center

interferometer

Retroreflector

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2.2.3 Calibration of vessel sensor for the NSRL

✓In order to make the calibration process more efficient, and to get the results which could actually reflect the real working state of the vessel sensor. A calibration system which can calibrate more sensors was used at the calibration of vessel sensor for the NSRL

✓The CCD Laser Displacement sensor, product of Keyence Copporation, was used.

✓Main specifications of the Model LK-G30

Measurement range:	±5mm
Repeatability:	0.05μm
Linearity:	±0.05% of F.S.
Temperature characteristic:	0.01% of F.S./° C


Upper parts of HLS sensors
GEOKON
GEOKON
12#


The CCD Laser Displacement sensor
KEYENCE

The CCD Laser Displacement sensor

Data showed

Adjustable table

Work liquid: water +milk

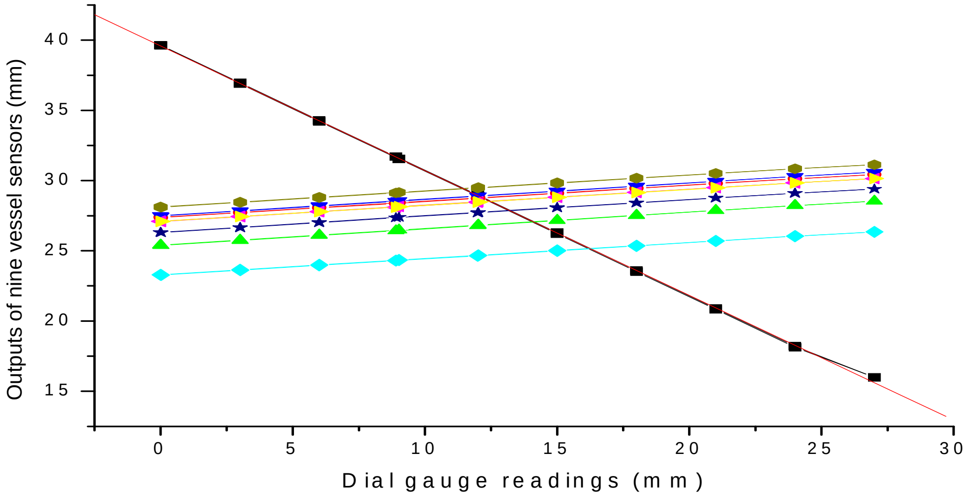
To pour into or draw off water here

2.3 Test of the a small system before used on-site

- Test of a nine-vessel HLS system for BEPCII (introduced at IWAA2004)

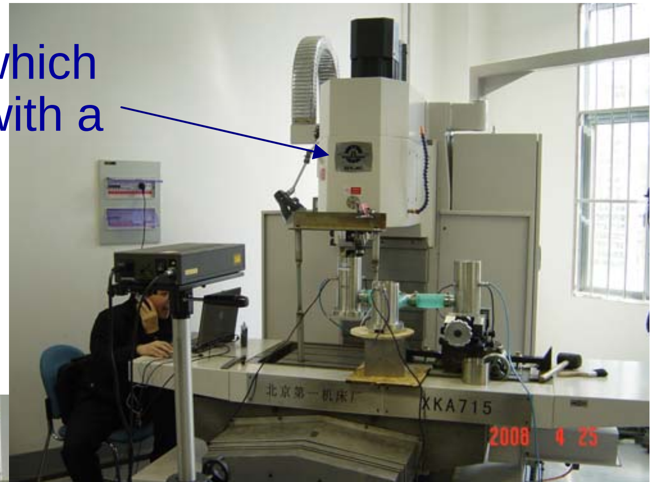
- ✓ In this system we raised and lowed the No.1 vessel by 3 mm increments. Then the water level of No.1 vessel would go down or up of 3*(9-1)/9=2.6667 mm a step. Otherwise the water level in other vessels would go up or down of 3/9=0.3333mm a step.
- ✓ Here we used dial gauge instead of HP Laser Measurement System to directly measure the elevation change of the No.1 vessel.

the test result is



➢Test of a three-vessel HLS system for SSRF

CNC Machining Centre which can move up and down with a pace of 2μm precisely.



a vessel sensor is fixed on a connecting board, and the connecting board is fixed with the spindle of CNC Machining Centre

The laser measurement system measures the movement meanwhile

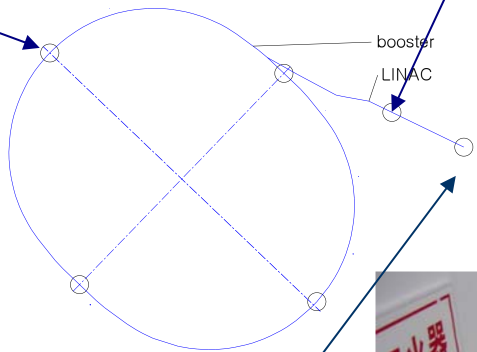
序号	干涉仪读数	步长1	传感器28	传感器32	读数差	步长2	*步长差*
0		-0.993					
1	-0.993	-0.995	5.62	7.947	-2.327	-1.016	***0.021***
2	-1.988	-0.994	4.958	8.301	-3.343	-0.999	***0.005***
3	-2.982	-0.996	4.302	8.644	-4.342	-0.995	***-0.001***
4	-3.978	-0.997	3.661	8.998	-5.337	-0.981	***-0.016***
5	-4.975	-0.996	3.032	9.35	-6.318	-1.002	***0.006***
6	-5.971	-0.994	2.395	9.715	-7.32	-0.981	***-0.013***
7	-6.965	-0.996	1.771	10.072	-8.301	-0.999	***0.003***
8	-7.961	2.957	1.108	10.408	-9.3	2.95	***0.007***
9	-5.004	2.986	3.025	9.375	-6.35	2.975	***0.011***
10	0.994	2.962	6.951	7.23	-0.279	3.009	***-0.047***
11	1.0022		6.96	7.232	-0.272		

As plan, a test HLS system will be established at NSRL in October 2009, with five sensors will be installed

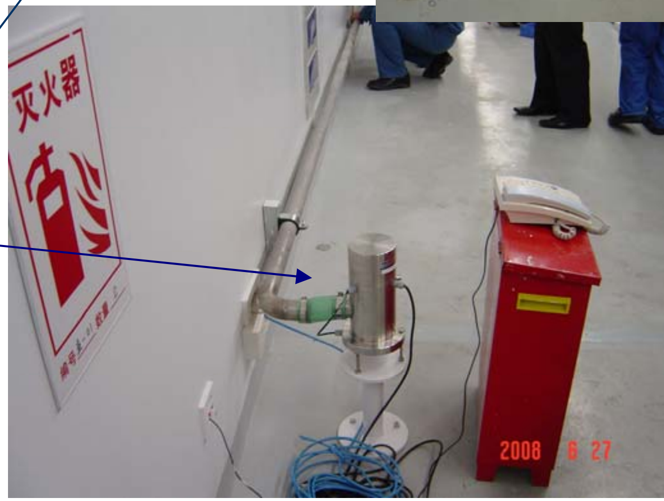
3 HLS at SSRF, the most complicated in China so far

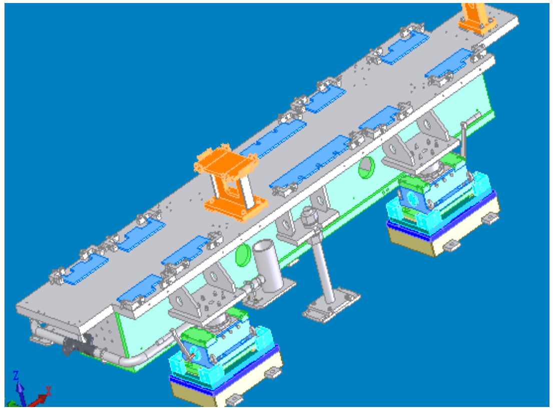
HLS sensor along the Booster

HLS sensor along the Linac

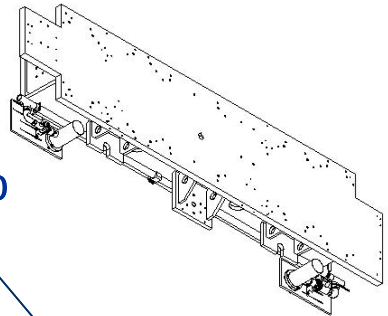


The first sensor in LINAC

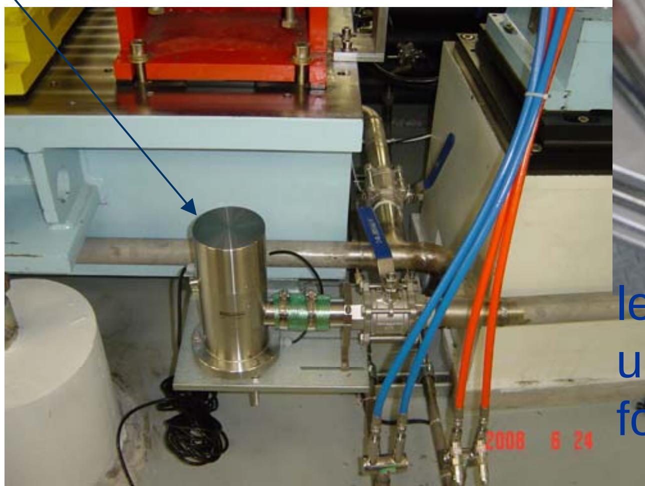




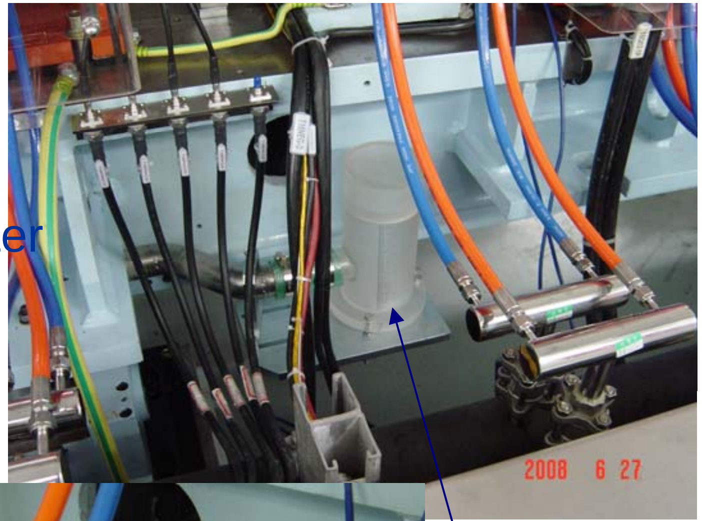
on the inner side of th egird a sensor was installed

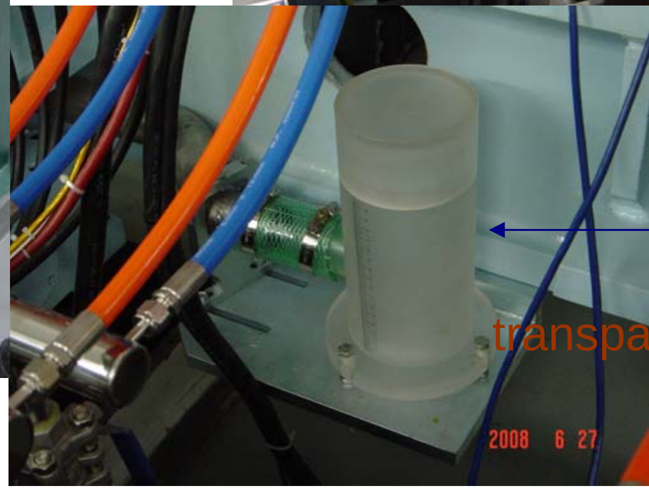


on the outside of the gird two sensors were installed



lead caps are put on the upper parts of the sensors for radiation protection



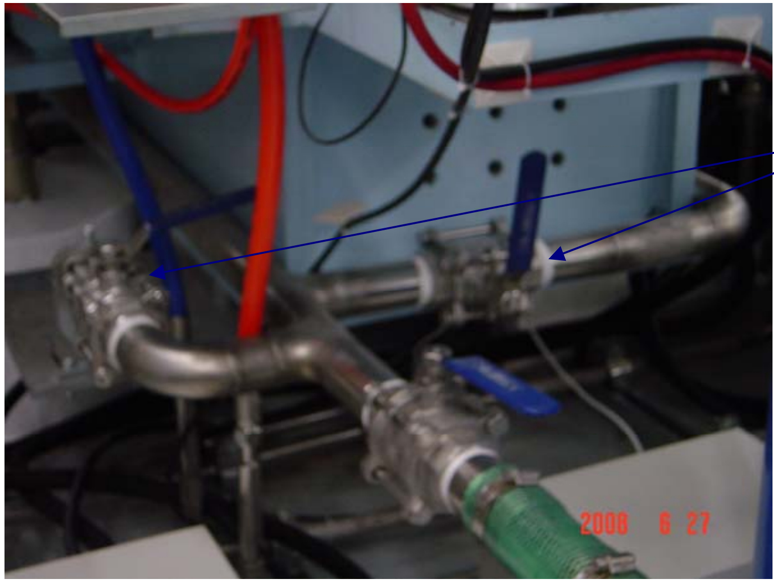


transparent vessels in Linac

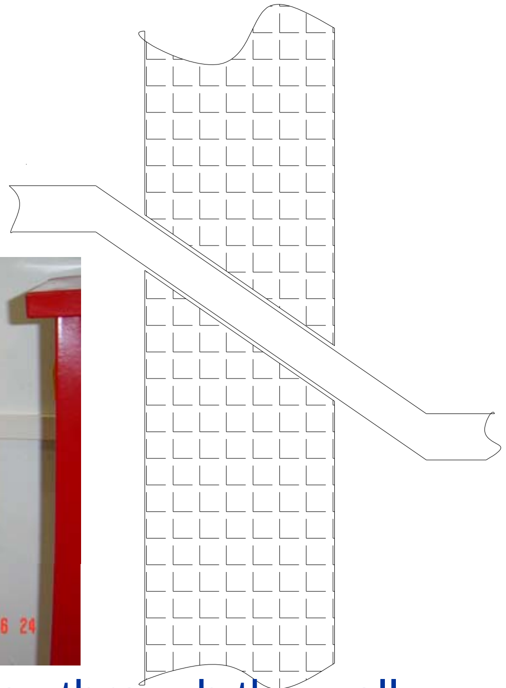
transparent vessels in booster

transparent vessels

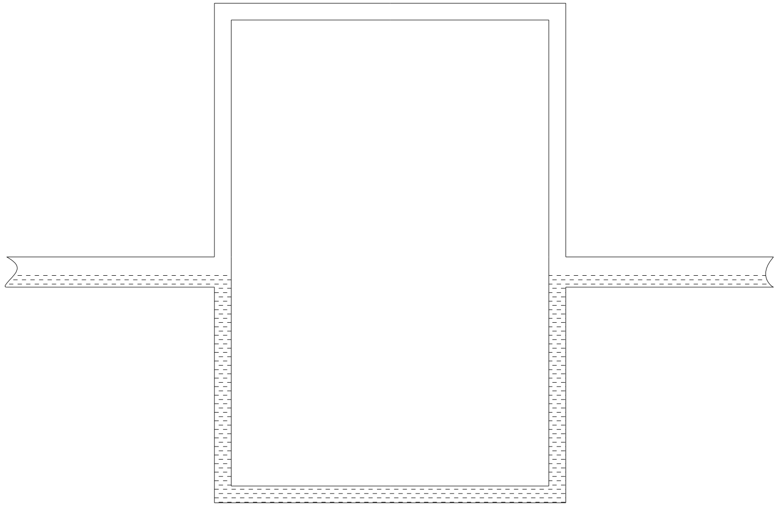
During pouring water into the system we could monitor the water height by the transparent vessels installed in the system



A ball valve is emplaced ahead of every vessel sensor along the pipe.

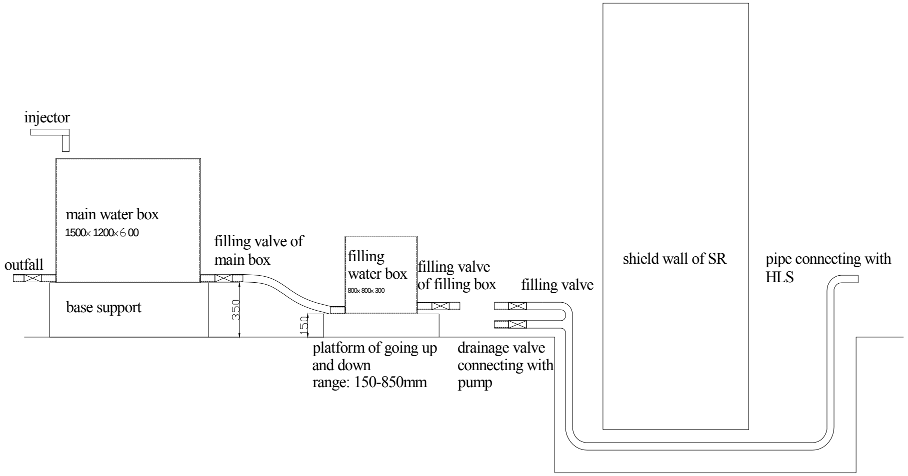


When the pipe passes through the walls between the Linac and Booster, Booster and the Storage Ring,this structure would be better for the radiation pretection



A gate shape of pipe when it pass a special part along the tunel

A soft pipe is used as the air-pipe where the main pipe have to be lowered



Filling and draining system

The installment of HLS at SSRF was finished in June 2008. After six months of work, the system was passed the appraisal of the expert group organized by the engineering committee

4 Some questions followed with interest

- Accuracy of sensor and accuracy of the system

Measuring accuracy of HLS is not only determined by that of sensors. It is influenced by many factors.

Main influencing factors are:

1. Temperature, (which has been studied and solved on the whole)
2. Pressure, (which has been studied and solved on the whole)
3. Effect of the tides, (which has been studied)
4. Influence of the geoids and gravity on the measurements, (which has been studied)

- Different calibration method used on different type of sensors

Can the above calibration method be used at the calibration of non-contact sensor?

The next part of this presentation is adapted from the report by WU Jun (SSRF), HE Xiaoye (NSRL)

SSRF静力水准系统研制报告（II）—（数据部分）

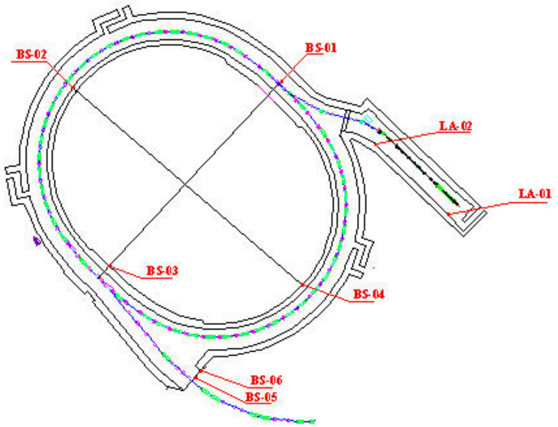
吴军、何晓业

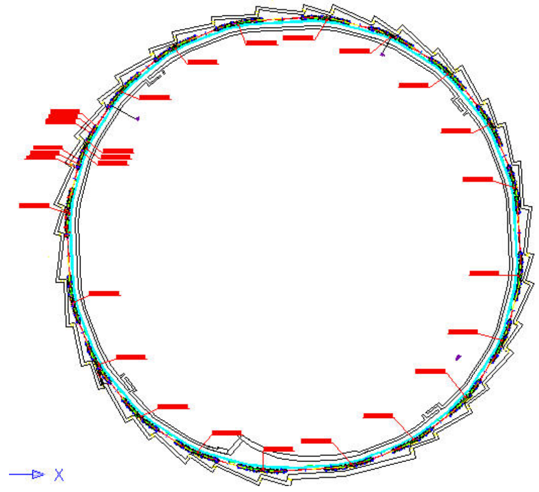
2008－12－26

5 Data of HLS at SSRF from Sep. to Dec.,2008

♣ Distribution and the name of sensor

There are all 36 sensors in the HLS system at SSRF. There are two measuring points (LA1 and LA2)in the linac tunnel near the wall along which the water pipe is arranged. Meanwhile there are four measuring points around and near the booster girds and the water pipe is erected beside or under the girds (BS1 to BS4),and other two sensors near the wall next to SR(BS5,BS6)(follow Fig). The SR of SSRF is divided into 20 sections in every which there are three girds.The remaining sensors are assembled on the middle gird in every section(named C1 to C20) except the C14 in which every one of the three girds is assembled three sensors on (sensors' named from C141 to C149, and C145=C14).





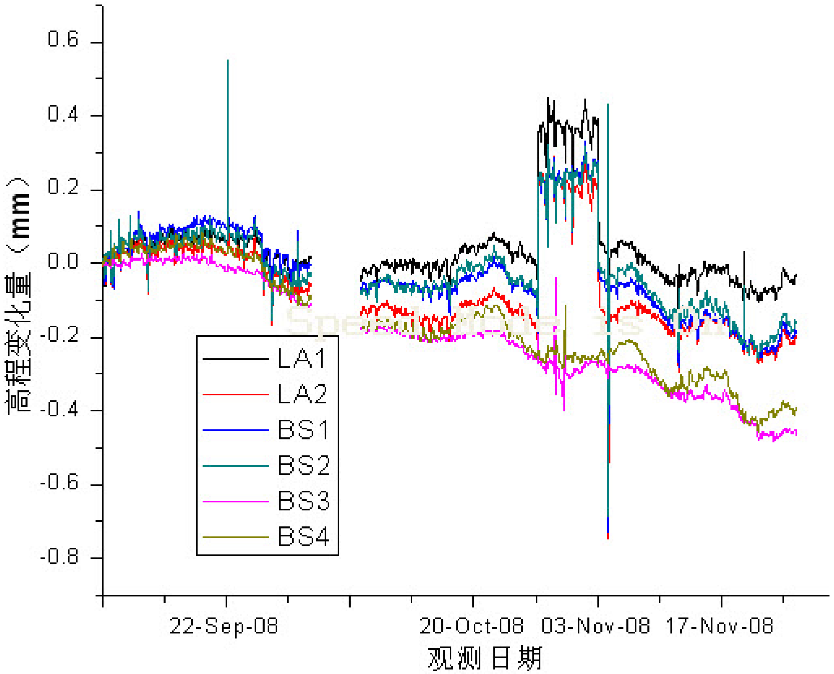
♣About the system operation

- ★ The data here are aquired from Sep.8,2008 to Nov. 25,2008. The system gather one group of data every 20 minutes and total 5608 group of data have been gotten. Every group data include the reading of height and temperature of every sensor in the HLS.
- ★ During October 1 to 7, the system was preserved. So there are not data for this period.
- ★ During this period the SR was preserved for two times: on Sep. 7 a cavity was installed in the section of 1 to 6, and from Oct. 28 to the early of Nov. insertion units were installed in section 7 and 13.
- ★ From Oct. 28 to Nov.3 Linac and Booster were shut off for the water system preservation.

♣Analysis of the data

➢Ground motion for long time

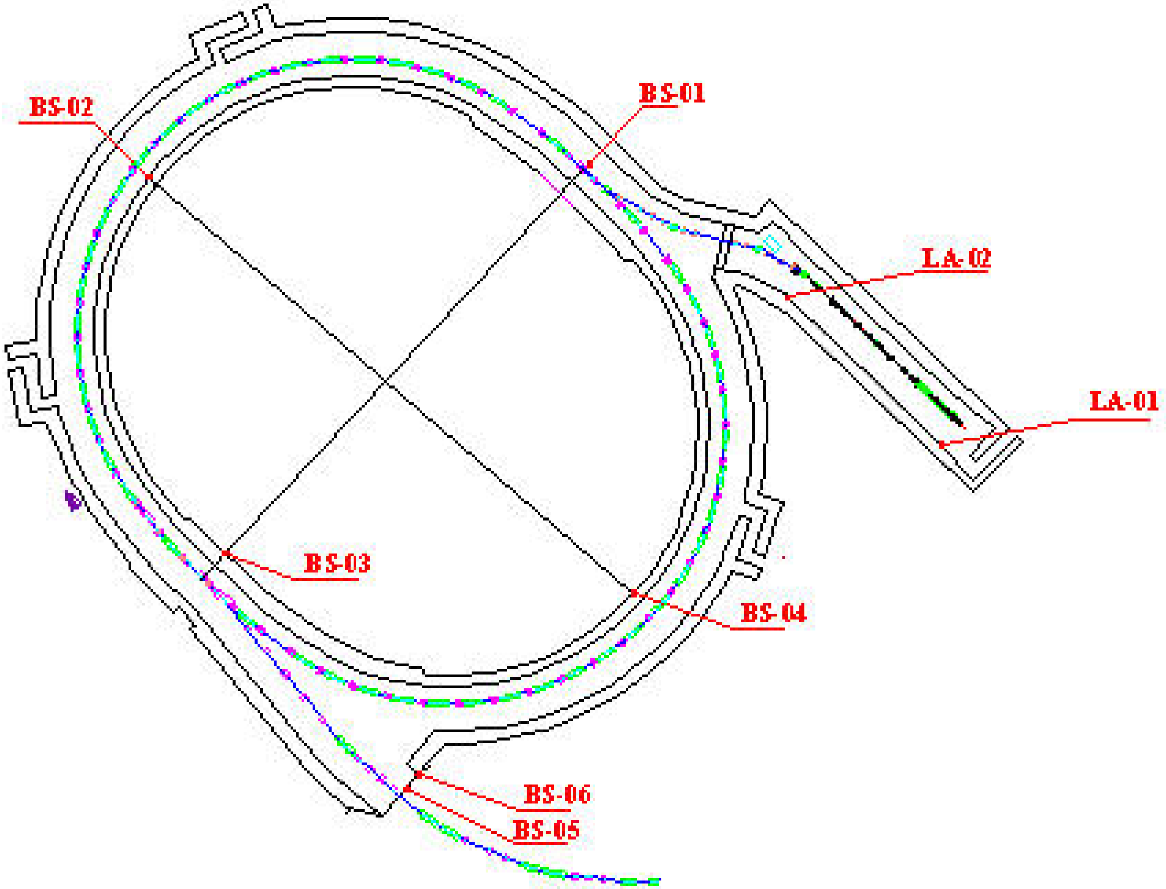
Ground displacement of the Linac and Booster referring to the point of BS5, following Fig:



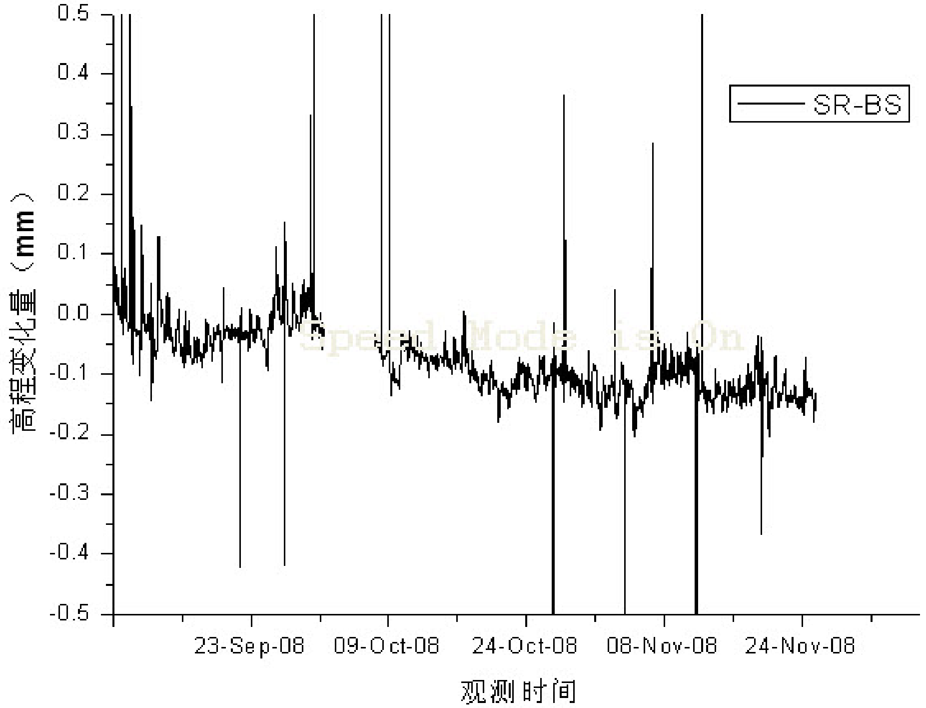
直线、增强器地基相对引出段BS5来说，都在相对下降，幅度0.1~0.4mm不等。

直线加速器LA2沉降速度比LA1要快，数值上约0.2mm。

增强器地基沉降是BS3和BS4连线上，下降比较快，而两头BS1和BS2及BS5都相对较慢。

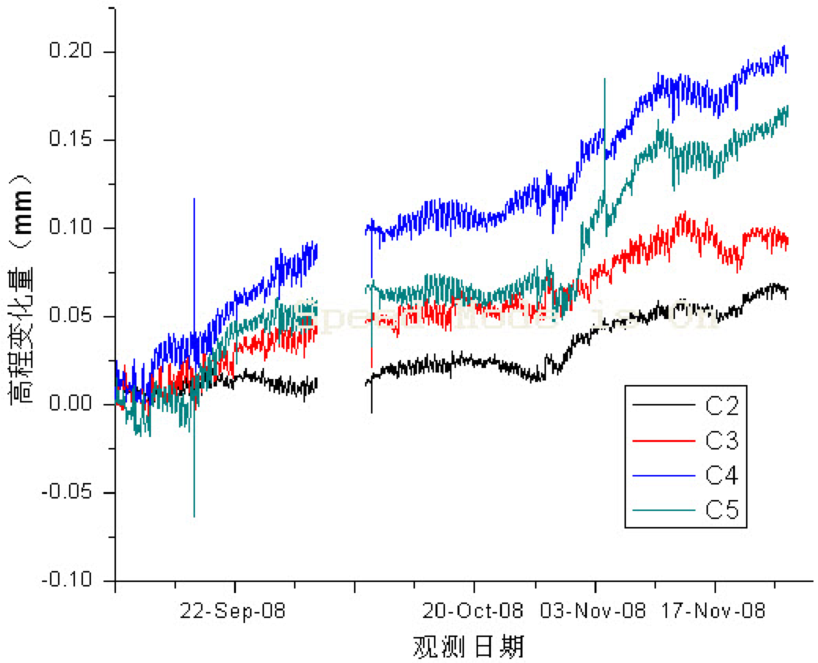

BS-02
BS-01
LA-02
LA-01
BS-03
BS-04
BS-06
BS-05

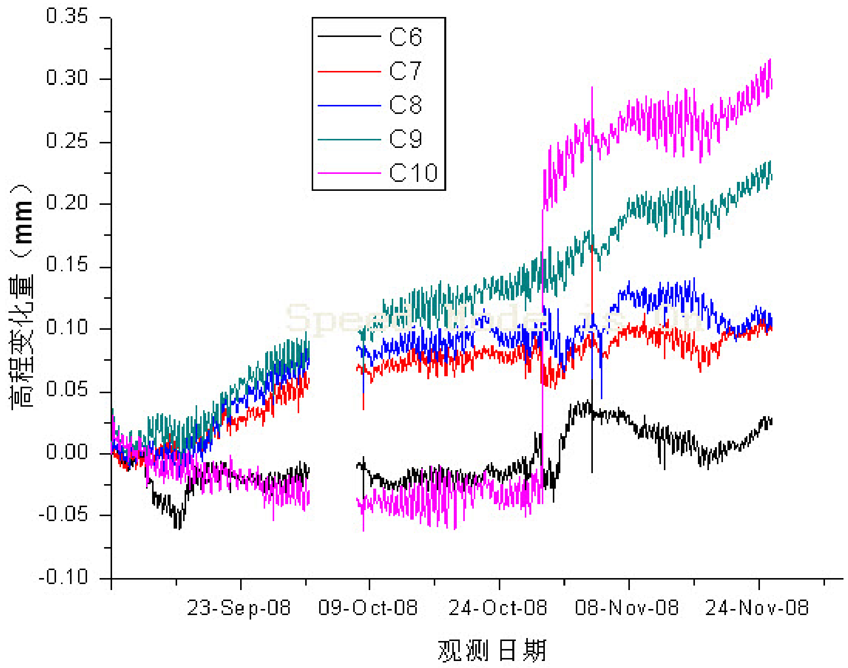
- Relative change of ground between Booster and SR (C1 to BS6):



增强器和储存环地基之间的相对变化不大，储存环地基略有提高，幅度0.1mm左右。

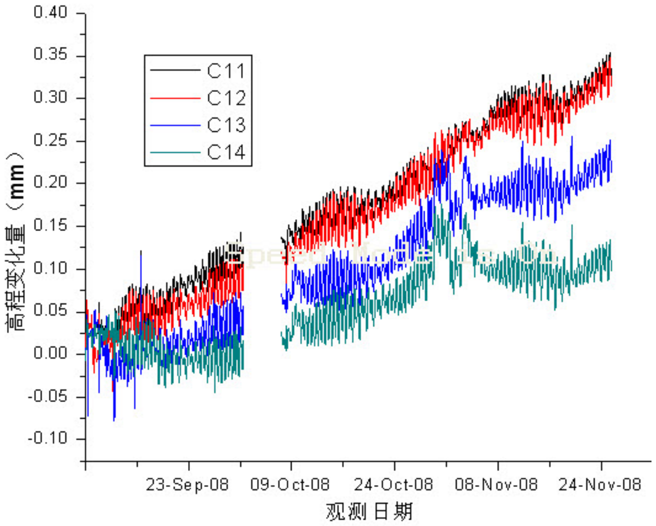
➤ Ground motion in SR (based on point C1）

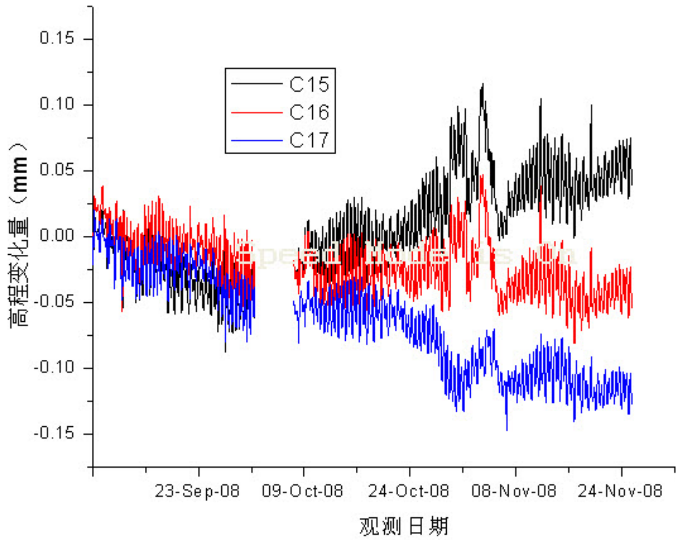




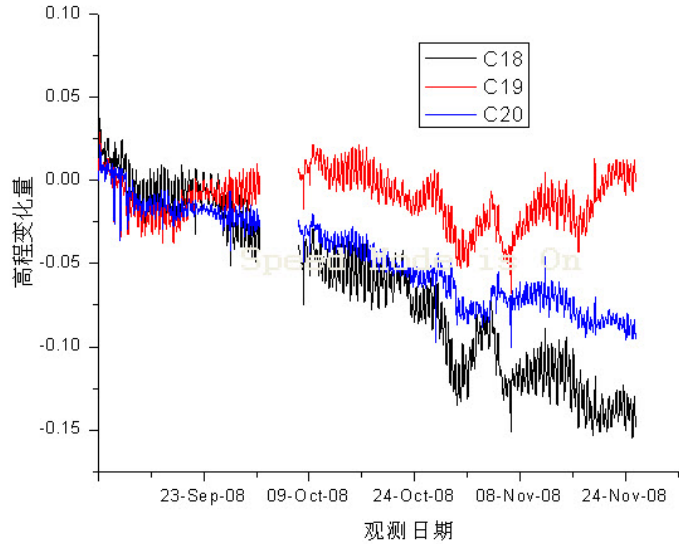
图中显示储存环C2~C10均相对C1在上升，该趋势还将继续.

续：



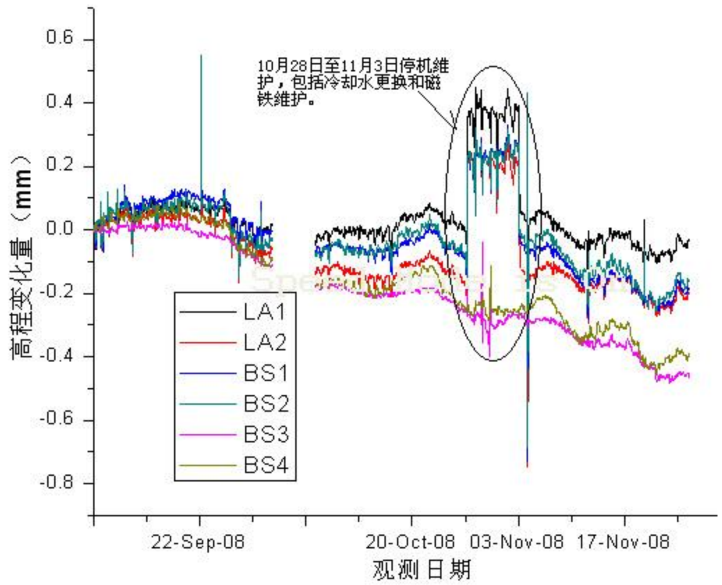


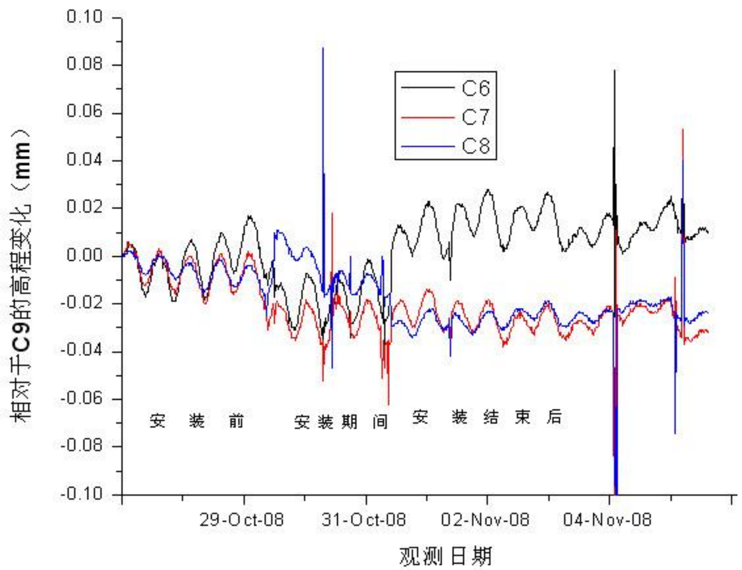
图中显示C11~C15仍然相对C1上升，幅度最大近0.35mm,C16~C20相对C1下降,最大幅度0.15mm,变化的趋势仍在延续。



The survey result of HLS is according to that of level survey

➢ Ground motion during maintenance on site

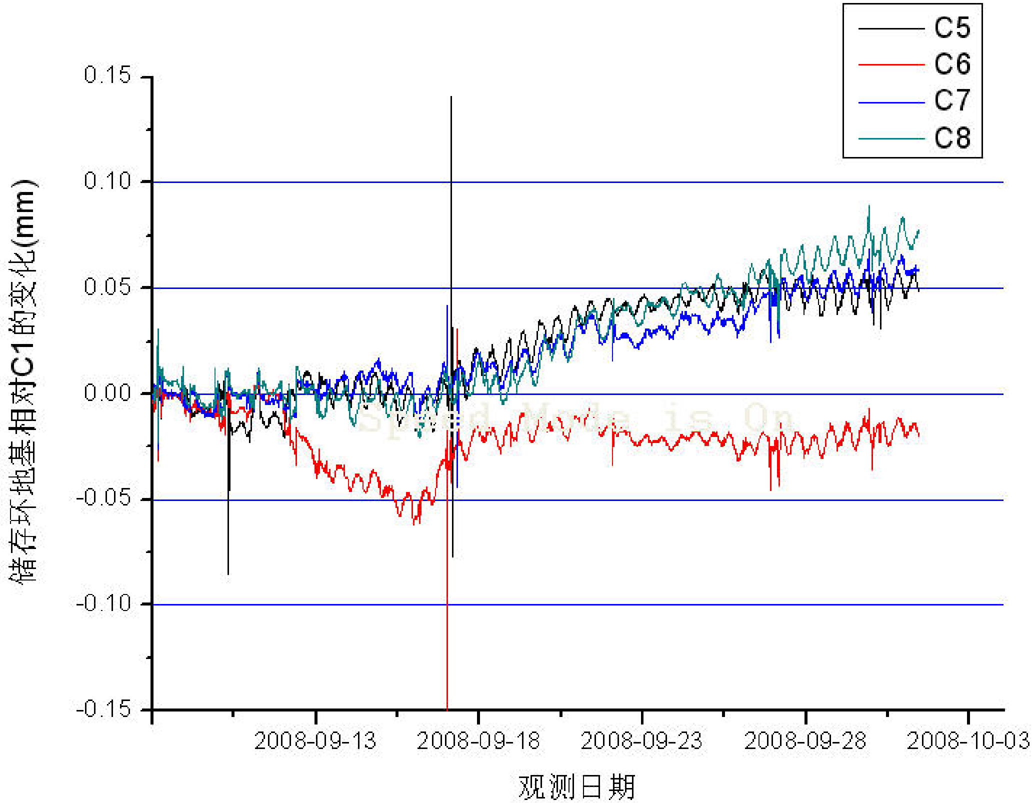




上图显示离BS5较远的4个测点同时出现跃变，时间刚好是停机维护的时间，但是具体是何原因，需要进一步研究。

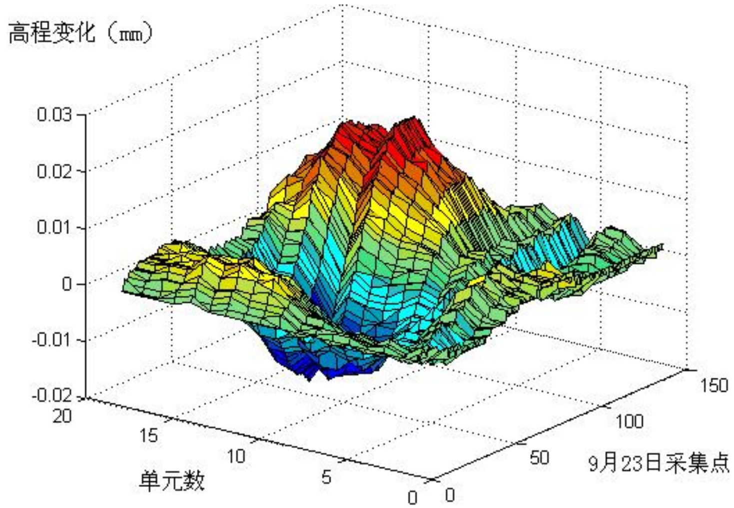
上图显示，7～8单元间插入件安装过程中，在安装前地基变化都一致，安装过程中，波动比较紊乱，安装结束后C7,C8有较明显的下降，幅度0.03mm

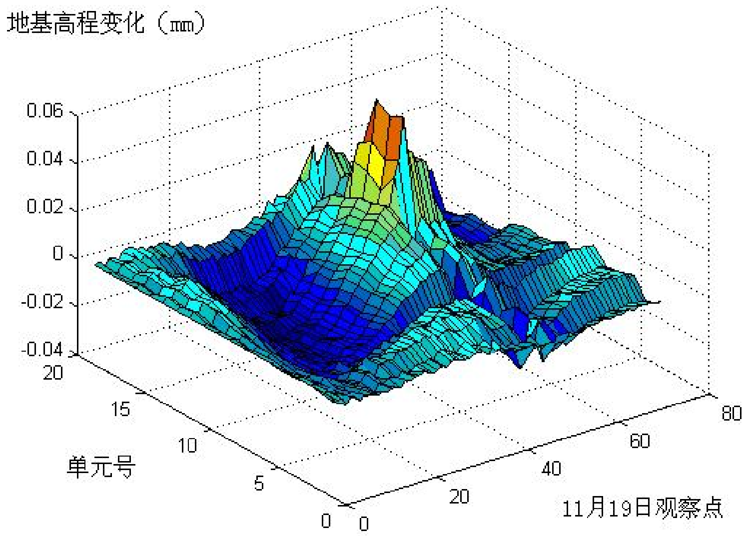
续：



图中显示：9月初高频腔安装期间，6单元地基有明显的下沉，最终该段比其他部分地基相对下沉。

➢ Ground motion of SR in one day





C10离C1距离最远，变化也就最为剧烈。

该结果与观测到的束流的天变化是在同一个量级，由于观测点的不同，规律是否一致还有待于研究。

从这两副图中，可以明显看出地基在一天内受潮汐影响规律的波动，不同的是11月19日中午时分，地基有不规则的跳变，其原因可能是地壳的运动引起的。

➢Test of the designing quota of ground

★ **Designing quota**

Static quota of ground displacement in SR：

- Slab deformation at ring tunnel and experimental hall:
  - ✓ Δz <100μm/10m/year; (first operation year <250μm/10m) ;
  - ✓ Δz <10μm/10m/day;
  - ✓ Δz <1μm/10m/hour;
- Sedimentations of injector and ring foundations :Δz < 5mm
- Static load :

  500kg static load: Δz <6μm (under); <1μm(2m away);

★ Testing method:

- For "Δz <100μm/10m/year（first operation year 250μm/10m）": Becaue the maichine just has been commision for three months then, this quota could be tested in the future;
- For "Δz <10μm/10m/day": (displacement of one point in one day)× 0.462.

The distances between two neighboring points of HLS in SR are 21.6m, supposing the ground motion between two neighboring points is symmetrical, then the factor is 10/21=0.462, as the multiplier.

- For "Δz <1μm/10m/hour": (displacement of one point in one hour)× 0.462.Here

（C9（14：00）－C9（13：00））x 0.462。

◆ Statistics of relative change of the neighboring points in one day（μm/10m/day)

区间	变化值（μm/10m/day）	区间	变化值（μm/10m/day）
C1~C2	1.4	C11~C12	-2.7
C2~C3	-1.4	C12~C13	0.5
C3~C4	0	C13~C14	-0.9
C4~C5	-0.9	C14~C15	0.5
C5~C6	-2.7	C15~C16	-1.3
C6~C7	0.5	C16~C17	1.3
C7~C8	-0.5	C17~C18	-0.5
C8~C9	3.7	C18~C19	0.9
C9~C11	1.8	C19~C20	-1.8
		C20~C1	-1.4
		均方根 σ	1.584

2008－09－23日变化不同单元统计表

区间	变化值（μm /10m/day）	区间	变化值（μm /10m/day）
C1~C2	-0.5	C11~C12	-0.5
C2~C3	0	C12~C13	0.5
C3~C4	-1.4	C13~C14	2.8
C4~C5	0	C14~C15	1.8
C5~C6	0	C15~C16	-1.8
C6~C7	0.5	C16~C17	-0.9
C7~C8	0.9	C17~C18	-2.3
C8~C9	0.9	C18~C19	1.4
C9~C11	0.5	C19~C20	-2.3
		C20~C1	0.5
		均方根 σ	1.313

2008－10－15日变化不同单元统计表

◆Statistics result in different days

日期	变化值 σ （μm /10m/day）
2008-09-08(维护期)	4.35
2008-09-13(维护期)	4.214
2008-09-20(运行期）	2.041
2008-09-23(运行期）	1.584
2008-09-25(运行期）	0.899
2008-09-30(运行期）	1.54
2008-10-10(运行期）	3.52
2008-10-15(运行期）	1.313
2008-10-20(运行期）	0.695
	均方根值：2. 606

1）维护期的隧道变化比运行时略大。2）统计量均小于10 μm /10m/day。

◆Change of neighboring points in one hour (μm/10m/hour）(October 8,2008)

区间	变化值（μm/10m/hour）	区间	变化值（μm/10m/hour）
C1~C2	0	C11~C12	0
C2~C3	-0.5	C12~C13	0.5
C3~C4	0.5	C13~C14	-0.5
C4~C5	-0.5	C14~C15	0.5
C5~C6	-0.5	C15~C16	-0.5
C6~C7	-0.5	C16~C17	0.5
C7~C8	0.9	C17~C18	-0.9
C8~C9	-0.5	C18~C19	0.9
C9~C11	0	C19~C20	0
		C20~C1	-0.5
		均方根 σ	0.534

4:00~5:00时间段内变化

区间	变化值（μm/10m/hour）	区间	变化值（μm/10m/hour）
C1~C2	0	C11~C12	0
C2~C3	0	C12~C13	0
C3~C4	-0.5	C13~C14	0.5
C4~C5	0	C14~C15	0
C5~C6	0.5	C15~C16	0.5
C6~C7	0	C16~C17	-1.4
C7~C8	-0.5	C17~C18	0.9
C8~C9	0	C18~C19	0
C9~C11	-0.9	C19~C20	0.5
		C20~C1	0.5
		均方根 σ	0.519

18:00~19:00时间段内变化

◆Statistics result of relative change in every one-hour period on October 8,2008 （μm /10m/hour）

时间（小时）	变化值σ （μm /10m/hour）
00:00～01:00	0.497
02:00~03:00	0.519
04:00~05:00	0.534
06:00~07:00	0.519
08:00~09:00	0.807
10:00~11:00	0.536
12:00~13:00	0.618
14:00~15:00	0.989
16:00~17:00	0.636
18:00~19:00	0.519
20:00~21:00	0.462
22:00~23:00	0.497
	均方根值：0. 617

1）白天工作时段内隧道变化略大于晚上。2）统计量均小于1μm /10m/day。

THANKS