Present Status of Shanghai Light Source (SSRF)

Dekang LIU

2004/12/8
A. Status of SSRF

- Overview of the project progress
- SSRF Design Optimization
- Project Budget and Schedule

B. Status of I & C for SSRF

* Status of Control System
* Status of Instrumentation
The SSRF project proposal was officially approved by the Chinese central government in January 2004!
Overview of the Project Progress
SSRF (Shanghai Synchrotron Radiation Facility): An intermediate energy 3rd generation light source;

The SSRF will be located in Shanghai Zhang-Jiang High Tech Park (Pudong new development district);

- The SSRF site occupies a area of 600m×300m
- About 25km from Pudong international airport
- Close to Subway and magnetic leveled train line
- Convenient to access the Shanghai down town area
Site of SSRF

- Pudong Airport
- Hongqiao Airport
- Magnetic leveled train: 35Km/7min, 430km/h Max
An Architect’s-eye of the SSRF Layout
Layout of SSRF

600m

300m
Brief History of the SSRF Project

- **Dec. 1993:** Three Chinese scientists proposed formally to central government to build a third generation light source;

- **March 1995:** The Chinese Academy of Sciences and the Shanghai municipal government made a joint proposal to construct the SSRF in Shanghai;

- **June 1997 and March 1998:** The state science and technology leading group and the state planning committee approved the SSRF R&D program;

- **Jan. 1999~March, 2001:** The SSRF R&D with budget of 80M Yuan was being performed;

- **Jan. 2004:** The SSRF project was finally approved
About 10 year’s efforts to get this light source project approved;

There are still one more project steps before performing the groundbreaking this year;

- Project feasibility study report review approval

At July of 2004

- Project detailed design study report review and approval
Hardware Prototype in Pre-R/D (1999-2001)

Bending Magnet (made in IHEP, Beijing)
Quadrupole Magnet

(Made in Kelin, Shanghai)

Sextupole Magnet

Made in CUSTC, Hefei
Bending Magnet Power Supply

500A/100V, $\pm 1 \times 10^{-5}$/24hrs
6m Antechamber Section
Kicker Magnet and Its Pulser

4\(\mu\)s half-sine-wave
0.12T peak field  jitter time < \(\pm 6.5\)ns
Low Level RF Control System
High Power RF System

500MHz, 180kW CW

RF local control station
BPM And Its Mapping System

2μm resolution
Evolution of the SSRF Designs

There have been 4 main SSRF design versions since 1996, and the SSRF has been evolved to a high performance and cost-effective light source for the past 8 years, which includes:

- Upgraded the SSRF storage ring energy from 2.2 GeV to 3.5 GeV;
- Optimized the storage ring with high flexibility, low emittance and high beam orbit stability;
- Optimized the SSRF complex operating with top-up injection modes;
- ...


300 MeV Linac
DUV FEL
3.5 GeV Storage Ring
Booster
Beam Lines and Experimental Stations
1996

1998

2001

2003
SSRF Accelerator complex

- 100MeV Electron Linac
- 3.5GeV Booster
- 3.5GeV Storage Ring
- Beam Line and Experimental stations
## The SSRF Design Evolution

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (GeV)</td>
<td>2.2 (2.5)</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Circumference (m)</td>
<td>345.36</td>
<td>384</td>
<td>396</td>
<td>432</td>
</tr>
<tr>
<td>Emittance (nm*rad)</td>
<td>3.78 (4.88)</td>
<td>11.8</td>
<td>4.8 (11.8)</td>
<td>2.95</td>
</tr>
<tr>
<td>No. of cells/super-periods</td>
<td>16/2</td>
<td>20/10</td>
<td>20/10</td>
<td>20/4</td>
</tr>
<tr>
<td>Straight sections (number_length)</td>
<td>12_7m 2_8m 2_18m</td>
<td>10_6.6m 10_4.6m 10_5m</td>
<td>10_7.24m 10_5m 8_7.0m</td>
<td>4_12.0m 8_5.0m</td>
</tr>
</tbody>
</table>
Latest SSRF Design Optimization

- Optimization to enhance the SSRF capability and cost-effectiveness
  - Lower emittance and high brightness
  - Short, standard and long straight sections for IDs and accelerator demands
  - Top-up injection operation

- Optimization to improve beam stability
  - Effective control of various perturbation sources
  - Active feedbacks to stabilize beam orbit
Latest SSRF Design Optimization

- Adoption of advanced technologies
  - Superconducting RF system
  - Digital beam position monitor system (at BEPC)
  - Orbit feedbacks and transverse beam feedback
  - High stable Digital power supplies
  - In-vacuum mini-gap undulators
The Project Budget

- Project budget estimation

  - Total project budget: (1200M RMB) ~150M$
    - Building and conventional facility ~43M$
    - Accelerators and Beamlines ~79M$
    - Contingency ~10M$
    - R&D and other project items ~18M$

    (not including land fee and staff salary)

- Annual operation budget: ~12M$

  (not including staff salary)
Cost Estimate and Schedule

- Proposed Schedule

  Break-grounding would be completed before the end of this year.

  Spring. 2005 ~ Nov. 2007  Procurement, Fabrication, Construction, Installation and injector commissioning


  Test operation for SR users

  May. 2009  light beam available
**The main requirements**

* Whole machine can be run with safety and reliability.

* An easy to use. Ideally, this should be a GUI that is already familiar to scientists and engineers.

* Tight integration with standard software packages

* Access to control system via the WEB.

* Use standards. To reduce the time of design & build
* Use of a standard solution for protection system
  A clearly defined strategy used for handling machine protection and Human safety.

* EMI, EMC needs to be including in design.

* Use of modular I/O system for various subsystem

* Ease to extend
Hardware Structure

I

Work Station
E-Net

II

In/Out VME/pxi/IPC

III

FieldBus/Ethernet AB/Omron/Yagogawa

Device controller

controller

controller

controller

Equip.

Equip.

Equip.

Equip.

Equip.

Equip.

Equip.

Equip.

......
Middle Ware serve the EPICS gateway; DB access; status control; system configuration; safety certification.
EPICS Developing Environment

Standard System Software
- Sun Solaris
- RedHat Linux Version 9
- MS-Windows XP, 2003
- HP-UX 10.x
- VxWorks
- EPICS Version R3.14.6
- Borland VisiBroker 6.0

Standard Development Tools
- Borland C++ Builder 6.0
- gcc 3.x
- Jbuilder X
- Borland Together 6.2
- MS-Visio 2003
Network Structure

1. Based on 1000M fast Ethernet
   * Safety access certification
   * Remote access
   * Remote access
   * Wireless

2. Network Management
   * Reconfiguration by VLAN
   * Remote access
   * QOS

3. Reliability & Easy to use
   * Dual fiber redundancy technique will be adopted
   * Double protection for UPS
   * Industrial level E-Net will be used for special usage
Physical Application Consideration

*SSRF will use MathLAB as platform of physical application

*Mathlab application can be accessed through MCA linked with EPICS CA

*In SLAC, many software tools and application software have been developed for light source such as

- AT for accelerator and MCA,
- Linear Optic Correction Algorithm
- Various commissioning software for light source
Main equipment to be controlled

1. Magnet Power supply

<table>
<thead>
<tr>
<th></th>
<th>LINAC</th>
<th>LL</th>
<th>Booster</th>
<th>HL</th>
<th>Ring</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>1</td>
<td>1</td>
<td></td>
<td>1</td>
<td>1</td>
<td>+/-5E-5</td>
</tr>
<tr>
<td>Q</td>
<td>2</td>
<td>11</td>
<td>2</td>
<td>12</td>
<td>200</td>
<td>+/-5E-4</td>
</tr>
<tr>
<td>S</td>
<td></td>
<td>2</td>
<td>140</td>
<td>80</td>
<td>+/-5E-3</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
<td>7</td>
<td></td>
<td></td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>7</td>
<td>56</td>
<td>10</td>
<td>160</td>
<td></td>
</tr>
<tr>
<td>Fast/C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>80</td>
</tr>
<tr>
<td>Total</td>
<td>45</td>
<td>19</td>
<td>61</td>
<td>23</td>
<td>661</td>
<td>809</td>
</tr>
</tbody>
</table>
There are several options

1.) Analog to digital control mode (20 years ago)

- Power supply controller
- CAMAC controller
- SBD
- VAX780
- Power supply
- Load
2.) Distributed control system for PS (before 10 years)

This method have been used in 100MeV LINAC
3.) SNS project PS control

Figure 1: DC Power Supply Control Arrangement.

Figure 2: Injection Bump Supply Control Arrangement.

DC Power control  Inject BumpPS control
performance:

* One PSC link with 6 PSI
* each PSI with 16bit D/A, 4X16bit A/D, 15 D/O, 16 D/I
* Readback and setting on time
* Max sampling 10Khz data record, it can work on Burst mode.
* 5000 history data can be recorded
* Fiber isolated
* PS can be tested through series channel or VME
SLS Power supply control
Structure of SLS Power Supply

Software structure
Performance:

* High dynamic range up to 1000A
* High accuracy (7ppm for corrector 1Khz)
* High reliability & stability (<15ppm for bending)
* Link with control system without losing accuracy
* Module can be used for all kind of power supply
  * Without drift
* High integration
  * Saving spare parts & easy to maintaining

Now we are discussing this issue & make decision soon based on its performance /cost.
2. RF system control

According to physical design, there are three sets of RF station used for superconducting cavities in the storage ring and one set RF station used for booster. This RF station control is based on the EPICS system, and the whole RF control system (180kW klystron + cavity + low level system) has been tested in the Pre-R/D term. Hardware and software have been tested.

Question to be discussed:
How to deal with superconductor cavity control and cryogenic system?
Layout of RF control station

To main control system
Main-page of RF control

ICS

VME bin

PVs of RF station are over 700
3. Tested result of timing system for SSRF

Running Mode

B-1. Single Bunch Ins

a

B-2. Multi Bunch Ins x 150

b

B-3. Mixed Bunch
c

300ns

1.44us

150

2ns

1.44us

1.44us

2Hz PPS LINAC

GUN 2998MHz

Booster

300 Buckets

K1

K2

K3

Ring 499.65MHz 720 Buckets

LINAC

0.5s(2Hz)

Booster

Ring

a

b

Booster

Ring

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b

b
Logical Diagram of Timing Signals

- RF499.65MHz
- Booster RF/300 0.600us
- Ring RF/720 1.44us
- Synchrotron Freq
  - RF/3600 7.205us

- PPS Hz for GUN
  - Syn. with 50Hz
- Linac Modulator
- Linac 2998MHz
- GUN Pulse
- Booster In
- Booster Inject SEP
- Booster Inject Kicker
- Booster Magnet Field
- Booster Ramping
- Booster Extract Kicker
- Ring In Beam Pulse
- Ring Inject Kicker
- Beam Puls in the Ring

- 0.600us
- 0.44us
- 9.5(2Hz)
- 3us
- 300ns/150ns
- 60us
- <150ns
- 3.5 GeV
- 100 MeV
- <150ns
- 7.350ns
- 300ns
- 4us
- 1.32ns

- 7.205us/0.139MHz
- 3.5 GeV
- 100 MeV
- 3.5 GeV
- 100 MeV
- 7.350ns
- 300ns
- 4us
- 1.32ns
Features:

- Event system complete all timing tasks
- A two level multi-star topology
- All fiber cables are equally long
- Single source fanout to multi receiver
- OM-3 multimode fiber has typical thermal delay drift of 65ps/km/°C 300m will induced 81ps during temperature deviation of 4° C.
- A delay drift system will correct the this error
Only two reference source 3~12 VAC 499.65MHz RF Clock

Question to be discussed:

1. Whether fiber cable compensated phase is needed between Rf master and LINAC?
2. How to deal with long compensated fiber cable for installation round ring?
3. How to lock the phase between 496.654Mhz and RF of LINAC?
EVG

EVR

Jitter $< 31.4 \text{ps}$

Event trigger out

Distributed clock synchronized with RF 500Mhz

1MHz
Beam instrumentation

<table>
<thead>
<tr>
<th>Instrumentation</th>
<th>LINAC</th>
<th>LEL</th>
<th>Booster</th>
<th>HEL</th>
<th>Ring</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse current monitor</td>
<td>3+1</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>WCM, BCM, FCT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profile monitor</td>
<td>5+1</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>Energy spread</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Faraday Cup</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Split</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>BPM</td>
<td>3</td>
<td>4</td>
<td>56</td>
<td>5</td>
<td>152</td>
<td>220</td>
</tr>
<tr>
<td>stripling</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>SLM</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Xray pinhole</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>12</td>
<td>65</td>
<td>15</td>
<td>161</td>
<td>268</td>
</tr>
</tbody>
</table>
Distributed beam monitor

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LINAC</td>
<td>15</td>
</tr>
<tr>
<td>LEL</td>
<td>12</td>
</tr>
<tr>
<td>booster</td>
<td>65</td>
</tr>
<tr>
<td>HEL</td>
<td>15</td>
</tr>
<tr>
<td>Ring</td>
<td>161</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>268</strong></td>
</tr>
</tbody>
</table>
Beam instrumentation data acquisition
BPM Data processing diagram

New DBPM Resolution <1um

Functional diagram

Software solution

SW structure

To control system
Test result of DBPM in BEPC machine
DBPM Hardware Architecture

VME-PCI8000, PCI-MXI2-VME
(Remote Controller )

(i)

EPICS Based
(Embedded Controller )

(ii)
Electronics modes:

<table>
<thead>
<tr>
<th>DBPM modes</th>
<th>Time Span of 8K samples</th>
<th>Turns per sample</th>
<th>Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turn-by-turn</td>
<td>6568.8 s</td>
<td>1 turn</td>
<td>620 KHz</td>
</tr>
<tr>
<td>Ramp-26ms</td>
<td>26 ms</td>
<td>4 turns</td>
<td>155 KHz</td>
</tr>
<tr>
<td>COD</td>
<td>840 ms</td>
<td>128 turns</td>
<td>4.8 KHz</td>
</tr>
</tbody>
</table>

BPM signal
RF
CLK
NIM crate
Oscillator
DBPM electronics
Measure PC
Spectrum analyzer

e+
e-
Damping Time of BEPC

8192 Samples in TBT Mode
(4mA)

<table>
<thead>
<tr>
<th>DCCT</th>
<th>Damping Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>8mA</td>
<td>~ 6.34ms</td>
</tr>
<tr>
<td>6mA</td>
<td>~ 6.89ms</td>
</tr>
<tr>
<td>5mA</td>
<td>~ 7.05ms</td>
</tr>
<tr>
<td>4mA</td>
<td>~ 7.04ms</td>
</tr>
<tr>
<td>3mA</td>
<td>~ 12.27ms</td>
</tr>
</tbody>
</table>
MEDM Panel

Mode Set & Display

Gain Setting, Calibration

Data Sampling Panel
100MeV LINAC Control System Diagram

*Since 2002-up to now, it will be extended to 300MeV for DUV-FEL research*
100MeV LINAC Tunnel

Present status

*All components have been installed
*Now, RF power is being tested
*Each subsystem have been tested.
*System commissioning will start soon
Modulator station

MEDM modulator page

VME/IOC
Summery

1. During past few years, we accumulated some experience on the IOC level control such as RF local station, LINAC local control based on EPICS.

2. To set up some prototype (such as DBPM, event system) and tested it with EPICS.

3. We still have not experience for large scale accelerator such as Database management and physical application.

4. We still need to study some new technology such as digital PS, embedded IOC (Libera) etc.

5. Standard selection of HW & SW (such as VME/PXI; many kind of PLS, Field bus etc.)
Acknowledgement

We should appreciated many labs and friends to give us so kind of support when we start our project.

*During past few years KEK have held 3 times seminar of EPICS in China with success.

*Many experts from SLAC give us lot information about beam instrumentation and physical application on SPEAR III.

*Some new technique such as event system, digital PS, DBPM from SLS, Diamond, PAL and IT Inc ... .

Any comments and suggestion are welcome!!
Thank you for your attention and please enjoy with us!!