SSRF and its Future

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X-ray Light Source Facilities in China

**SSRF, SXFEL and SHINE** (Shanghai)
- 3.5GeV SR facility
- 3.9nm·rad emittance
- 432m storage ring

**HEPS** (Beijing)
- 6GeV SR facility
- 0.06nm·rad emittance
- 1360m storage ring

**HALS** (Hefei)
- 2.4GeV SR facility
- 0.03nm·rad emittance
- 672m storage ring

- A Soft X-ray FEL based on 1.5GeV C-band linac is under phased construction and commissioning
- A Hard X-ray FEL based on 8GeV SRF linac started its construction in April 2018

- Construction will start by end of 2018, and its commissioning is expected in 2024.

- Its construction is expected to start in 2021.
Shanghai Synchrotron Radiation Facility

- A 3.5GeV third generation light source with seven phase-I beamlines;
- Construction started from Dec. 25, 2004, completed on Apr. 29, 2009;
- User operation from May 6, 2009, since then, more than 20000 users from all over the country served;
- 15 Bls are in operation, 16+ Bls are under construction started from 2016, 5 Bls under planning.
## Main Parameters of Storage Ring

- **Storage Ring Energy:** 3.5 GeV
- **Circumference:** 432 m
- **Natural Emittance:** 3.9 nm-rad (2.9 achieved now)
- **Beam Current:** 250 mA
- **Beam Lifetime:** ~20 hrs  (Top-up injection since December 2012)
- **Straight Sections:** 4×12.0 m, 16×6.5 m
- **RF Voltage:** 4.0~6.0 MV
- **Max. Beam Power:** ~600kW
**Beamline Construction Roadmap**

40 beam lines and 60 end stations anticipated
### 15 Beamlines in operation

<table>
<thead>
<tr>
<th>Beamline</th>
<th>Source</th>
<th>Photon energy(keV)</th>
<th>Energy resolution (ΔE/E)</th>
<th>Flux</th>
<th>Spot size(H×V)</th>
<th>Spatial resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macromolecular Crystallography</td>
<td>IVU</td>
<td>5~18</td>
<td>≤2×10^-4</td>
<td>4.1×10^{12}</td>
<td>67×23 μm^2</td>
<td></td>
</tr>
<tr>
<td>XAFS</td>
<td>Wiggler</td>
<td>4~23</td>
<td>&lt;2×10^-4</td>
<td>3.6×10^{12}</td>
<td>0.16×0.1mm^2</td>
<td></td>
</tr>
<tr>
<td>X-ray Diffraction</td>
<td>BM</td>
<td>4~22</td>
<td>1.9×10^-4</td>
<td>1.2×10^{11}</td>
<td>0.21×0.13mm^2</td>
<td></td>
</tr>
<tr>
<td>X-ray Imaging</td>
<td>Wiggler</td>
<td>9~65</td>
<td>1.6×10^-3</td>
<td>1.6×10^{10}</td>
<td>50×50mm^2(spatial resolution&lt;1.0μm)</td>
<td></td>
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<tr>
<td>Hard X-ray Micro-focus</td>
<td>IVU</td>
<td>5~20</td>
<td>1.4×10^-4</td>
<td>1.1×10^{11}</td>
<td>0.12×0.13μm^2</td>
<td></td>
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<tr>
<td>SAXS</td>
<td>BM</td>
<td>4~22</td>
<td>5.3×10^-4</td>
<td>3.0×10^{11}</td>
<td>0.39×0.48mm^2</td>
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<tr>
<td>Soft X-ray Spectromicroscopy</td>
<td>EPU</td>
<td>0.2~2.2</td>
<td>17900@244eV</td>
<td>2.2×10^8</td>
<td>30nm</td>
<td></td>
</tr>
<tr>
<td>XIL</td>
<td>EPU</td>
<td>85-150eV</td>
<td></td>
<td>1.0×10^{14}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beamline</td>
<td>Source</td>
<td>Photon energy (keV)</td>
<td>Energy resolution (ΔE/E)</td>
<td>Flux</td>
<td>Spot size (H×V) Spatial resolution</td>
<td></td>
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</tr>
<tr>
<td>High Throughput Crystallography</td>
<td>BM</td>
<td>5~20</td>
<td>≤3×10^{-4}</td>
<td>3.0×10^{11}</td>
<td>150×180 μm²</td>
<td></td>
</tr>
<tr>
<td>Micro-Crystallography</td>
<td>IVU</td>
<td>5~18</td>
<td>&lt;2×10^{-4}</td>
<td>5.0×10^{11}</td>
<td>10×7 μm²</td>
<td></td>
</tr>
<tr>
<td>Complex Crystallography</td>
<td>IVU</td>
<td>7~15</td>
<td>&lt;2×10^{-4}</td>
<td>1.5×10^{12}</td>
<td>120×80 μm²</td>
<td></td>
</tr>
<tr>
<td>BioSAXS</td>
<td>IVU</td>
<td>7~15</td>
<td>&lt;5×10^{-3}</td>
<td>4.0×10^{12}</td>
<td>345×110 μm²</td>
<td></td>
</tr>
<tr>
<td>FTIR and Microscope</td>
<td>BM</td>
<td>10-10000 cm^{-1}</td>
<td>0.1 cm^{-1}</td>
<td>2.0×10^{12}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dream line (ARPES and PEEM)</td>
<td>EPU</td>
<td>0.02-2</td>
<td>10000@244 eV</td>
<td>10^{10}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SiP•ME²_AP-XPS</td>
<td>BM</td>
<td>0.04-2</td>
<td>10000@244 eV</td>
<td>&gt;10^{10}</td>
<td>166×17 μm²</td>
<td></td>
</tr>
<tr>
<td>SiP•ME²_HR-ARPES</td>
<td>EPU</td>
<td>7-70 eV</td>
<td>20000@21.6 eV</td>
<td>10^{11}</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Hard X-ray Stations

X-ray Imaging

XRD

XAFS

Microprobe

SAXS

Bio-SAXS

FTIR and Microscope

Macromolecular Crystallography

High Throughput Crystallography

Micro-Crystallography

Complex Crystallography
Soft X-ray Stations

ARPES and PEEM

AP-XPS

AP-PIPOS

STXM

nano-ARPES

ARPES+MBE+UV laser+fs laser

STM

XIL
User Distribution of Region (to Dec 31, 2017)

International User Group:
- Singapore 3
- Australia 4
- The Republic of Korea 17
- Japan 6
- Sweden 2
- Canada 4
- Denmark 1
- USA 5
- Thailand 1
- Portugal 1
- Russia 1
- France 2
- New Zealand 1
- Saudi Arabia 1
- Germany 2
- Switzerland 1
SSRF user status

Up to December of 2017:
user groups: 2,297
proposals: 9,387
affiliation: 462
users: 20,129
SSRF User’s publications

Up to Dec. 2017, users have published ~4200 journal papers with 7 phase-I beamlines.

Publications for each year and in top journals keep increasing rapidly.
Selective conversion of methane to hydrogen, ethane and duxrex is a crucial reaction for catalytic industry. The work reported by Bao et al. forwarded a single-site iron mechanism, which has been directly confirmed by in-situ X-ray absorption fine structure (XAFS) tests conducted at BL14W1 beamline of SSRF.

Science highlight: Ebola Virus Mechanism Research

It explained a new virus membrane fusion excitation mechanism (the fifth mechanism) from the molecular level. The new mechanism is quite distinct from previous four mechanisms known to virologists and has become a major breakthrough in international virology in recent years; the research provides a new target for the design of antiviral drugs. It has deepened people's understanding of Ebola virus invasion mechanism, and provided important theoretical basis for addressing, preventing and controlling the outbreak of Ebola virus diseases.

Published in Cell (Jan. 2016), by Prof. F. Gao's team from the CAS Institute of Microbiology and the Chinese Center for Disease Control and Prevention.
Science highlight: Discovery of Weyl and Three Component Fermions

In 1929, German scientist H. Weyl predicted the existence of a massless fermion with a definite handedness, or “chirality”. Physicists never found a fundamental particle with these characteristics.

In January 2015, Ding Hong team from CAS Institute of Physics discovered a condensed-matter analog of the Weyl fermion ultimately in tantalum arsenide with the ARPES(Angle-resolved Photoemission Spectroscopy) at SSRF 09U beamline, the so called “Dreamline”

Two years afterwards, Ding Hong team discovered the Three Component Fermions, which is beyond the conventional classification of the Fermions in universe. These discoveries open new prospective for understanding and utilizing topological matters.

Nat. Phys. 11, 724 (2015)
Nature 546, 627 (2017)
Science highlight: Breakthrough in Production and Storage of Hydrogen

Low-temperature hydrogen production from water and methanol using Pt/α-MoC catalysts
*Nature*, 2017, 544, 80-83

Atomic-layered Au clusters on α-MoC as catalysts for the low temperature water-gas-shift reaction
*Science*, 2017, 357, 389-393

“The new process ‘has a technological edge in terms of reaction rate’” —— Prof. Dion Valchos

Ding Ma’s group, Peking University

Top 10 Advances in Science of China in 2017
Science highlight: Origin of $O_2$ : Earth’s oxygen–hydrogen cycles

There is no oxygen on the earth until $\sim 2$ billion year ago, when there is a giant oxygen evolution from inner core of the earth.

Observe the formation of FeO$_2$. At 92 Gpa and 2050 K, FeOOH decompose to FeO$_2$ with H$_2$.

Industrial applications

- Pharmaceutical
- Chemical
- Metallurgical
- Energy
- Materials
- Aerospace

...

区域经济研讨
SSRF Phase-II Beamline Project

- involving in about 1700 users from 450 institutions.
Objectives

- Significantly updated research platform for frontier science.
- Innovation platform for national strategic technology.
- Unique platform for industrial innovation.
- Regional high-tech promotion platform.
- Major advances in science and technology of synchrotron radiation.
Project Construction Goal

6 years (2016 – 2022)

- **16+ New Beam Lines**: to greatly enhance the experimental capabilities and expand the application fields;
- **Light Source Improvements**: increase short straight sections, various ID devices, bunch lengthening system, cryogenic system;
- **User supporting system**: 5 Labs for off-line supporting including material, chemical, environmental, biological and medical sciences, in-situ instrumentations, data center;
- **Labs for BL engineering**: X-ray optics, mechanics, vacuum, control and electronics, FEA, test beamline;
- **Utilities and buildings**: buildings for endstation of super-long beamline, user supporting, user training and data center.

SSRF will be serving more than 5000 users each year
## SSRF Phase-II beamlines (16+)

<table>
<thead>
<tr>
<th>Disciplines</th>
<th>Beamlines</th>
<th>Source</th>
<th>Energy range</th>
<th>Scientific goals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy science</strong></td>
<td>E-line</td>
<td>IVU+EPU</td>
<td>130eV~18keV</td>
<td>Energy conversion and control</td>
</tr>
<tr>
<td></td>
<td>D-line</td>
<td>IVU+BM</td>
<td>10<del>10000cm(^{-1}) 5</del>25keV</td>
<td>Structure of non-equilibrium systems</td>
</tr>
<tr>
<td></td>
<td>Radioactive materials</td>
<td>W</td>
<td>5~50keV</td>
<td>Radioactive material</td>
</tr>
<tr>
<td></td>
<td>Hard X-Ray Spectroscopy</td>
<td>BM</td>
<td>5~30keV</td>
<td>Catalysis</td>
</tr>
<tr>
<td><strong>Environ. Science</strong></td>
<td>Hard X-ray Nanoprobe</td>
<td>IVU</td>
<td>5~25keV</td>
<td>Nano technology, cell, environ. components</td>
</tr>
<tr>
<td></td>
<td>Medium-energy Spectroscopy</td>
<td>IVU</td>
<td>2.1~16keV</td>
<td>Environmental pollutants</td>
</tr>
<tr>
<td></td>
<td>3D Nano Imaging</td>
<td>BM</td>
<td>5~14keV</td>
<td>Nano imaging</td>
</tr>
<tr>
<td><strong>Material Science</strong></td>
<td>S(^2)-resolved ARPES</td>
<td>Twin EPU</td>
<td>50~2000eV</td>
<td>Magnetic and electronic properties</td>
</tr>
<tr>
<td></td>
<td>RIXS station</td>
<td>EPU</td>
<td>250~1700eV</td>
<td>Electronic structure</td>
</tr>
<tr>
<td></td>
<td>Laue microdiffraction</td>
<td>Super B</td>
<td>7~30keV</td>
<td>Local microstructure and defects</td>
</tr>
<tr>
<td></td>
<td>Surface diffraction</td>
<td>CPMU</td>
<td>4.8~28keV</td>
<td>Microstructure of surfaces and interfaces</td>
</tr>
<tr>
<td></td>
<td>Laser Electron Gamma Source</td>
<td>ID</td>
<td>0.4~20MeV</td>
<td>Nuclear astrophysics/structure</td>
</tr>
<tr>
<td><strong>Life Science</strong></td>
<td>P2 Protein Crystallography</td>
<td>IVU</td>
<td>7~18keV</td>
<td>Moderate-risk infectious viruses</td>
</tr>
<tr>
<td></td>
<td>Membrane Protein</td>
<td>IVU</td>
<td>7~15keV</td>
<td>Membrane protein</td>
</tr>
<tr>
<td><strong>Industry Applications</strong></td>
<td>Ultra Hard X-ray Applications</td>
<td>SCW</td>
<td>30~150keV</td>
<td>Engineering materials and rocks</td>
</tr>
<tr>
<td></td>
<td>Time-resolved USAXS</td>
<td>IVU</td>
<td>8~15keV</td>
<td>Self-assembly and fiber-spinning</td>
</tr>
<tr>
<td></td>
<td>Fast X-ray imaging</td>
<td>CPMU</td>
<td>8.7~30keV</td>
<td>Fast process imaging</td>
</tr>
</tbody>
</table>
Construction plan

Very tight schedule due to limited manpower
Continue exploring new sciences and new needs

- Joint Lab with the Palace museum
- Joint Lab with TMSR
- Joint Lab for Optics development
- Joint Lab for nano-mechanics

SSRF
SSRF II

Two approaches:
✓ Upgrade existing ring to diffracted limited storage ring
✓ Rebuild a new storage ring with circumference length of 1000m
Thank you for your attention!