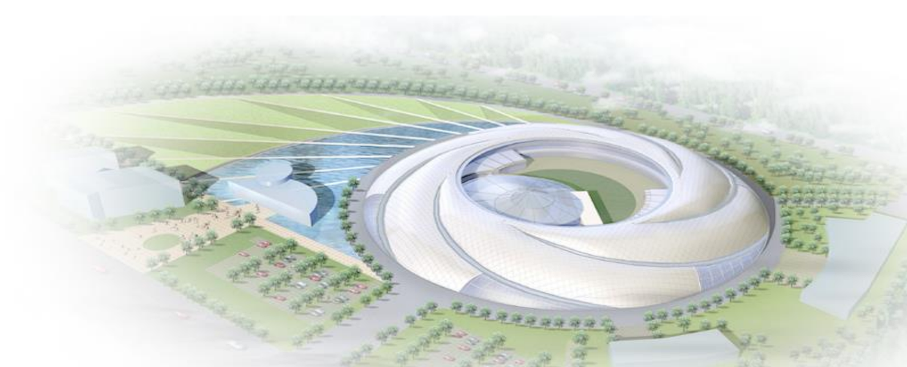
中国科学院上海应用物理研究所
Shanghai Institute of Applied Physics, Chinese Academy of Sciences

International Symposium on Simplicity, Symmetry and Beauty of Atomic Nuclei,
In honor of Prof Arima’s 88 year-old birthday, Shanghai, Sept. 27, 2018

SSRF and its Future

Renzhong Tai （邰仁忠）
Shanghai Institute of Applied Physics, CAS



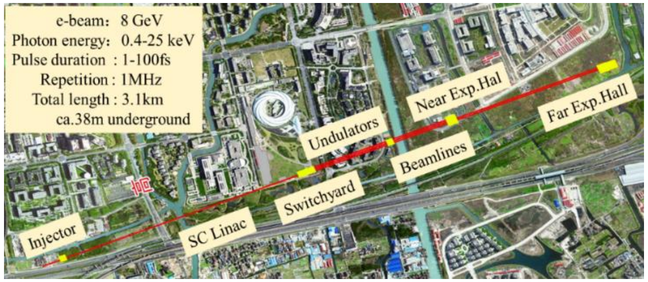
恭贺米寿
松鹤延年

X-ray Light Source Facilities in China

SSRF, SXFEL and SHINE (Shanghai)

- 3.5GeV SR facility
- 3.9nm·rad emmitance
- 432m 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



HEPS (Beijing)

- 6GeV SR facility
- 0.06nm·rad emmitance
- 1360m storage ring

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

HALS (Hefei)

2.4GeV SR facility
0.03nm·rad emmitance
672m storage ring

- Its construction is expected to start in 2021.

中国科学院上海应用物理研究所
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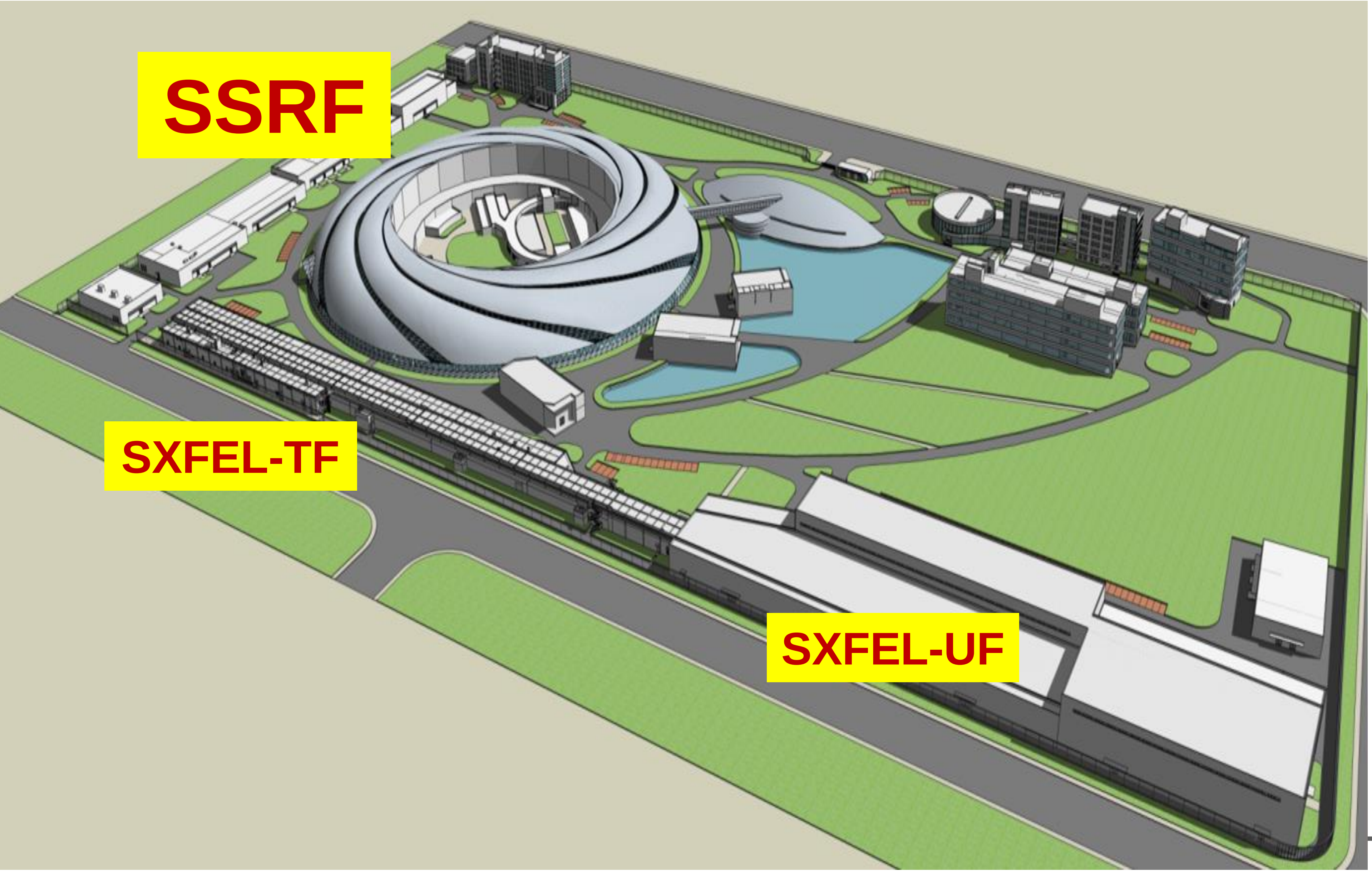
SSRF Campus



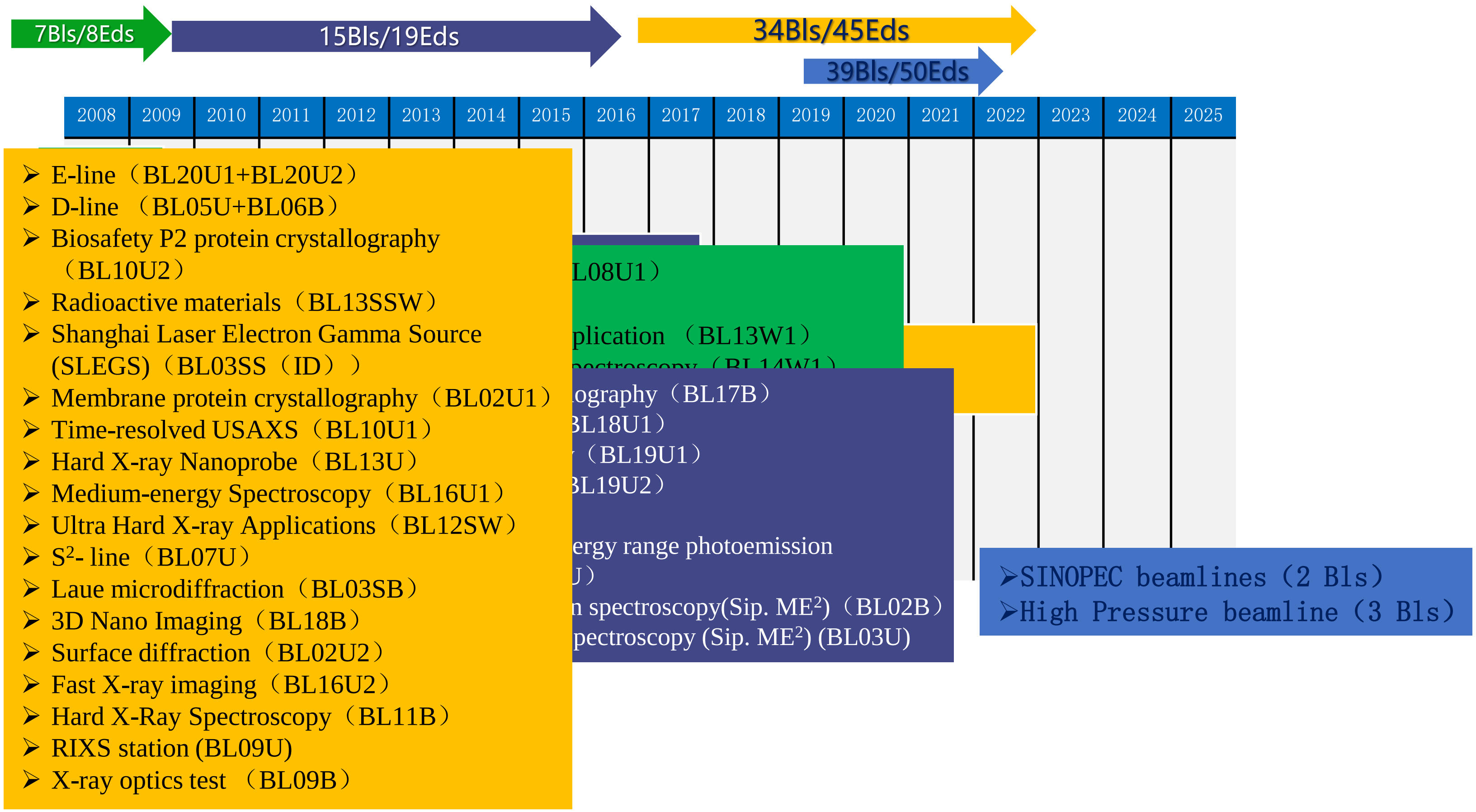
Shanghai Synchrotron Radiation Facility

- 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

Beamline	Source	Photon energy(keV)	Energy resolution (ΔE/E)	Flux	Spot size(H×V) Spatial resolution
Macromolecular Crystallography	IVU	5~18	$\le 2\times10^{-4}$	4.1×10^{12}	67×23 μm^2
XAFS	Wiggler	4~23	$<2\times10^{-4}$	3.6×10^{12}	0.16×0.1mm^2
X-ray Diffraction	BM	4~22	$1.9\ \times10^{-4}$	1.2×10^{11}	$0.21\ \times0.13$mm^2
X-ray Imaging	Wiggler	9~65	1.6×10^{-3}	1.6×10^{10}	50×50mm^2(spatial resolution<1.0μm)
Hard X-ray Micro-focus	IVU	5~20	1.4×10^{-4}	1.1×10^{11}	$0.12\times\ 0.13$ μm^2
SAXS	BM	4~22	5.3×10^{-4}	3.0×10^{11}	0.39×0.48mm^2
Soft X-ray Spectromicroscopy	EPU	0.2~2.2	17900@244eV	2.2×10^{8}	30nm
XIL		85-150eV		1.0×10^{14}	

15 Beamlines in operation

Beamline	Source	Photon energy(keV)	Energy resolution (ΔE/E)	Flux	Spot size(H×V) Spatial resolution
High Throughput Crystallography	BM	5~20	$\leq 3\times10^{-4}$	3.0×10^{11}	150×180 μm^2
Micro-Crystallography	IVU	5~18	$<2\times10^{-4}$	5.0×10^{11}	10×7 μm^2
Complex Crystallography	IVU	7~15	$<2\times10^{-4}$	1.5×10^{12}	120×80 μm^2
BioSAXS	IVU	7~15	$<5\times10^{-3}$	4.0×10^{12}	345×110 μm^2
FTIR and Microscope	BM	10-10000 cm^{-1}	0.1 cm^{-1}	2.0×10^{12}	
Dream line (ARPES and PEEM)	EPU	0.02-2	10000@244eV	10^{10}	
SiP▪ME^2_AP-XPS	BM	0.04-2	10000@244eV	$>10^{10}$ (40~1650eV)	166×17 μm^2
SiP▪ME^2_HR-ARPES	EPU	7-70eV	20000@21.6 eV	10^{11}	

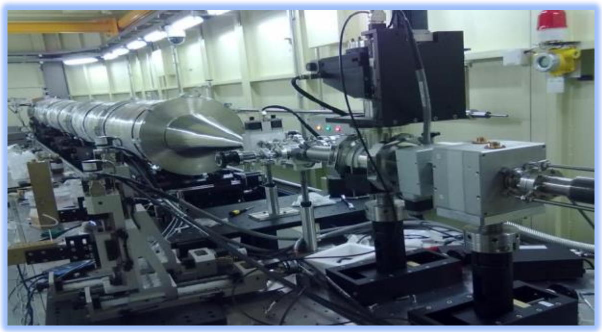
Hard X-ray Stations

X-ray Imaging

XRD

XAFS

Microprobe



SAXS

Bio-SAXS

FTIR and Microscope

Macromolecular Crystallography

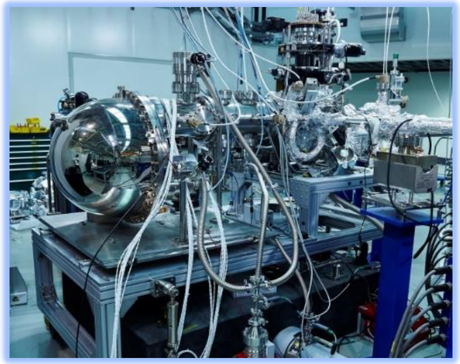
High Throughput Crystallography

Micro-Crystallography

Complex Crystallography

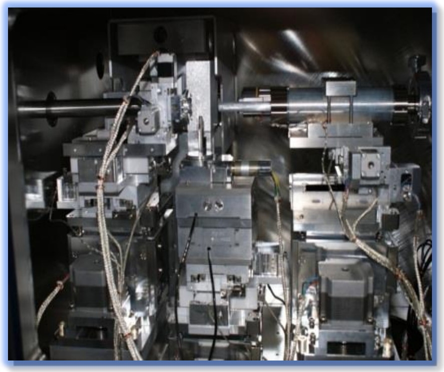
Soft X-ray Stations

ARPES and PEEM

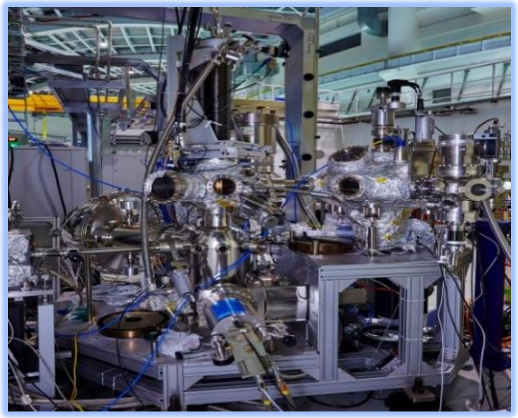


AP-XPS

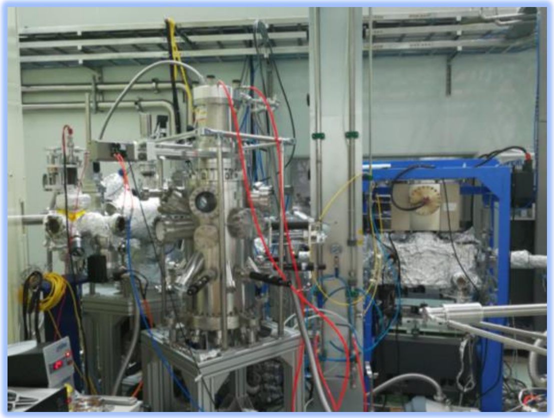
AP-PIPOS



STXM

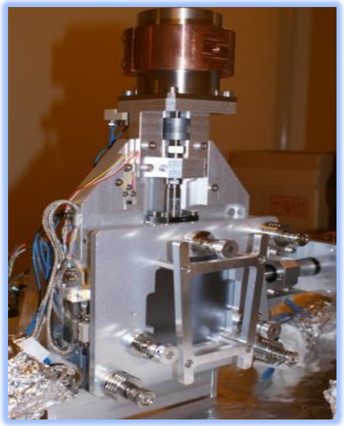


nano-ARPES



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

Russia1

France 2

New Zealand 1

Saudi Arabia 1

Germany 2

Switzerland 1

SSRF user status

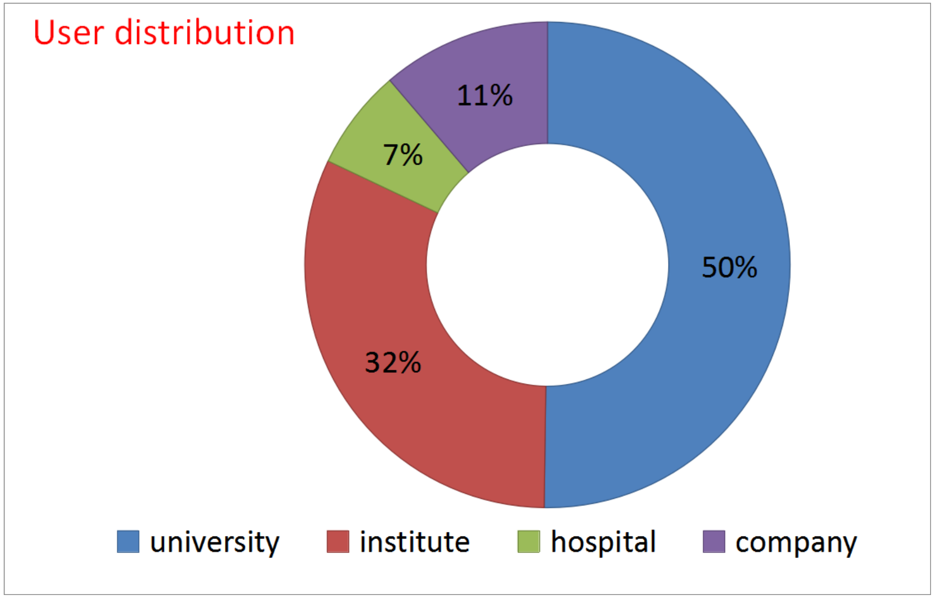
Up to December of 2017:

user groups： 2,297

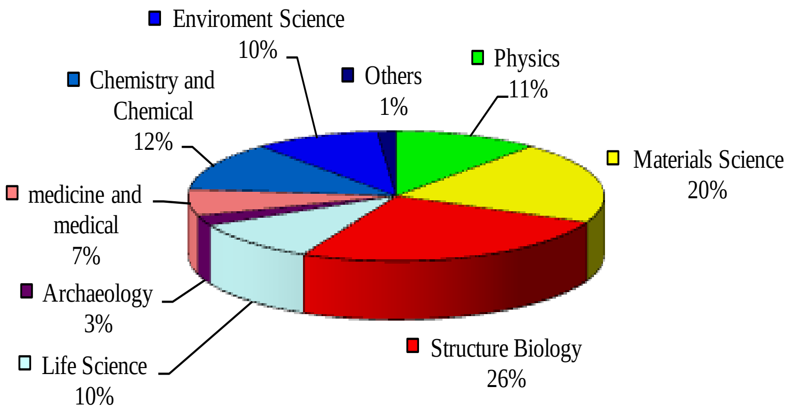
proposals： 9,387

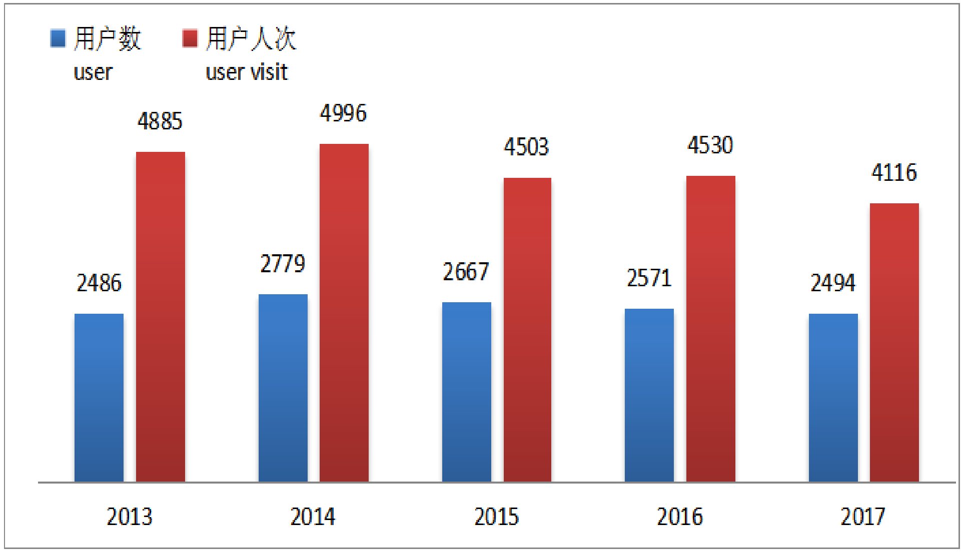
affiliation： 462

users： 20,129



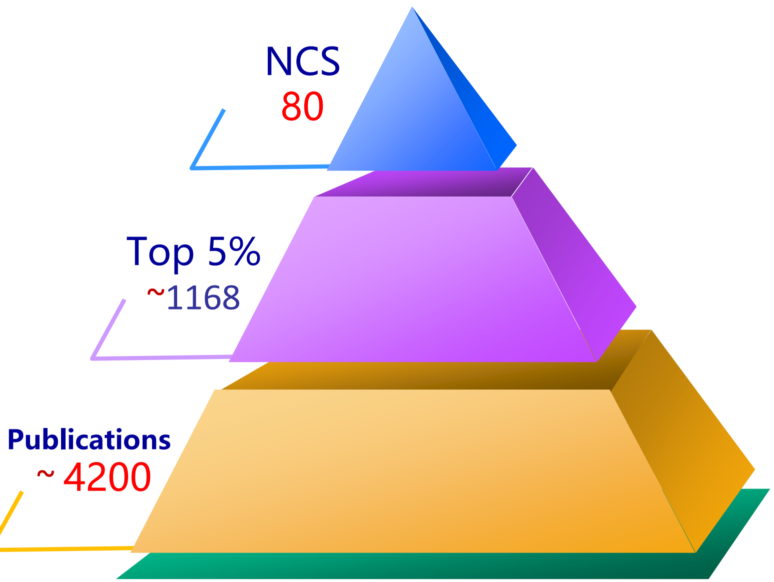
Distribution of users' research fields

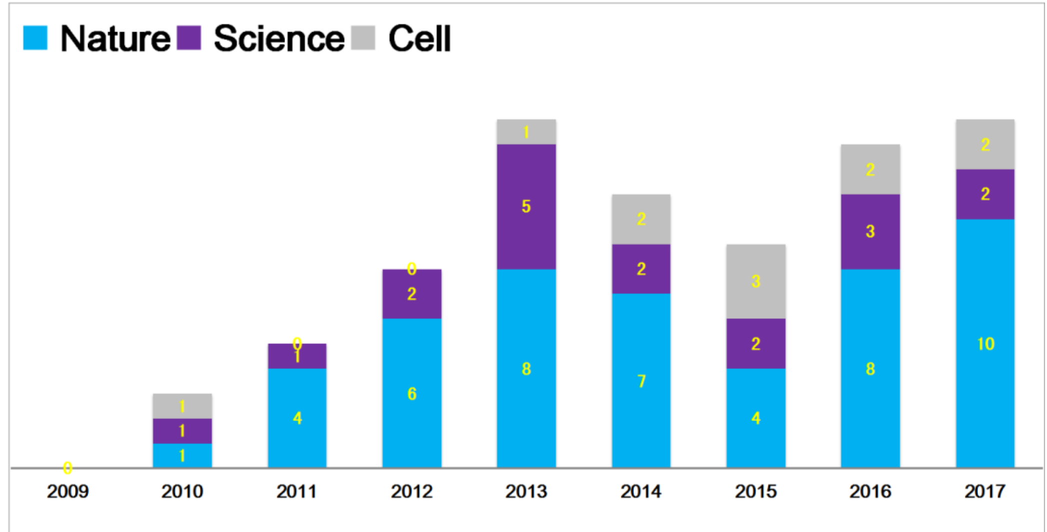


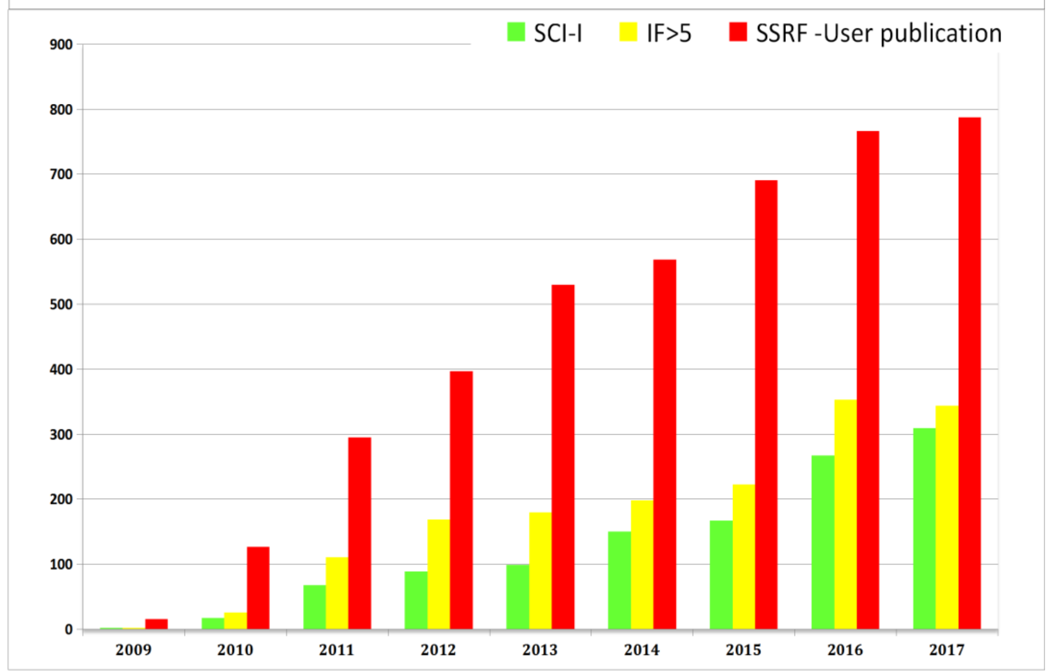


SSRF User's publications

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

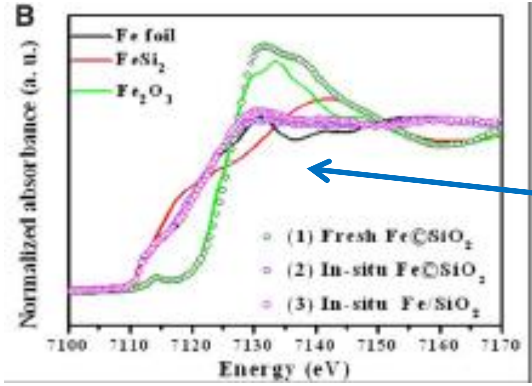


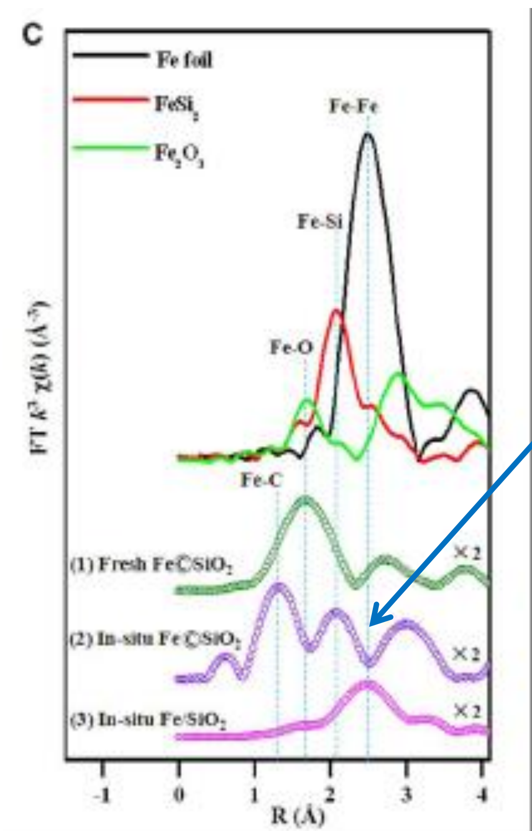


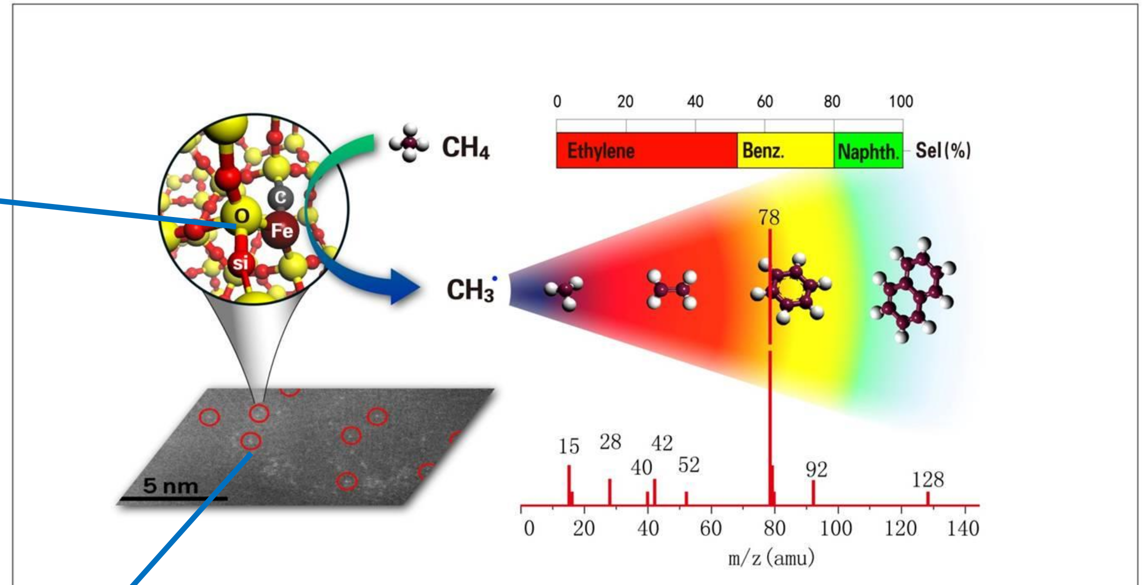


Publications for each year and in top journals keep increasing rapidly

Science highlight: Direct Conversion of Methane to Hydrogen





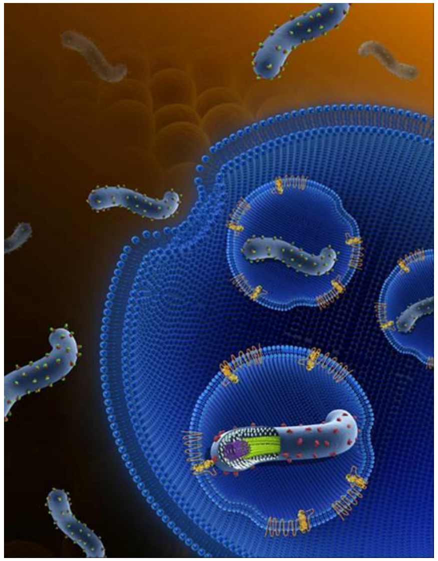


Selective conversion of methane to hydrogen, ethane and dutrex is a crucial reaction for catalytic industry. The work reported by Bao et al. forwarded a single-site iron mechanism, which has been directly confirmed by in-situ X-ray absorption fine structure (XAFS) tests conducted at BL14W1 beamline of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

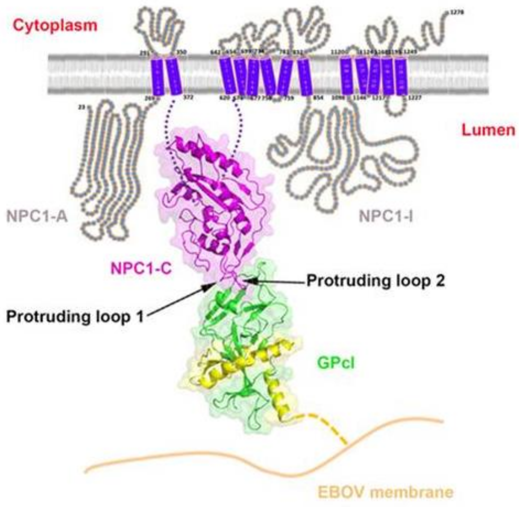
Bao, et. al. *Science*, **2014**, *344*, 616-619.

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.



Ebola Virus Invasion Mode



Reaction of virus and receptor

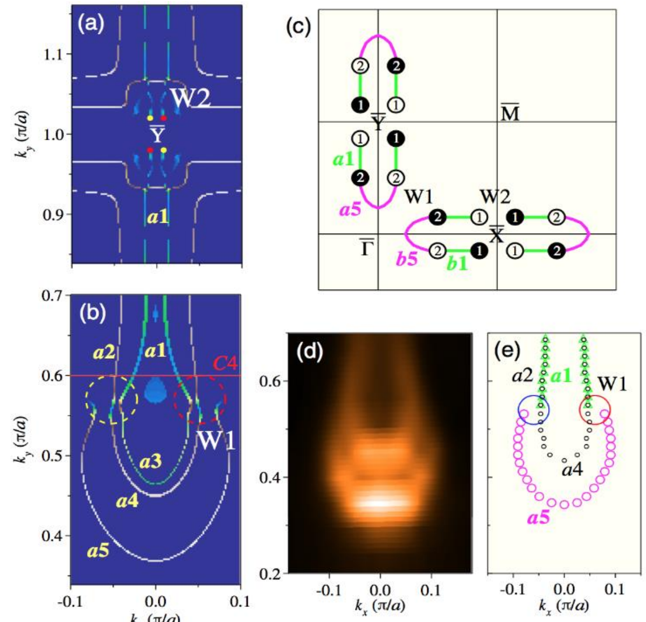
Published in Cell(Jan. 2016) , by Prof. F. Gao's team from the CAS Institute of Microbiology and the Chinese Center for Disease Control and Prevention.

Science highlight: Discovery of Weyl and Three Component Fermions

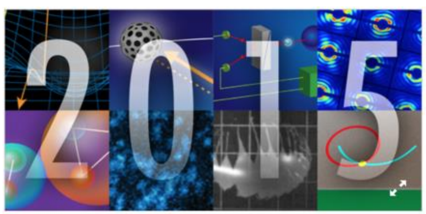
In 1929, German scientist H. Weyl predicted the existence of a massless fermion with a definite handedness, or “chirality”. Physicists never found a fundamental particle with these characteristics.

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 Spectrosopy) 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.



Wel Fermion surface arcs observed on TaAs



physicsworld TOP 10 BREAKTHROUGH 2015

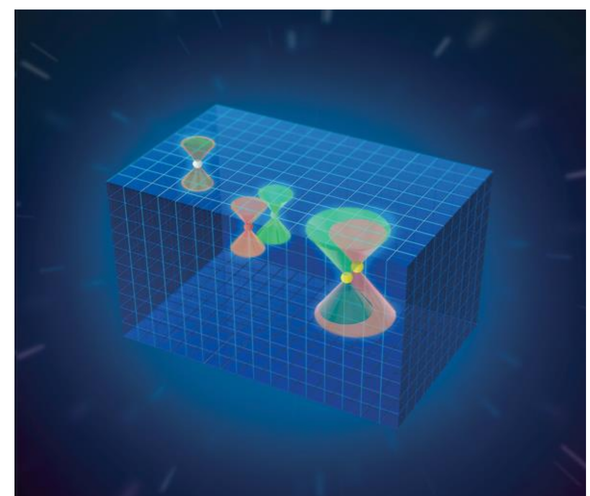
PHYSICAL REVIEW JOURNALS 125 YEARS

Nat. Phys. 11, 724 (2015)
Phys. Rev. X 5, 031013 (2015)
Phys. Rev. Lett. 115, 217601 (2015)

Nature 546, 627 (2017)
Nat. Phys. (2018)

2015 Top 10 Scientific Breakthroughs in China

科技部发布2015年度中国科学十大进展

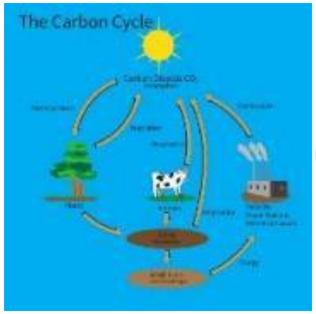


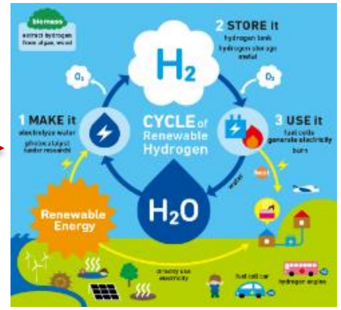
A summary of the Dirac, Weyl and Three Component Fermions discovered in Solid States Matters

2017 Top 10 Scientific Breakthroughs in China

Science highlight: Breakthrough in Production and Storage of Hydrogen

Carbon Age → **Hydrogen Age**



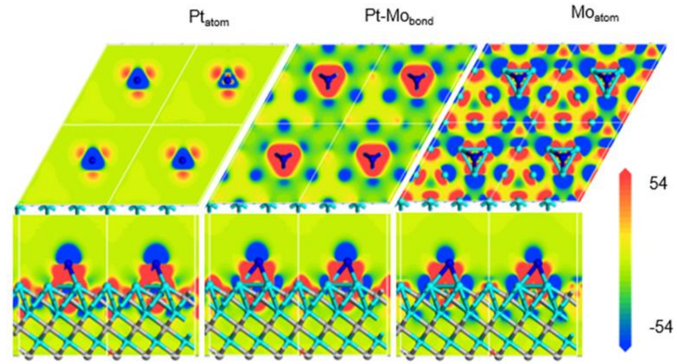


Low-temperature hydrogen production from water and methanol using Pt/α-MoC catalysts

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



C&EN CHEMICAL & ENGINEERING NEWS

New process for generating hydrogen fuel

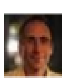
Catalyst produces hydrogen from methanol and water at relatively low temperatures

By Stu Borman

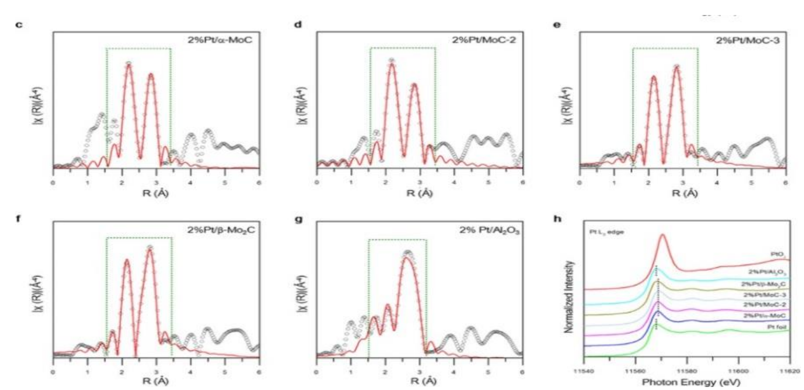
"The new process 'has a technological edge in terms of reaction rate'"—— Prof. Dion Valchos

CHEMISTRY WORLD

Catalyst fuels hydrogen car vision



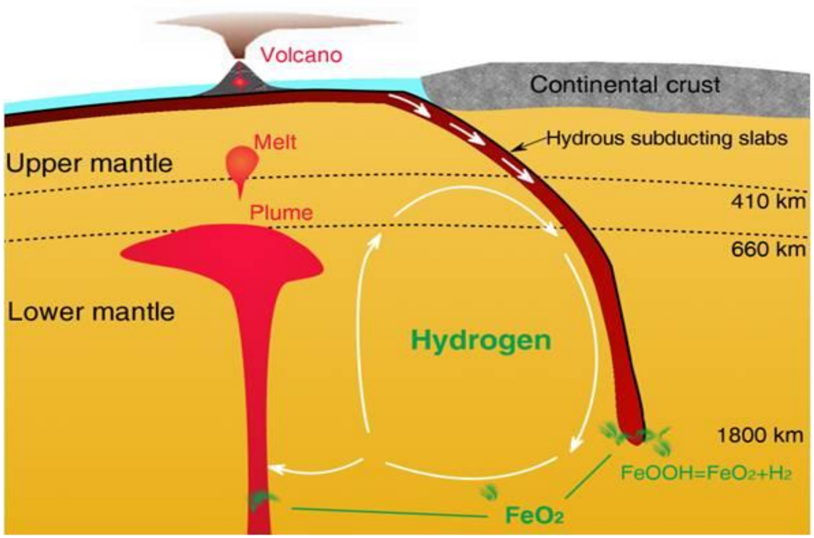
BY ANDY EXTANCE | 29 MARCH 2017



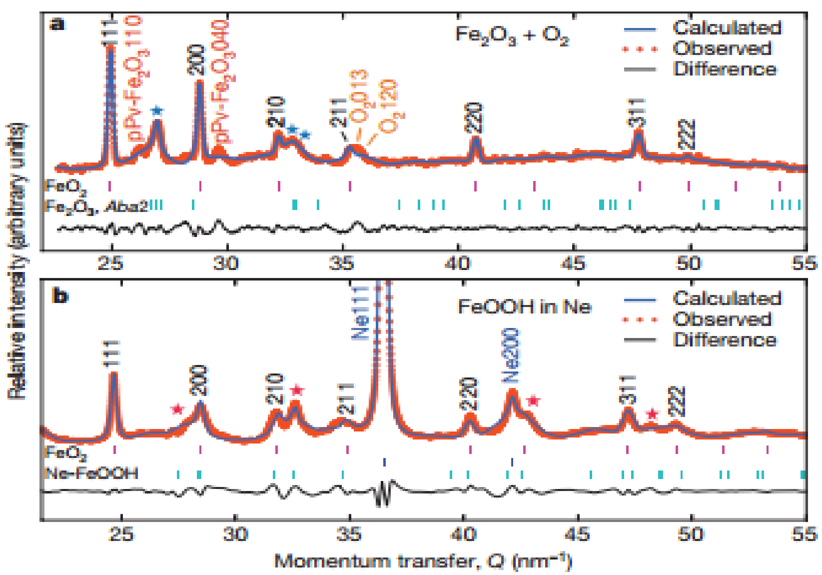
Ding Ma's group, Peking University

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 ~ 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.

Mao H. K. et. Al. Nature 534, 241 (2016)

Industrial applications

NOVARTIS
Medicilon
中国石化 SINOPEC
P&G
上海通用汽车 SHANGHAI GM
Roche
VIVA
金地智慧 Goldlandsw
中国石油
BAOSTEEL
GE
gsk GlaxoSmithKline 葛兰素史克
GenScript
SinoBio
HISUN 海正药业
SAINT-GOBAIN PAM
中国钢研科技集团有限公司 CHINA IRON & STEEL RESEARCH INSTITUTE GROUP
Pfizer
辉瑞公司
Lilly
BeiGene
中广核 CGN 核能
苏州热工研究院有限公司
ELOTEX Bermocoll
中国航天科技集团公司 China Aerospace Science and Technology Corporation

......

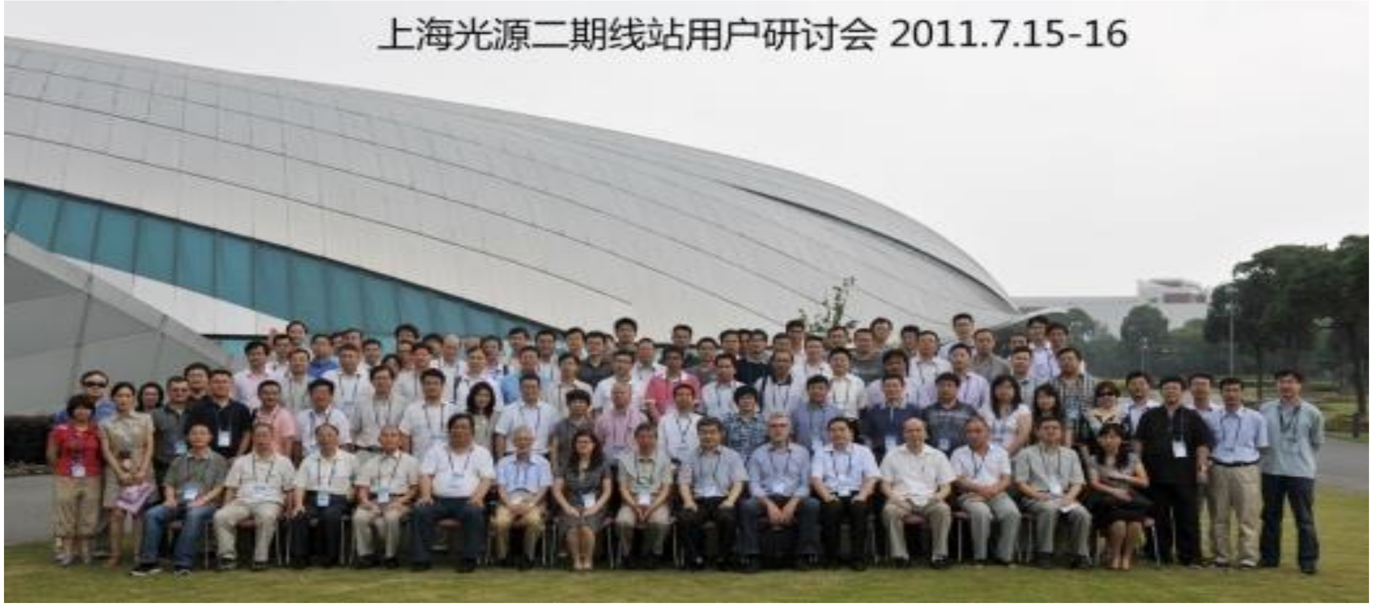
- Pharmaceutical
- Chemical
- Metallurgical
- Energy
- Materials
- Aerospace
- …

区域经济研讨

中小企业沙龙

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)

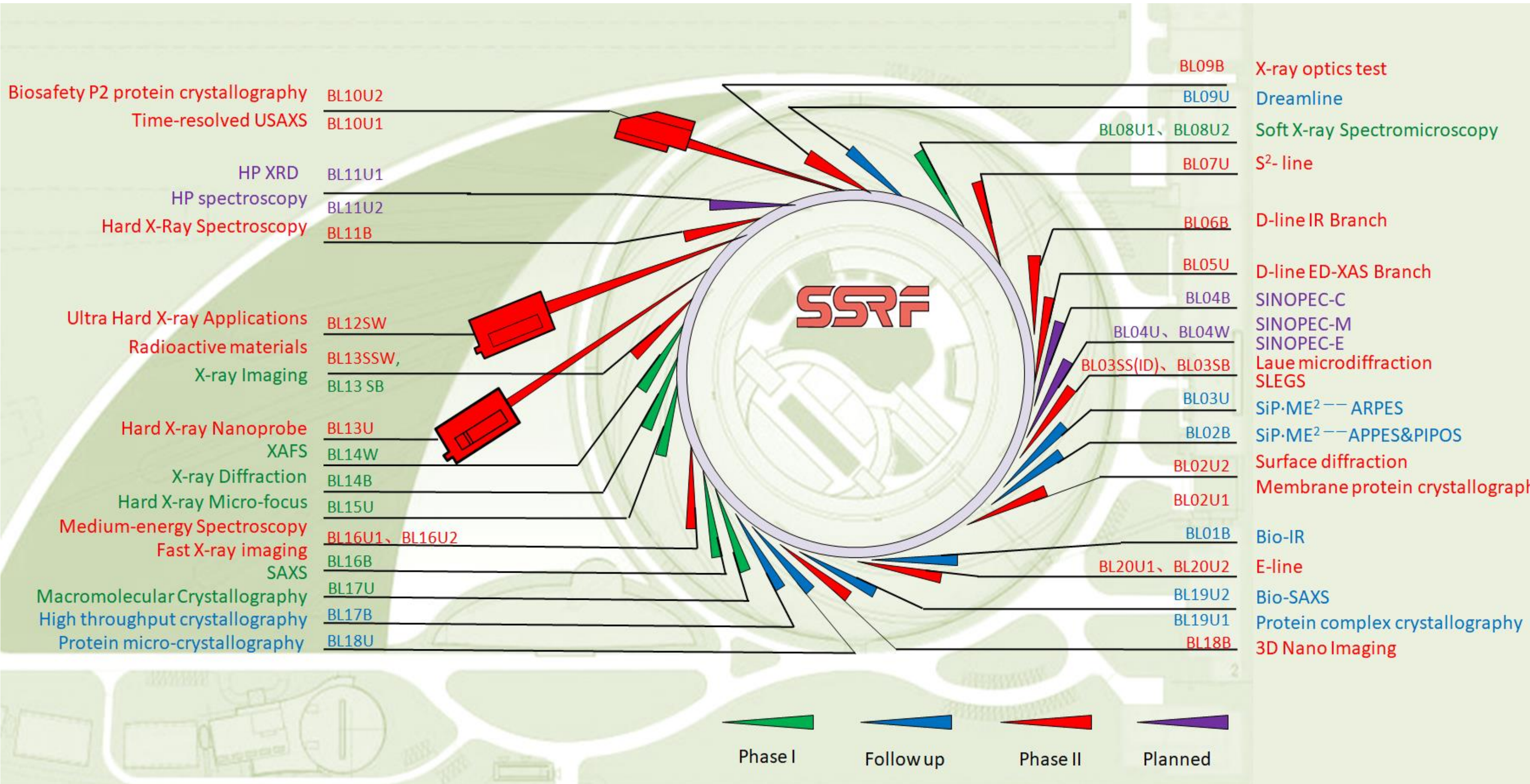
- **16+ New Beam Lines** : to greatly enhance the experimental capabilities and expand the application fields;
- **Light Source Improvements**: increase short straight sections, various ID devices, bunch lengthening system, cryogenic system;
- **User supporting system** : 5 Labs for off-line supporting 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

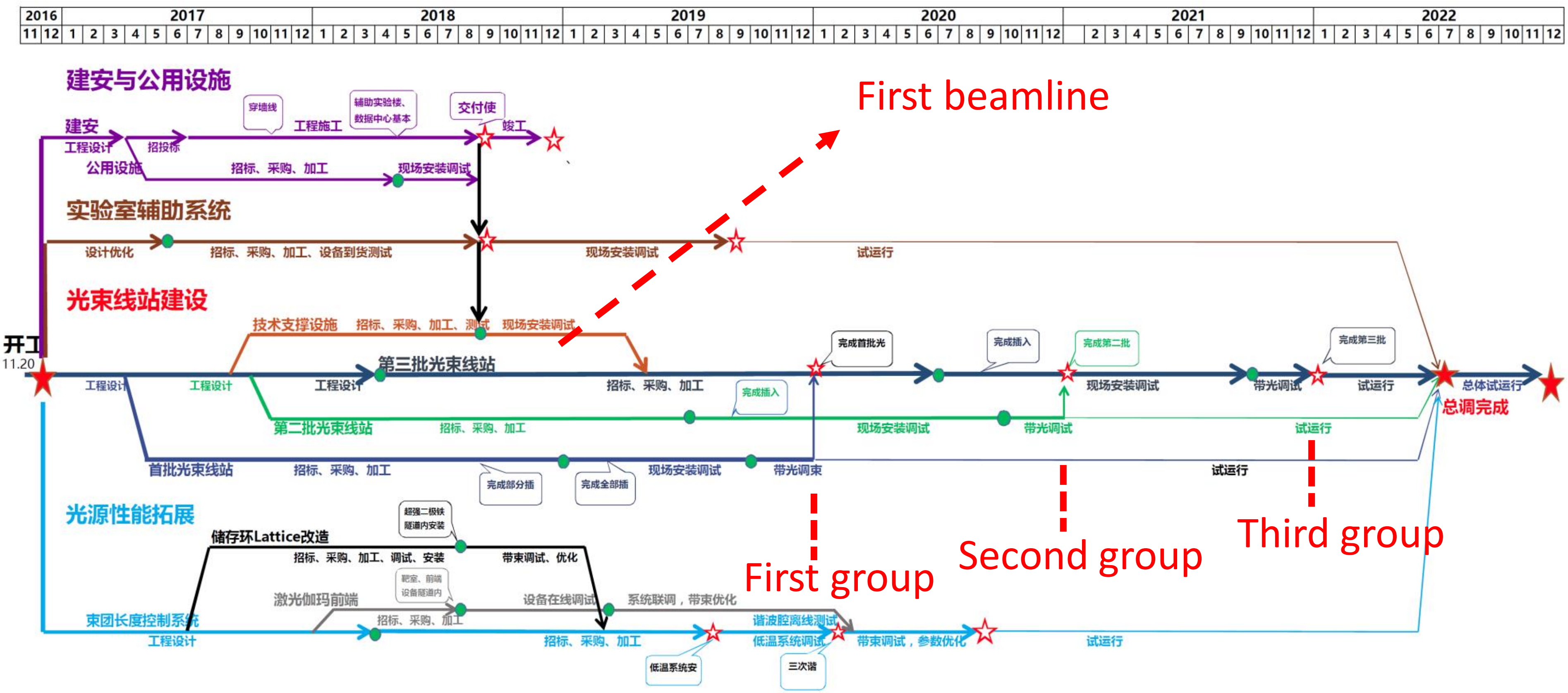
SSRF Phase-II beamlines (16+)

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

SSRF Beamlines layout



Construction plan



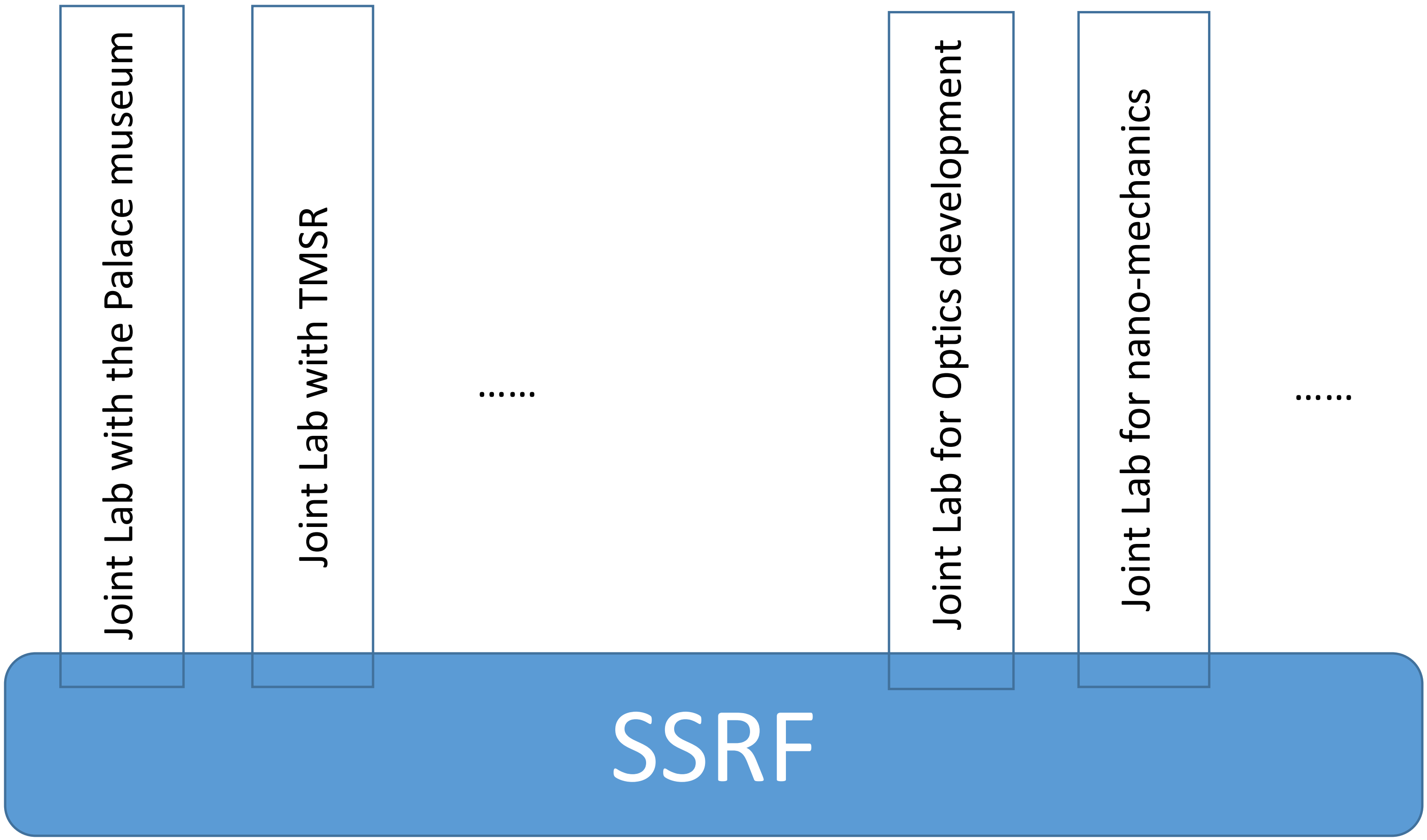
首批线站
能源材料线站（E-line）
动力学结构研究线站（D-line）
纳米自旋与磁学线站
时间分辨超小角散射线站
膜蛋白晶体结构线站
P2生物安全防护蛋白质晶体结构线站
表面衍射线站

第二批线站
中能谱学线站
快速X光成像线站
稀有元素分析线站
时间分辨超小角散射线站
RIXS站
搬迁成像线

第三批线站
硬X射线纳米探针线站
超硬多功能线站
微束白光劳厄衍射线站
纳米三维成像线站
激光伽玛线站

Very tight schedule due to limited manpower

Continue exploring new sciences and new needs



SSRF II

Two approaches:

- ✓ Upgrade existing ring to diffracted limited storage ring
- ✓ Rebuild a new storage ring with circumference length of 1000m

2018

Now


Thank you for your attention!
谢谢