Status of SXFEL and DCLS project in China

Qiang Gu

For the project team

Outline

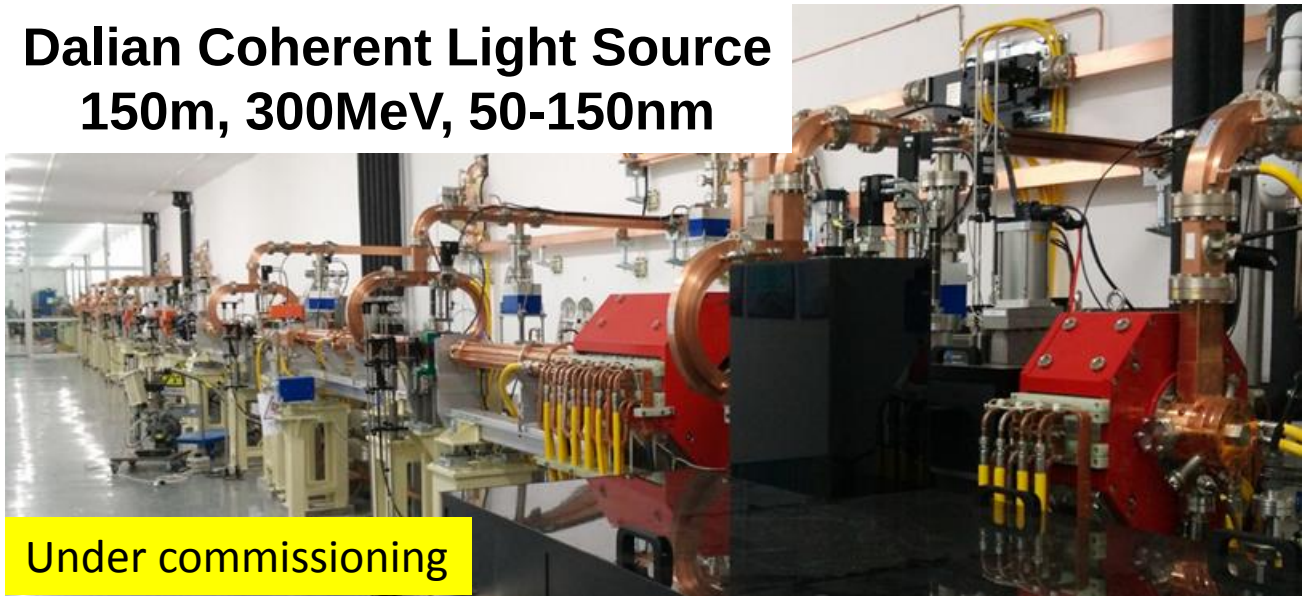
- Introduction to the high gain FELs in China
- Status of DaLian Coherent Light Source (DCLS)
- Status of Shanghai X-ray Free Electron Laser Test Facility (SXFEL-TF) and the User Facility (SXFEL-UF)
- Summary

Introduction to the high gain FELs in China

- Later on in late 1990s, a high-gain FEL program called SDUV-FEL was initiated. It started the FEL tests (SASE, HGHG and ECHO) since 2009 and closed in 2016.
- In 2007, a soft X-ray FEL test facility (SXFEL-TF) was proposed and began its construction in 2014. Its user facility project just funded and started 2016.
- In 2012, an EUV-FEL, DCLS, was initiated and funded in 2013.
- Recently, a proposal of hard X-ray FEL facility has been approved and will be opened to the users till 2025.

Shanghai DUV FEL,
65m, 180MeV, 250-350nm

Dalian Coherent Light Source
150m, 300MeV, 50-150nm



Under commissioning

Under commissioning

Shanghai X-ray FEL Test Facility
300m, 840MeV, 9-40nm

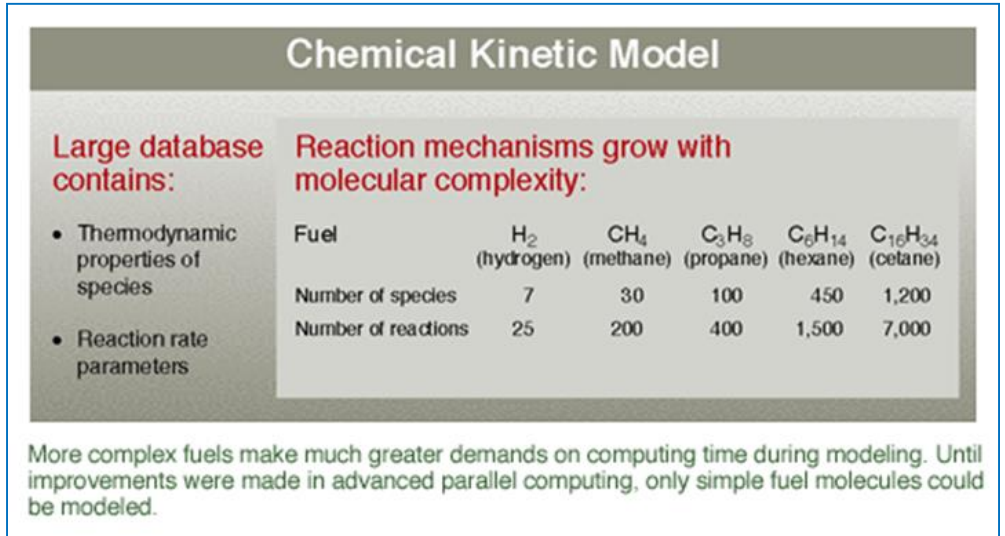
Under construction

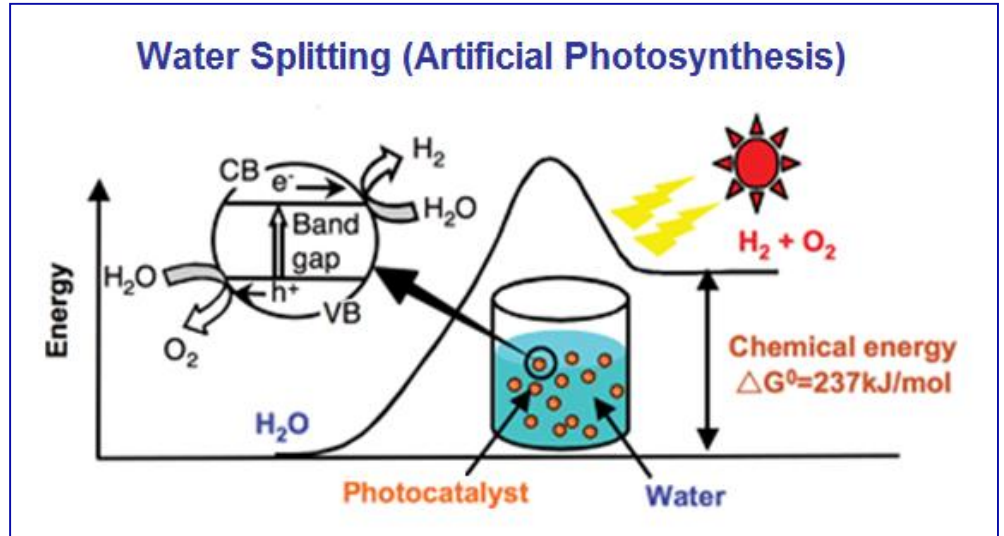
Shanghai X-ray FEL User Facility
530m, 1.6GeV, 2-10nm

DaLian Coherent Light Source

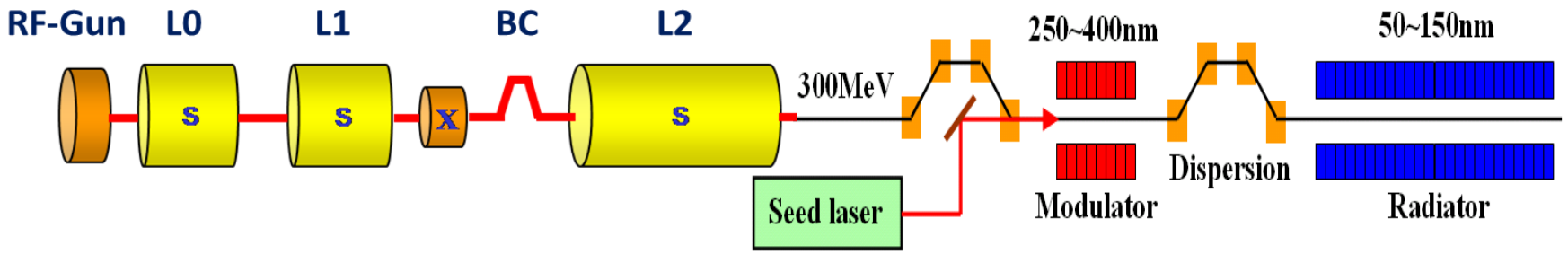
Introduction to DCLS

- DCLS is the first user facility based on the Free electron laser technology and user guided large scientific instrumentation in China.
- DCLS is an extreme ultraviolet coherent light source for catalytic chemistry, surface chemistry, dynamics and spectra in energy chemistry. This facility has a great advantage in high sensitivity and ultrafast processes detection of atoms, molecules and surface electronic states.
- The project is funded by NSF, in collaboration with SINAP and NSRL





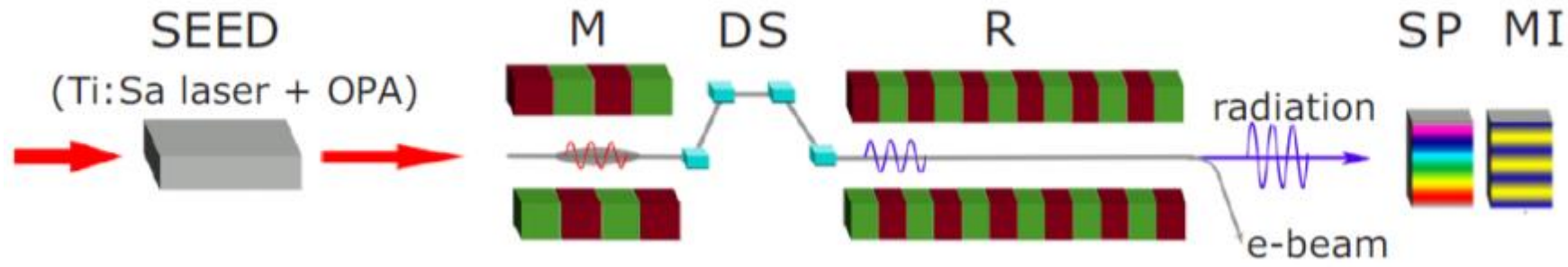
Layout and main parameters of DCLS

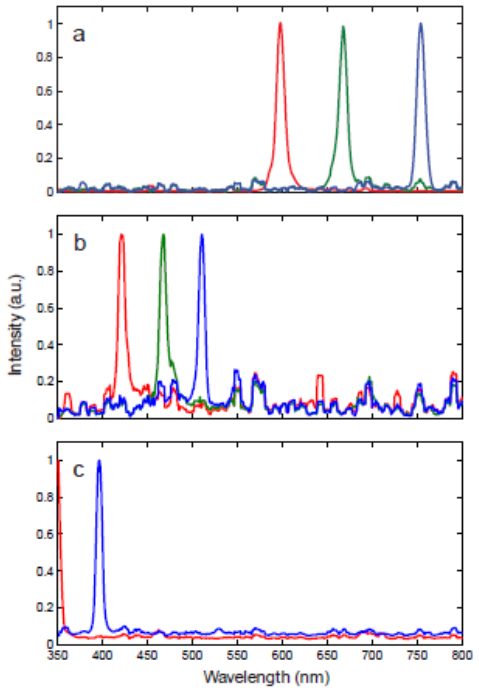


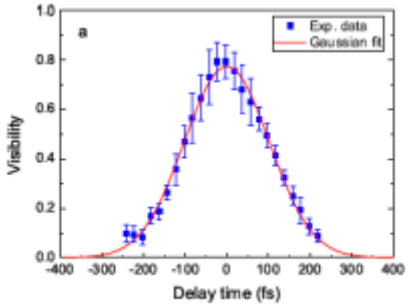
Norm. Emitt.	<2umrad
Bunch charge	500 pC
Peak current	300 A
Beam energy	300 MeV
Repetition rate	50 Hz

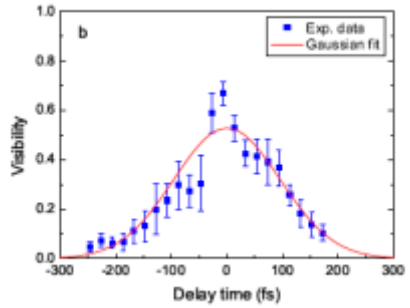
FEL wavelength	50~150 nm, tunable
Working scheme	HGHG
Peak power	100~300 MW
Bunch length(FWHM)	~100fs, ~1ps

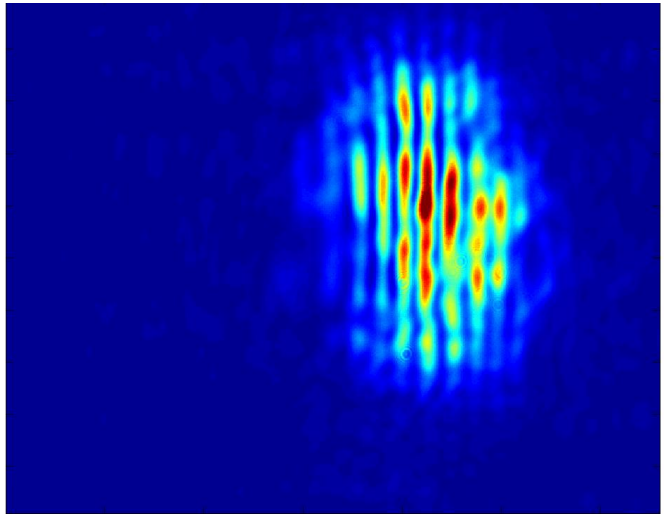
Wide tunable HGHG demonstration @SDUV











Milestones

2012.03 Starting of DCLS

2013.08 International Review of TDR of DCLS

2013.09 Sino-Germany Symposium I

2013.12 Prototype of Undulator

2014.04 Review of TDR of Beamline

2014.10 Starting of Construction

2015.10 Sino-Germany Symposium II

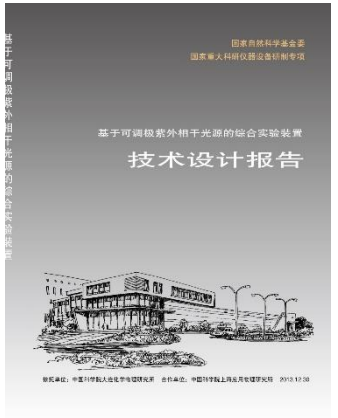
2016.04 LINAC installation

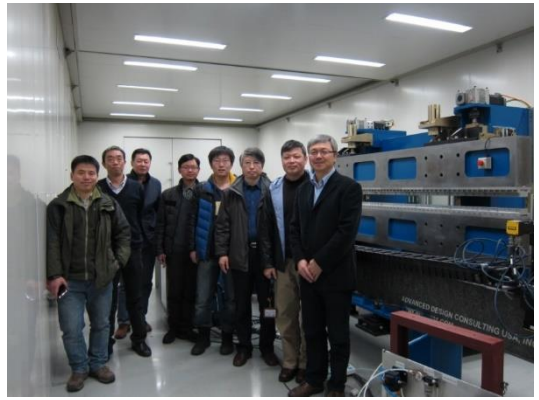
2016.09 Undulator spontaneous emission

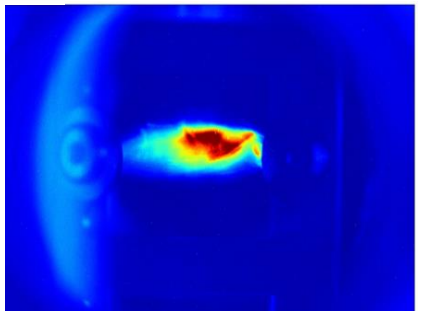
2016.11 FEL SASE lasing

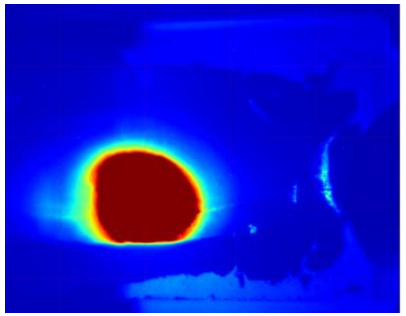
2016.12 FEL HGHG lasing

Wait for the first user experiment

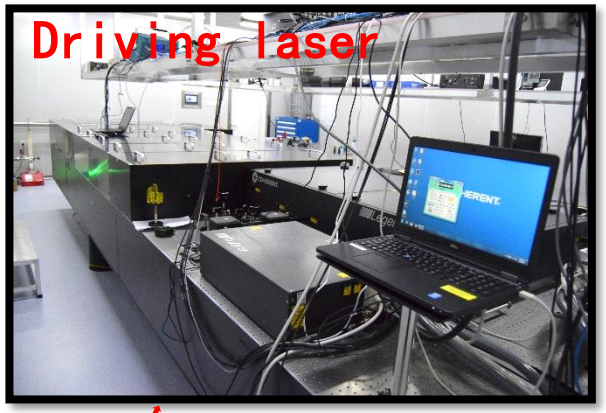


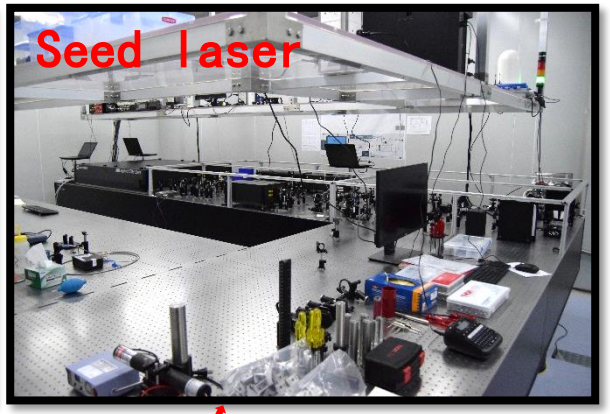


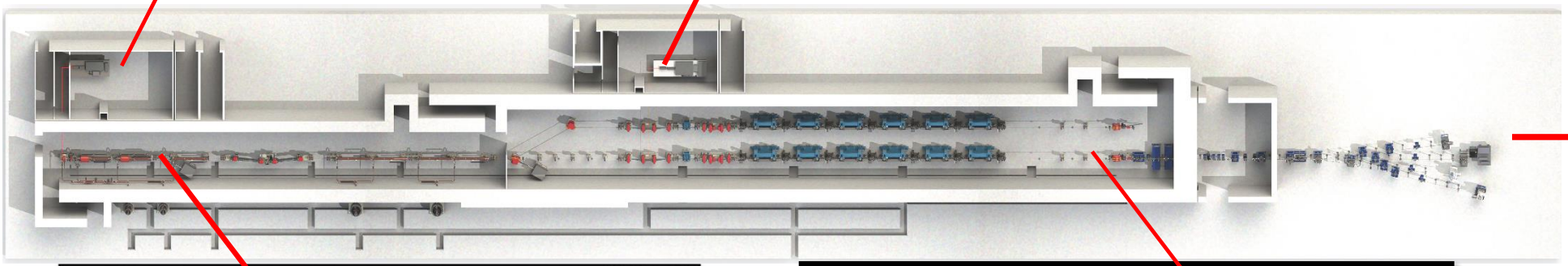


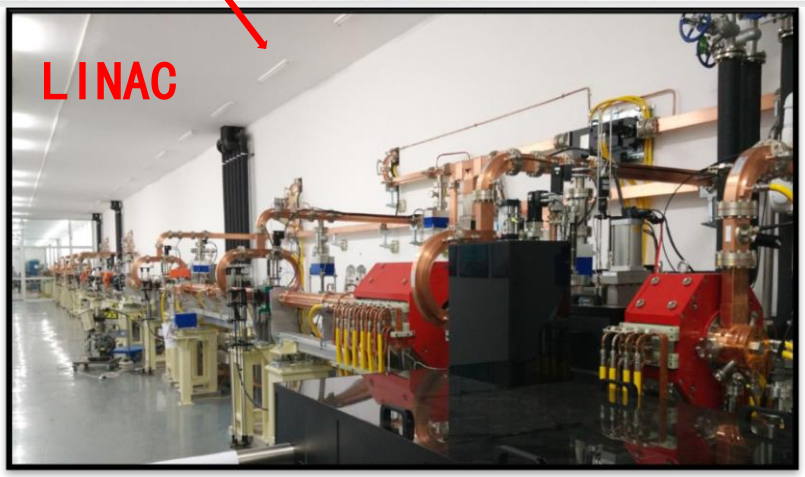


DCLS beamline

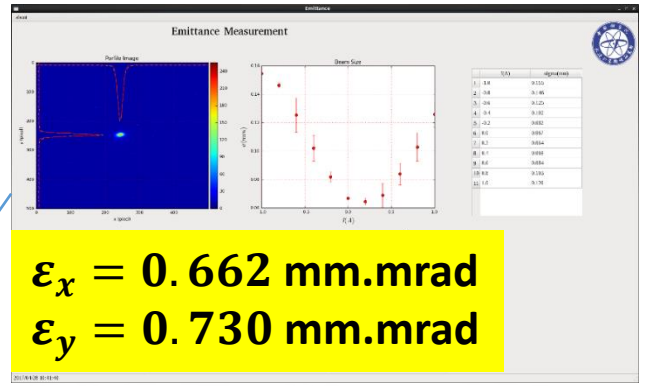




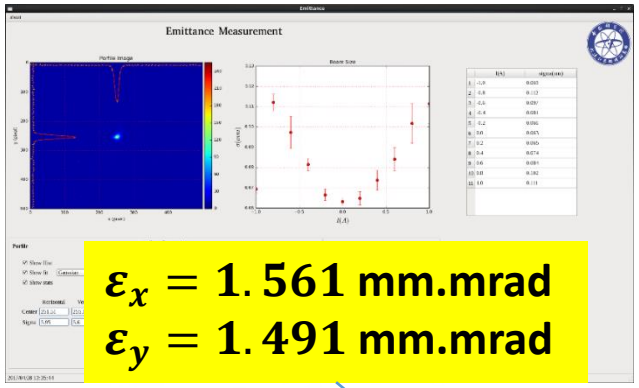




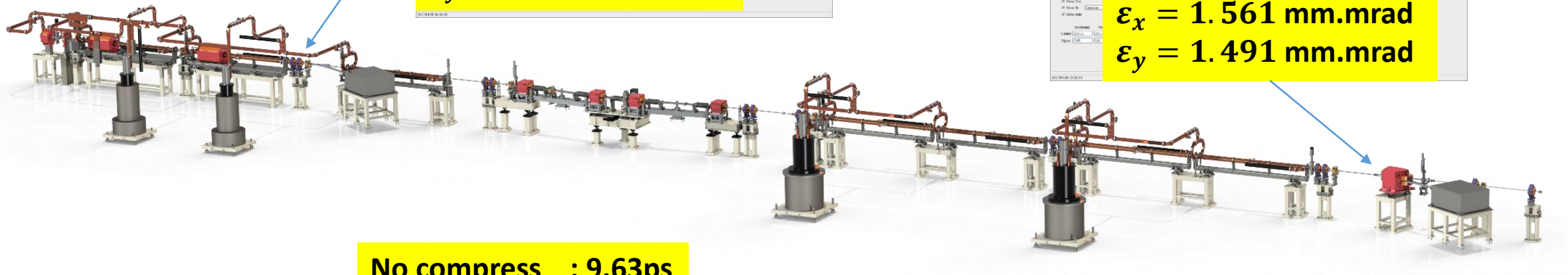
LINAC beam parameters



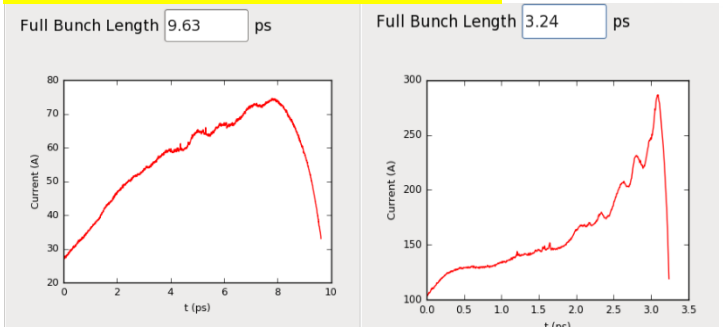
$\varepsilon_x = 0.662$ mm.mrad
$\varepsilon_y = 0.730$ mm.mrad

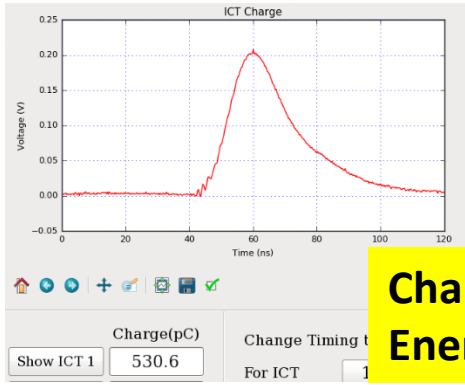


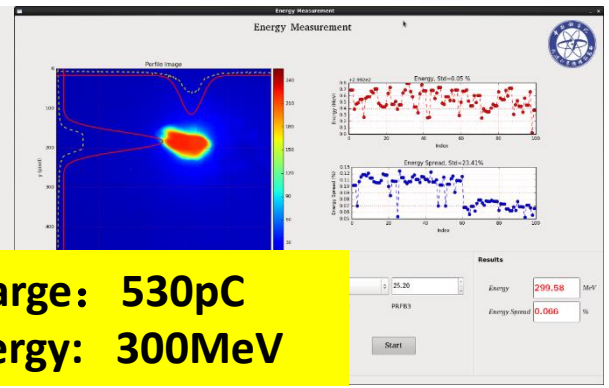
$\varepsilon_x = 1.561$ mm.mrad
$\varepsilon_y = 1.491$ mm.mrad



No compress : 9.63ps
After compress: 3.24ps

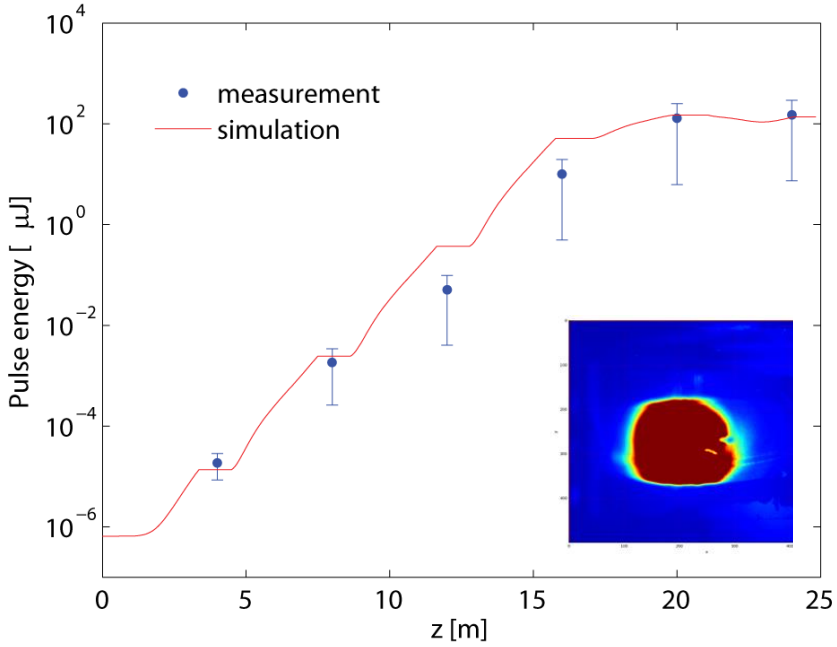


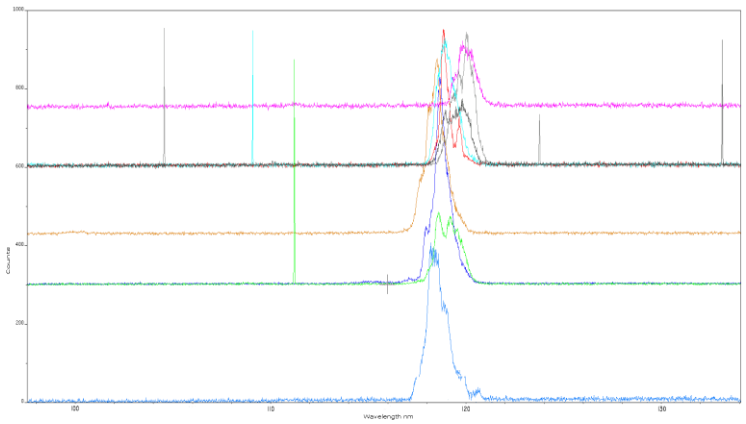




Charge： 530pC
Energy： 300MeV

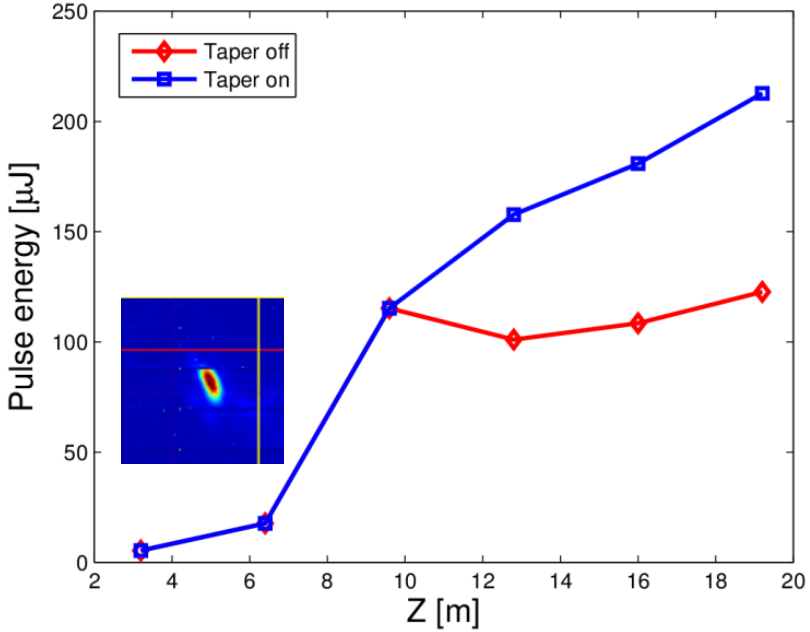
SASE 150μJ @118nm

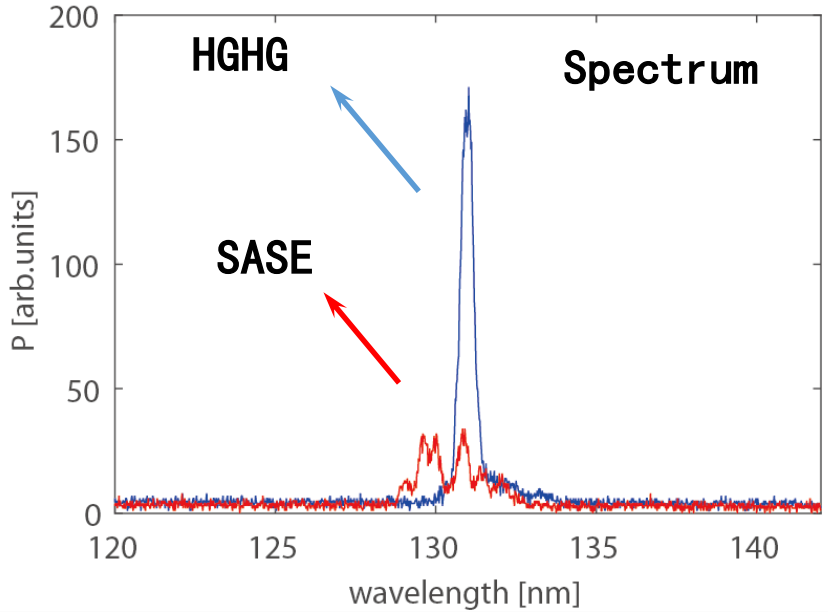




>100 μ J @ 90nm 118nm and 148nm

HGHG 210uJ @133nm

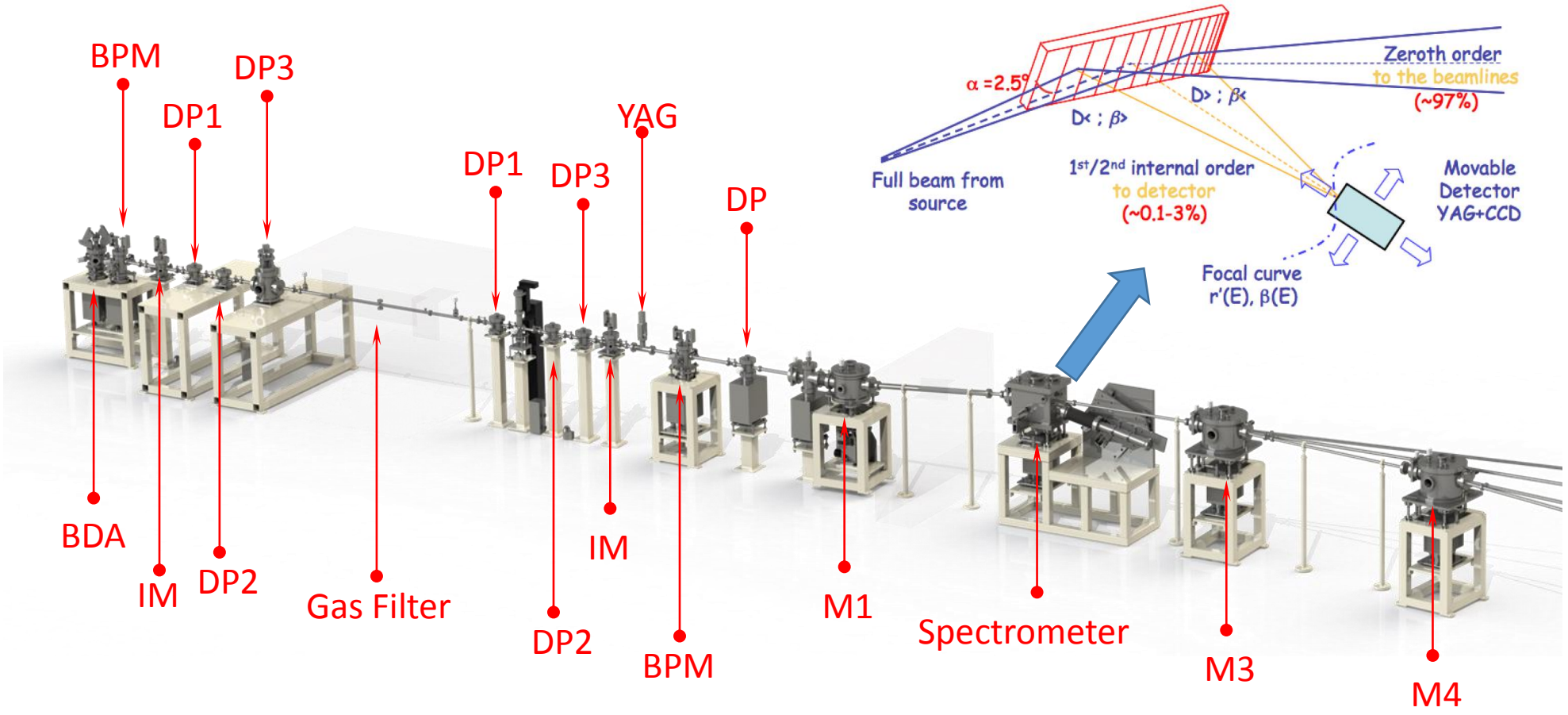




Summary of DCLS commissioning

Design number	*Achieved now*
➢ **Tunable Wavelength： 50 – 180 nm**	✓**133nm, 88nm,**
➢ **Pulse Energy： >100 uJ (1 mJ)**	✓**210 uJ**
➢ **Pulse length： 100 fs /1 ps**	✓**~1ps**
➢ **Beam Size: ~1mm**	✓**Not measured at end**
➢ **Bandwidth： Fourier transform limit**	✓**<0.1%(HGHG), 1%(SASE)**
➢ **Jitter： <100 fs**	✓**Not measured**
➢ **Rep Rate： 50 Hz**	✓**10Hz**
➢ **Fully coherent**	✓**Not mearsured**
➢ **Polarization: Horizontal**	✓**Not measured**

Beam line



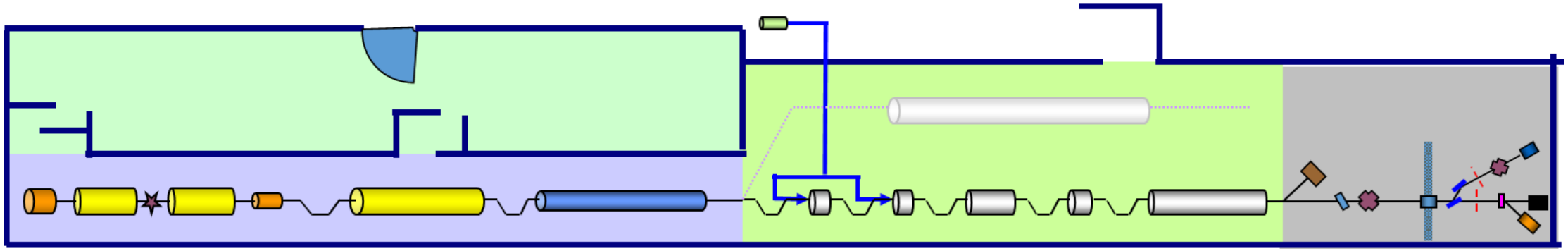
- **Photon Beam position, intensity, wavelength will be recorded in real time.**
- **Estimated beam transfer efficiency is about 85% after 2 mirrors**

Shanghai X-ray Free Electron Laser Test Facility

Introduction to the SXFEL-TF

- The SXFEL-TF is funded by the national government and hosted by SINAP, CAS.
- The goal of this project is to build a soft X-ray FEL facility with a wavelength of 8.8 nm using cascaded harmonic generation scheme. Besides the FEL facility, a 9-cell SRF cavity module will be developed by PKU in the meantime.
- Different lasing scheme, and various key components and technologies could be tested in the test facility and it will the approach to the hard X-ray FEL users facility in China.
- The total budget of the FEL facility is about 30M$ and the construction term is 3 years (2014.12~2017.12)

Layout and main parameters of SXFEL-TF



Linac

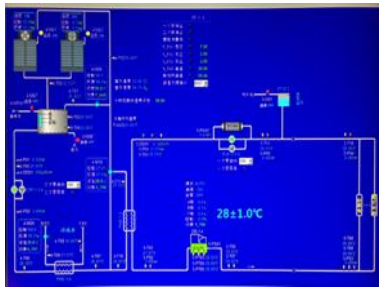
Bunch charge (nC)	0.5
Beam energy (GeV)	0.84
Bunch length (ps, FWHM)	≤ 1.0
Norm. emit. (mm.mrad, rms)	< 2.0
Energy spread (rms)	< 0.15%
Peak current (A)	≥ 500
Rep-rate (Hz)	1-10

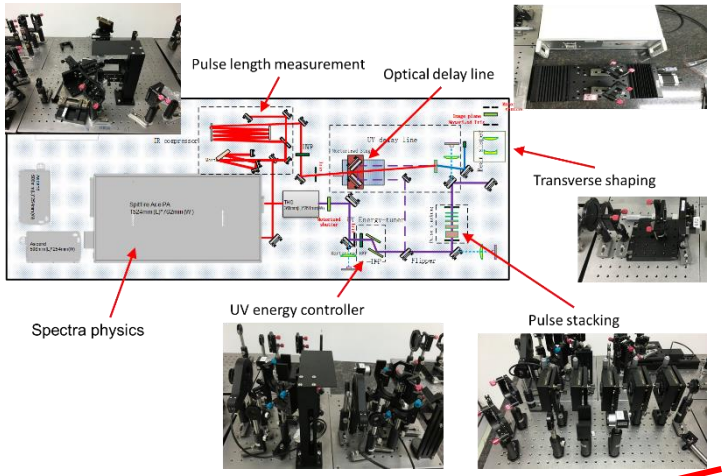
Radiator

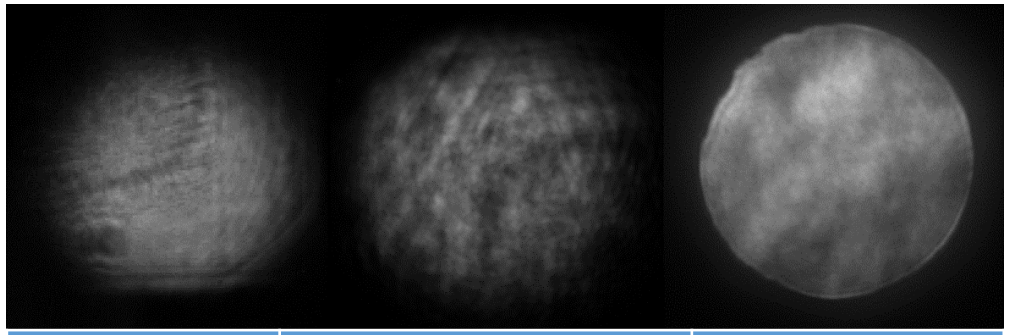
Scheme	HGHG-HGHG/ EEHG-HGHG	EEHG
Harmonics	6 × 5	30
FEL wavelength (nm)	8.8	8.8
FEL pulse length (fs)	< 100fs	< 100fs
FEL power (MW)	>100	>100

Milestones

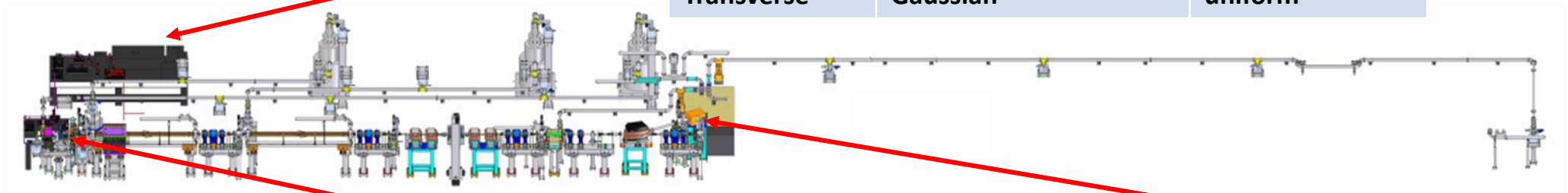
- 2007.7: Proposal submitted
- 2011.2: Approved by the national government
- 2014.4: PDR approval with budget planning
- 2014.12: Groundbreaking
- 2016.6: Building and utility system delivered to users
- 2016.9: Installation started
- 2016.12: first light observed

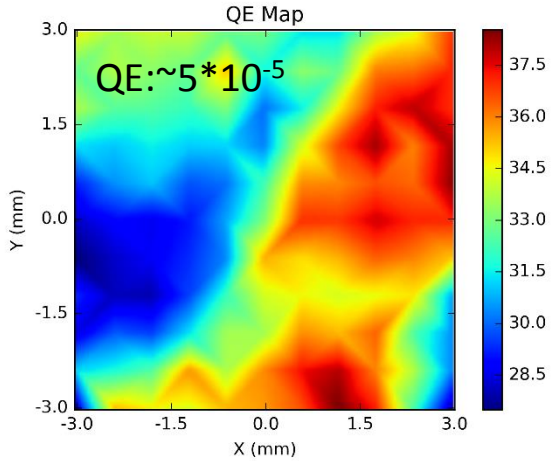


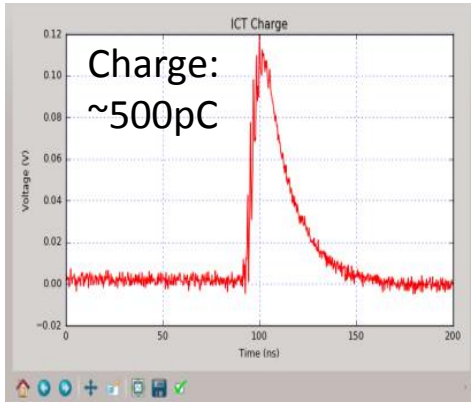


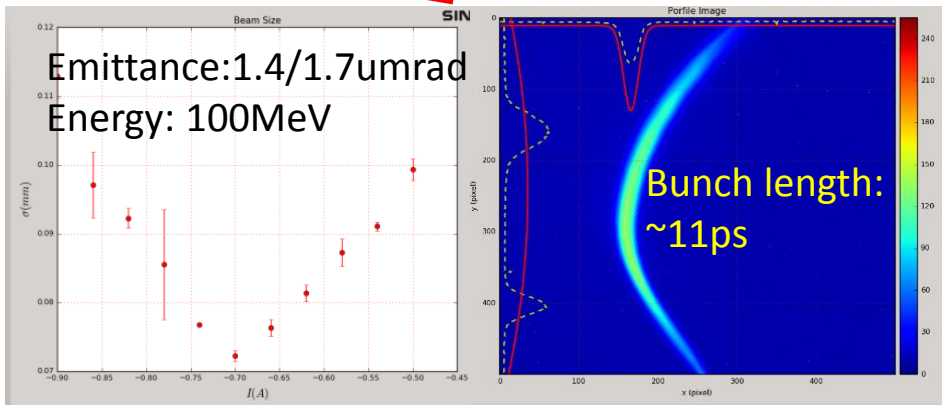


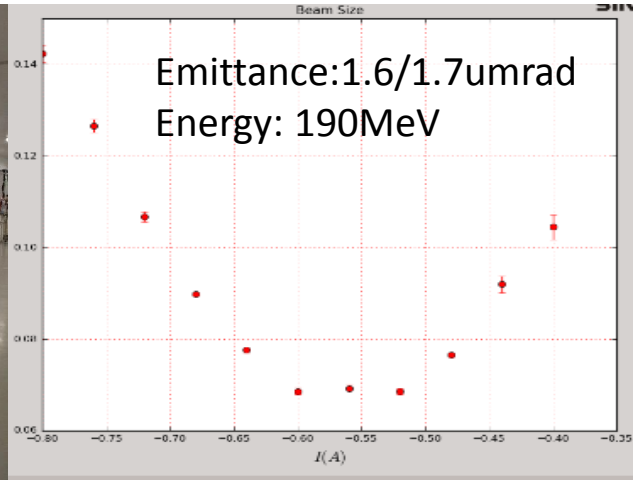
	spectra physics laser	Cathode
Pulse energy	>500uJ@266nm	>50uJ@266nm
Longitudinal	300fs(Gaussian)	~9ps(FWHM)
Transverse	Gaussian	uniform

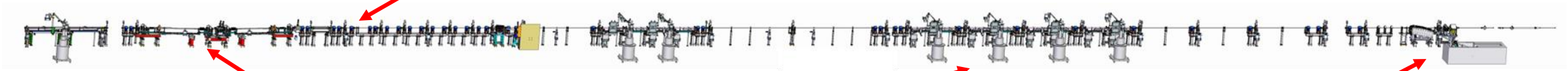


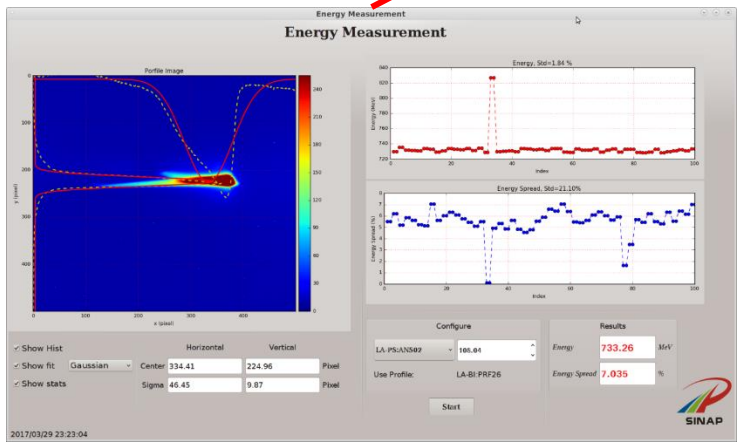




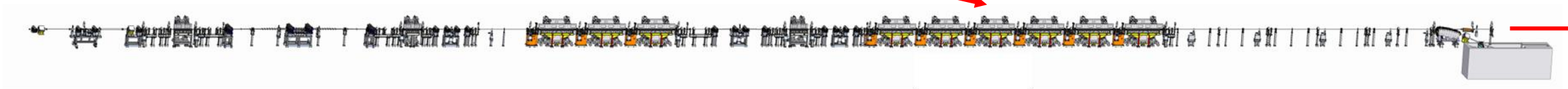


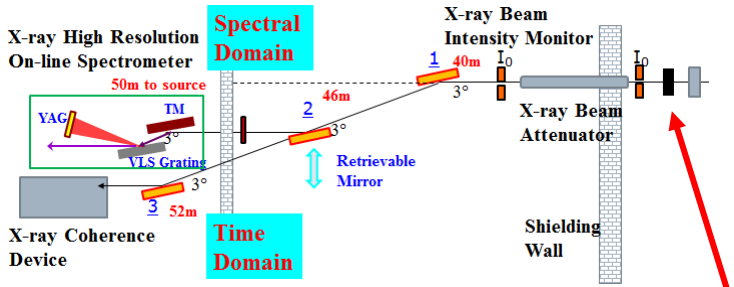


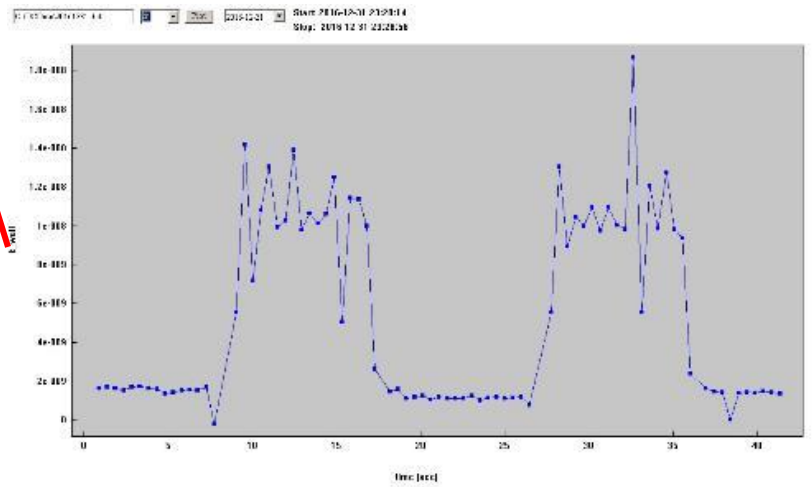




Energy: ~700MeV,
limited by C band TWS gradient



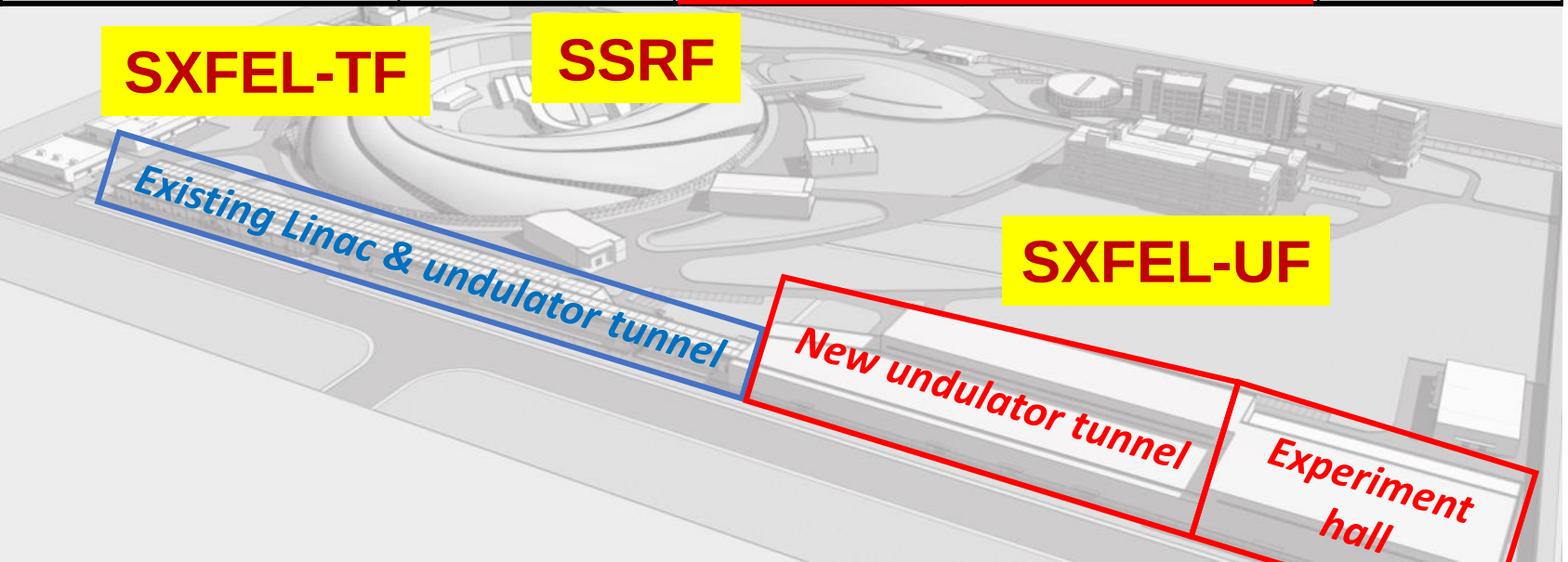

X-ray High Resolution
On-line Spectrometer
Spectral
Domain
50m to source
YAG
TM
VLS Grating
3°
2
46m
3°
1
40m
3°
X-ray Beam
Intensity Monitor
X-ray Beam
Attenuator
Retrievable
Mirror
3
52m
3°
X-ray Coherence
Device
Time
Domain
Shielding
Wall



Shanghai X-ray Free Electron Laser User Facility

Shanghai X-ray Free Electron Laser User Facility

Parameters	Test Facility	User FEL1	User FEL2	Unit
Output Wavelength	9	2~10	1.2-3	nm
FEL scheme	HGHG-EEHG	HGHG-EEHG	SASE, Self-seeding	
Bunch charge	0.5~1	~0.5	~0.2	nC
Beam Energy	0.84	1.0-1.6	1.0-1.6	GeV
Normalized emittance	<2.0	<1.0	<0.5	mm.mrad
Peak current	~0.5	0.7	0.7	kA
Rep. rate	1~10	10-50	10-50	Hz

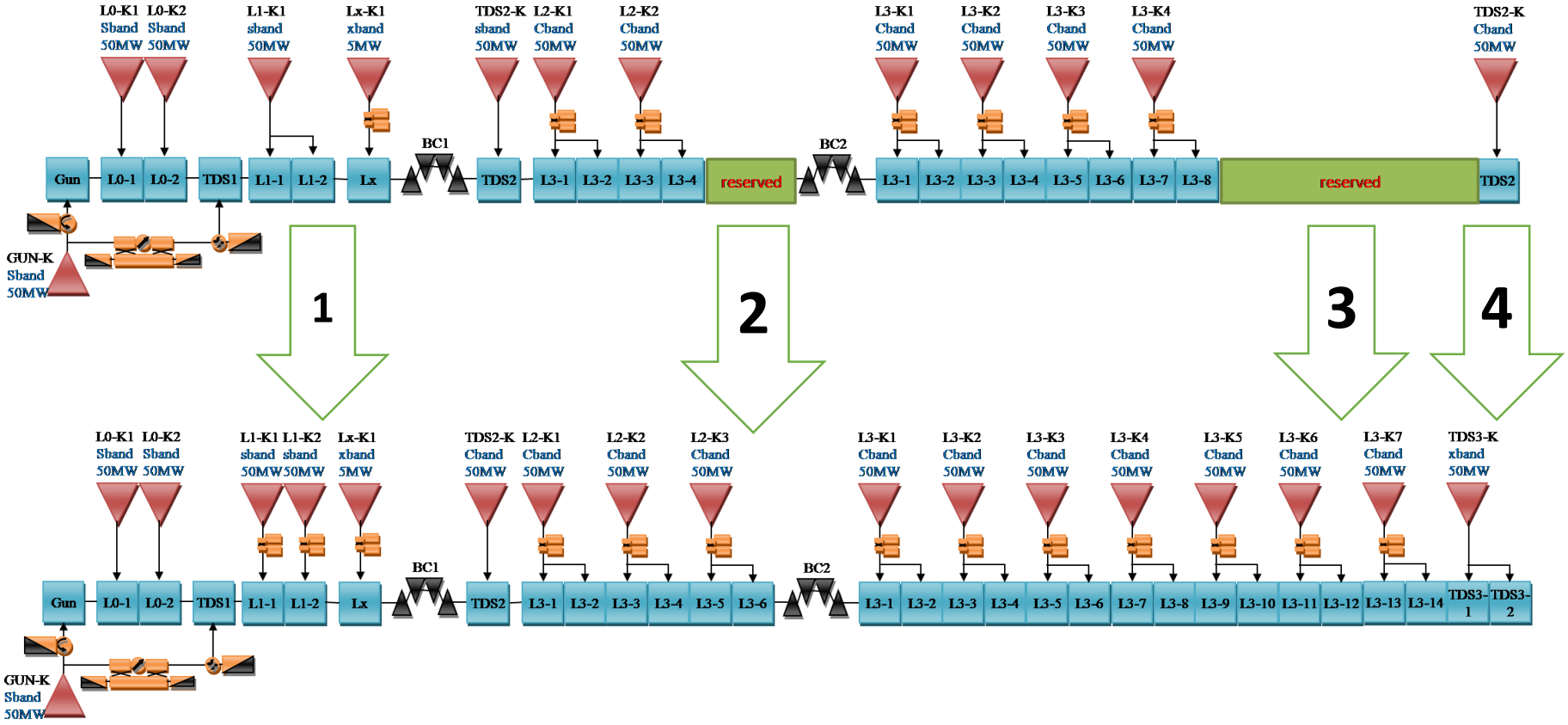


- SXFEL-UF is based on SXFEL-TF:
  - Linac upgrade
  - New FEL lines, a seeded FEL and a SASE FEL
  - 5 experiment stations
- Total budget is 100M$, funded mainly by Shanghai local government
- Construction of the facility started in 2016 and it will be opening to users in 2019

Linac upgrade

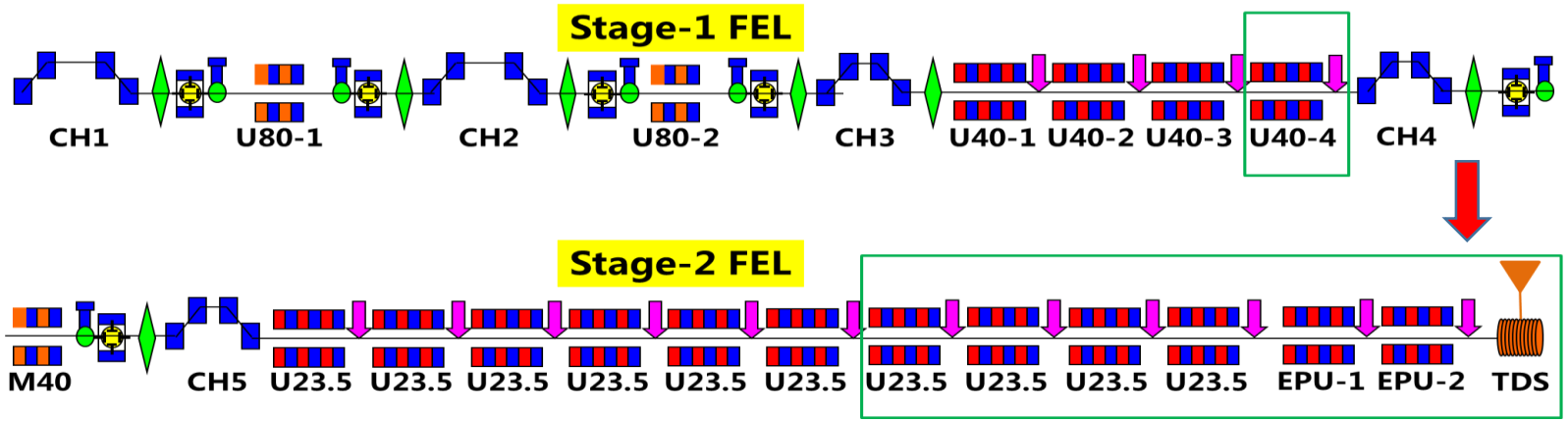
Energy upgrade：

- **1 S-band klystron and 2 SLEDs**
- **1 C-band unit**
- **3 C-band units**
- **1 X-band TDS**

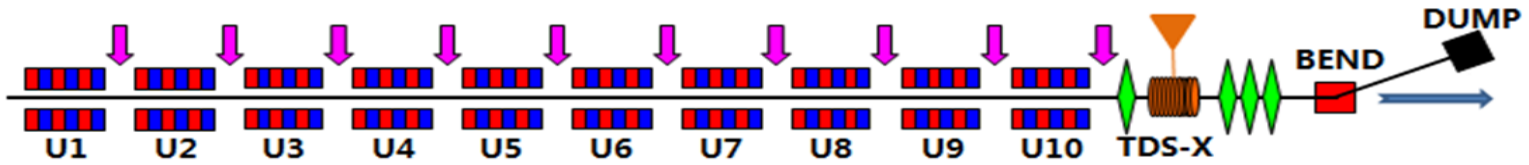


New FEL beamlines

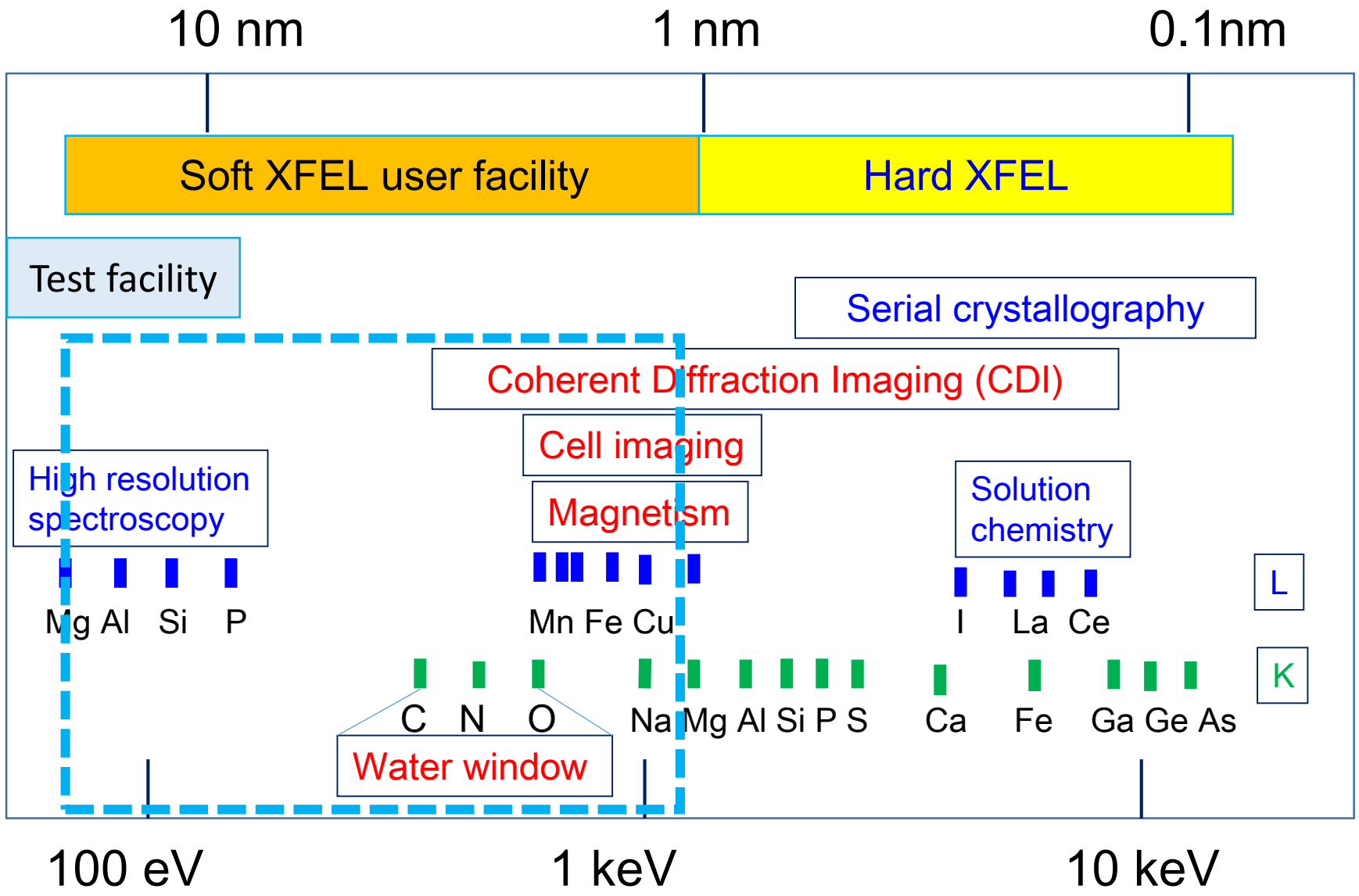
I: Seeded FEL line:
add 7 undulator units



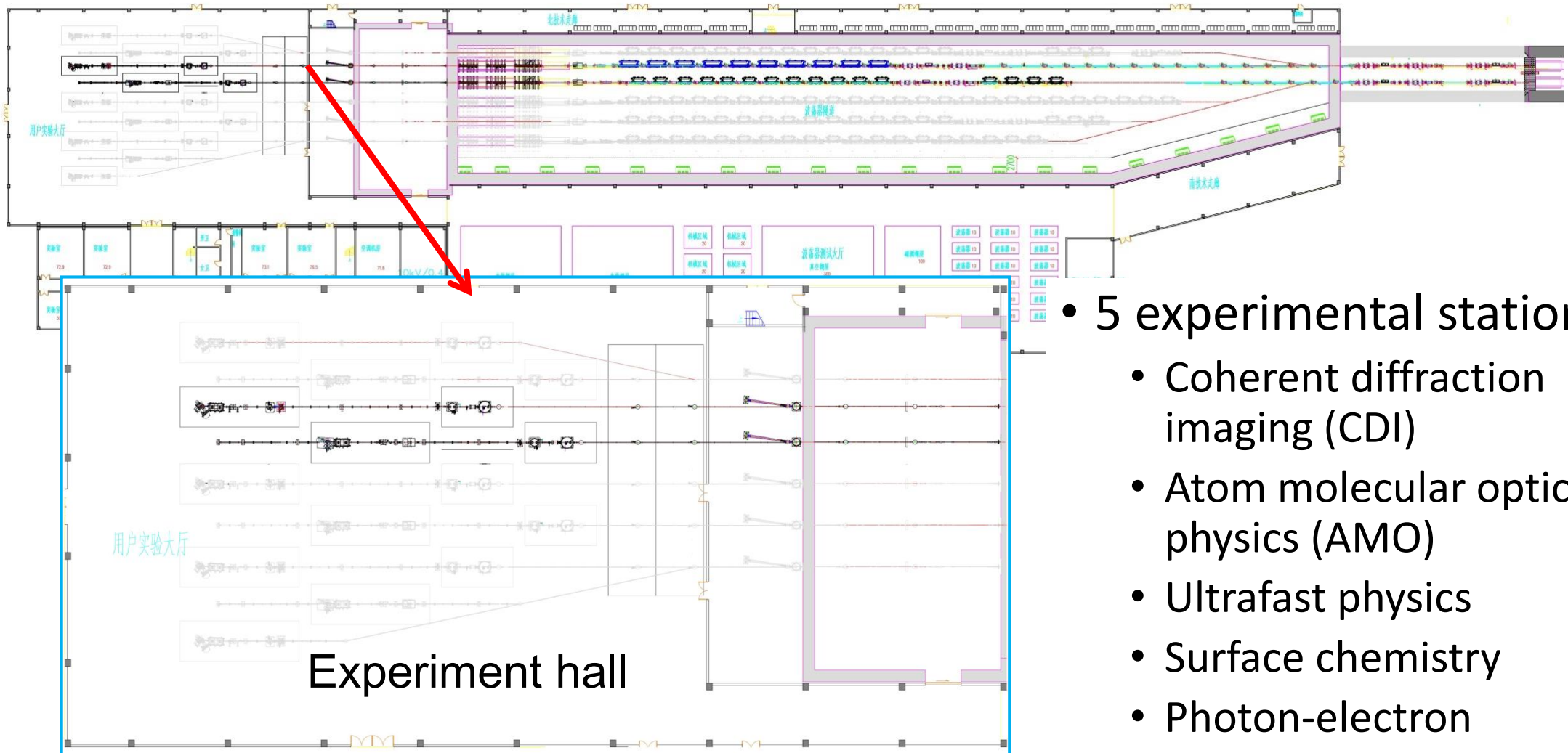
II: SASE FEL line:
10 IVUs



SXFEL-UF is Strongly supported by scientific community



First experiments



- 5 experimental stations:
  - Coherent diffraction imaging (CDI)
  - Atom molecular optical physics (AMO)
  - Ultrafast physics
  - Surface chemistry
  - Photon-electron

Summary

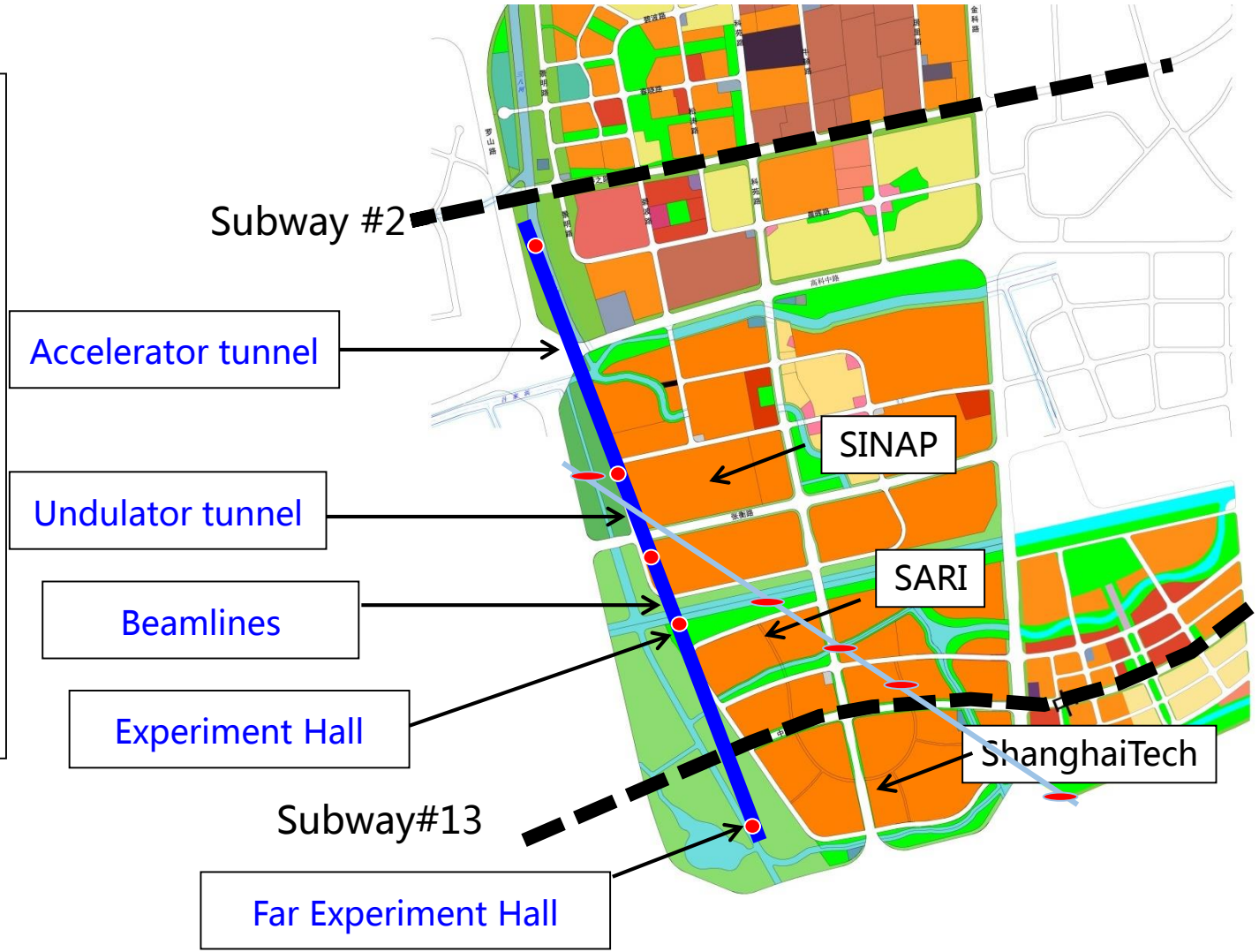
- SINAP involved in all the high gain FEL project in China and built these accelerators and FEL radiators with in-house team and technologies.
- DCLS has reached the end of commissioning. The electron beam and FEL radiation parameters have meted the design requirement. The experimental station now is waiting for the first FEL light.
- SXFEL-TF started the commissioning since end of 2016. The commissioning is difficult and we have found all the reason of the these problems. Some components, like C band TWS have serious problem and the recovery will take lot of effort and time.
- SXFEL-UF started the construction at end of 2016. The schedule seems tight and overlaps with SXFEL-TF, which could affect on both projects.

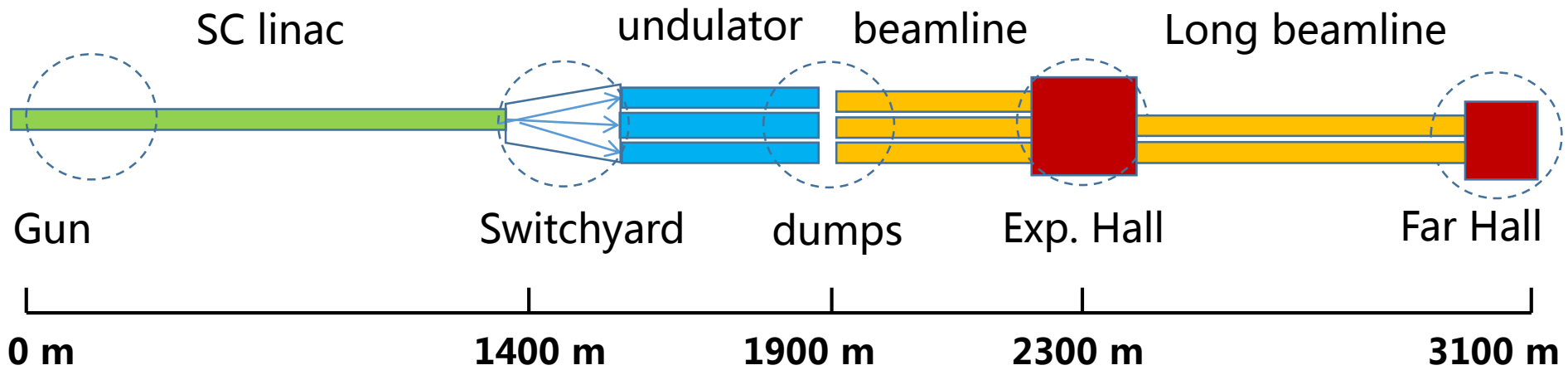
Thanks for your attention
Questions and comments please

Future hard X-ray FEL in SINAP, Shanghai

Hard XFEL

Length ~3km
Tunnel ~40m underground
Linac: ~8GeV
6 FEL undulators
10+ beamlines
Photon E: >12 keV
30+ end-stations




SC linac
undulator
beamline
Long beamline
Gun
Switchyard
dumps
Exp. Hall
Far Hall
0 m
1400 m
1900 m
2300 m
3100 m