



38th International Free-Electron Laser Conference, Santa Fe, USA

Status of the SXFEL Facility (Shanghai Soft X-ray Free-Electron Laser)

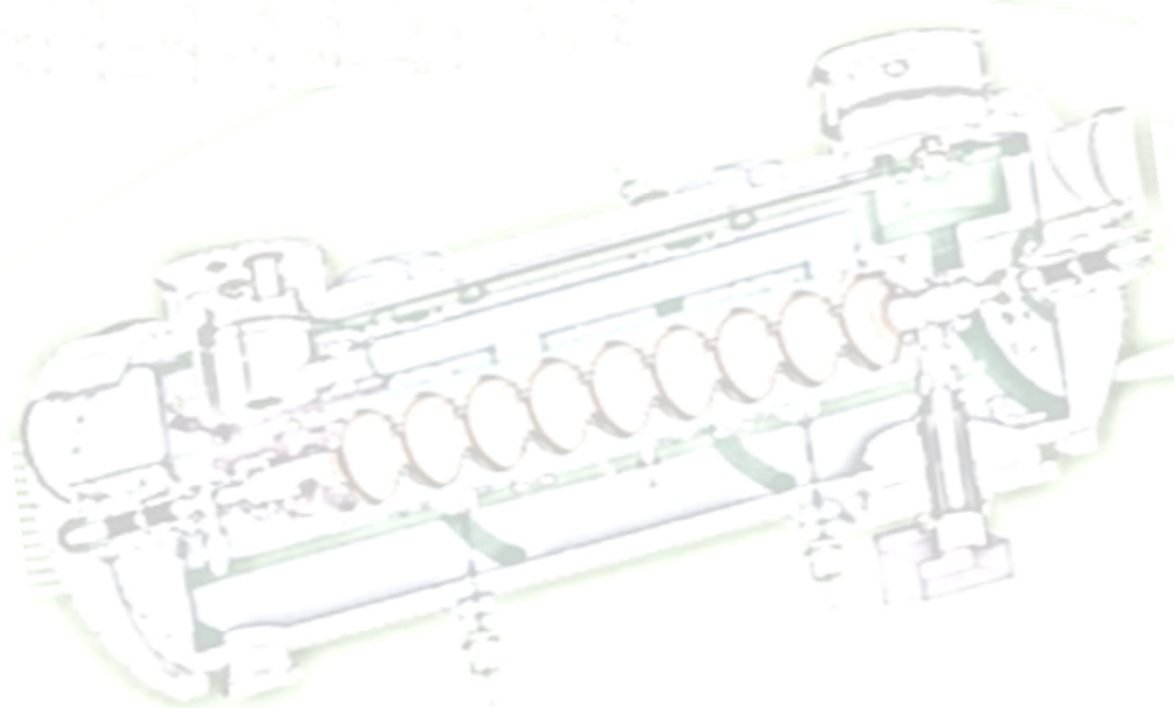
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on behalf of the FEL team@

Shanghai Institute of Applied Physics (SINAP)

Chinese Academy of Sciences (CAS)

2017.08.21



SXFEL at SINAP



SINAP : a photon science center in Shanghai

Shanghai Soft X-ray Free-Electron Laser
SXFEL

SSRF

3.5 GeV 3rd gen. light source
open since 2009, over 10000 users
13 beamlines in operation
20+ to come in 2016-2022

SXFEL: Project Scope



‘phased’ project

■ 1. SXFEL Test Facility (SXFEL-TF)

- Schedule: 2014.12 - 2017.12, under commissioning
- Budget: \$35M
- Design goals: ~300m tunnel, 840 MeV linac, 8.8nm seeded FEL
- Source: national funding agency

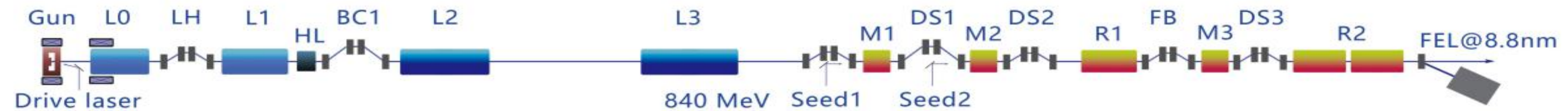
■ 2. SXFEL User Facility (SXFEL-UF)

- Schedule: 2016.10 - 2019.03, under construction
- Budget: ~\$110M
- Design goals: add 250mx50m FEL and experiment halls,
upgrade to 1.5 GeV, 2 FEL lines, 5 end-stations
- Source: local and national funding agencies

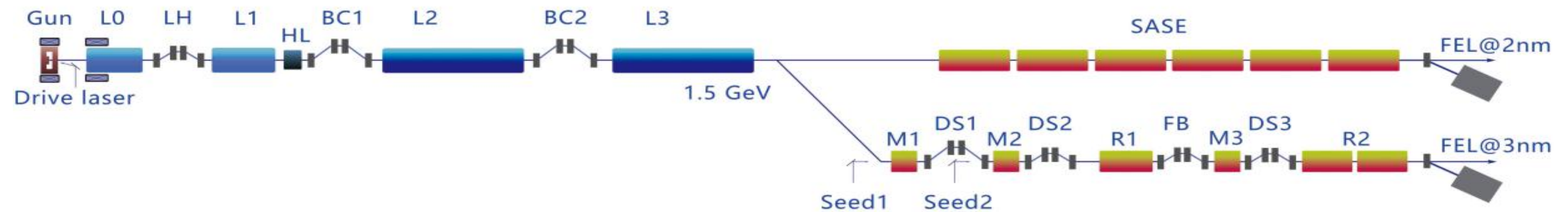
Parameters of SXFEL-TF & SXFEL-UF



SXFEL-TF



SXFEL-UF



Main Parameters	SXFEL-TF	SXFEL-UF
Beam Energy (GeV)	0.84	1.5
Norm. Emit. (mm·mrad , rms)	≤ 2	≤ 1.5
Bunch Charge (nC)	0.5	0.5
Peak Current (A)	≥ 500	≥ 700
Rep. Rate (Hz)	10	50
FEL Output (nm)	~ 8.8	$\sim 2-3$
FEL Output Peak Power (MW)	≥ 100	≥ 100

Goals of the Test Facility



- Prototype for (hard) X-ray FEL user facility
 - key technologies and components
- Novel XFEL principle/operation-mode researches
 - mainly seeded FEL (HGHG, EEHG, cascade, etc.)
- As part of FEL user facility

Civil construction of SXFEL-TF



2014.12.30, Ground breaking



2015.6



2015.10



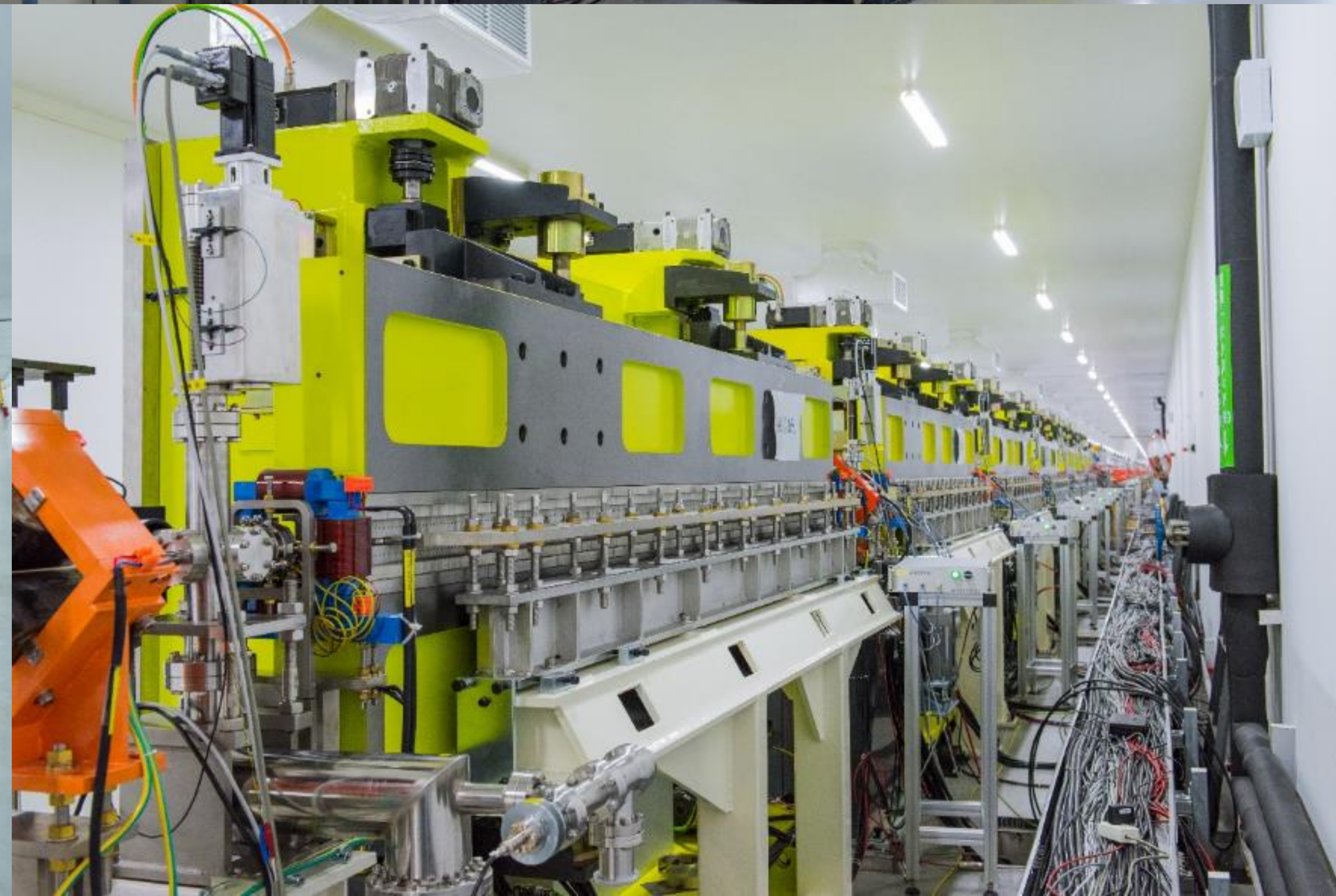
2015.12.30



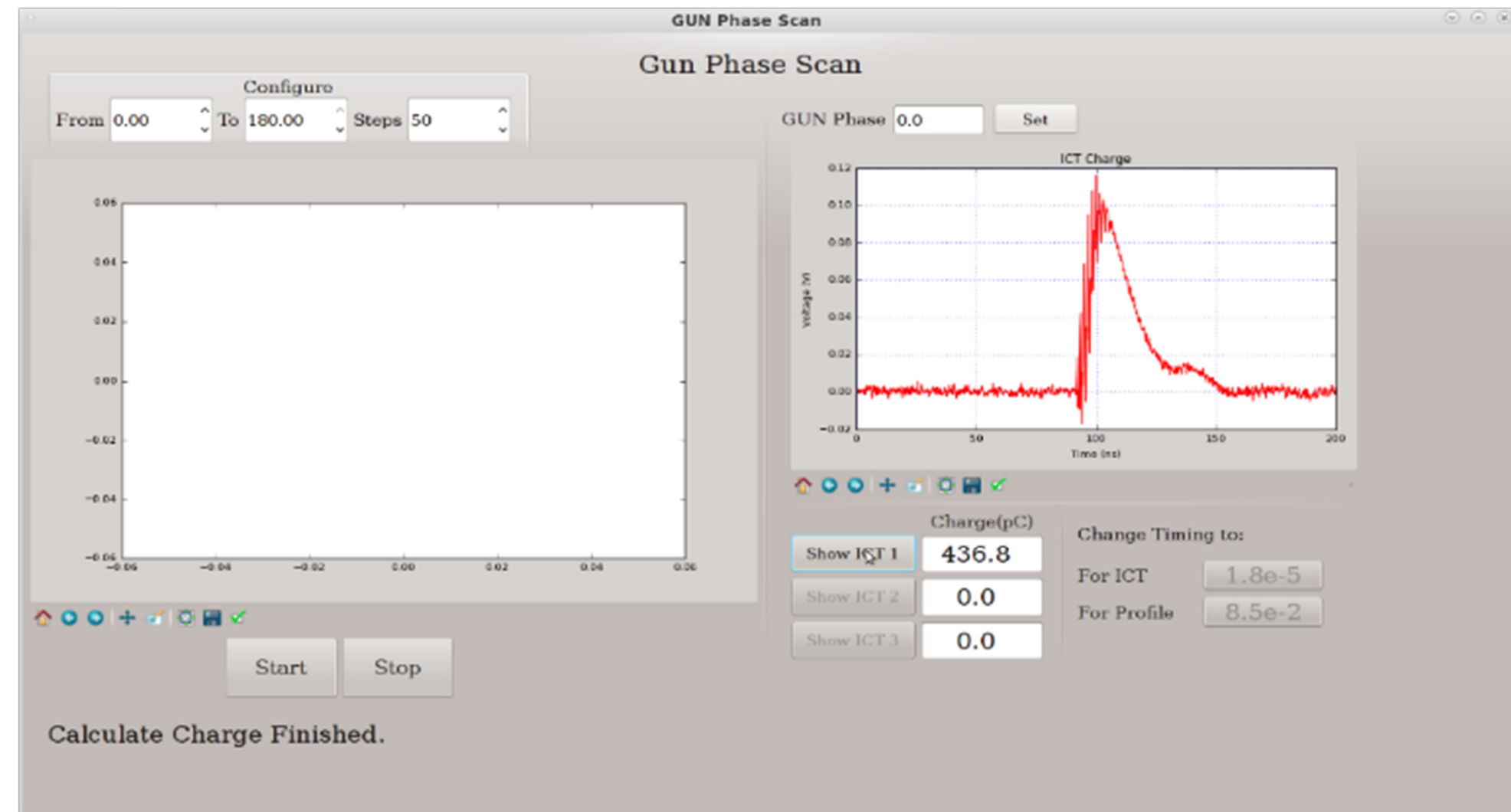
SXFEL-TF Tunnel completion, 2016.4



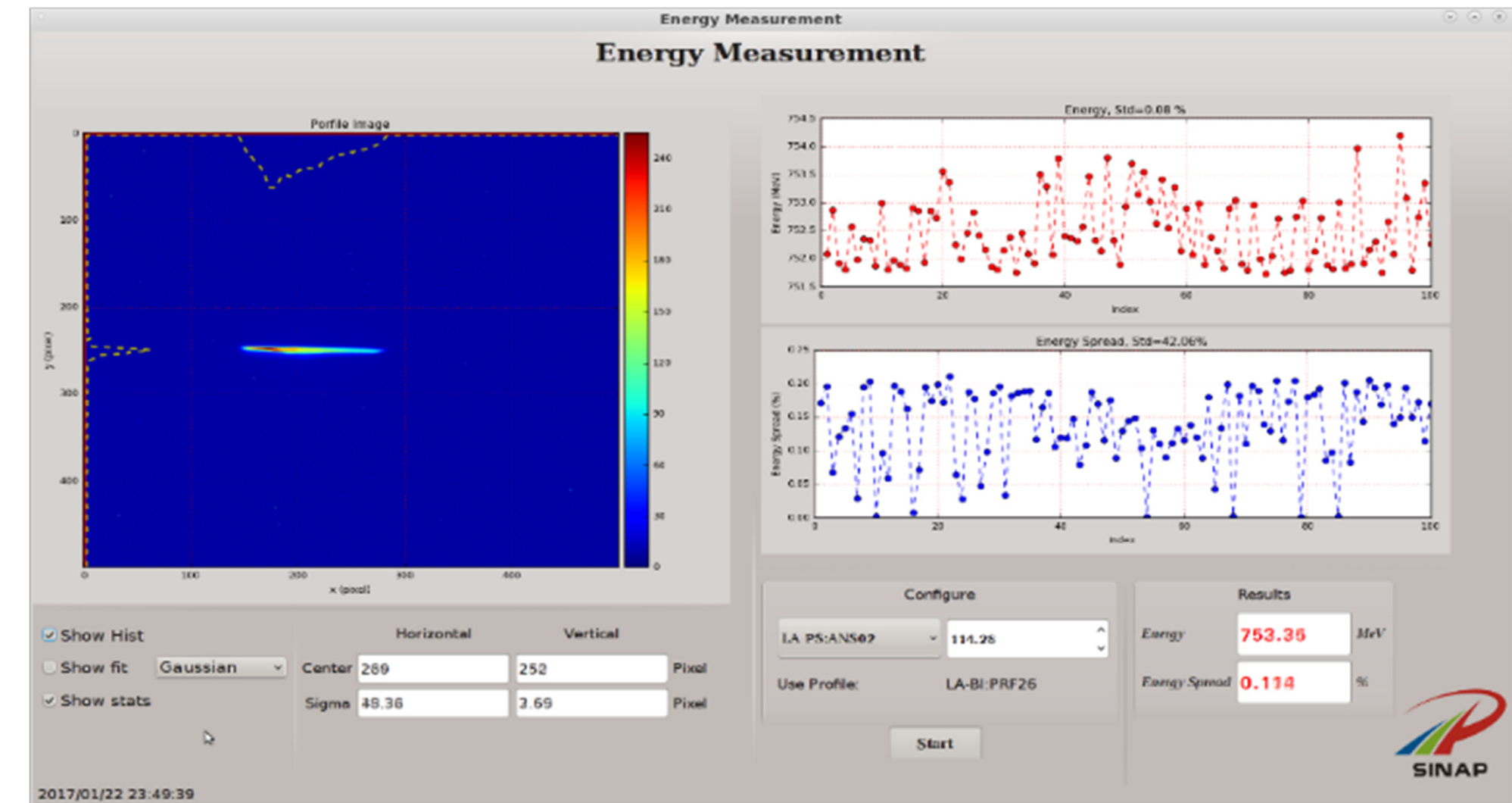
SXFEL-TF installation



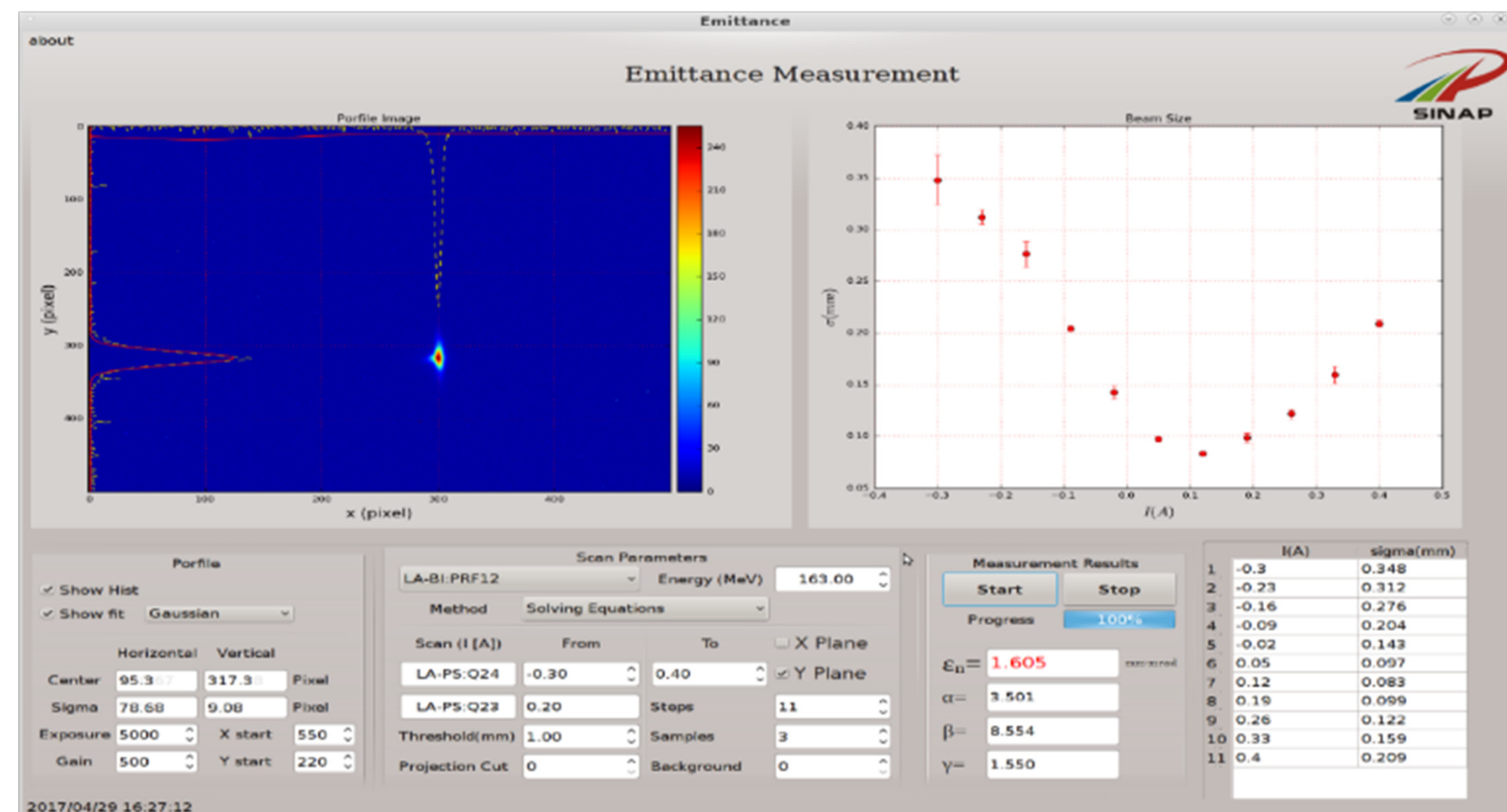
SXFEL-TF commissioning



Typical charge measurement



Typical energy measurement



Typical emittance measurement

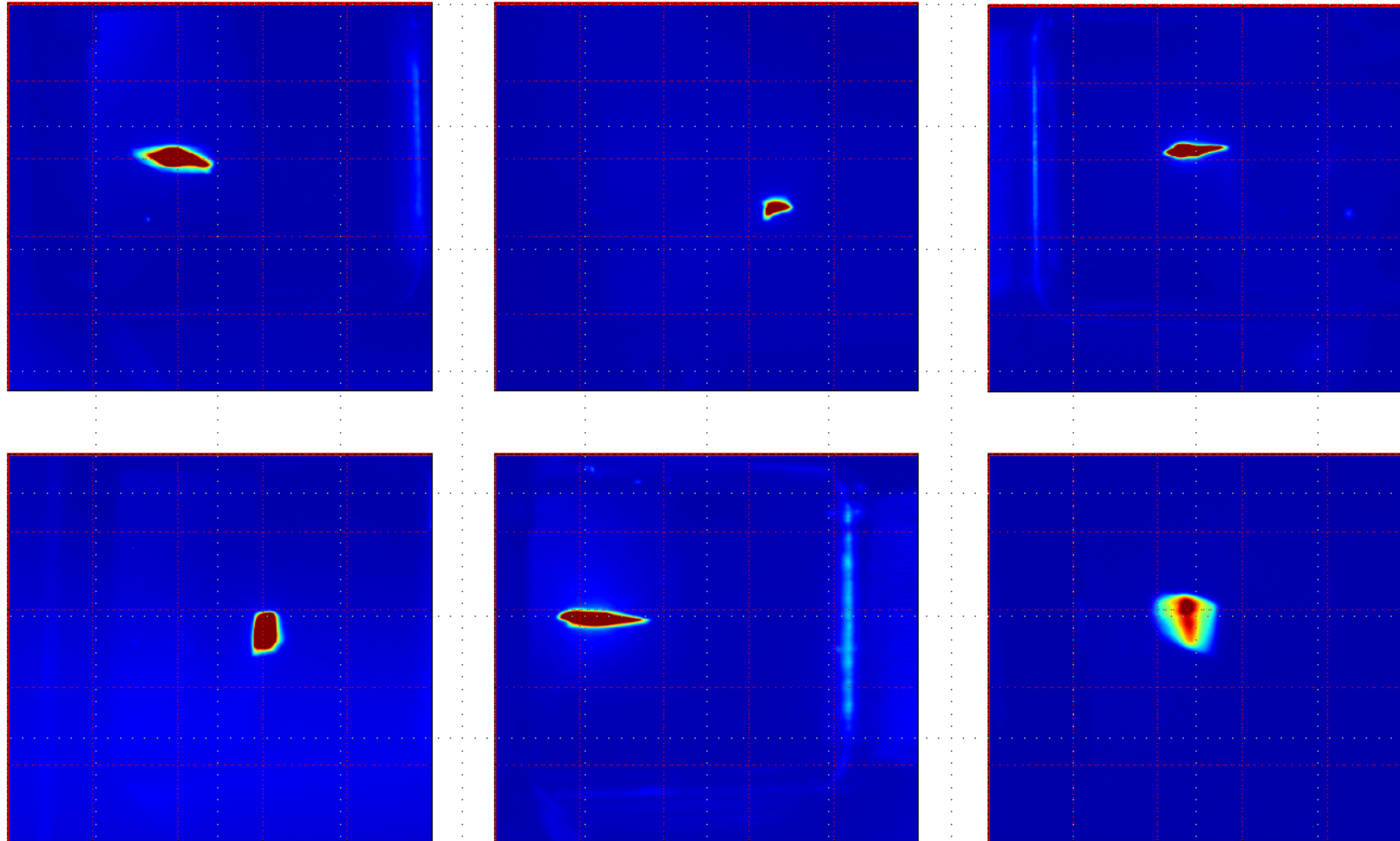
Beam parameters achieved during commissioning

- Bunch Charge: 100-500 pC
- Beam Energy: 400-650(/750) MeV
- Energy Spread: $\sim 0.1\%$
- Normalized Emittance: $\sim 1.5 \text{ mm} \cdot \text{mrad}$

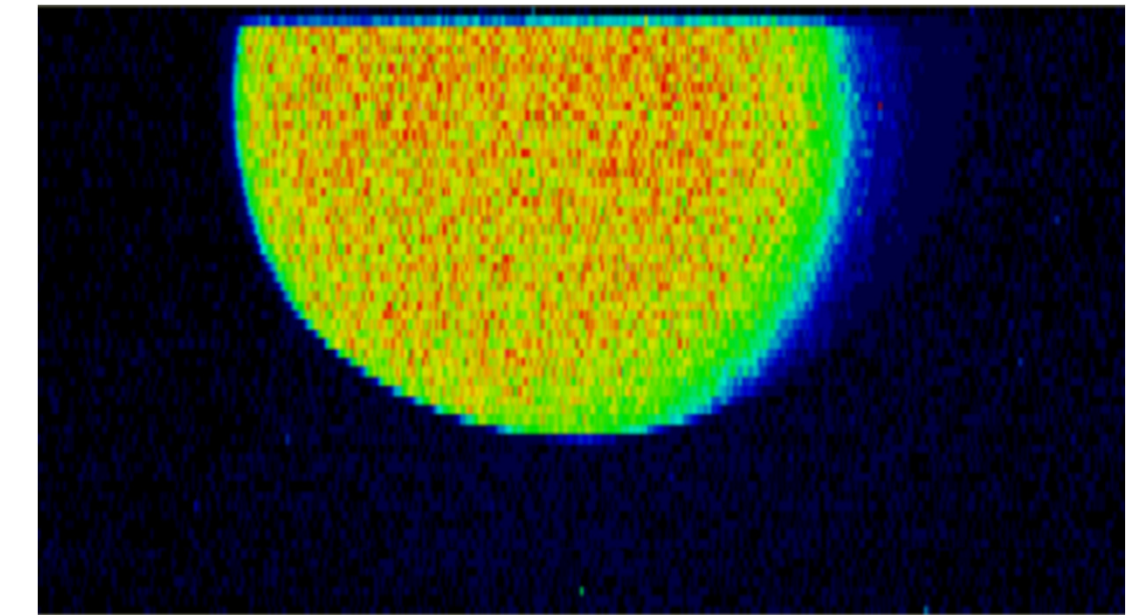
Main problems:

- Vacuum pollution / RF conditioning
- No linearizer

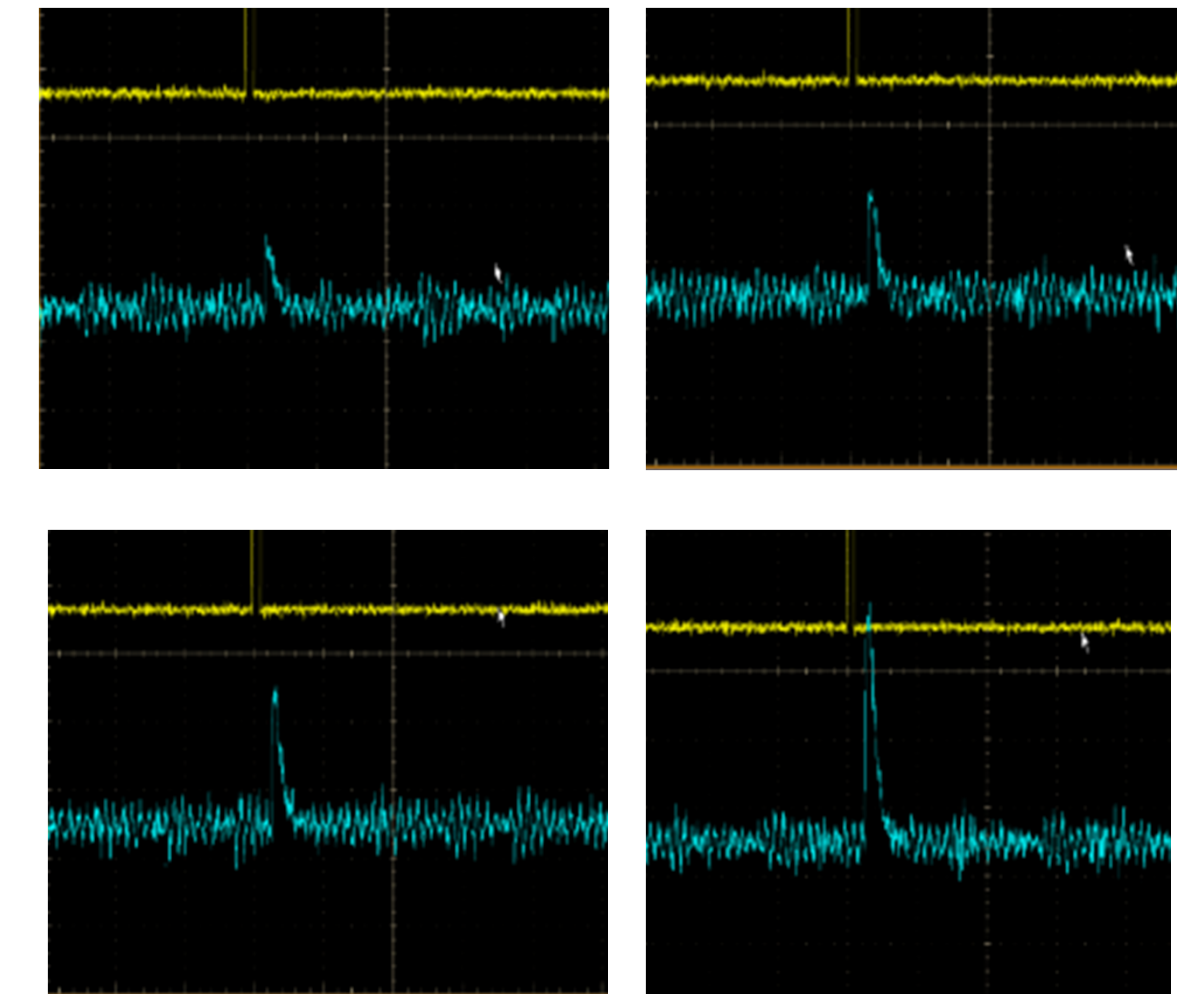
SXFEL-TF commissioning



Electron beam profile after each radiation undulator



Undulator radiation (X-ray CCD)



Undulator radiation (PD)

SXFEL-TF commissioning



First stage HGHG

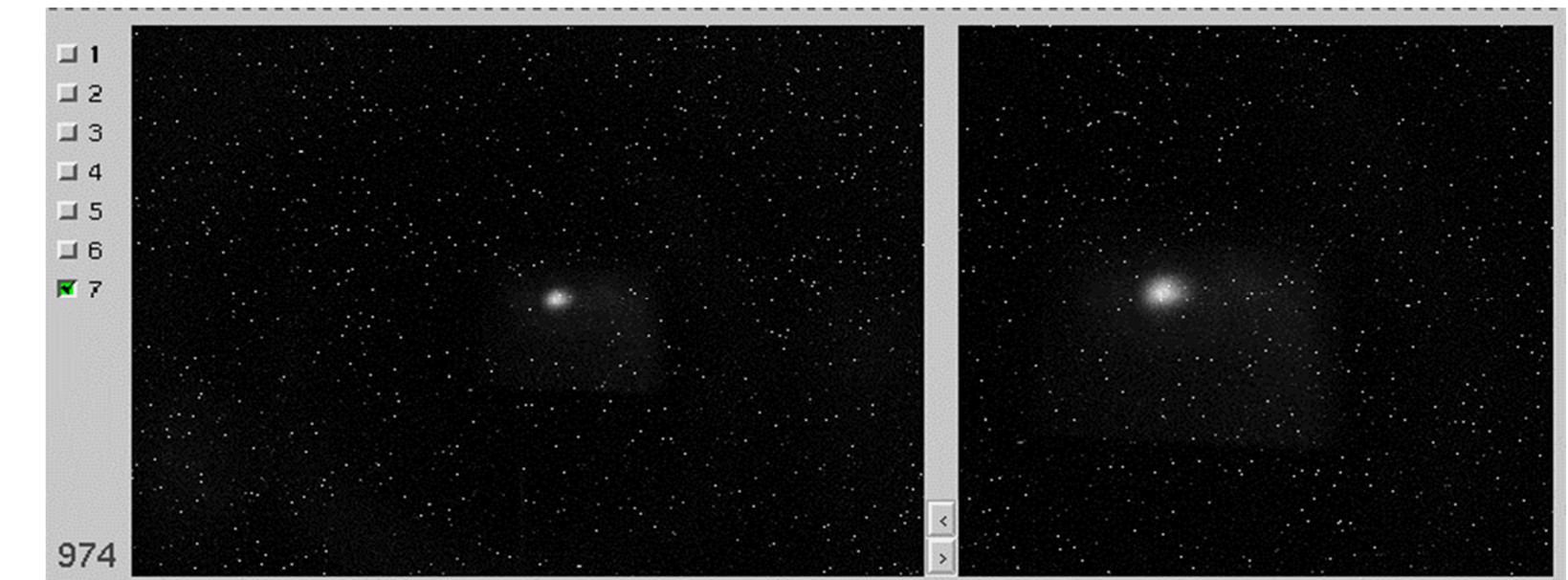
Bunch charge: 250 pC

Bunch length: ~4.5 ps (FWHM)

Electron energy: 480 MeV



4th harmonic@66nm



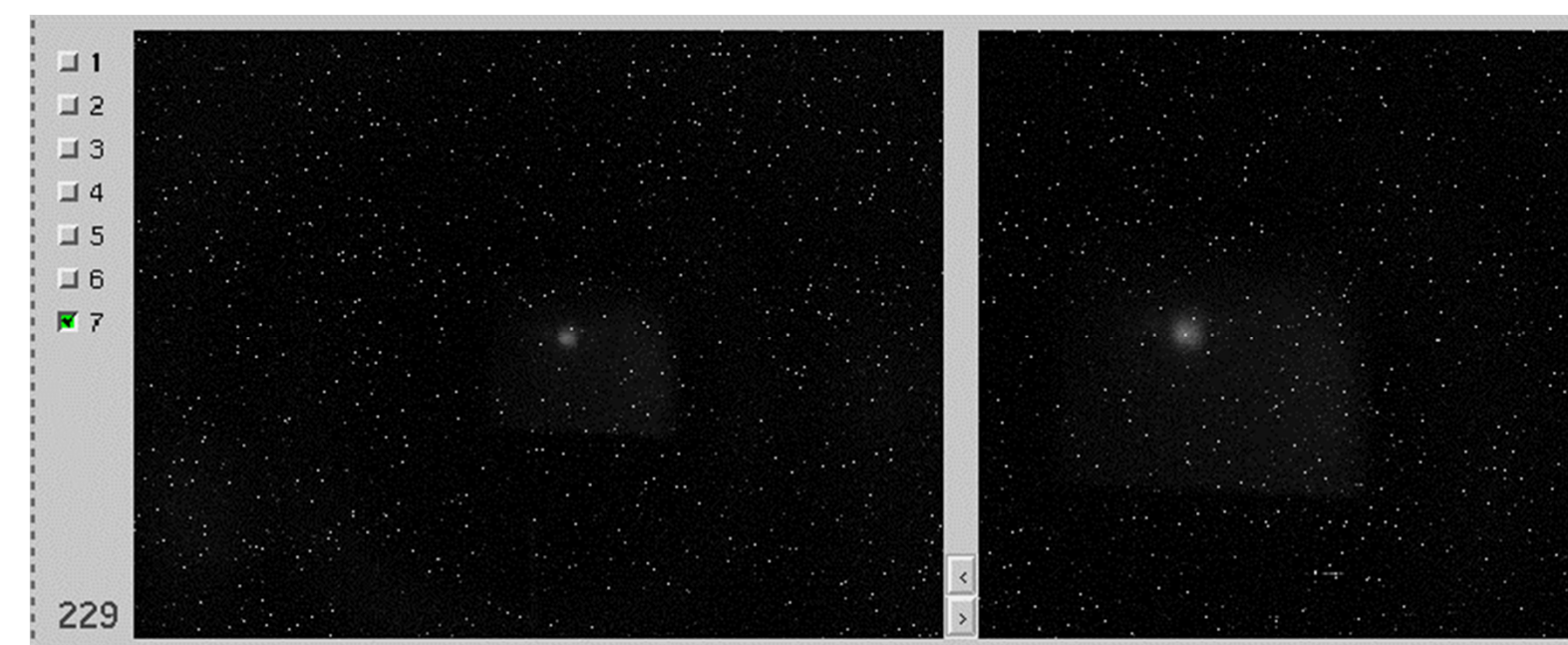
5th harmonic@53nm



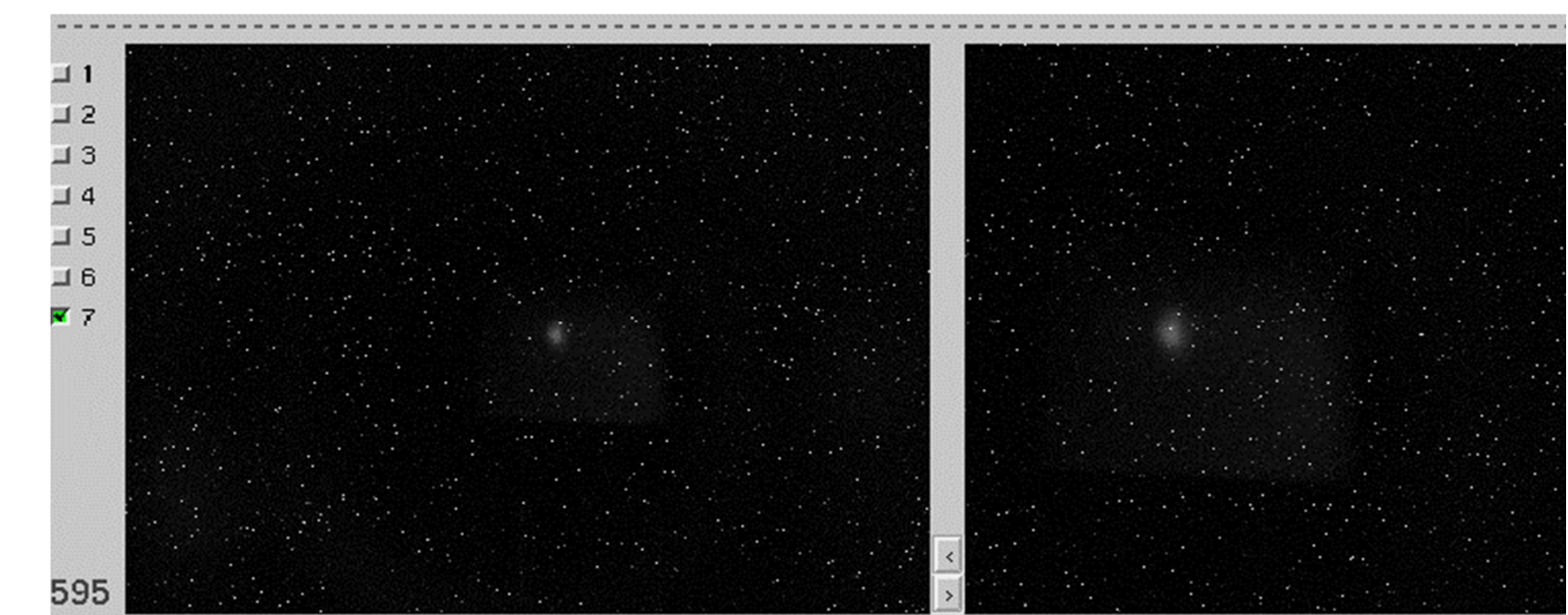
6th harmonic@44nm



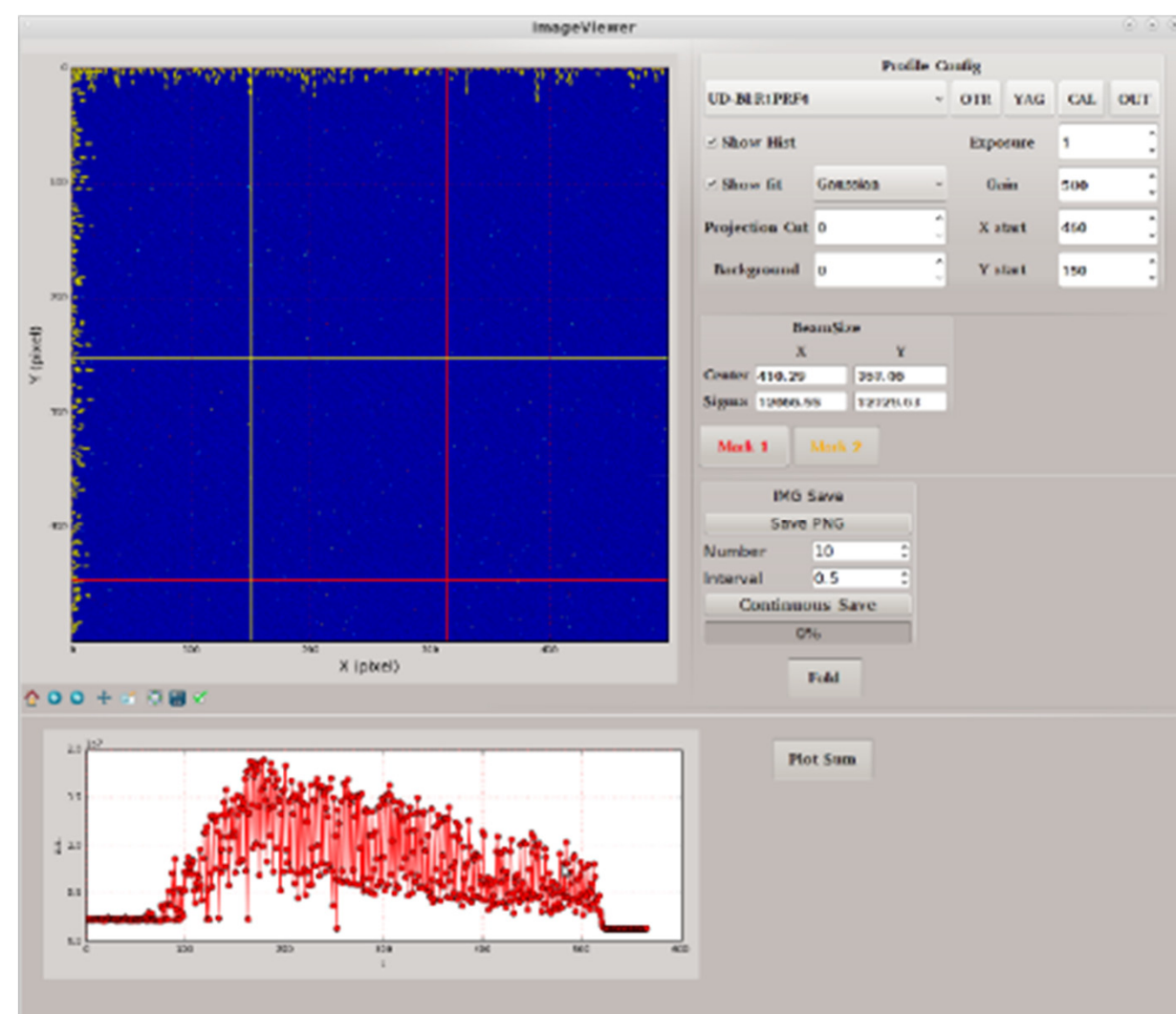
6th harmonic@44nm



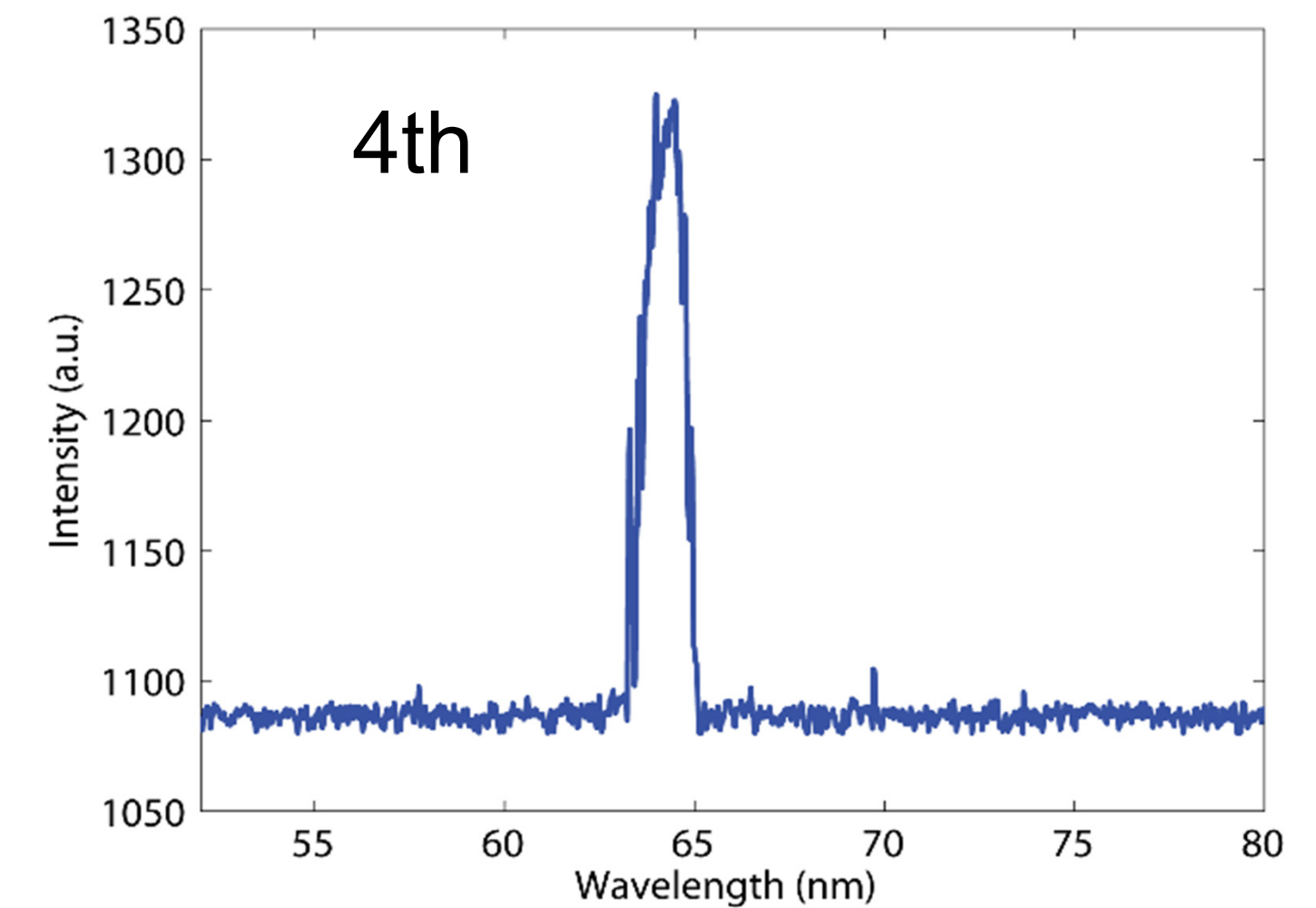
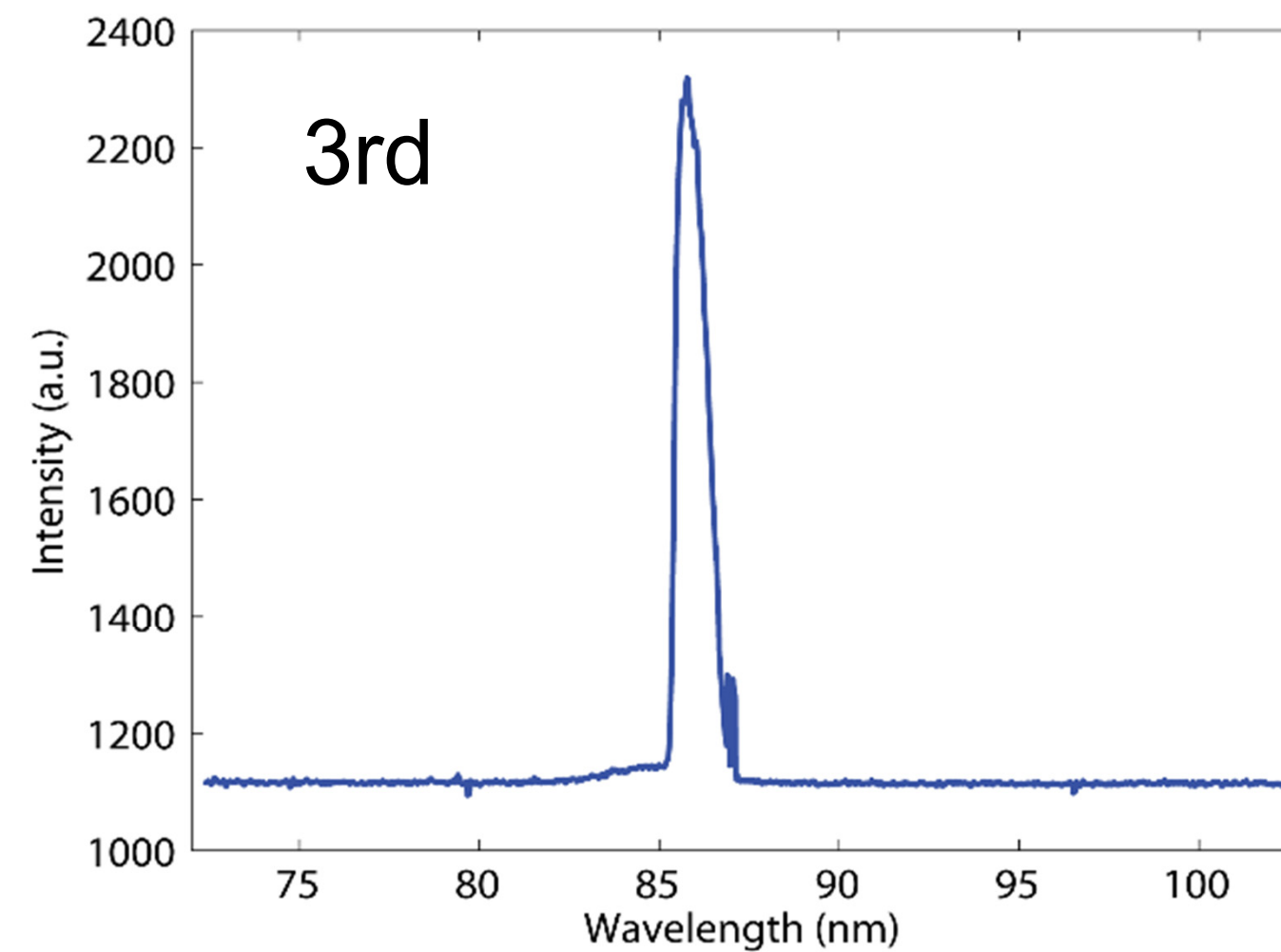
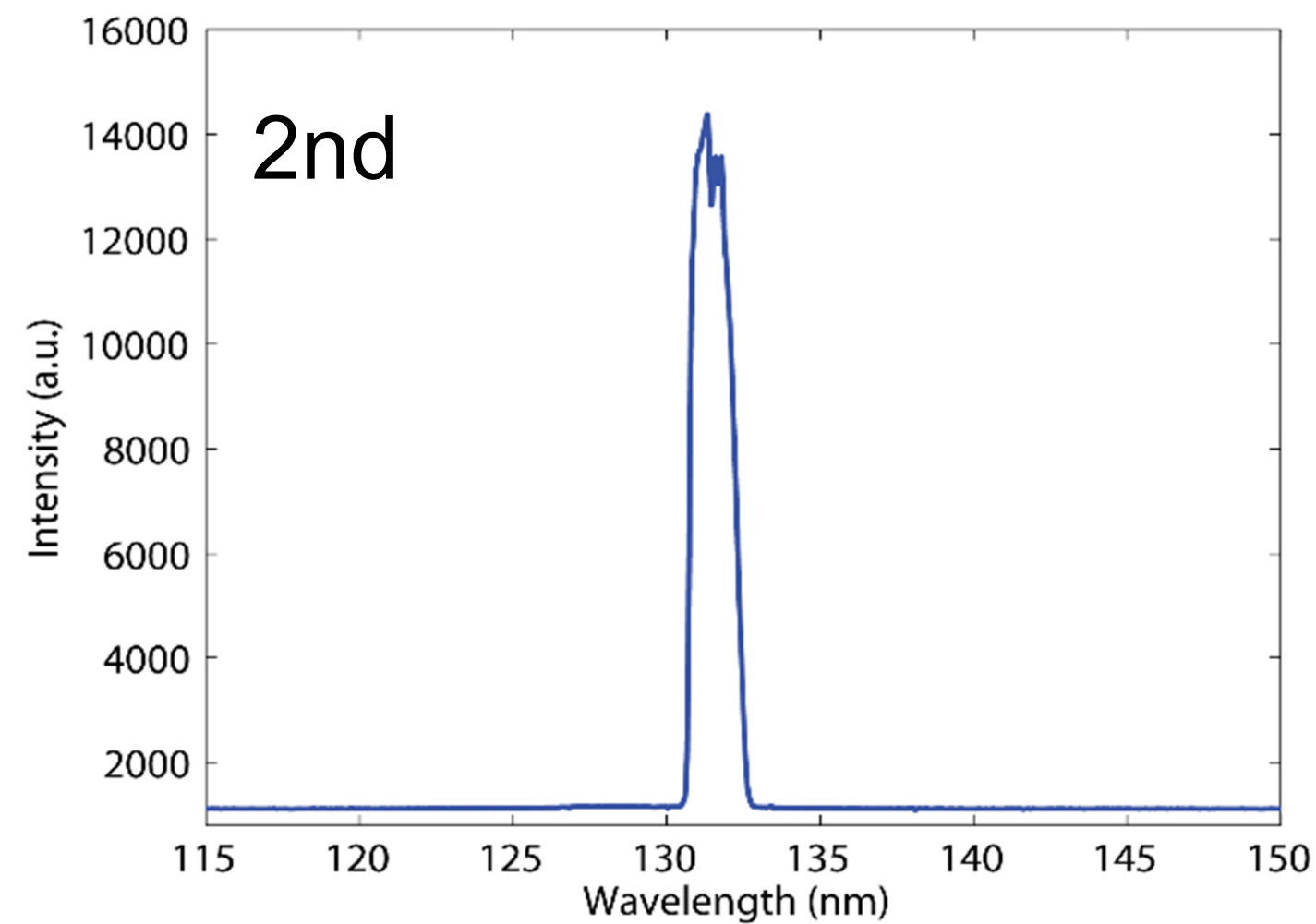
7th harmonic@38nm



8th harmonic@33nm

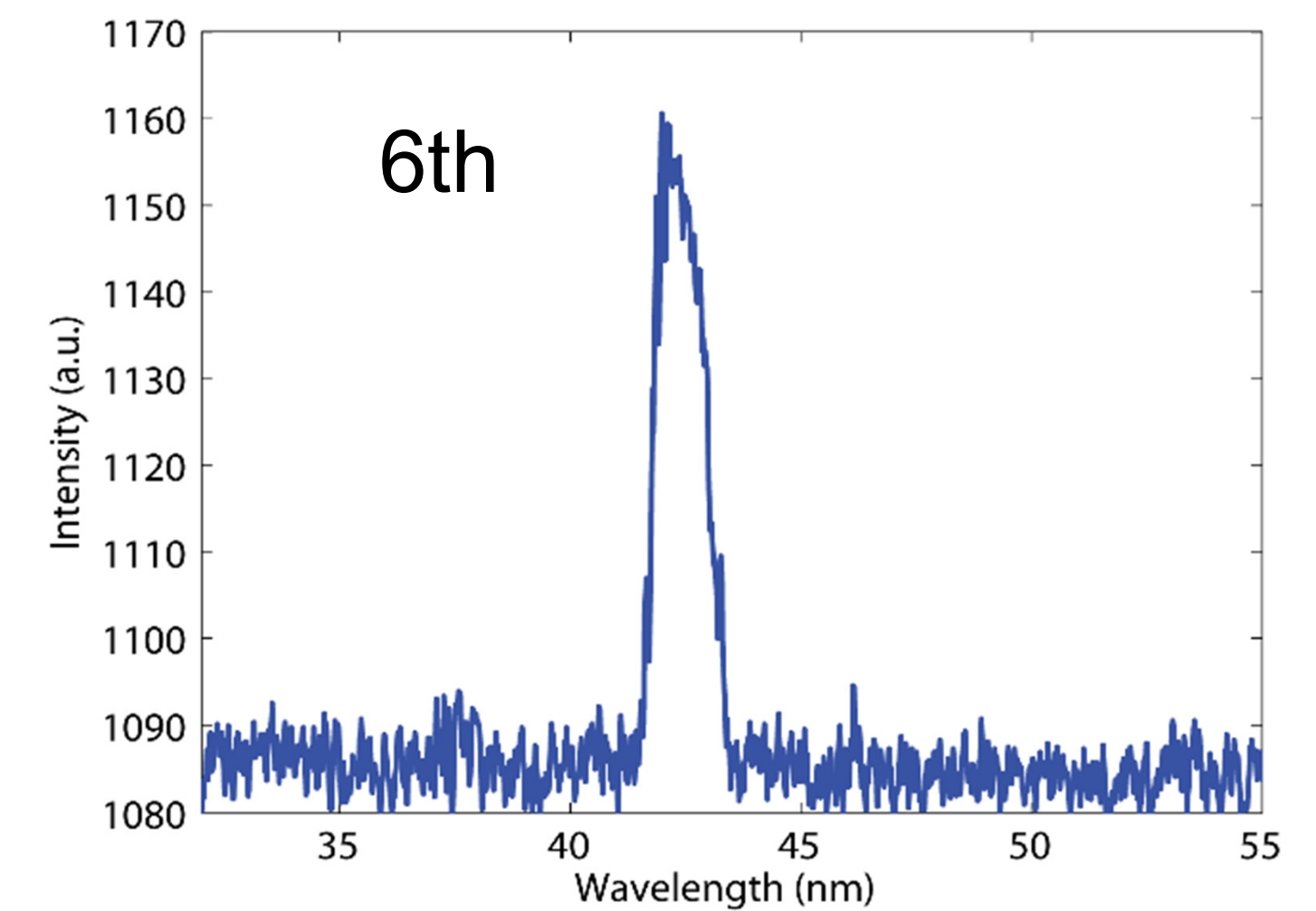
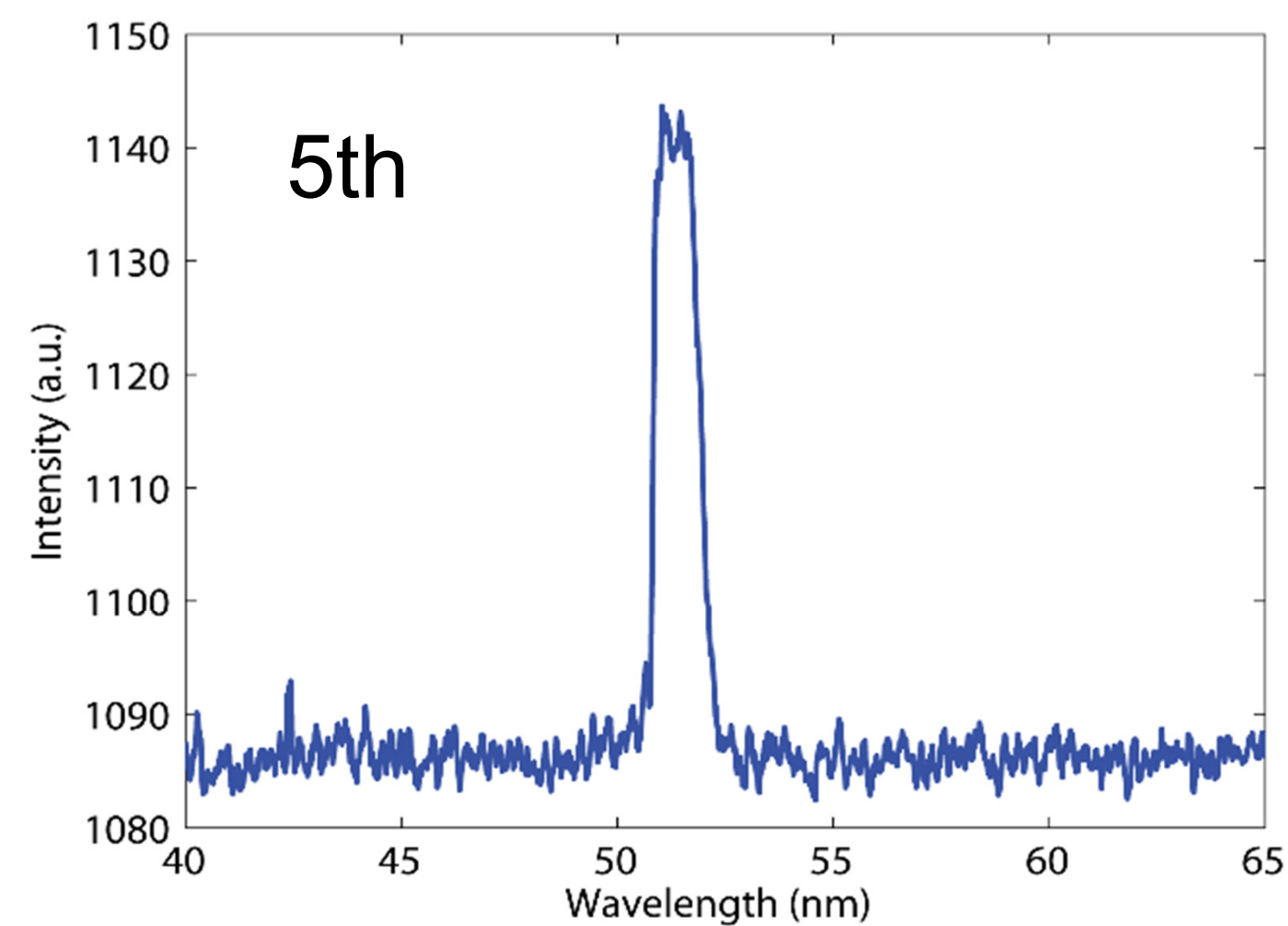


SXFEL-TF commissioning



Spectrum of the first stage
HG HG radiation

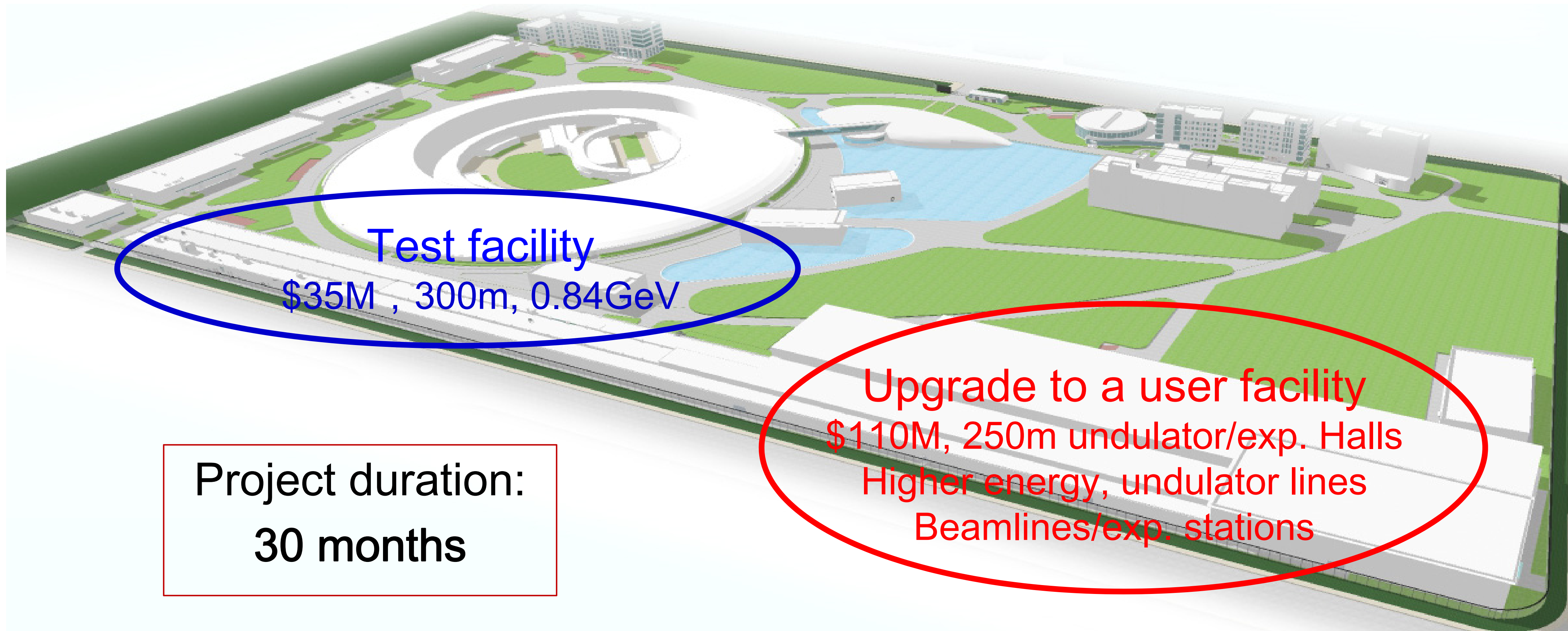
- Seed laser @ 260 nm
- Beam energy @ 630 MeV
- Bunch charge @ 300 pC



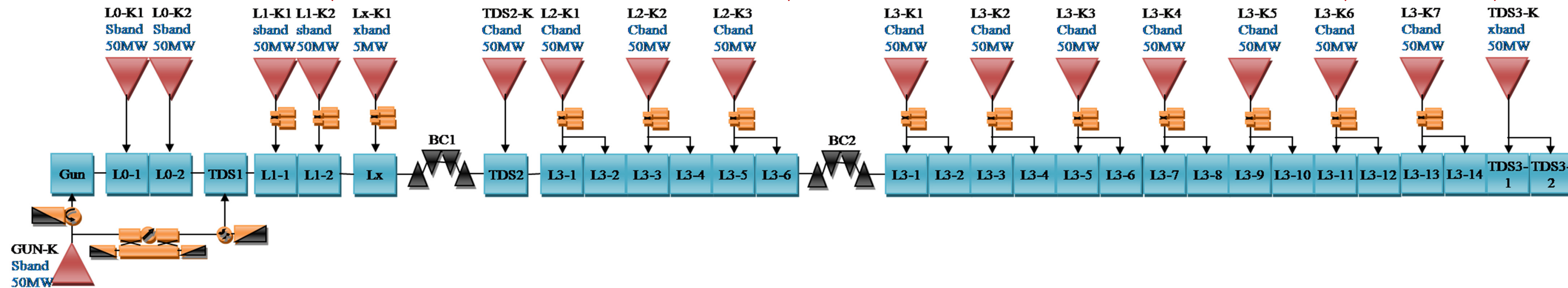
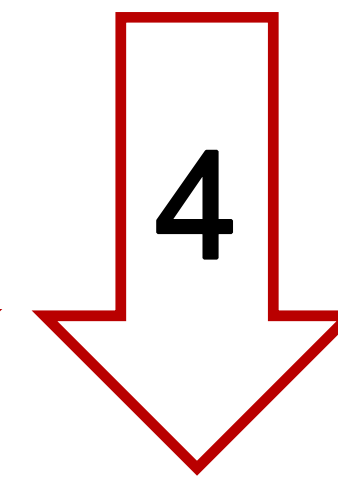
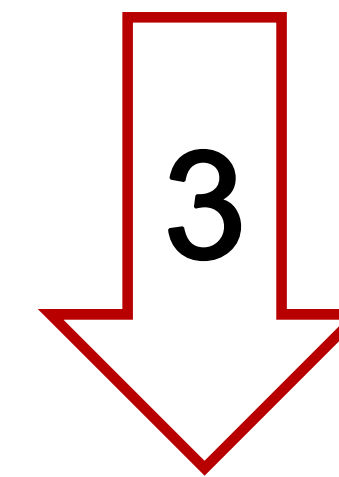
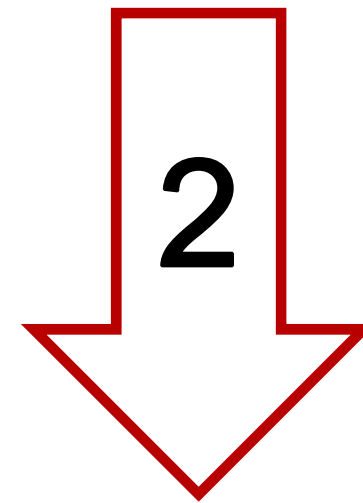
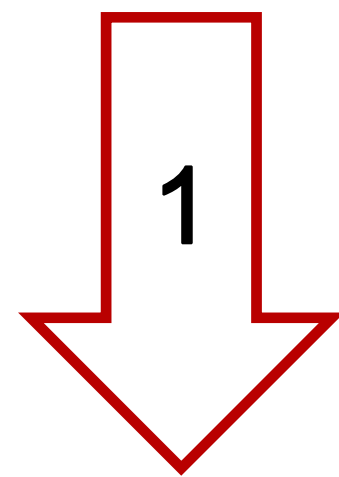
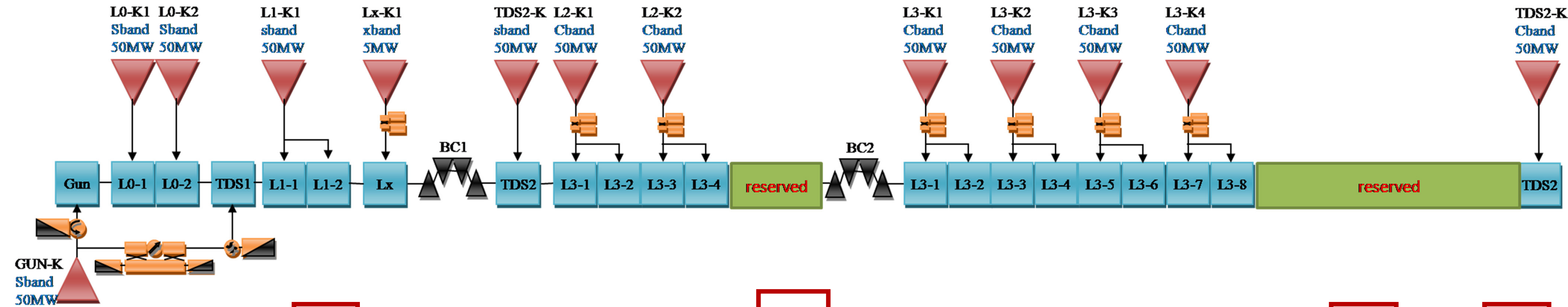
SXFEL User Facility: 2016-2019



- New funding for upgrading to user facility with \$110M.
- Build undulator/experimental halls and increase beam energy.
- Jointly with Shanghai Tech Uni.(mainly responsible for user stations)



SXFEL-UF: Linac energy upgrade



Goal:

- 500pC
- 1.5mm-mrad
- 1.5GeV
- 700A
- 50Hz

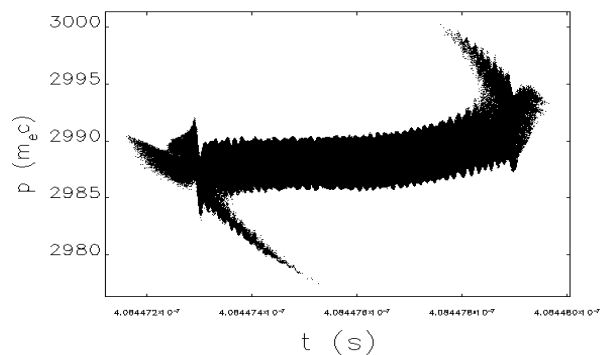
Adding:

1) 1 S-band klystron and
2 SLEDs

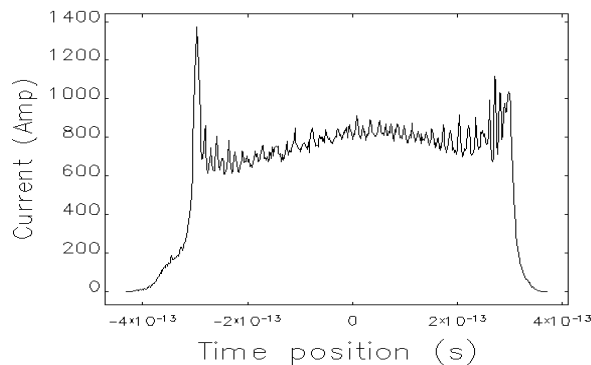
2) 1 C-band RF unit
3) 3 C-band RF units

4) 1 X-band deflecting
structure

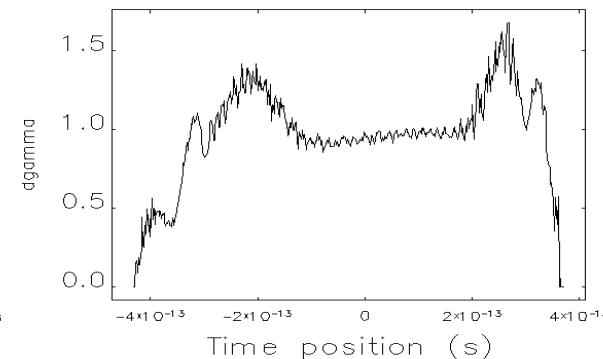
SXFEL-UF: Linac



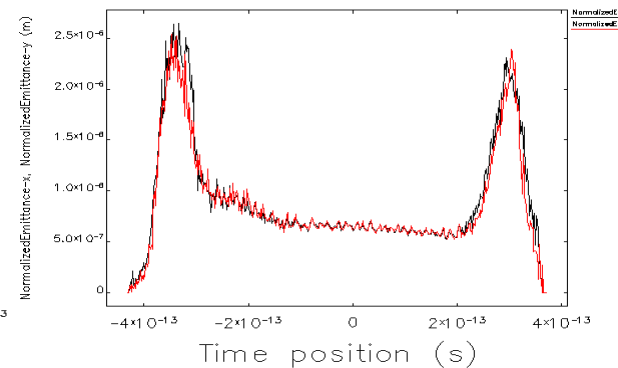
Energy



Current



Sliced energy spread



Sliced emittance

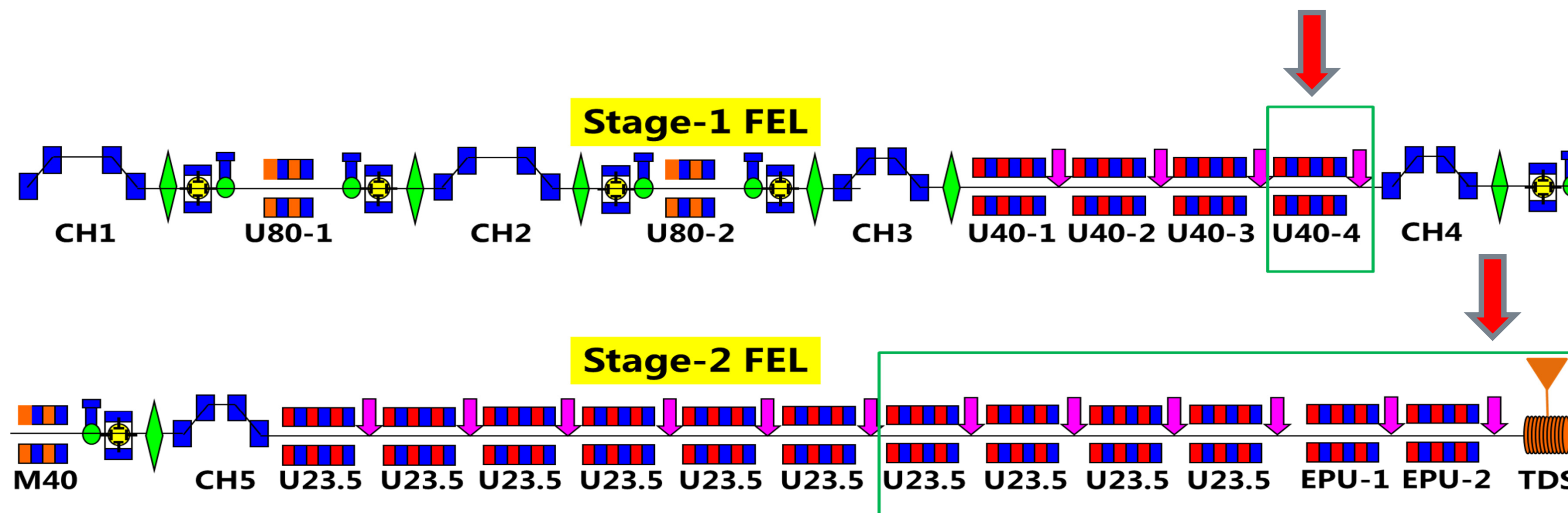
Working Parameters of the Linac

Linac components	Eout (MeV)	σ_z -Out (mm)	$\sigma\delta$ -Out (%)	E (MV/m)	$\phi_{rf} \backslash \theta_{bend}$ (Deg)	R56 (mm)
L0	130	0.86	0.14		-	-
L1	273	0.86	1.44	27	-29.2	-
X	256	0.86	1.51	19	180	-
BC1	-	0.13	-		3.968	-48
L2	640	0.13	0.42	38	4	-
BC2	-	0.07	-		2.217	-15
L3	1500	0.07	0.028	38	6	-

SXFEL-UF: FEL lines



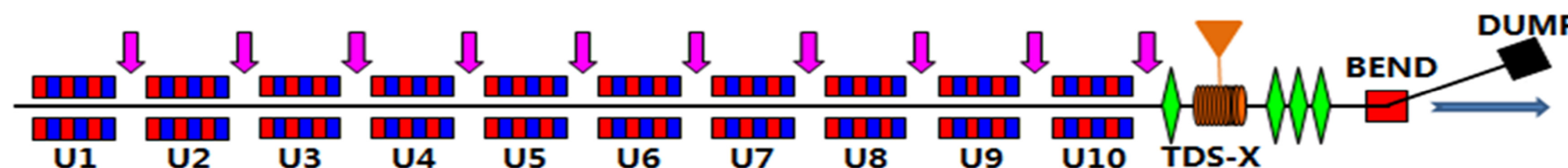
- **FEL1:** Seeded FEL line: add 7 undulator units



Goal:

- 100 - 410 eV
- ~50 fs
- ~10 uJ

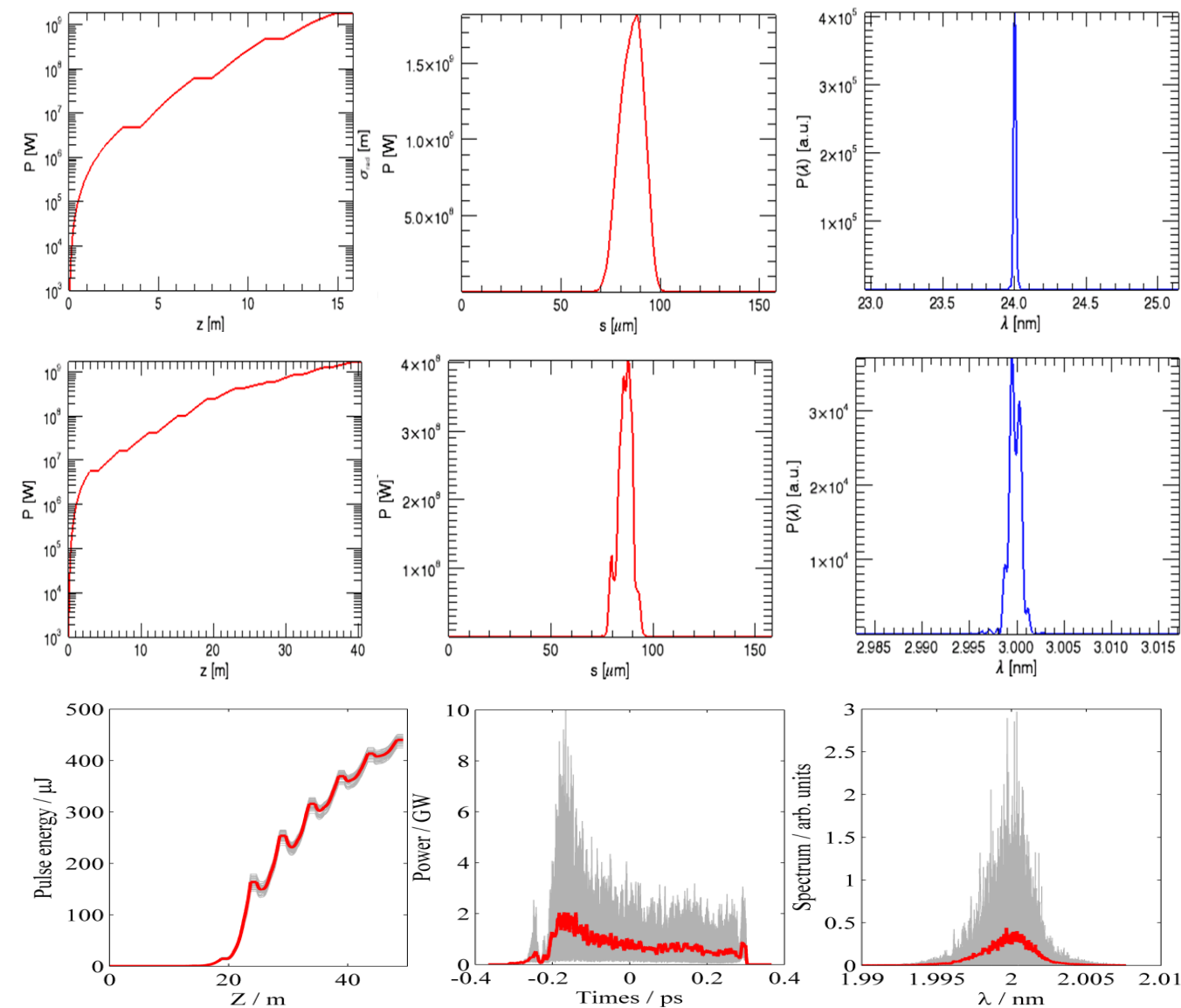
- **FEL2:** SASE FEL line: build 10 in-vacuum undulator sections



Goal:

- 100 - 620 eV
- ~100 fs
- ~100 uJ

SXFEL-UF: FEL lines



Seeded FEL beamline		
Stage1		
Modulator	Period/length/N	80 mm / 1.6m / 2
	Type	Planar, Hybrid
	Max. Peak Field	0.78 T
Radiator	Min. Gap	10 mm
	Period/length/N	40 mm / 3 m / 4
	Type	Planar, Hybrid
	Max. Peak Field	0.85 T
	Min. Gap	10 mm
Stage2		
Modulator	Period/length/N	40 mm / 1.6 m / 1
	Type	Planar, Hybrid
	Max. Peak Field	0.85 T
	Min. Gap	10 mm
	Period/length/N	23.5 mm / 3 m / 10
	Type	Planar, Hybrid
Radiator	Max. Peak Field	0.65 T
	Min. Gap	8.75 mm
Afterburner	Period/length/N	30 mm / 3 m / 2
	Type	Elliptical, APPLE-II
	Max. Peak Field	0.8/0.85/0.6 T*
	Min. Gap	4 mm
SASE FEL beamline		
Undulator Period/length/N		16 mm / 4 m / 10
Undulator Type		Planar, Hybrid, In-vacuum
Max. Peak Field		1.14 T
Min. Gap		4 mm

SXFEL-UF: 1st Undulator beam Line (Seeding)



Photon energy	Bandwidth (RMS)	Pulse energy	Photons /pulse	Size (RMS)	Divergence (RMS)	Pulse length (FWHM)	Sat. length	Rep. rate
597 eV (2.08 nm)	0.02%	1.2 μ J	$1.2 \cdot 10^{10}$	130 μ m	14 μ rad	38 fs	-	1-50 Hz
503 eV(2.46 nm)	0.007%	5.2 μ J	$6.0 \cdot 10^{10}$	140 μ m	12 μ rad	40 fs	30 m	1-50 Hz
396 eV (3.13 nm)	0.008%	26 μJ	$4.0 \cdot 10^{11}$	160 μm	11μrad	45 fs	23 m	1-50 Hz
298 eV (4.26 nm)	0.01%	47 μ J	$1.0 \cdot 10^{12}$	270 μ m	18 μ rad	50 fs	19 m	1-50 Hz
196 eV (6.33 nm)	0.011%	46 μ J	$1.5 \cdot 10^{12}$	300 μ m	22 μ rad	52 fs	15 m	1-50 Hz
98 eV (12.67 nm)	0.03%	53 μ J	$3.4 \cdot 10^{12}$	380 μ m	44 μ rad	70 fs	11 m	1-50 Hz

SXFEL-UF: 2nd Undulator beam Line (SASE)

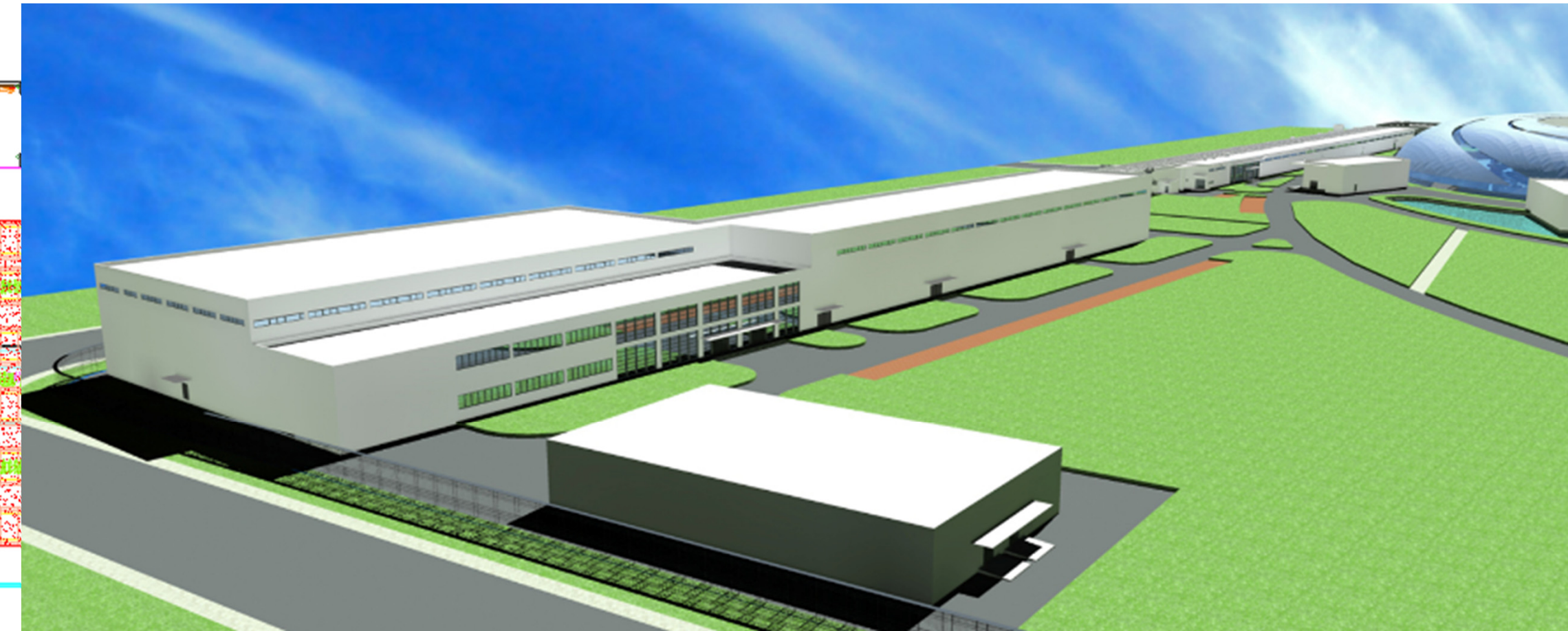
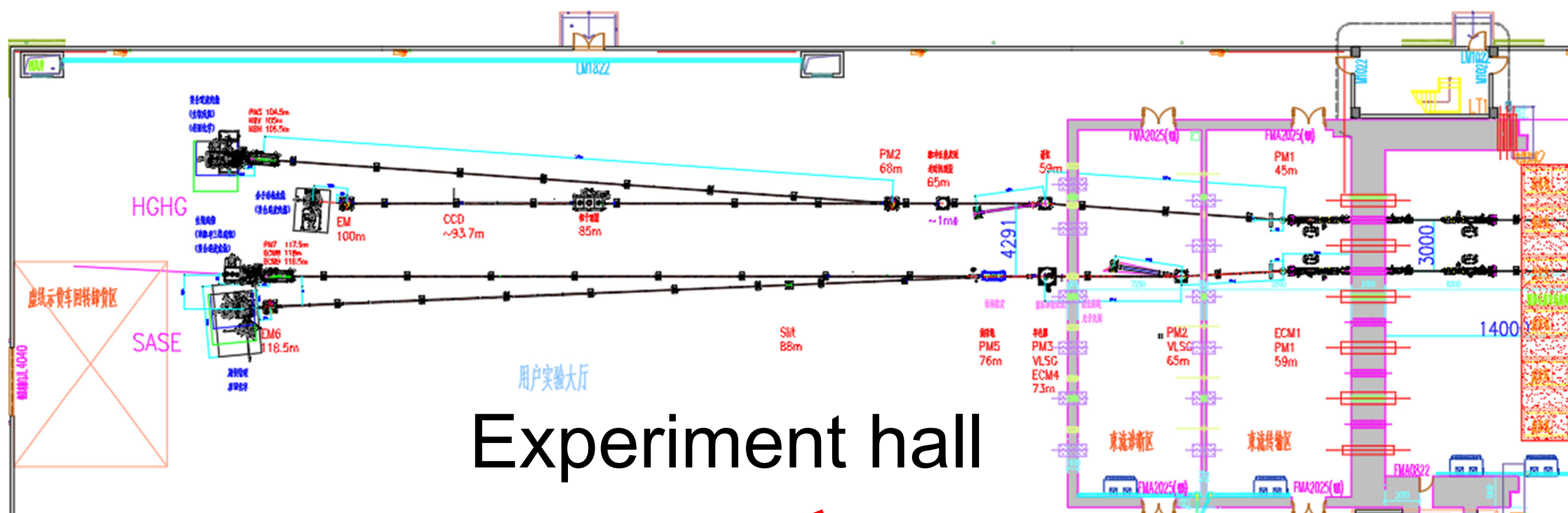


Photon energy	Bandwidth (RMS)	Pulse energy	Photons /pulse	Size (RMS)	Divergence (RMS)	Pulse length (FWHM)	Sat. length	Rep. rate
1033 eV (1.2 nm)	0.04%	0.2 μ J	1.2E09	106 μ m	10.0 μ rad	~135 fs	-	1-50 Hz
827eV (1.5 nm)	0.03%	20 μ J	1.5E11	86 μ m	10.0 μ rad	~98 fs	-	1-50 Hz
620 eV (2 nm)	0.06%	145 μJ	1.4E12	130 μm	10.0 μrad	~117 fs	40m	1-50 Hz
413 eV (3 nm)	0.07%	218 μ J	3.3E12	156 μ m	16.0 μ rad	~152 fs	30m	1-50 Hz
207 eV (6 nm)	0.12%	320 μ J	9.7E12	258 μ m	29.0 μ rad	~175 fs	24m	1-50 Hz
103 eV (12 nm)	0.20 %	398 μ J	1.5E13	664 μ m	48.0 μ rad	~217 fs	20m	1-50 Hz

SXFEL-UF: End-Stations



5 Experimental Stations: Coherent Diffraction Imaging, Atom Molecules Optics, Ultrafast Physics, Surface Chemistry, Photon-Electron Spectroscopy



SXFEL-UF



SXFEL-UF



Summary



- SXFEL Test Facility is under commissioning. Electron beam has been successfully generated, accelerated to more than 700 MeV and sent through the whole undulator line. First stage HGHG has been setup and characterized. New C-band structures and X-band linearizer will be installed within few months to get the beam ready for FEL commissioning.
- SXFEL User Facility is under construction. The building and infrastructure will be finished in July of next year and most of the hardware components will be ready by the end of 2018. The facility is expected to open to users in 2019.



Thanks!!!!