The Commissioning and Early User Operation of Dalian VUV Free Electron Laser

Weiqing Zhang on behalf of DCLS team

Dalian Institute of Chemical Physics, CAS

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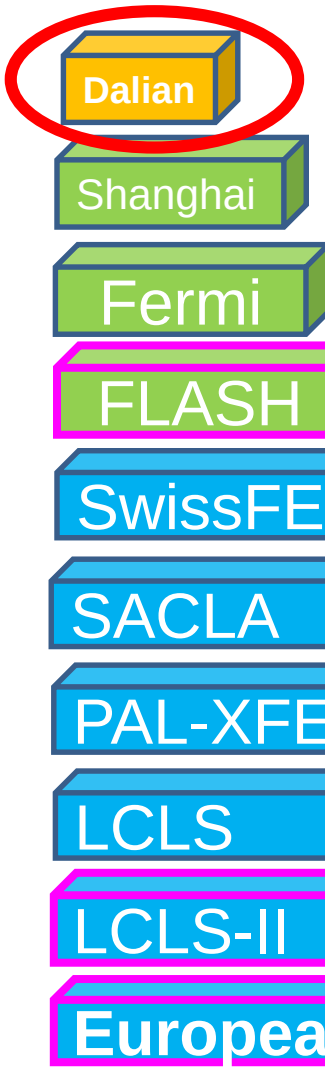
Lake Baikal
Amur
Harbin
Shenyang
NORTH KOREA
SOUTH KOREA
BEIJING
Tianjin
Yellow Sea
Huang He
Zhengzhou
Shanghai
Nanjing
Xi'an
Wuhan
East China Sea

Dalian


大連相干光源
Dalian Coherent Light Source

High Gain FEL



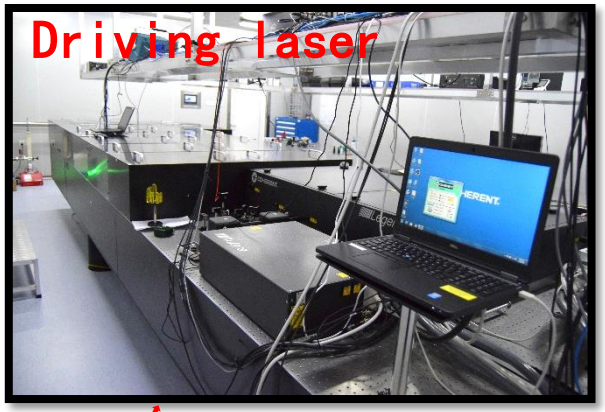
Length	Energy GeV	Budget ($)
150m	0.3	~25 m
300m	1.0	~35 m
350m	1.2	~0.18b
400m	1.2	~0.3 b
715m	5.8	~0.4 b
750m	8.0	~0.4 b
1.1km	10.0	~0.4 b
1.5km	14.5	~0.4 b
1.5km	4.0	~1 b
3.8km	17.5	~1.5 b

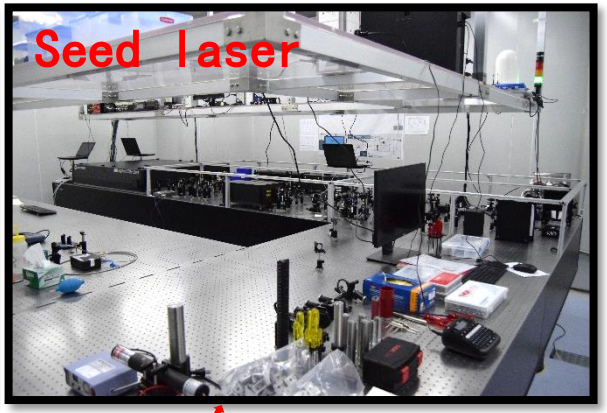
VUV Soft X-ray Hard X-ray SC FEL

Key number of DCLS

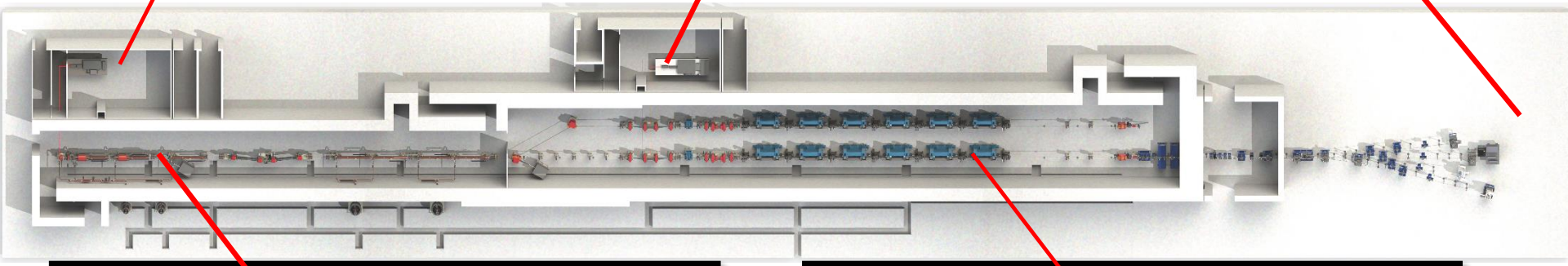
- **Tunable Wavelength： 50 – 180 nm**
- **Pulse Energy： >100 uJ (1 mJ)**
- **Pulse length： 100 fs /1 ps**
- **Bandwidth： Fourier transform limit**
- **Jitter： <30 fs**
- **Rep Rate： 50 Hz**

DCLS layout

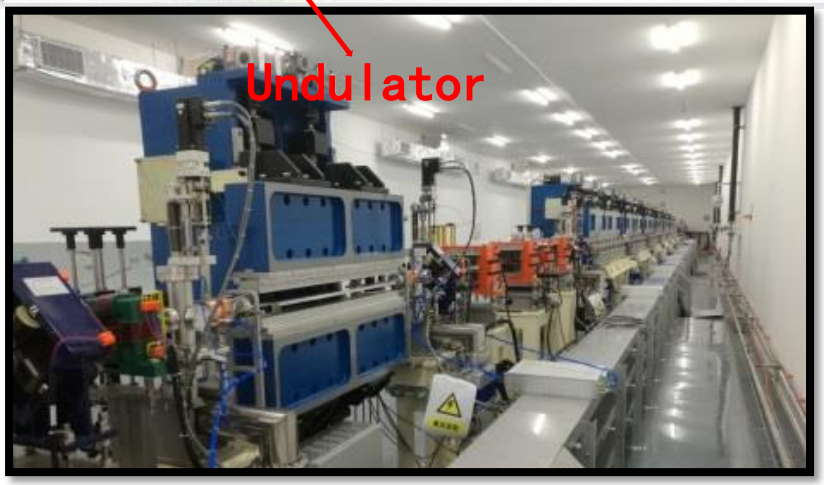

Driving laser


Seed laser

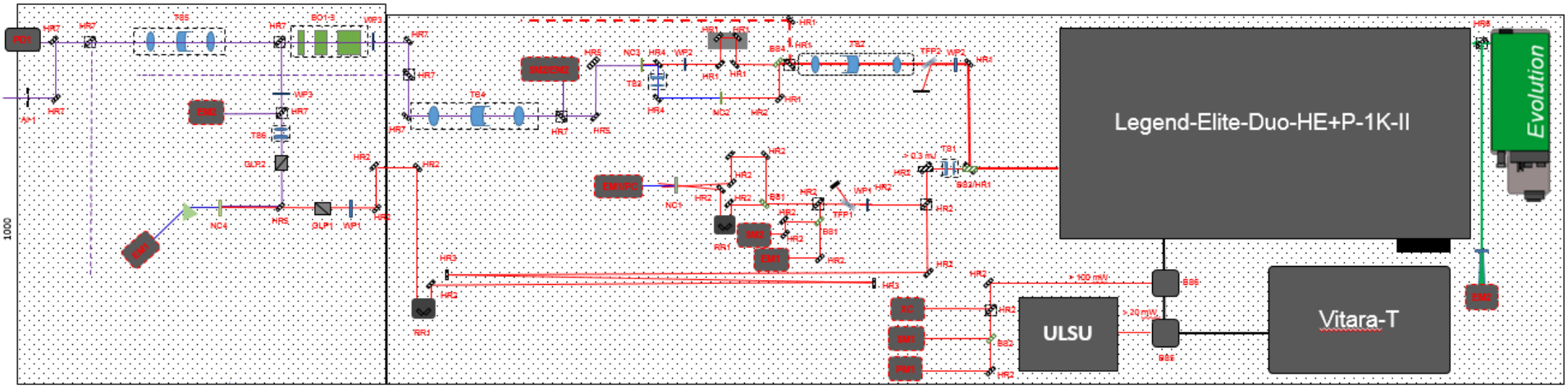

Experimental hall



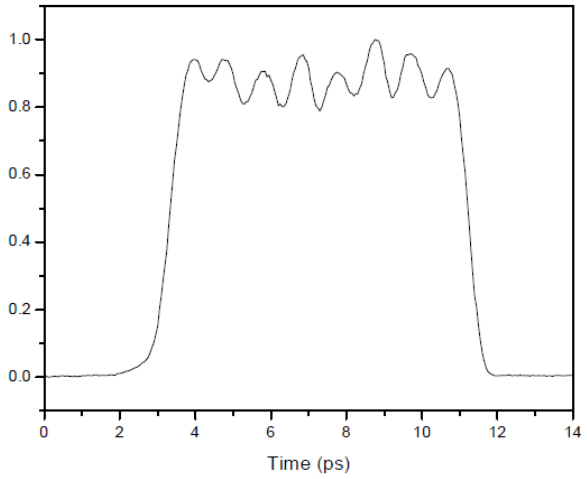

LINAC


Undulator

Driving laser system

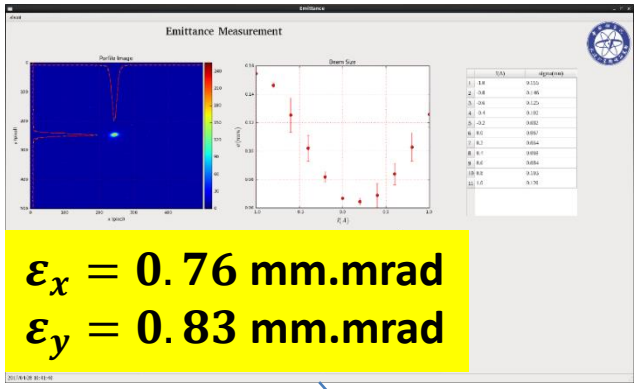


	Design	Achieved
Wavelength (nm)	260	259.58
Rep rate (Hz)	1-50	1-100
Pulse energy (μJ)	250	300
Energy stability (rms)	2.00%	0.90%
Spot size (mm)	1.3~2.6	2
Position stability (μm)	20	7
Longitudinal distribution	Flat top	Flat top
Pulse length (ps)	7	7

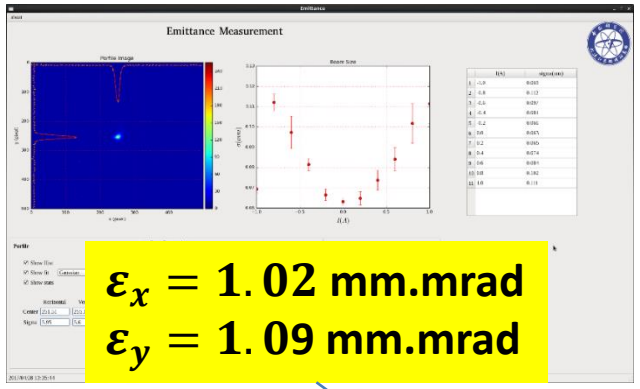


Longitudinal distribution

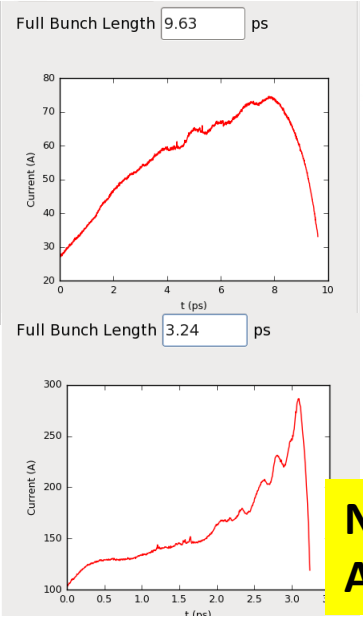
LINAC result

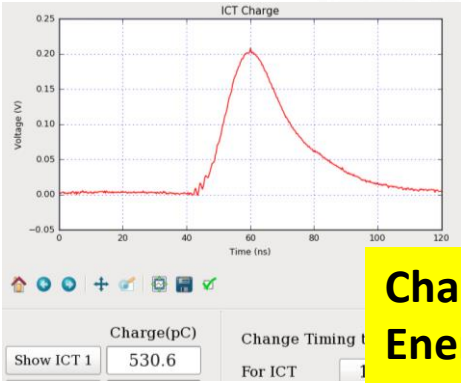


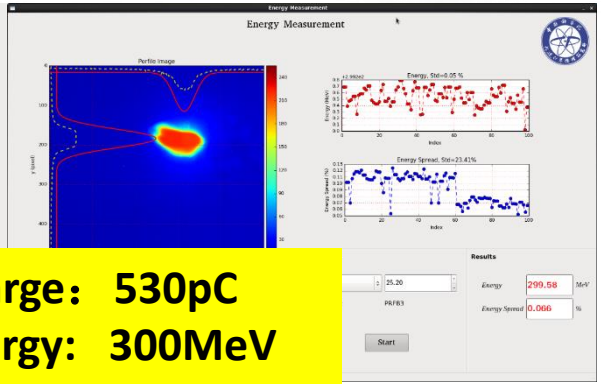
$\varepsilon_x = 0.76$ mm.mrad
$\varepsilon_y = 0.83$ mm.mrad



$\varepsilon_x = 1.02$ mm.mrad
$\varepsilon_y = 1.09$ mm.mrad





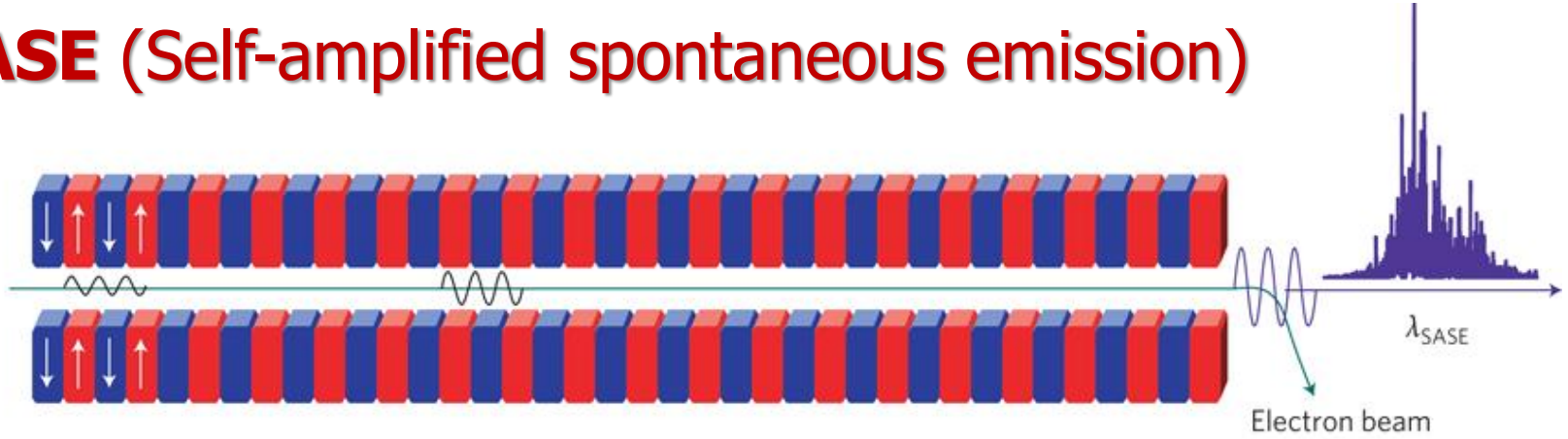


Charge： 530pC
Energy: 300MeV

No compress : 9.63ps
After compress: 3.24ps

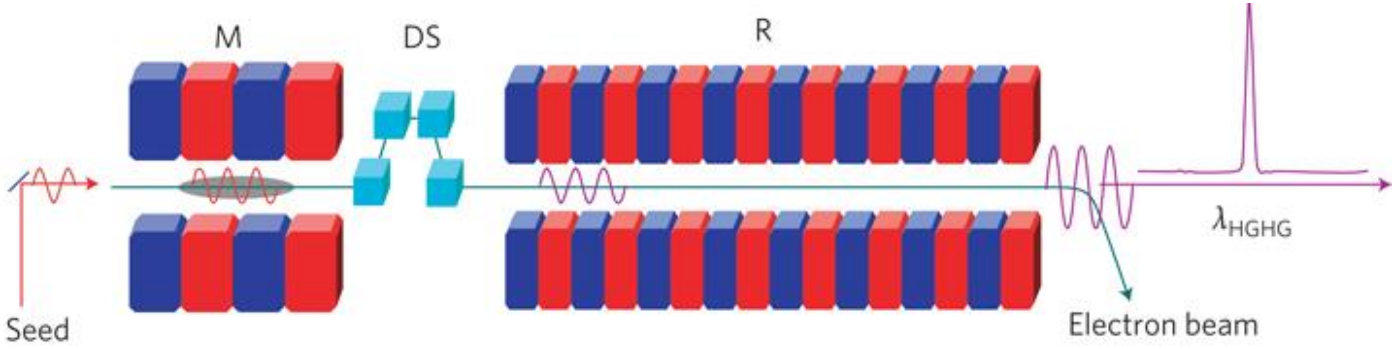
FEL Mode

a) **SASE** (Self-amplified spontaneous emission)



S. Milton *et al.*, Science **292**, 2037 (2001)

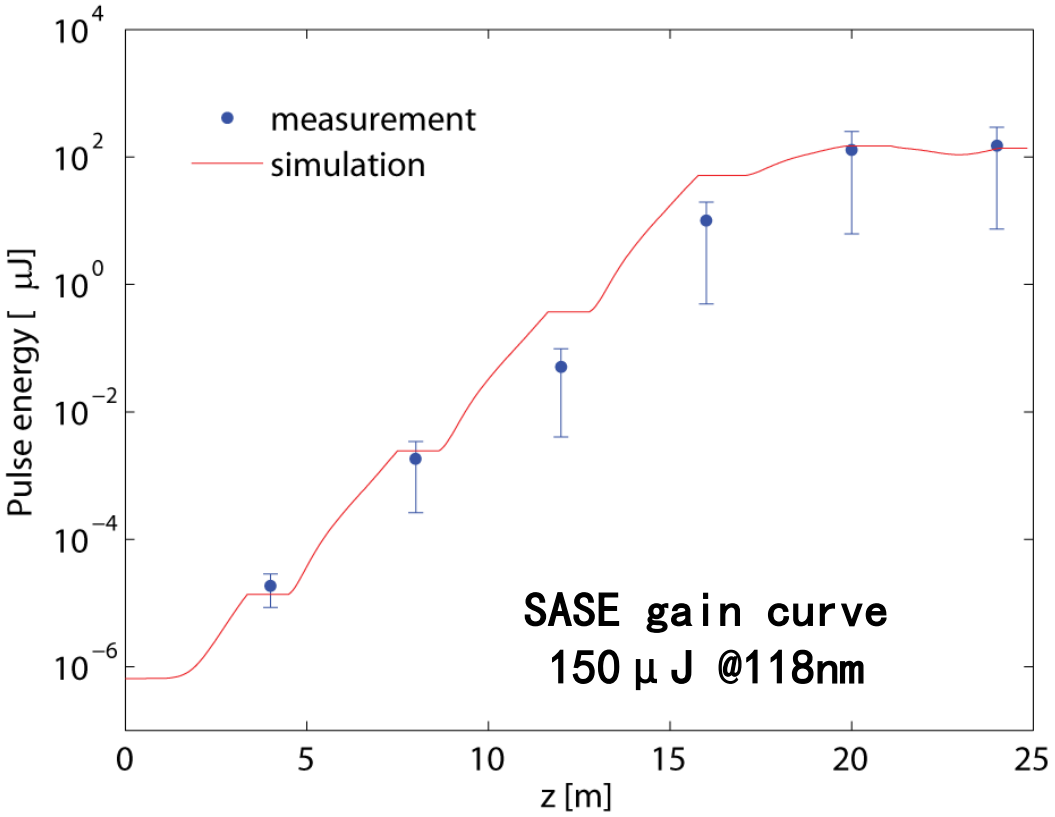
b) **HGHG** (High gain harmonic generation)

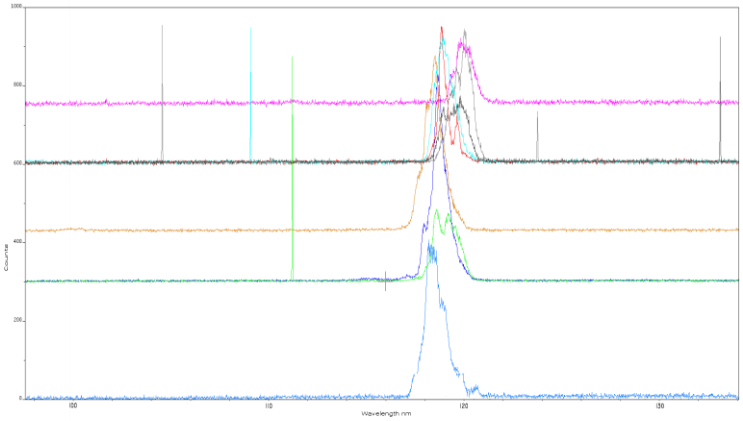


Yu et al, Science 289, 932(2000)

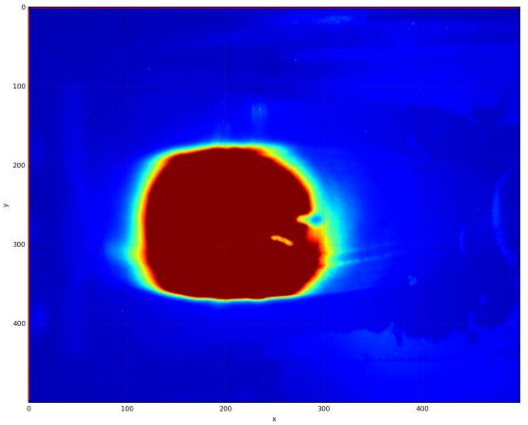
2016.11.25

SASE at DCLS





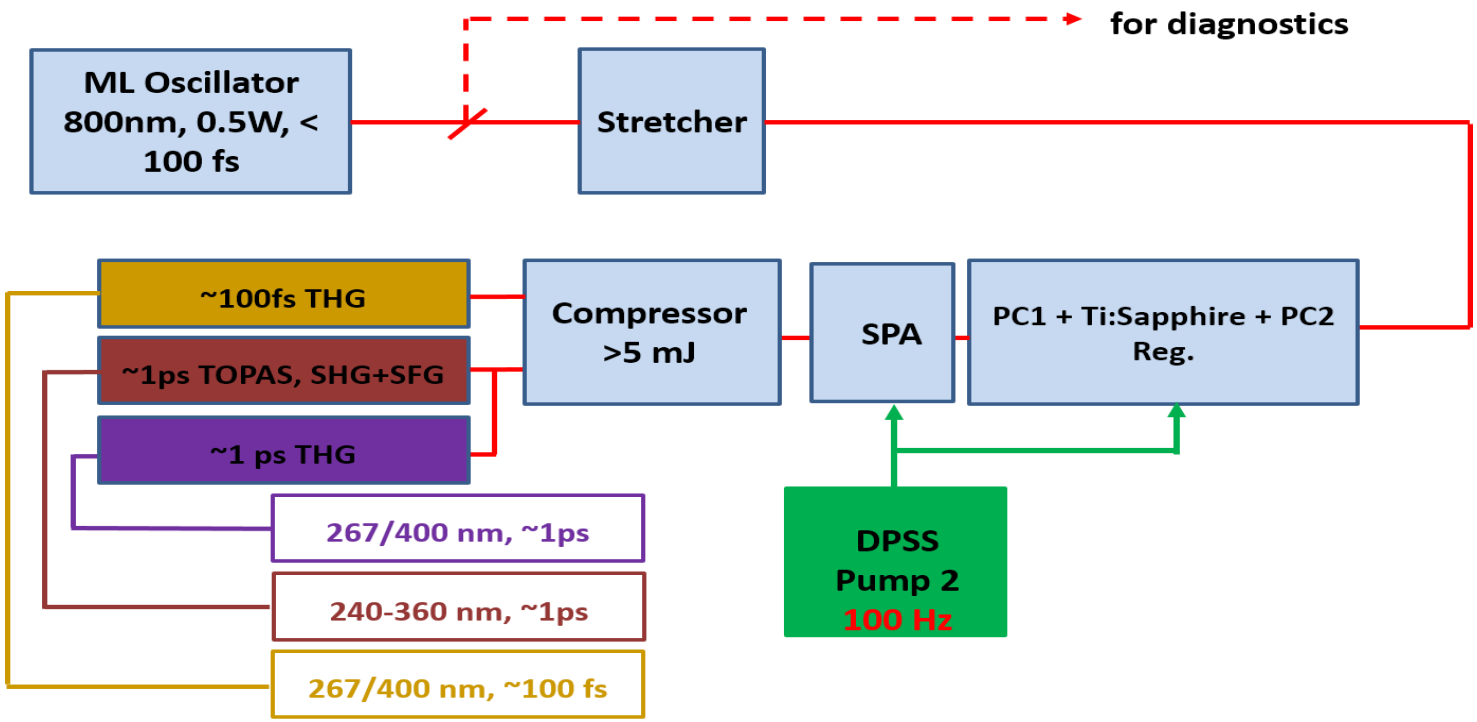
SASE spectrum



SASE spot image

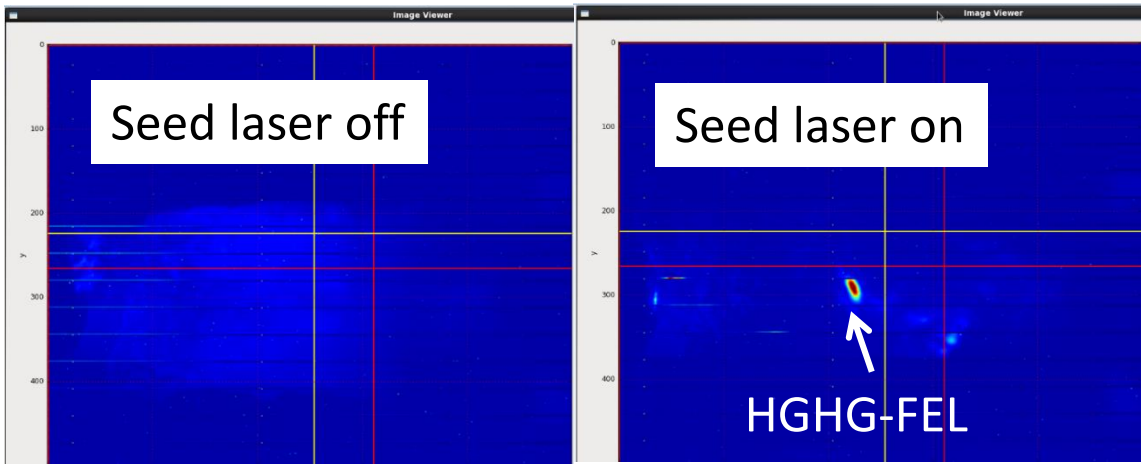
>100 μ J @ 90nm 118nm and 148nm

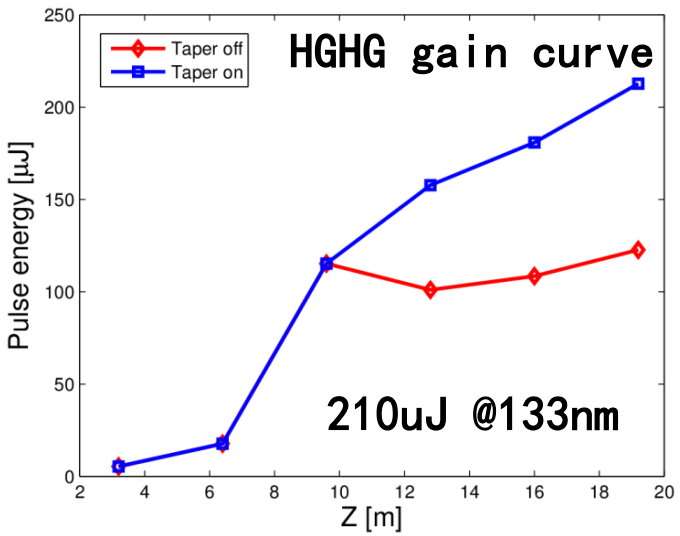
Seed laser system

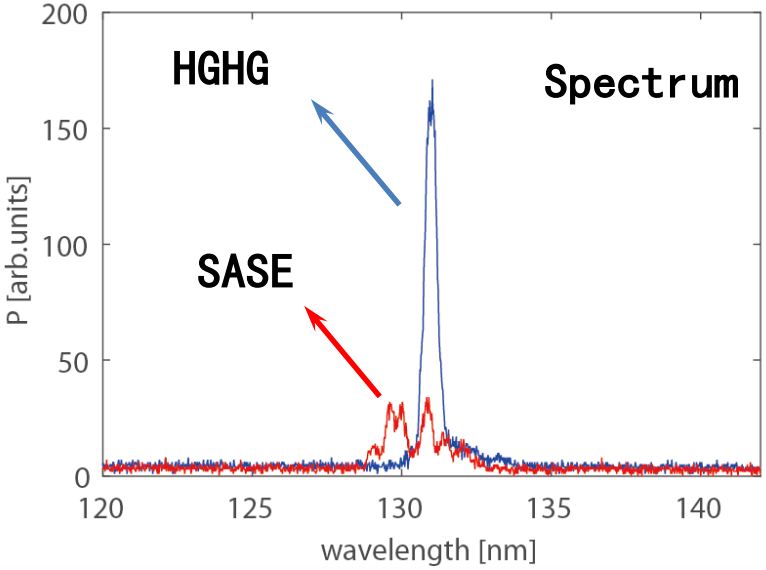


	Design	Achieved
Wavelength	240 – 360 nm	240-360 nm
Pulse energy (μJ)	>40 @1 ps	170
Beam size (mm)	2	2.6
Pulse duration (ps)	1	~1.2

HGHG at DCLS

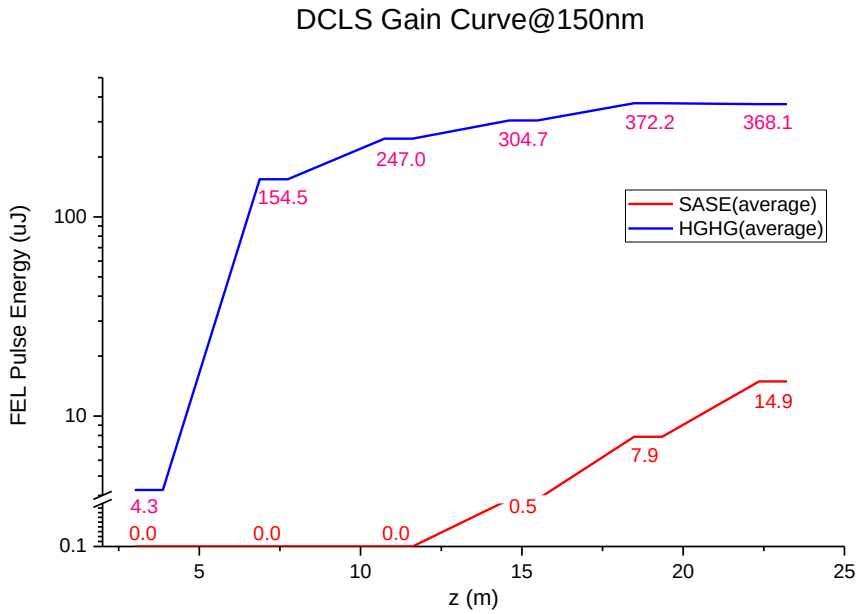


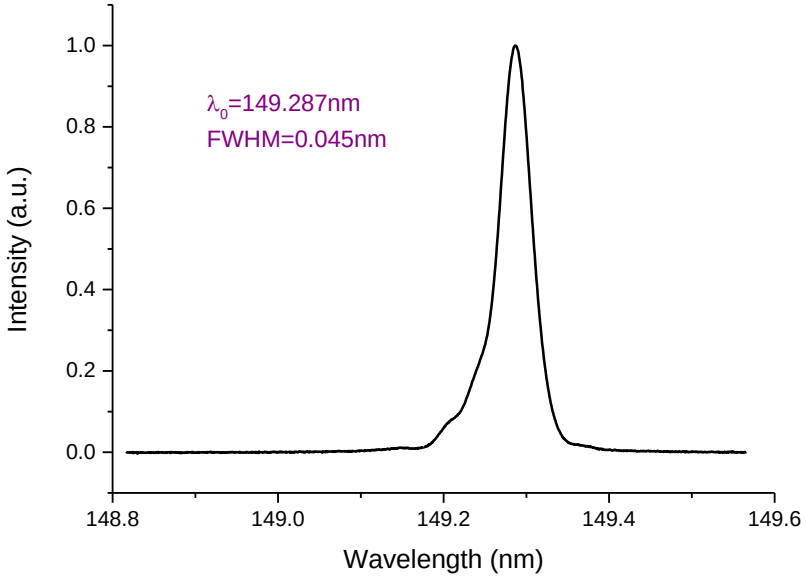




Seed laser is 266nm, which is 3rd of 800nm.
88nm (3rd harmonic of seed laser) is also achieved, energy is about 30uJ.

DCLS with OPA seed laser

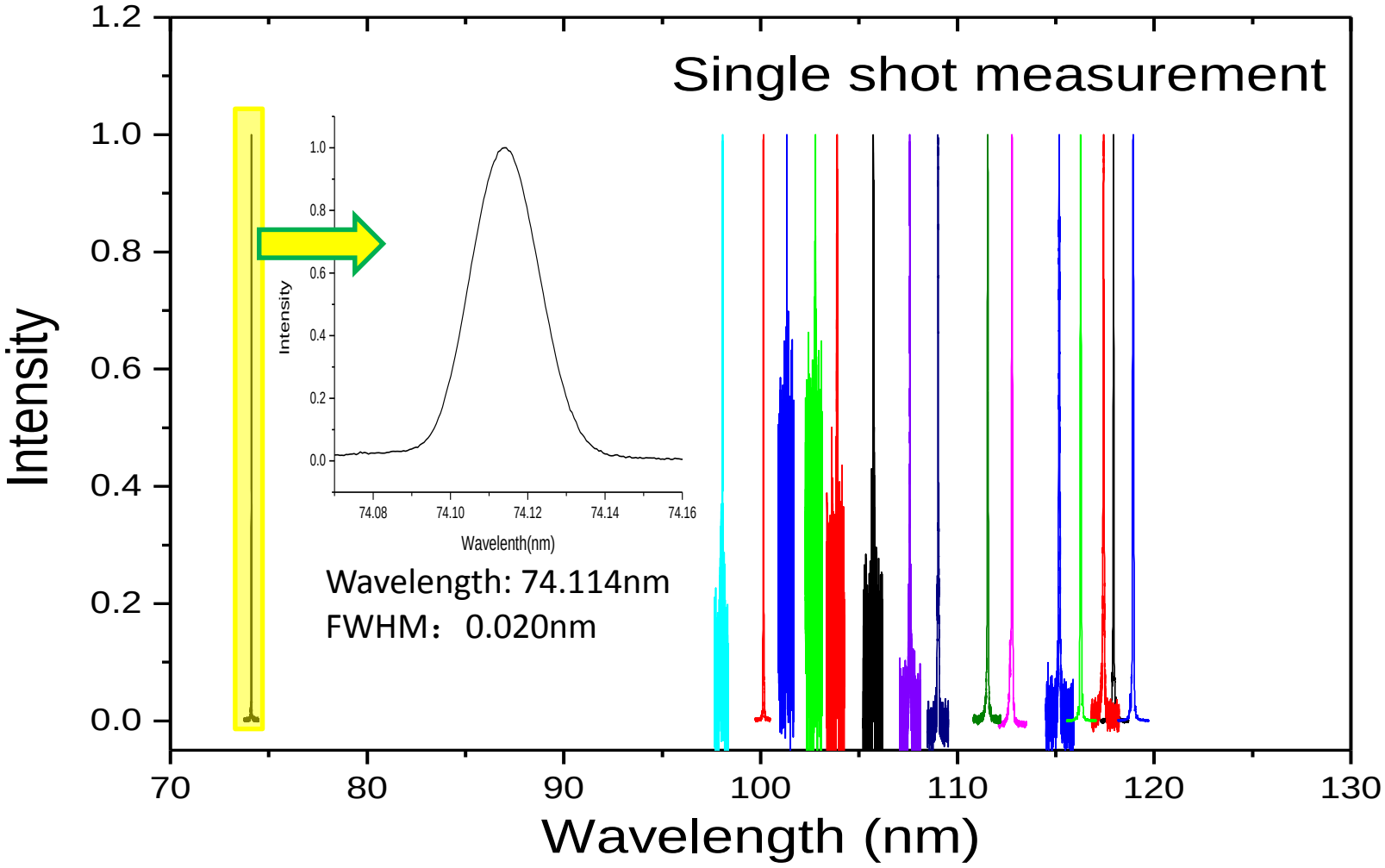




Seed laser is 298.57nm, which is from OPA.

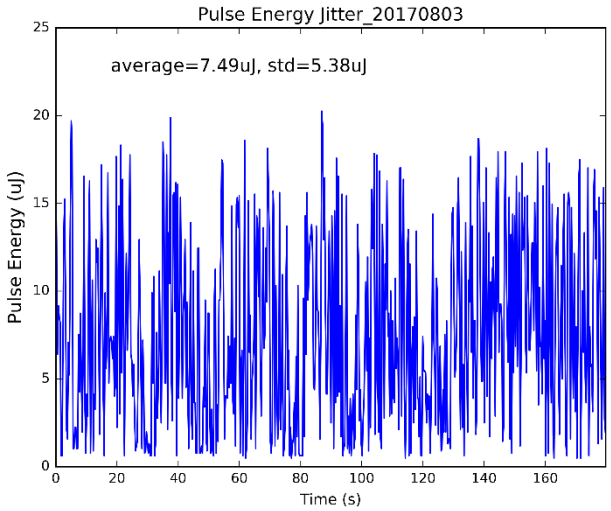
Power at second harmonic is more than 368 uJ. The bandwidth is about 0.03%.

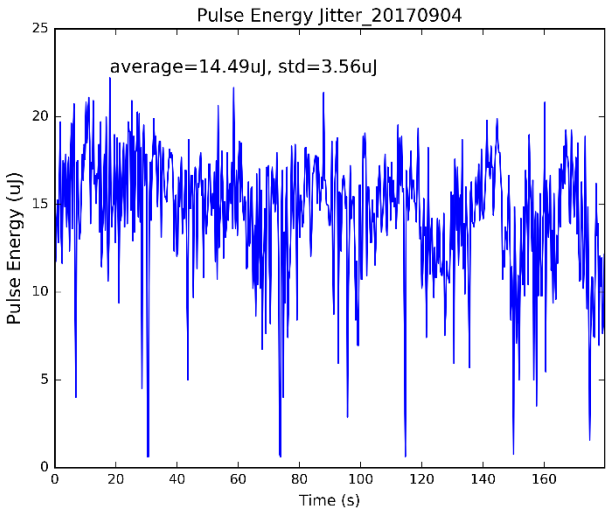
Tunable wavelength

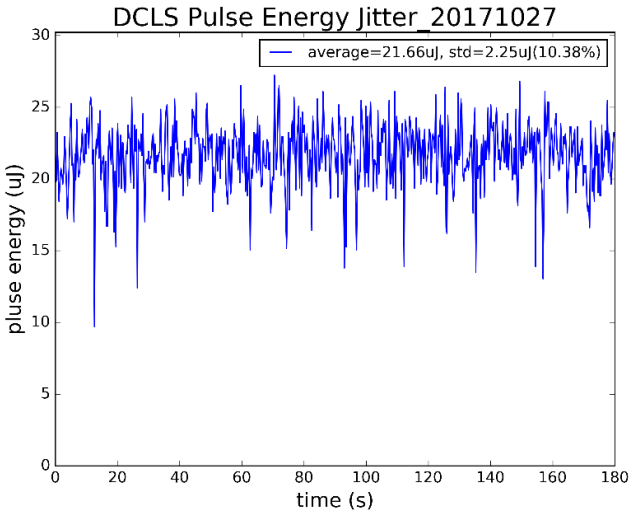


- **FEL is tunable with OPA and undulator gap. Tuning range is from 50-150nm.**
- **The bandwidth is narrow, about 3 times of Fourier transform limit.**

Pulse energy stability



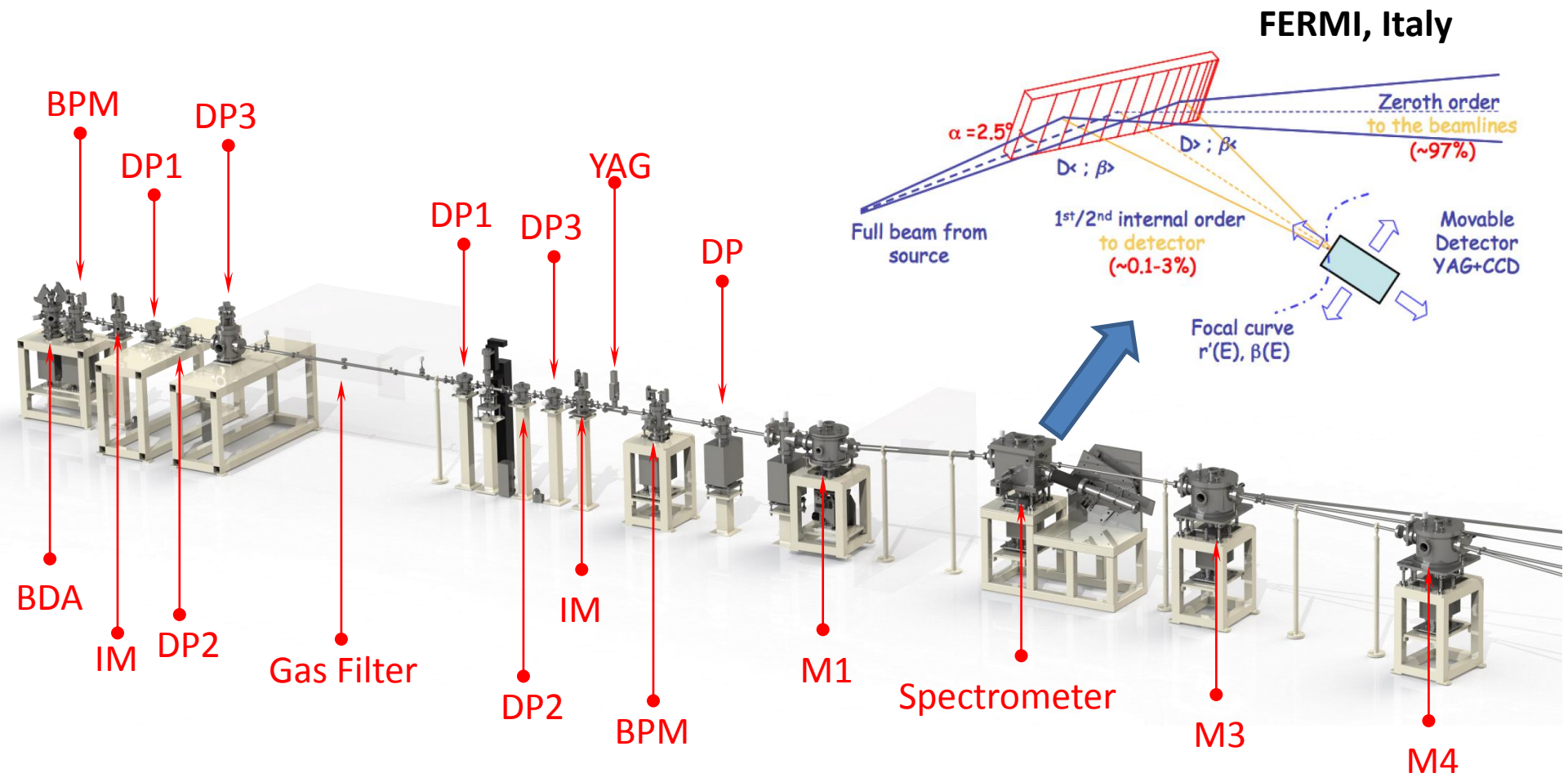




Pulse energy fluctuation is down to 10%

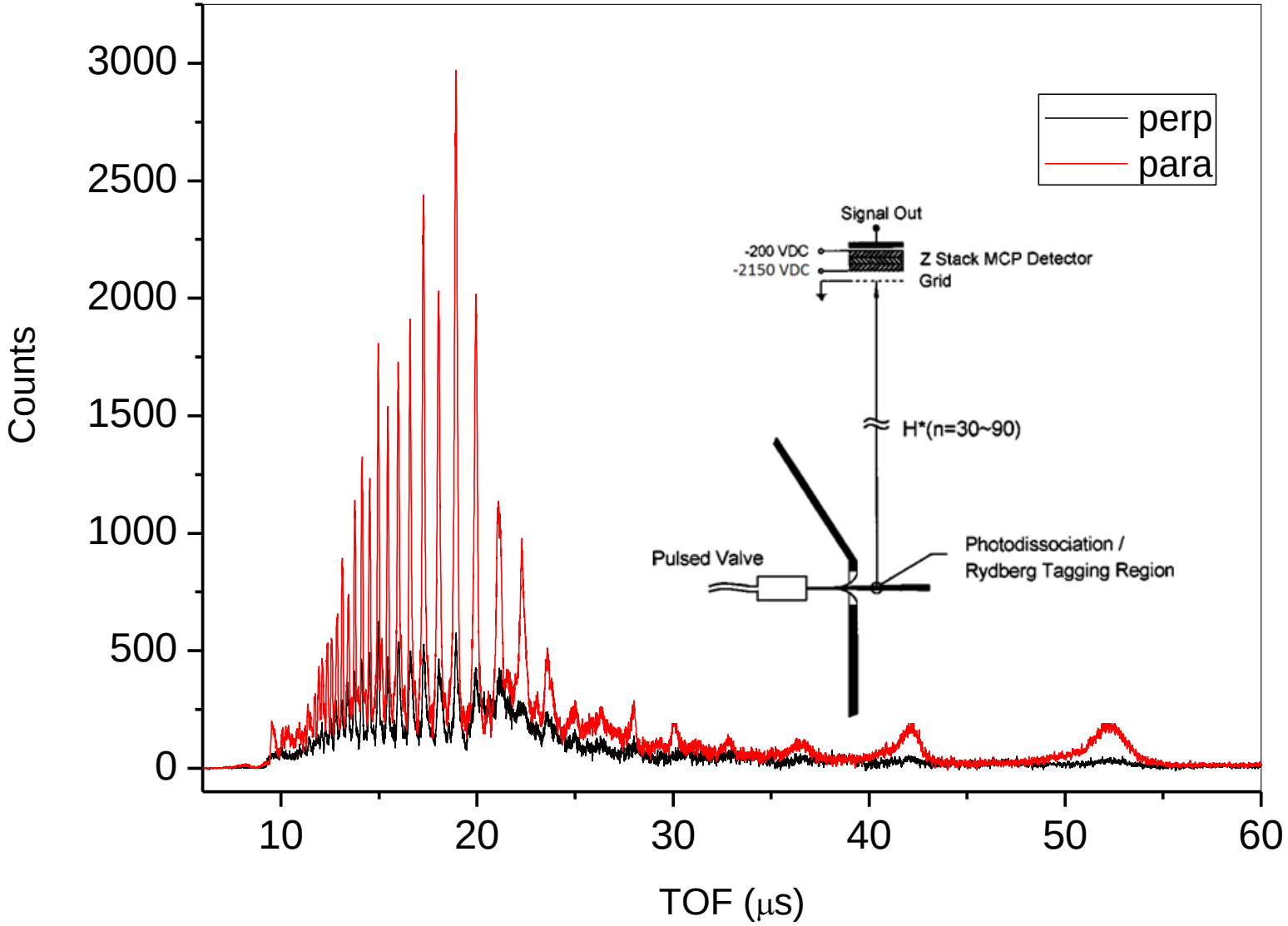
- **Better gun conditioning**
- **Close loop for LINAC power system**
- **Less timing jitter between e beam and seed laser**

Photon diagnostics and delivery system



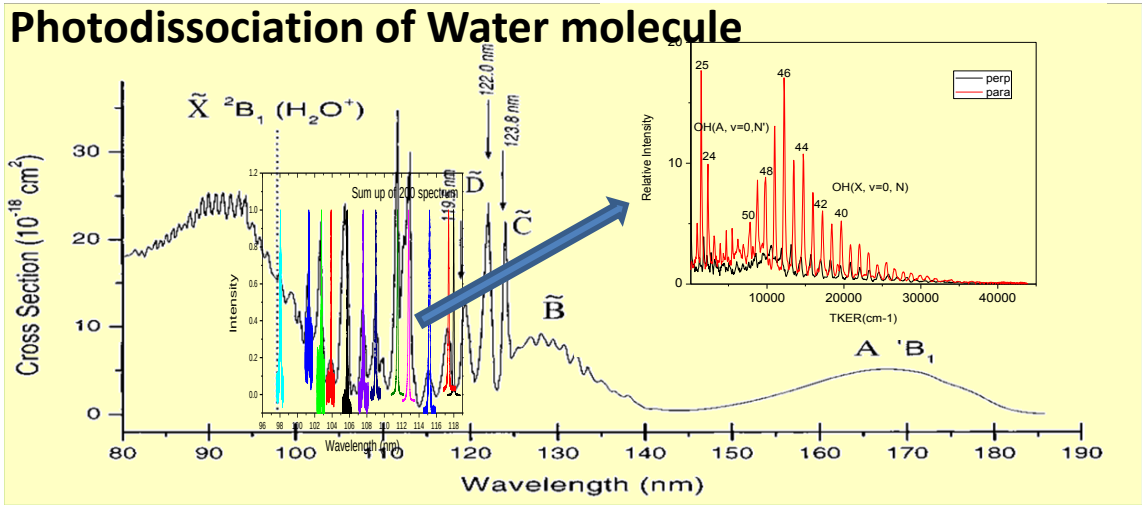
- **Photon Beam position, intensity, wavelength will be recorded in real time.**
- **Estimated beam transfer efficiency is about 85% after 2 mirrors.**

First user experiment



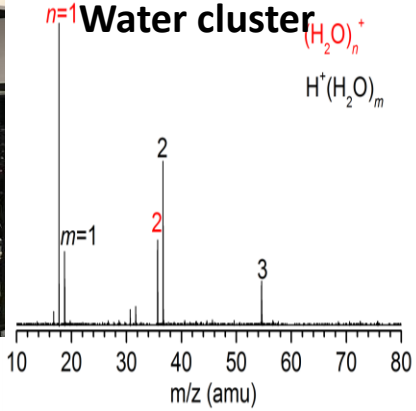
H2O photodissociation at 117.5nm (FEL VUV)

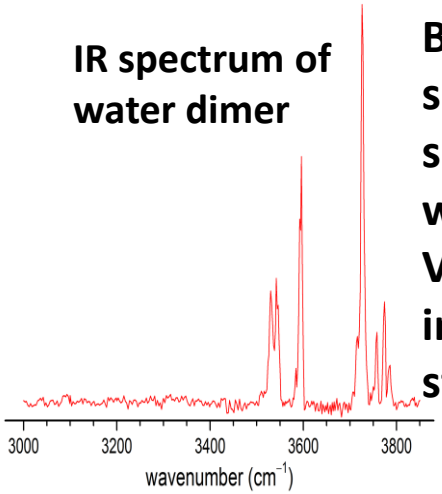
Experiment @ DCLS



Photodissociation dynamics of water molecule is done above 120nm before DCLS. Now it is extended to 98nm. Three body dissociation is found, which is very rare and interesting case.

IR spectrum of Neutral cluster





By VUV soft ionizing, we succeed to measure IR spectrum of neutral cluster, which is hard without strong VUV photon beam. It is very important to obtain cluster structure.

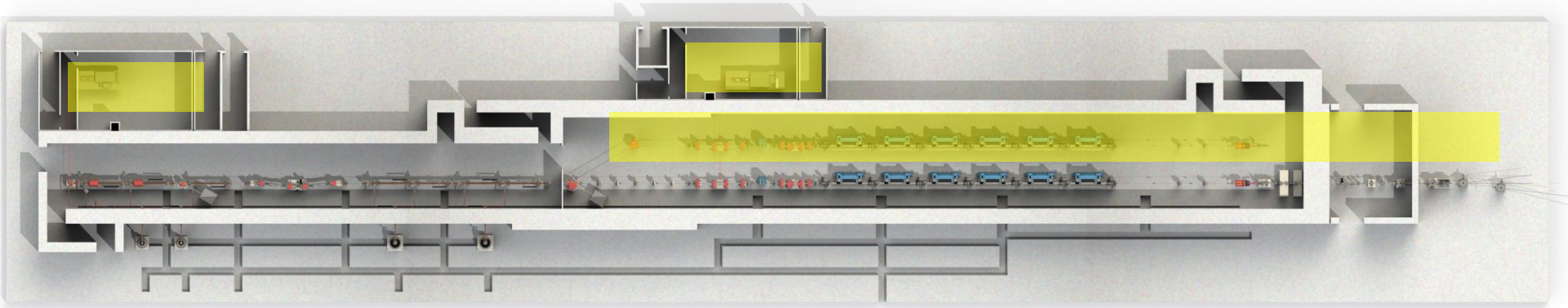
Since 2017.07, we provide more than 2000 hours for user measurement.

Key number of DCLS

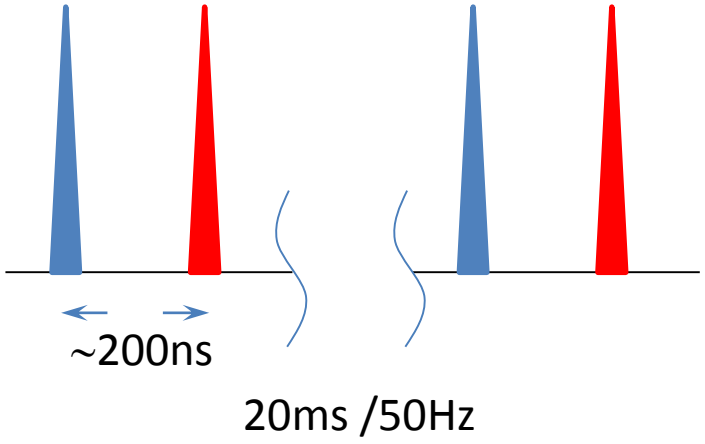
	Design number	*Achieved number at the moment*
➢	**Tunable Wavelength ： 50 – 180 nm**	**150nm-50nm,**
➢	**Pulse Energy ： >100 uJ (1 mJ)**	**350 uJ**
➢	**Pulse length： 100 fs /1 ps**	**~1ps**
➢	**Bandwidth ： Fourier transform limit**	**<0.05%(HGHG)**
➢	**Jitter： <30 fs**	**Not measured**
➢	**Rep Rate： 50 Hz**	**20Hz**

Poster number: MOP002

DCLS upgrade : 2nd FEL line



- **2nd FEL line is planed for installation in the middle of 2018.**
- **The property of new line, e.g., polarization, pulse duration, bandwidth, wavelength range, is still open to discuss.**
- **EPU is chosen at this stage**



Time structure of double pulse e beam

Idea from SwissFEL

Milestone

2012.03 Starting of DCLS

2013.08 Review of TDR of DCLS

2013.12 Prototype of Undulator

2014.10 Starting of Construction

2016.04 LINAC installation

2016.09 Undulator spontaneous emission

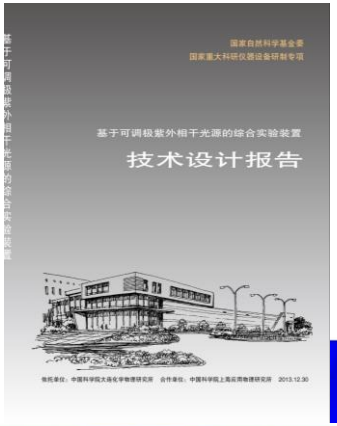
2016.11 FEL SASE lasing

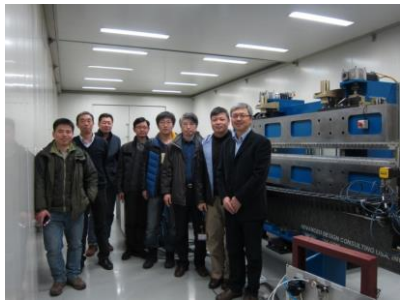
2016.12 FEL HGHG lasing

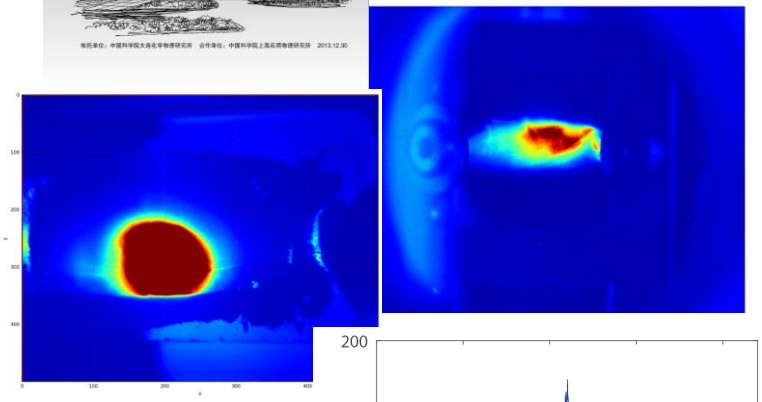
2017.06 First user experiment

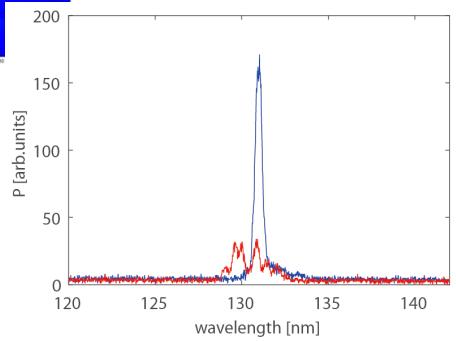
2017.08 Tunable wavelength

2018.07 2nd FEL line installation









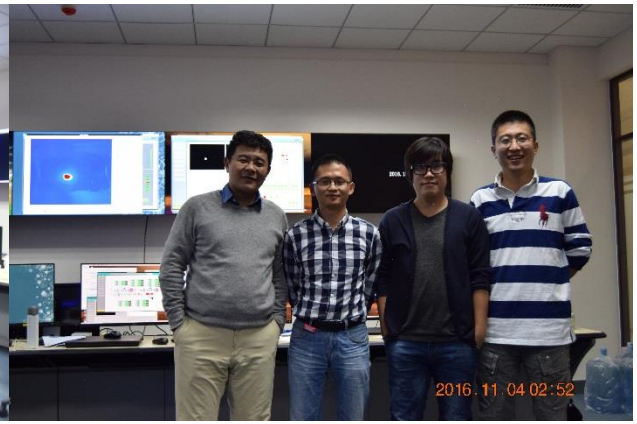
2012.05 First time to DCLS location

2013.08 Review of DCLS TDR

2014.11- 2016.01 DCLS Building construction

2016.05 Linac Installation

2016.09 e Beam getting through



2016.11 First SASE lasing

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Mr. Qinming Li
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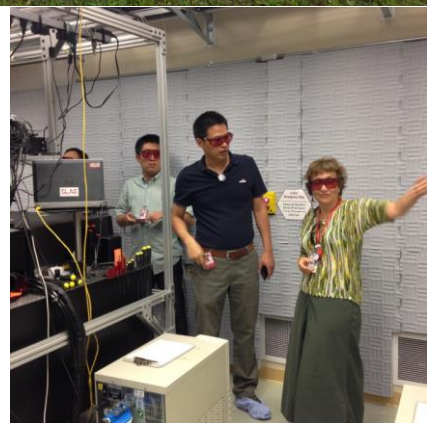

Thank you for attention

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