Generation of two-color Free Electron Laser in Dalian Coherent Light Source

Guanglei Wang

2018. 4. 11

Dalian Institute of Chemical Physics， CAS

Introduction

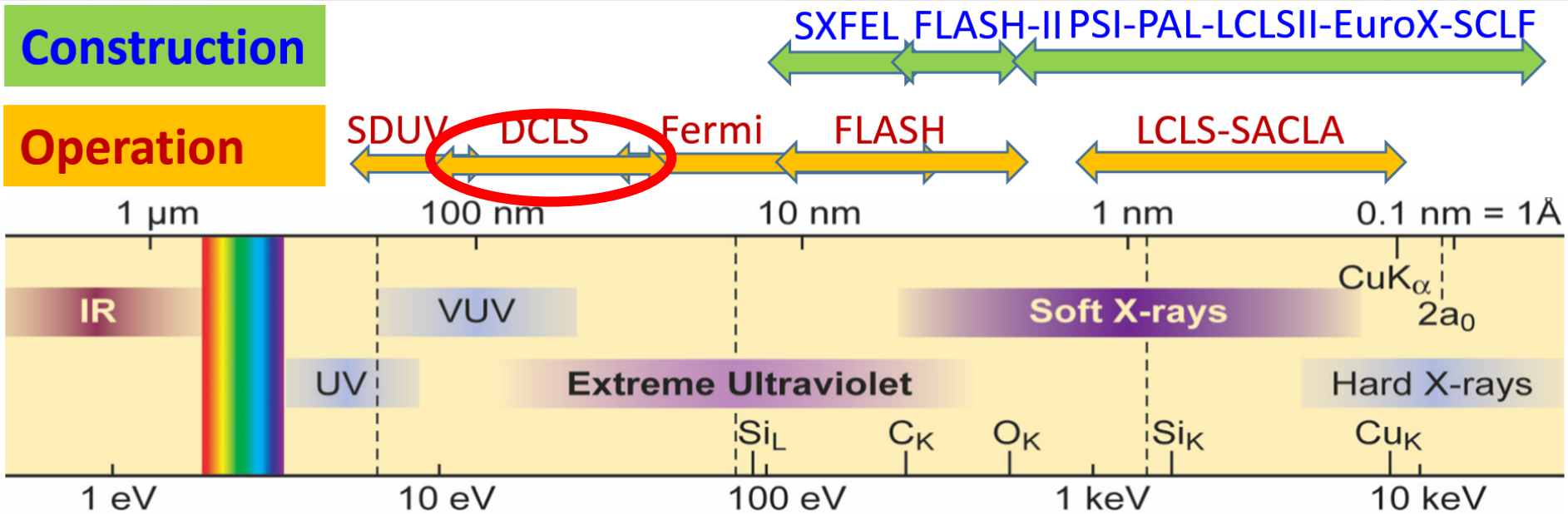
Overview of FEL facility

VUV | Soft X-ray | Hard X-ray

	Length	Energy (GeV)	Budget ($)
Dalian	150m	0.3	~25 m
SXFEL	300m	1.0	~35 m
Fermi	350m	1.2	~0.18b
FLASH	400m	1.2	~0.3 b
Swiss-FEL	715m	5.8	~0.4 b
SACLA	750m	8.0	~0.4 b
PAL-XFEL	1.1km	10.0	~0.4 b
LCLS	1.5km	14.5	~0.4 b
LCLS-II	1.5km	4.0	~1 b
SCLF	3.0km	8.0	~1.4 b
European XFEL	3.8km	17.5	~1.5 b

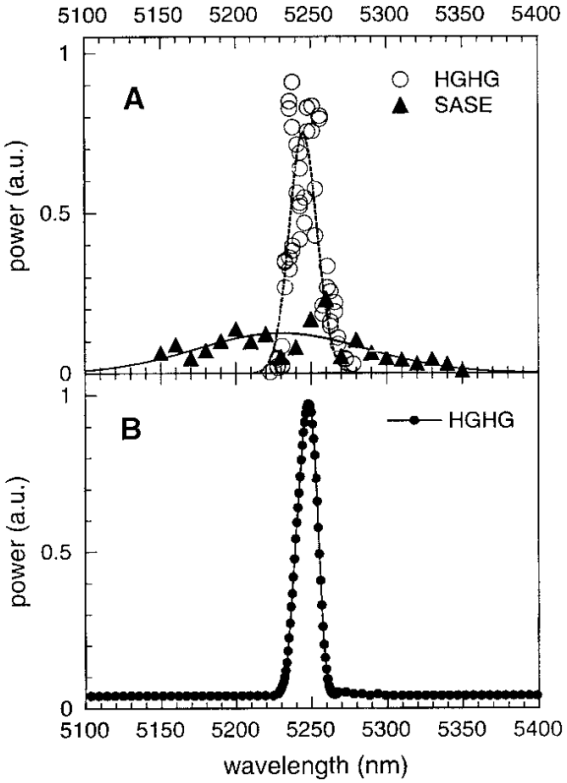
Overview of FEL facility

	VUV	Soft X-ray	Hard X-ray
	Length	Energy (GeV)	Budget ($)
Dalian	150m	0.3	~25 m
SXFEL	300m	1.0	~35 m
LCLS-II	1.5km	4.0	~1 b
SCLF	3.0km	8.0	~1.4 b
European XFEL	3.8km	17.5	~1.5 b

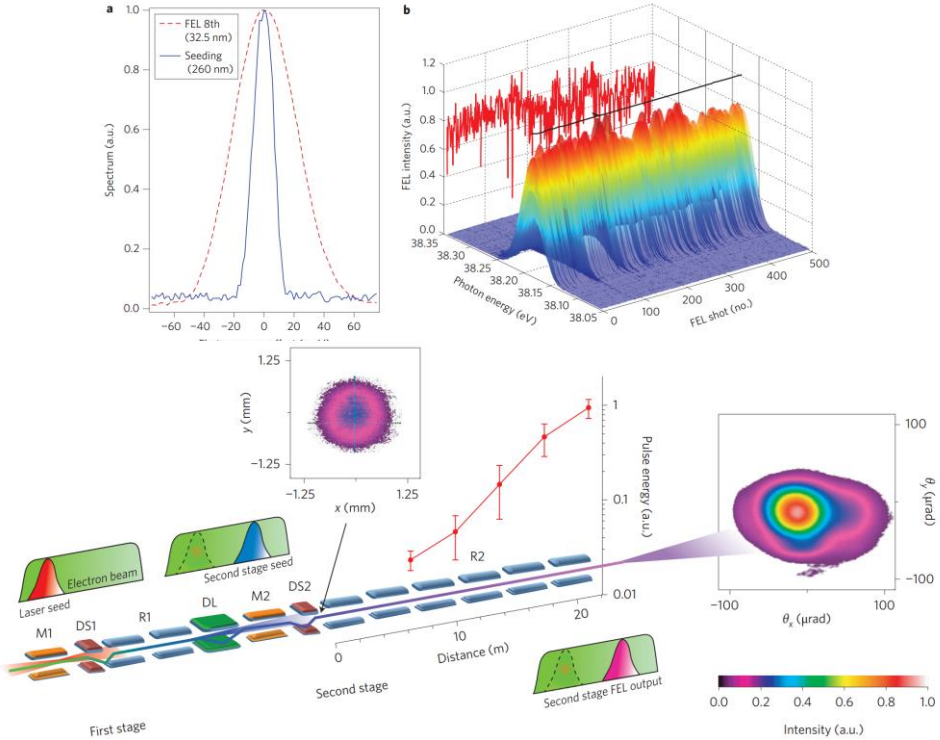


High Gain Harmonic Generation

- Induced energy modulation at longer wavelength is changed into harmonic content after compression with a chicane.
- A selected harmonic is picked up with a succeeding undulator.



L.-H. Yu, Science 289 (2000) 932



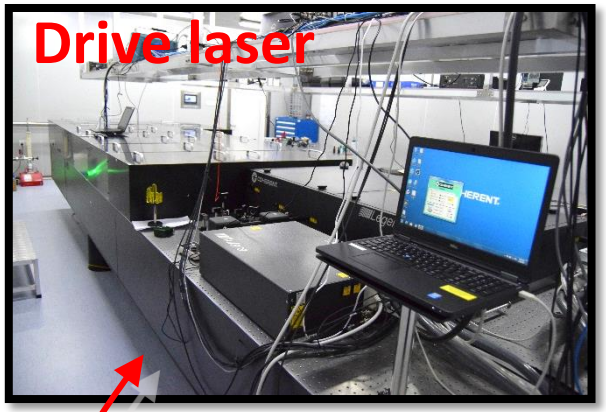
E. Allaria et al, Nature Photonics. 6 (2012) 699;
E. Allaria et al, Nature Photonics. 7 (2013) 913

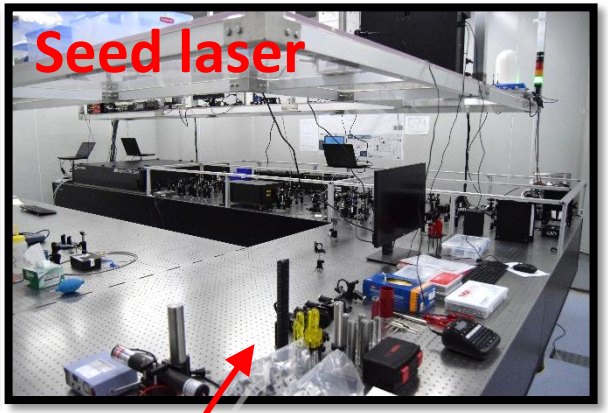
Dalian VUV FEL Performance

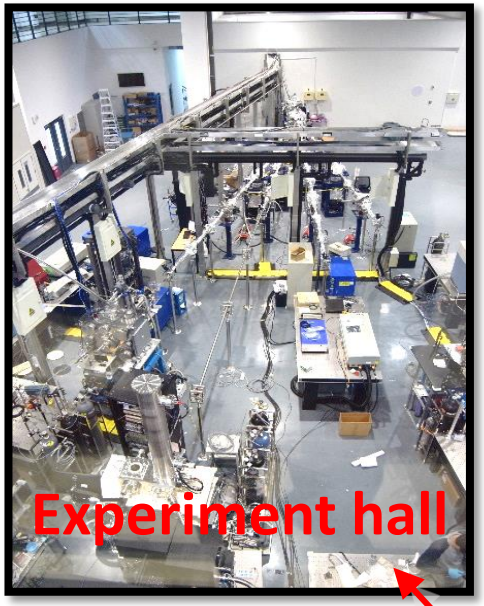
Wavelength tuning range：	50 – 180 nm
Pulse energy：	>100 uJ (1 mJ-Maximum)
Pulse duration：	100 fs /1 ps
Narrow bandwidth：	Fourier transform limited
Timing：	timing jitter < 100 fs
Frequency：	50 /100Hz (double pulse mode)
Coherence：	Longitudinal and temporal
Polarization:	FEL1(PMU), FEL-2(EPU)

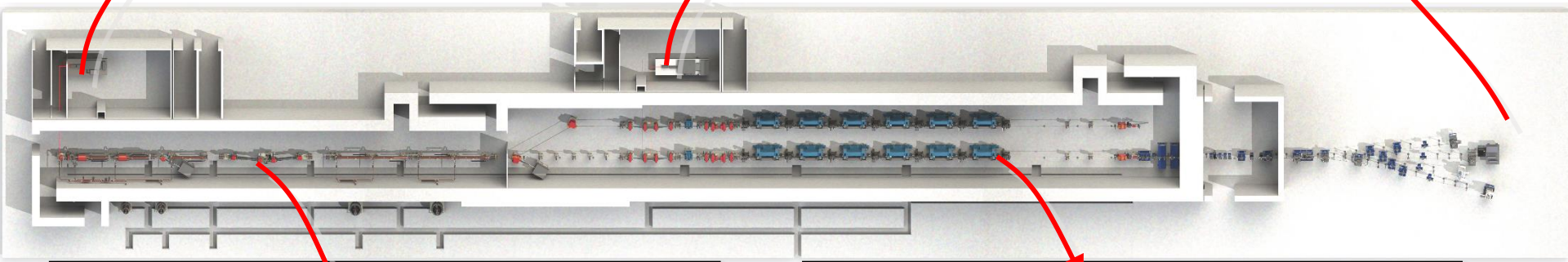
High brilliance/ Narrow bandwidth/ Ultra-fast/Coherence

Current status of Dalian VUV FEL



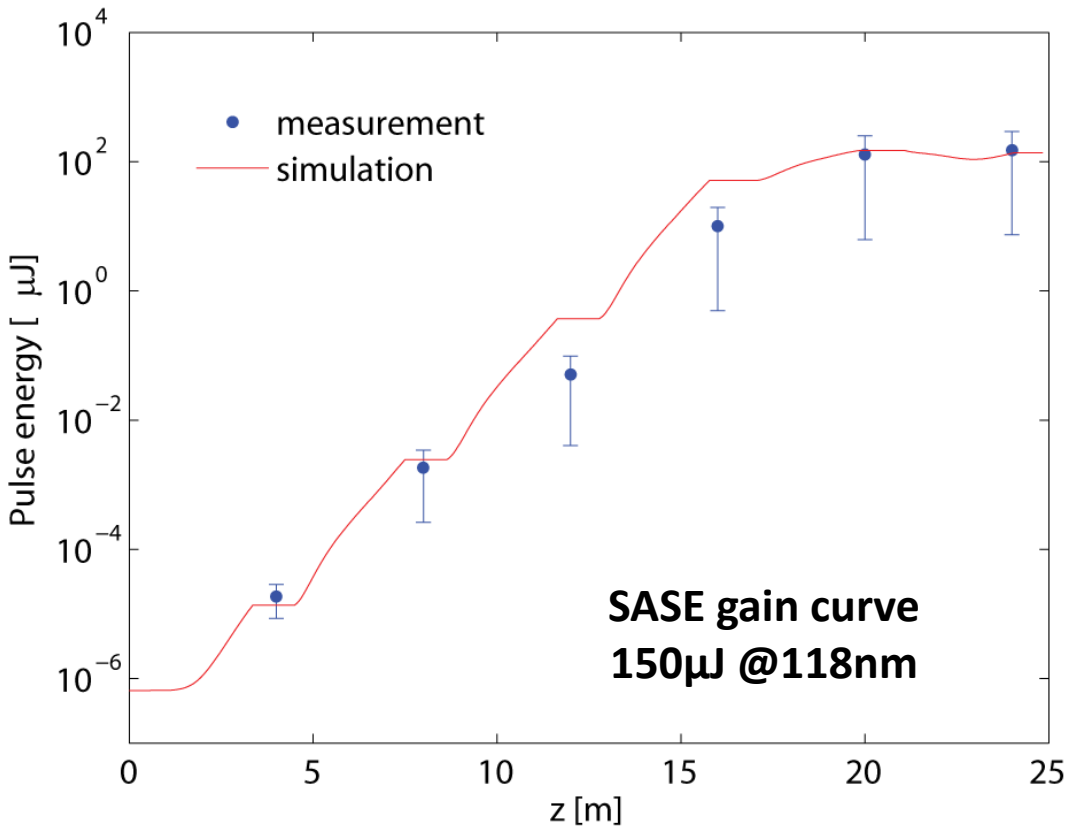


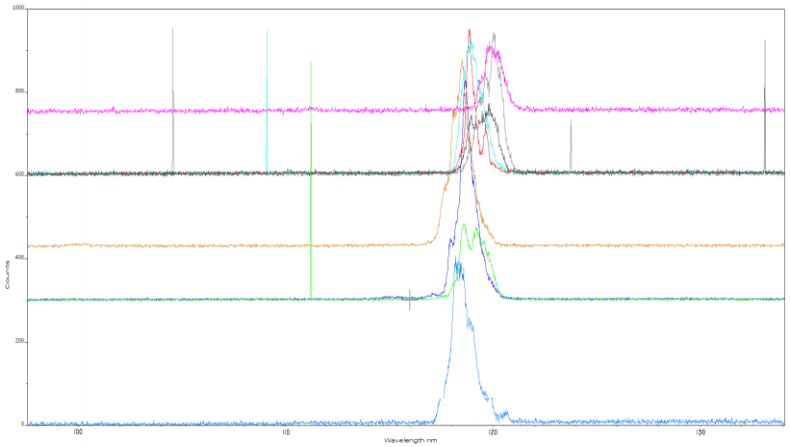




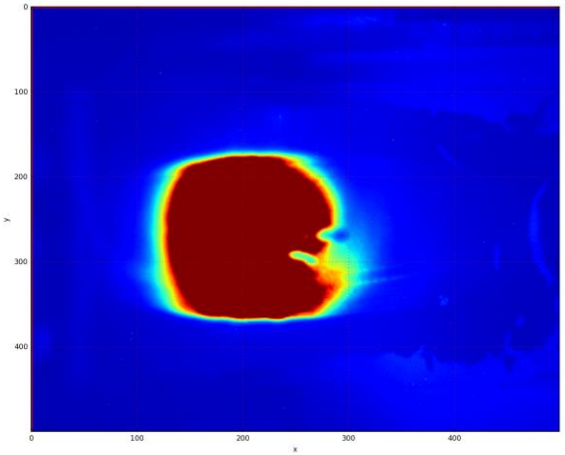
SASE saturation

2016.11.25





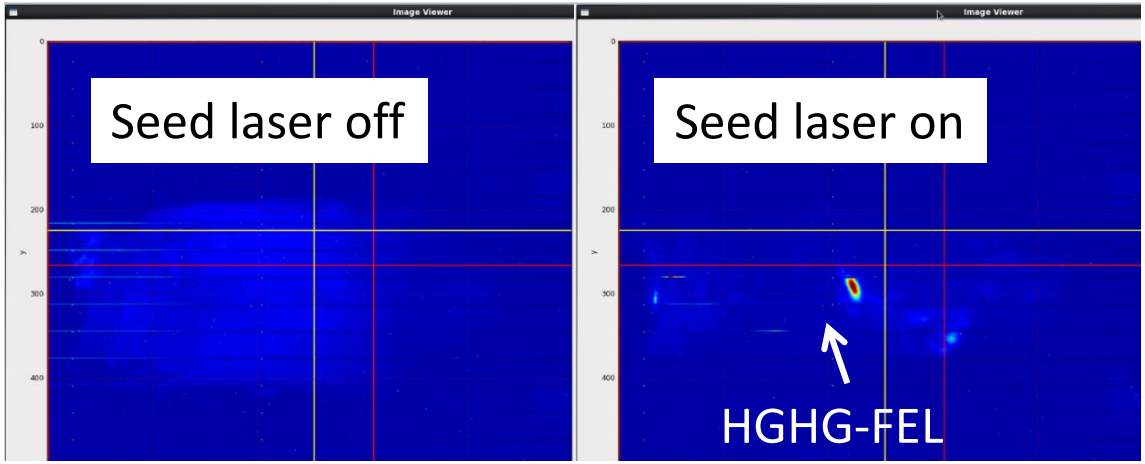
SASE spectrum

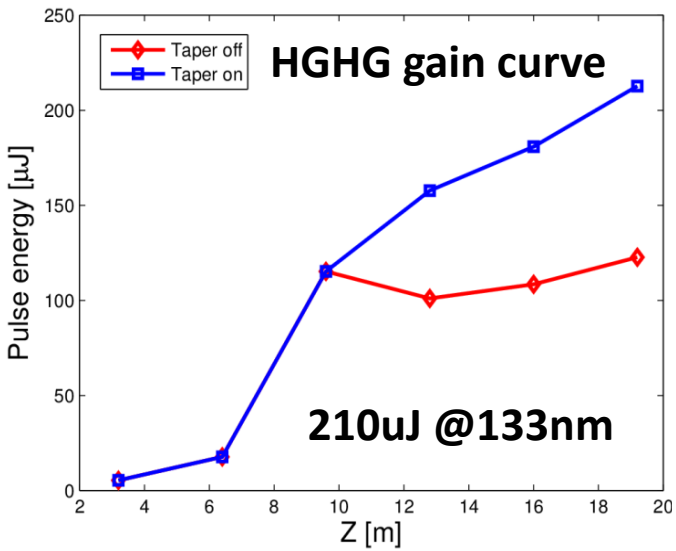


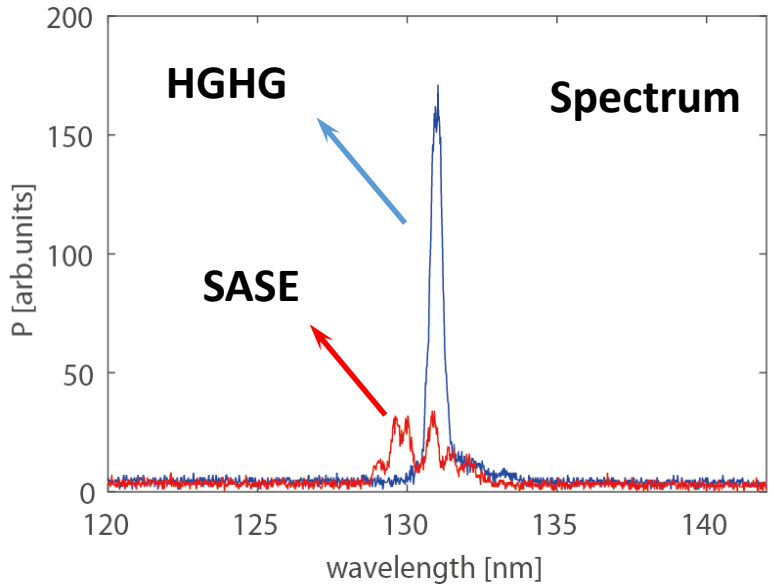
SASE spot image

HGHG saturation

2016.12.16



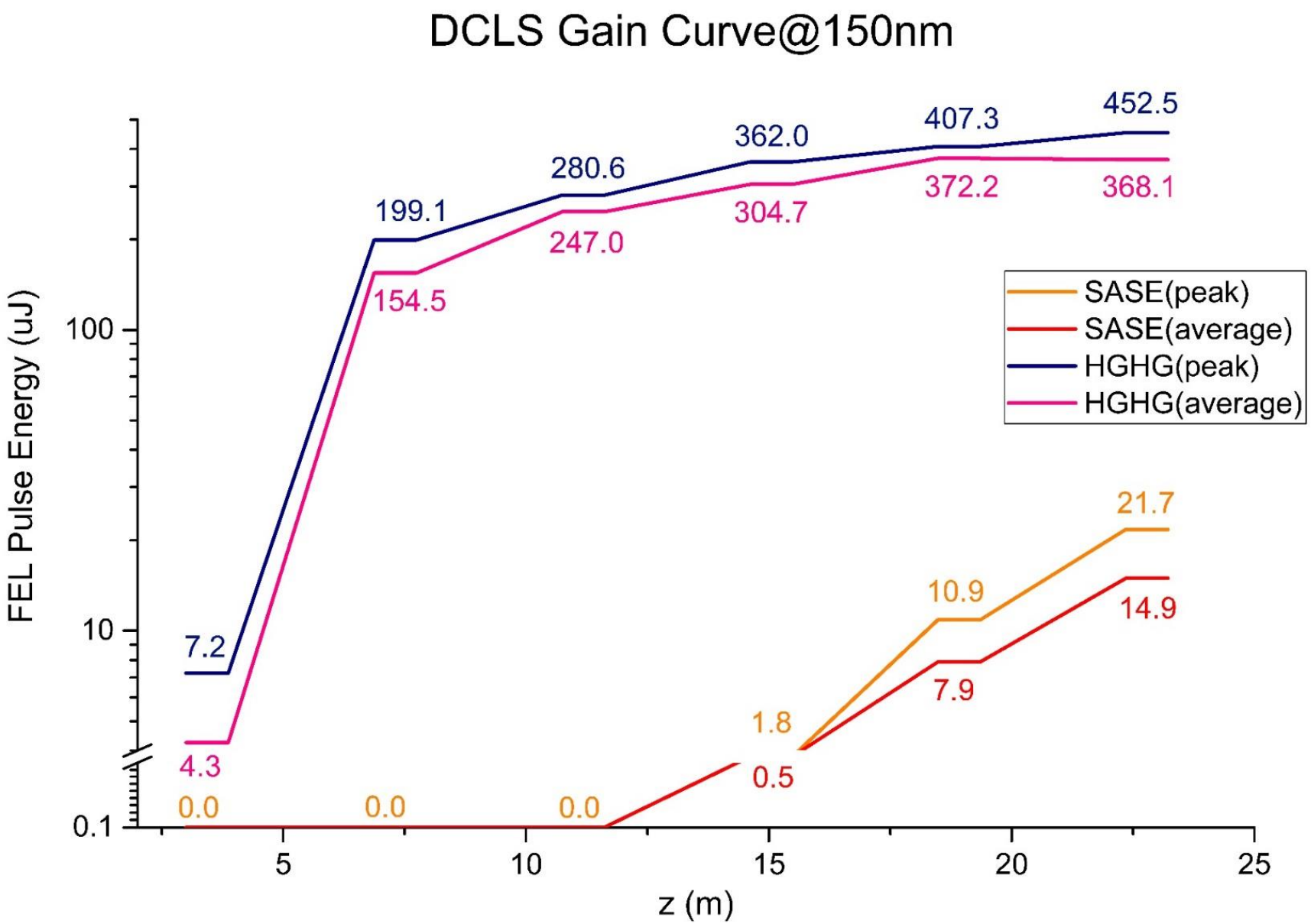




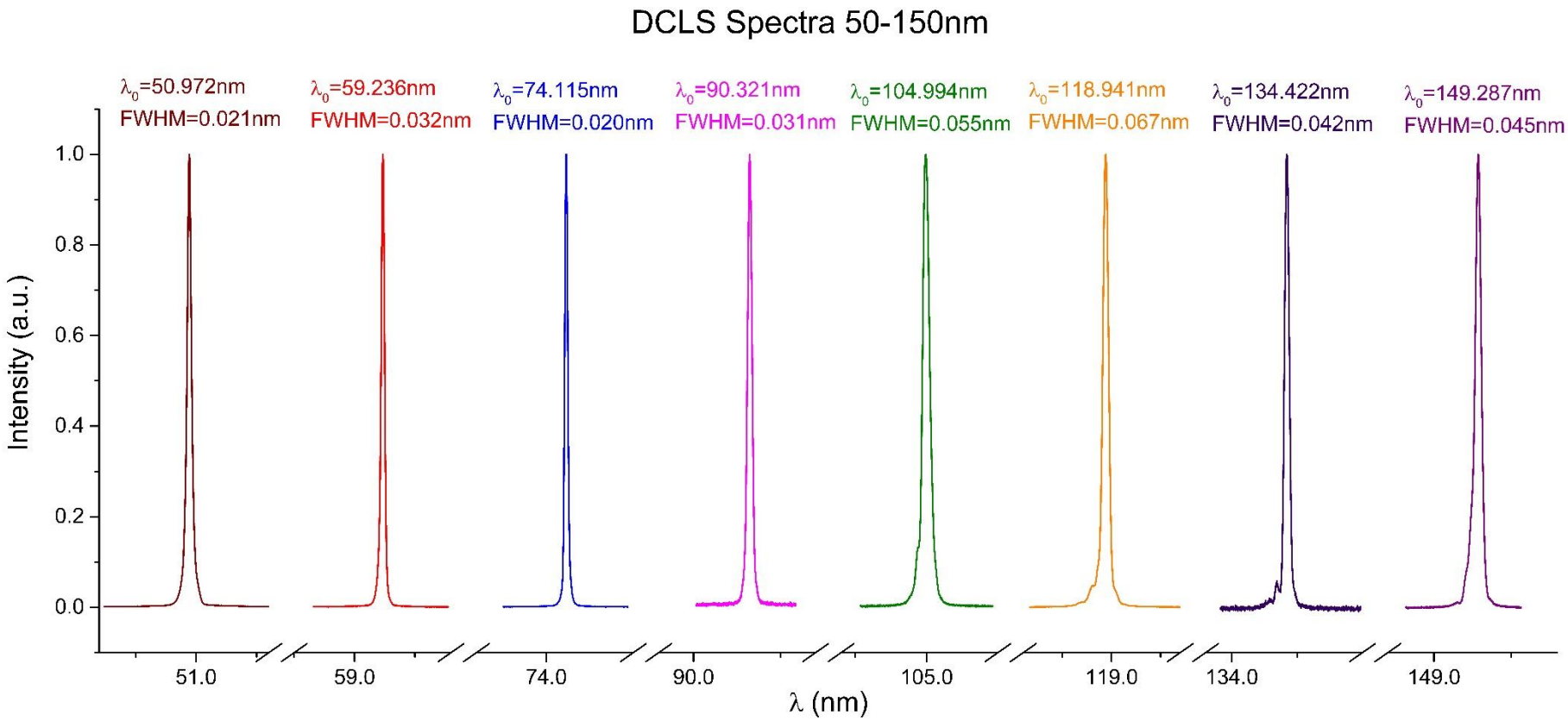
Seed laser is 266nm, which is 3rd of 800nm.

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

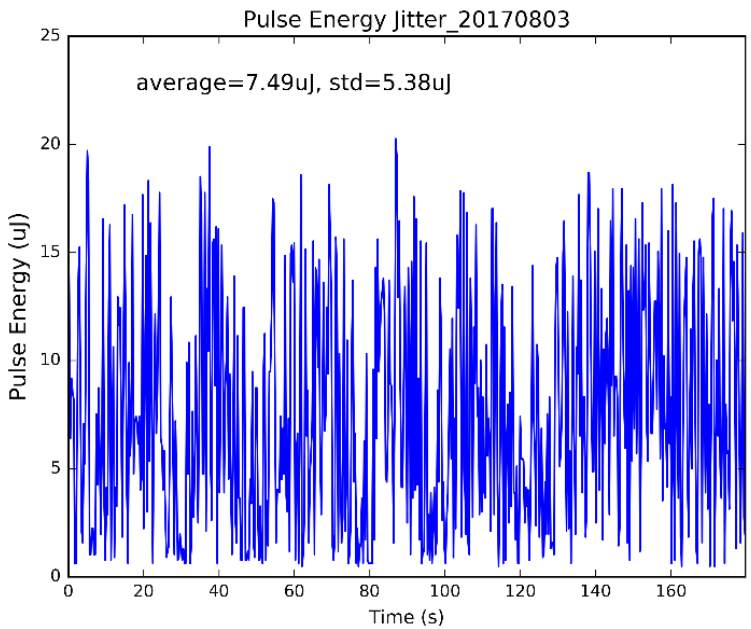
High brilliance

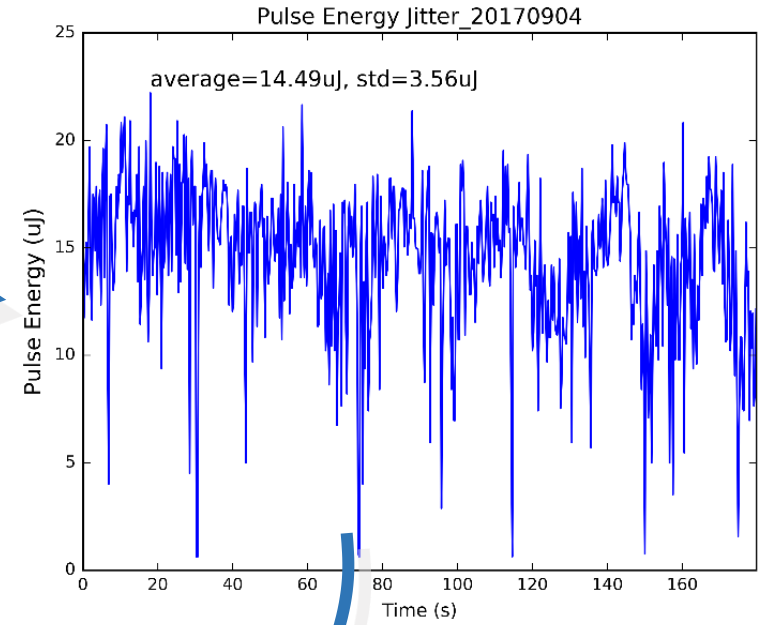


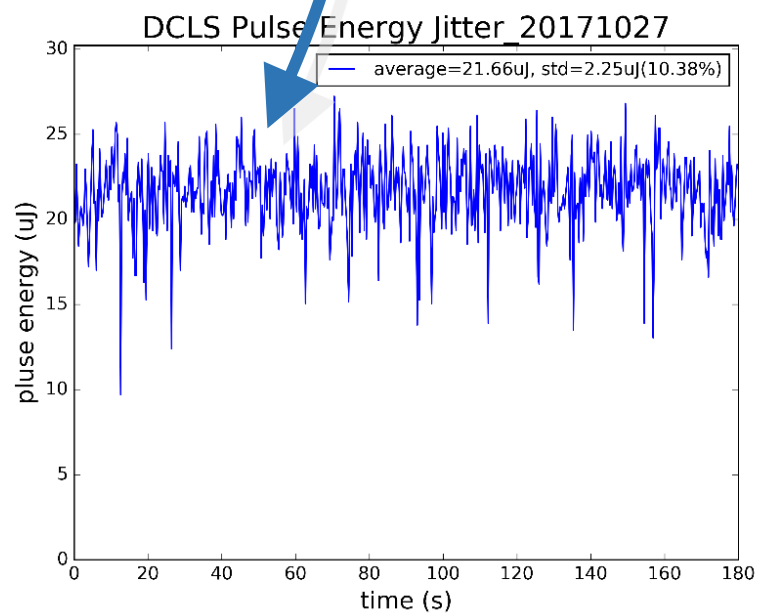
FEL wavelength tunability（50-150nm）



FEL stability





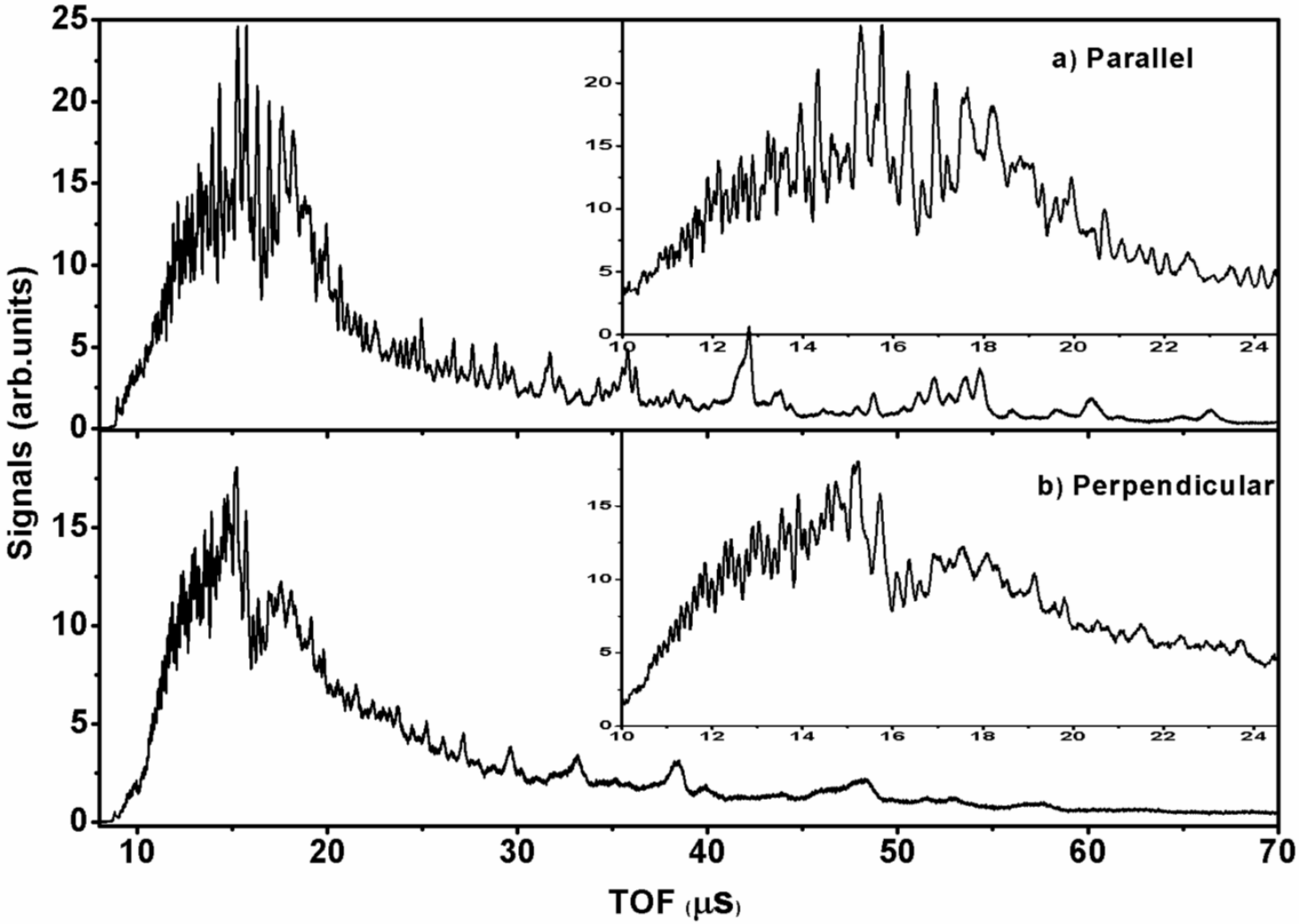


Pulse energy fluctuation is down to 10%

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

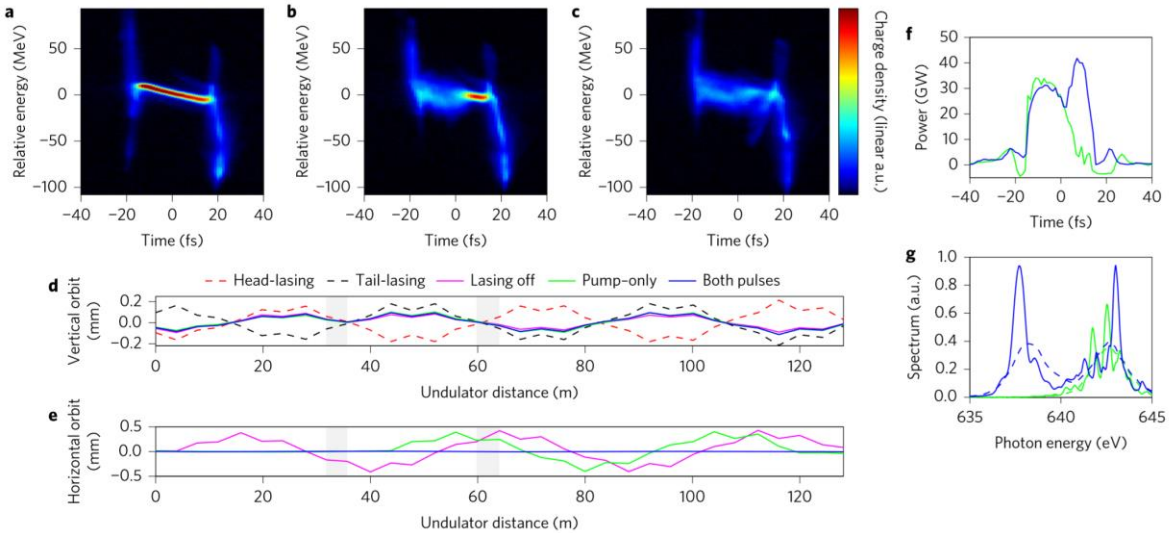
User experiment

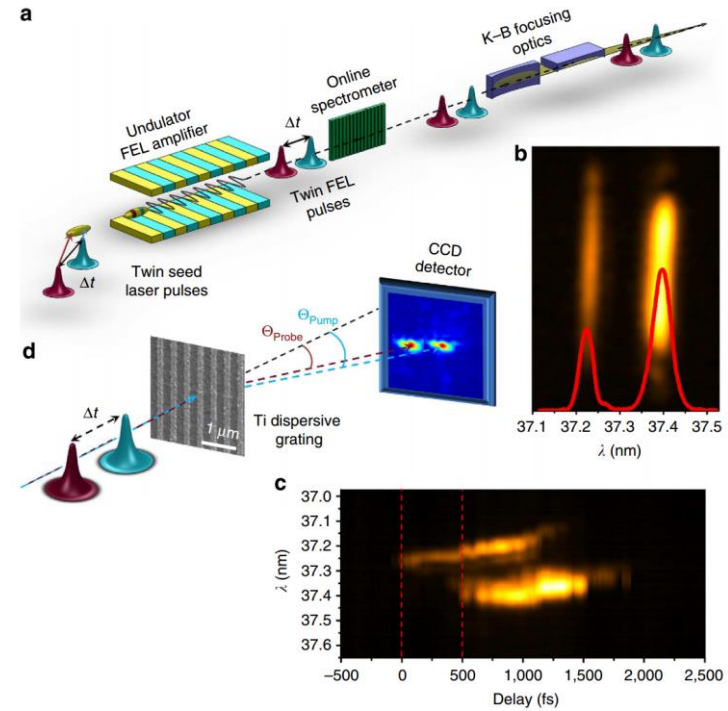
photodissociation dynamics of H_2O



Heilong Wang, et al., to be published in J. Chem. Phys.

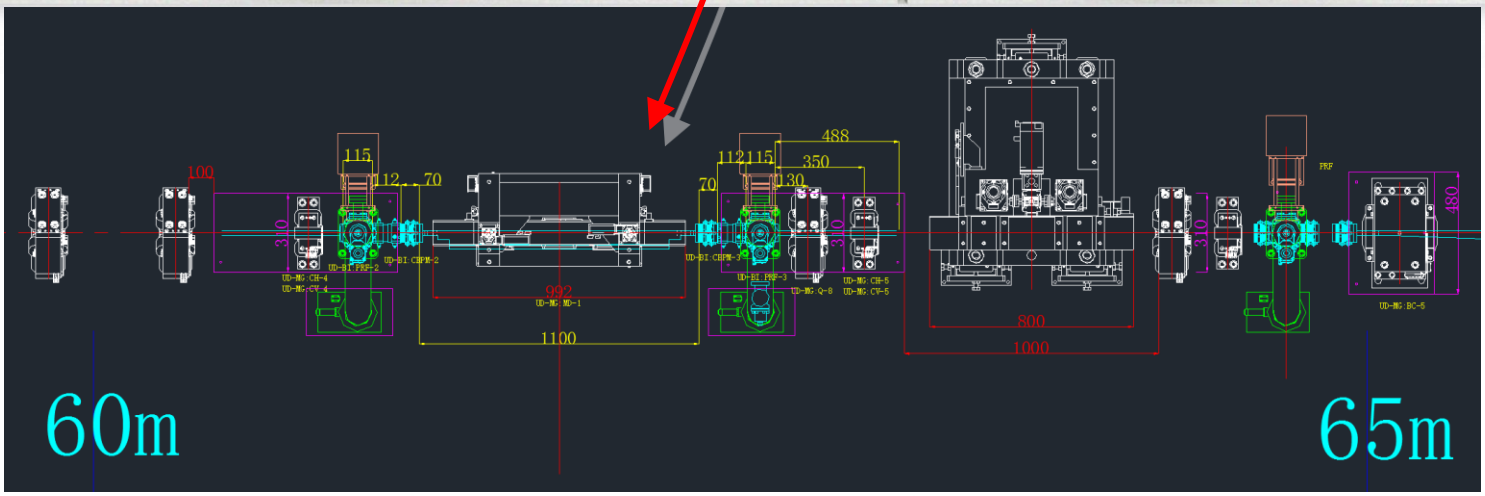
Review of two-color methods

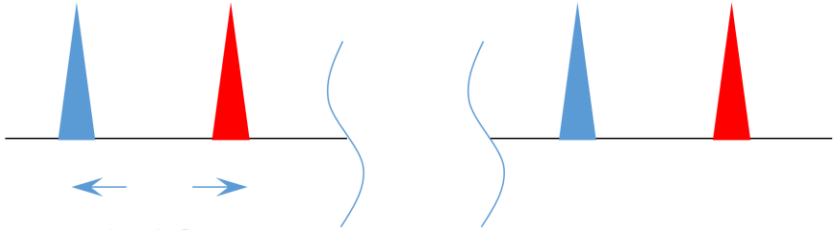




[1] A.A. Lutman, et al., Physical Review Letters 110 (2013) 134801.
[2] A. Marinelli, et al., Nature Communications 6 (2015) 6369.
[3] T. Hara, et al., Nature Communications 4 (2013) 2919.
[4] A.A. Lutman, et al., Physical Review Letters 113 (2014) 254801.
[5] G. De Ninno, B. Mahieu, E. Allaria, L. Giannessi, S. Spampinati, Physical Review Letters 110 (2013) 064801.
[6] B. Mahieu, et al., Optics Express 21 (2013) 22728.
[7] E. Allaria, et al., Nature Communications 4 (2013) 2476.
[8] C. Feng, et al., Nuclear Instruments and Methods in Physics Research Section A 712 (2013) 113.
[9] C. Feng, Y. Ding, Z. Huang, J. Kraywinski, A.A. Lutman, Proceedings of FEL, Nara, Japan, 2012, pp. 654 .
[10] E. Allaria, et al., Nature Photonics 6 (2012) 699.
[11] A.A. Lutman, et al., Nature Photonics 10 (2016) 745.
[12] C. Feng, et al., Nuclear Instruments and Methods in Physics Research Section A 807(2016)79–85.

Two-color VUV FEL



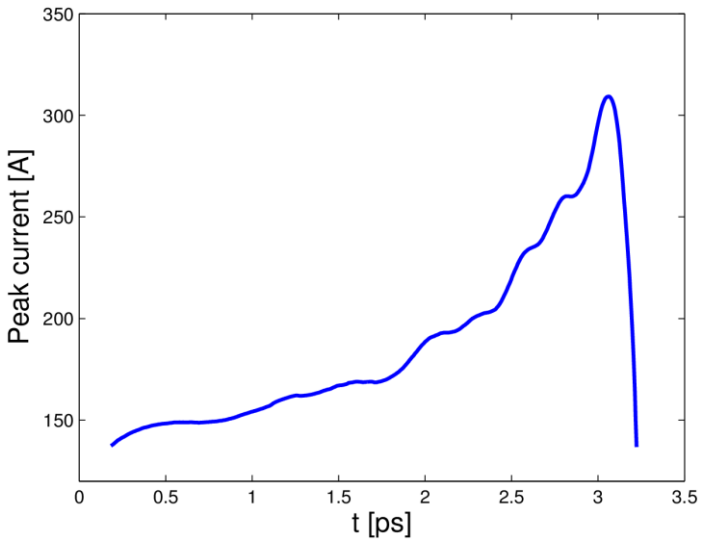


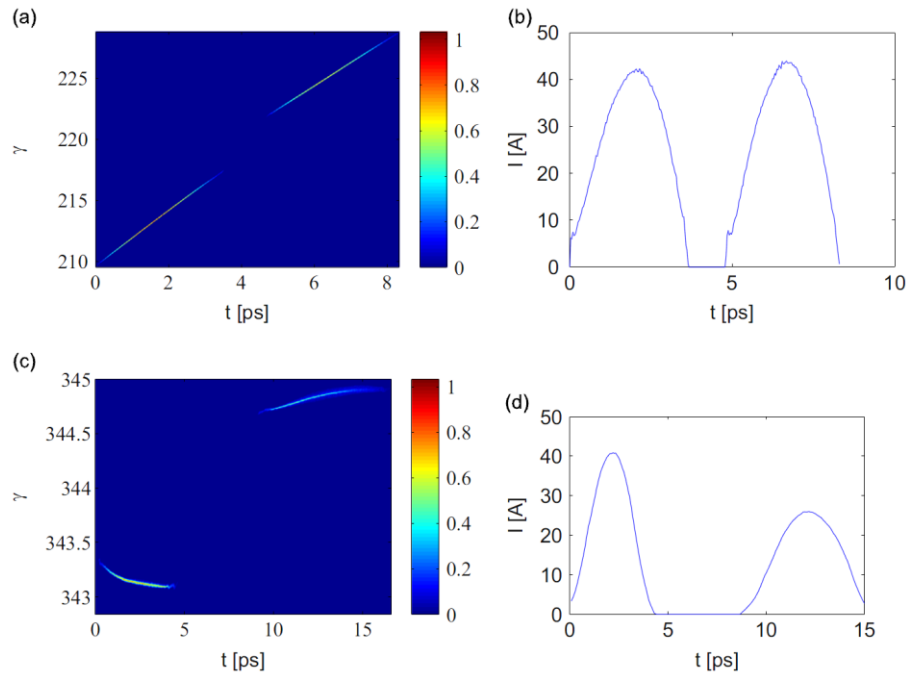
~1-10 ps

20ms /50Hz seed laser

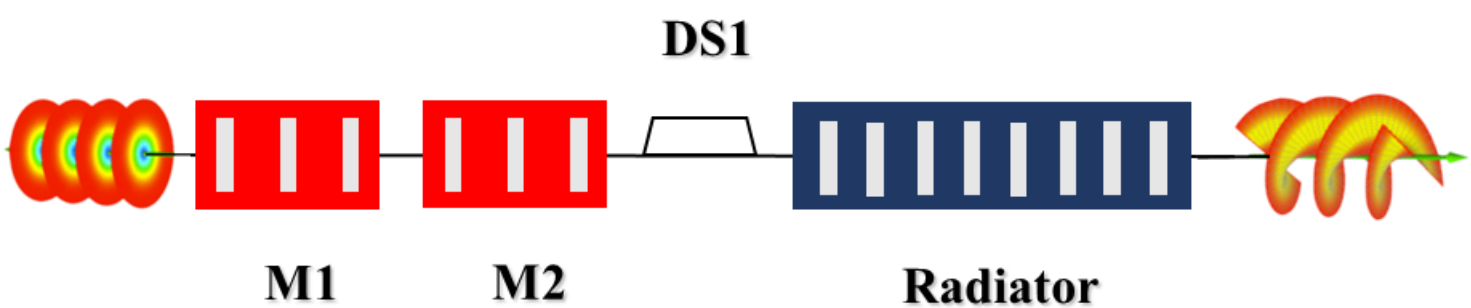
Two-color VUV FEL

- Time delay of the two FEL pulses is about several picoseconds.
- FEL wavelength of the two pulses is tunable between 50 to 150 nm.



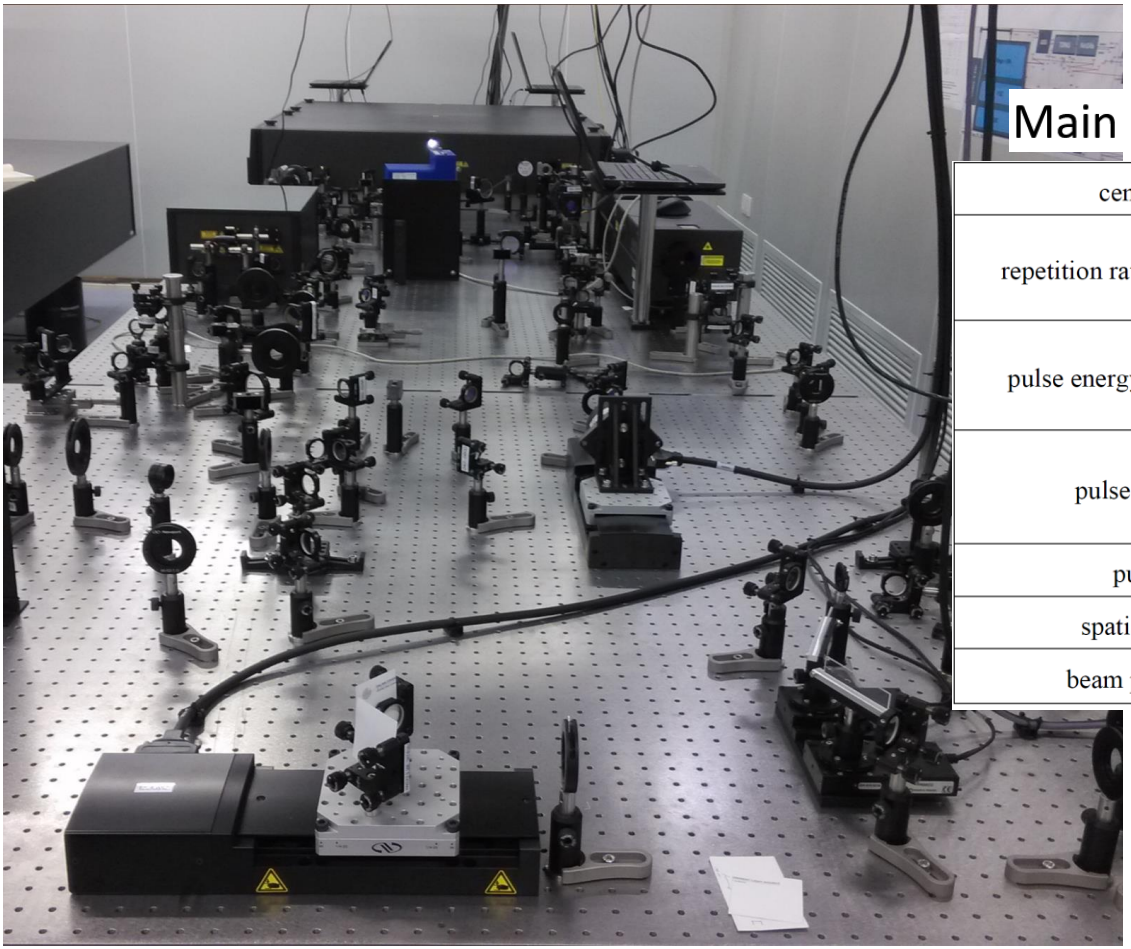


- Pump probe experiments with arbitrary OAM FEL could be realized.



C. Feng, et al., Nuclear Instruments and Methods in Physics Research Section A 807(2016)79–85.

Ti:sapphire laser(OPA) & VUV FEL

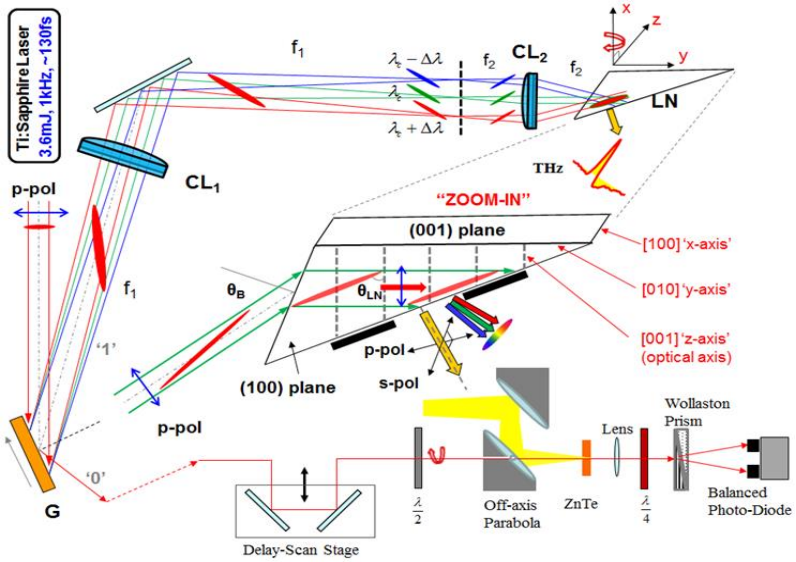


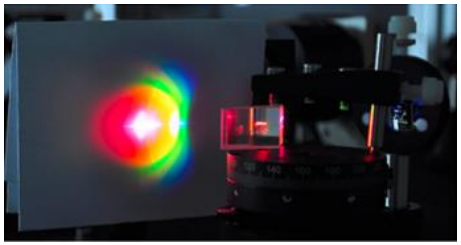
Main Parameters of the Ti:sapphire laser

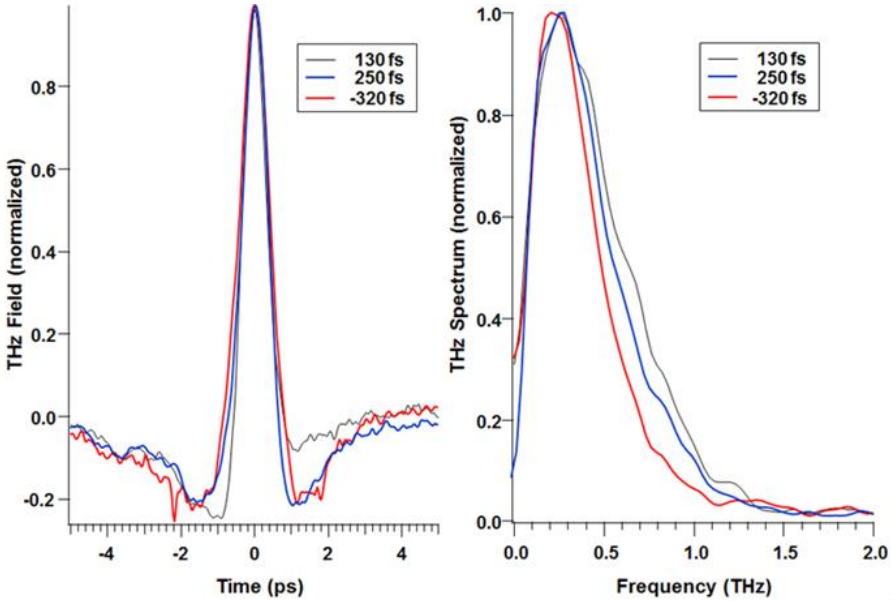
center wavelength		800 nm
repetition rate	oscillator [1)]	79.33 MHz
	amplifier[2,3)]	10-1000 Hz
pulse energy	Oscillator[4)]	matching with the amplifier
	amplifier[3)]	⩾ 10 mJ
pulse energy stability[3)]		⩽ 0.5% rms @800nm ⩽ 1.5% rms @ THG
pulse duration[3)]		< 50 fs
spatial mode quality[3)]		TEM_{00}, $M^2 < 1.3$
beam pointing stability[3)]		< 10 μrad, rms

- Timing jitter between the FEL and Ti:sapphire laser is about 30 fs;
- The ultrafast excited-state dynamics in isolated molecules can been studies by combining UV pump and VUV probe.

THz and VUV-FEL







Frequency range	0.1-3.5THz
Frequency resolution	<5GHz
Efficiency	~0.1% (max)
Pulse energy	~μJ level
Laser spot size	<2 mm

Bin Li *et al* 2017 *New J. Phys.* **19** 113025.

Thank you for you attention!