Recent FEL Designs For SXFEL and SHINE

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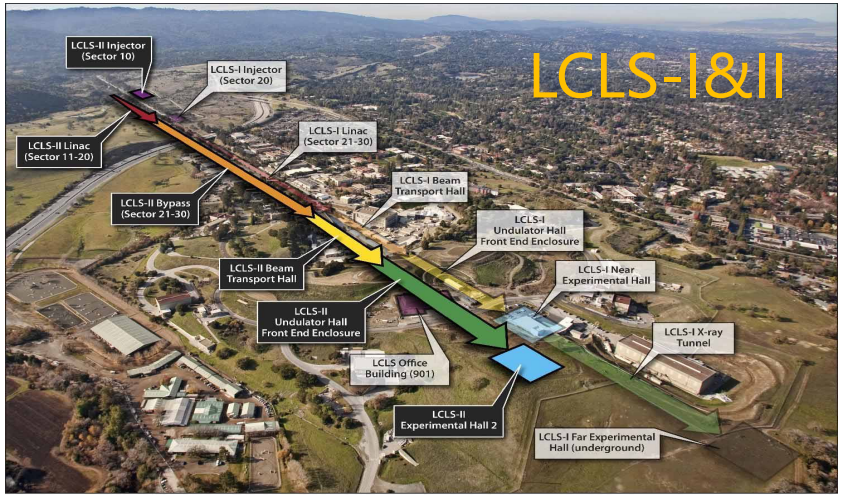
Outline

- Background
  - Free electron laser
  - SXFEL
  - SHINE
- Rapid polarization switch in SHINE FEL-II
- Fully Coherent Femtosecond X-Ray FEL in SXFEL
- Summary

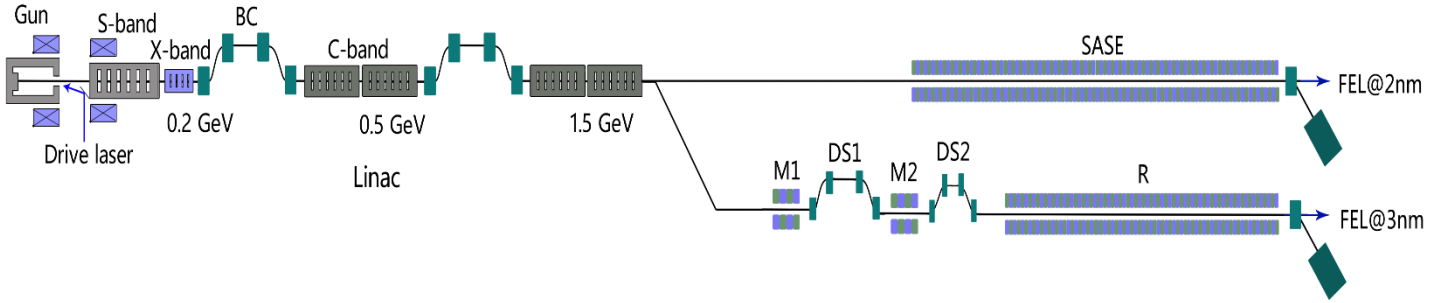
Background

Free electron laser



Background

SXFEL

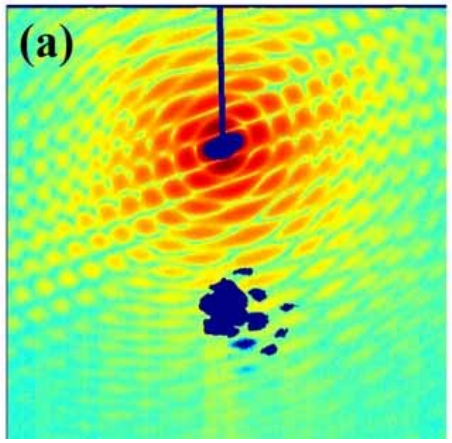


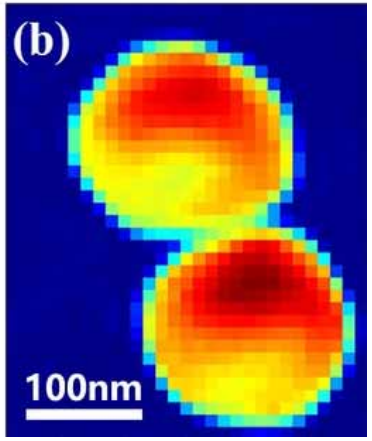
Parameters	SXFEL
Mode	SASE/Seeding
Beam Energy	1.5 GeV
Peak Current	0.7-1 kA
Shortest Wavelength	2/3 nm
Shortest Period	16 mm/23.5 mm

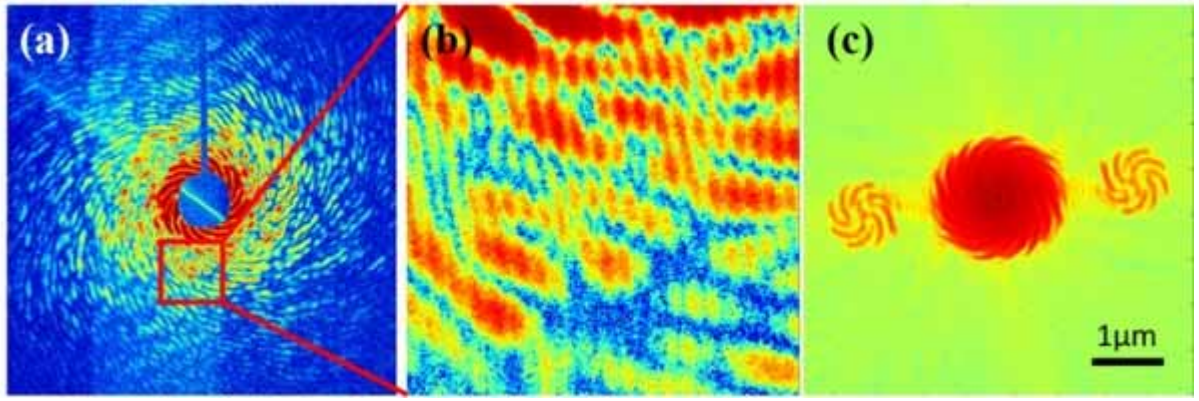
Test facility → user facility

Background

SXFEL

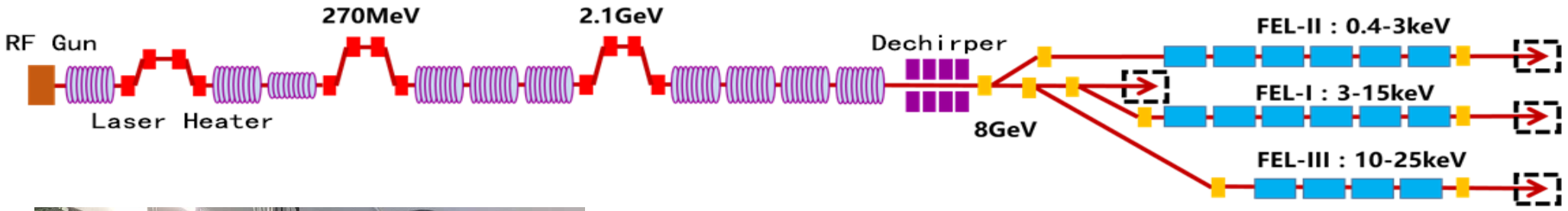






Background

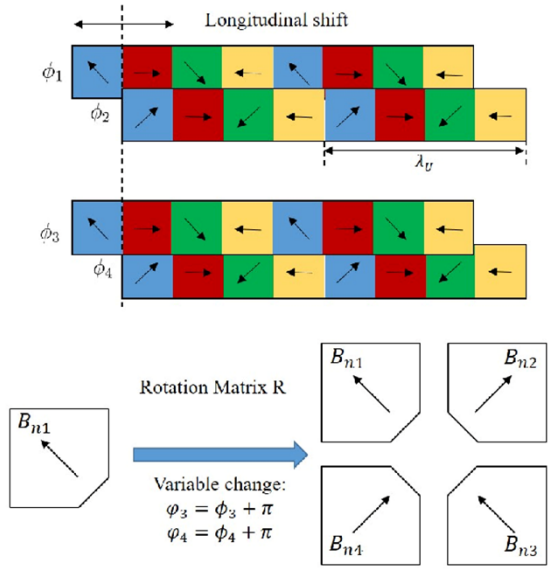
SHINE

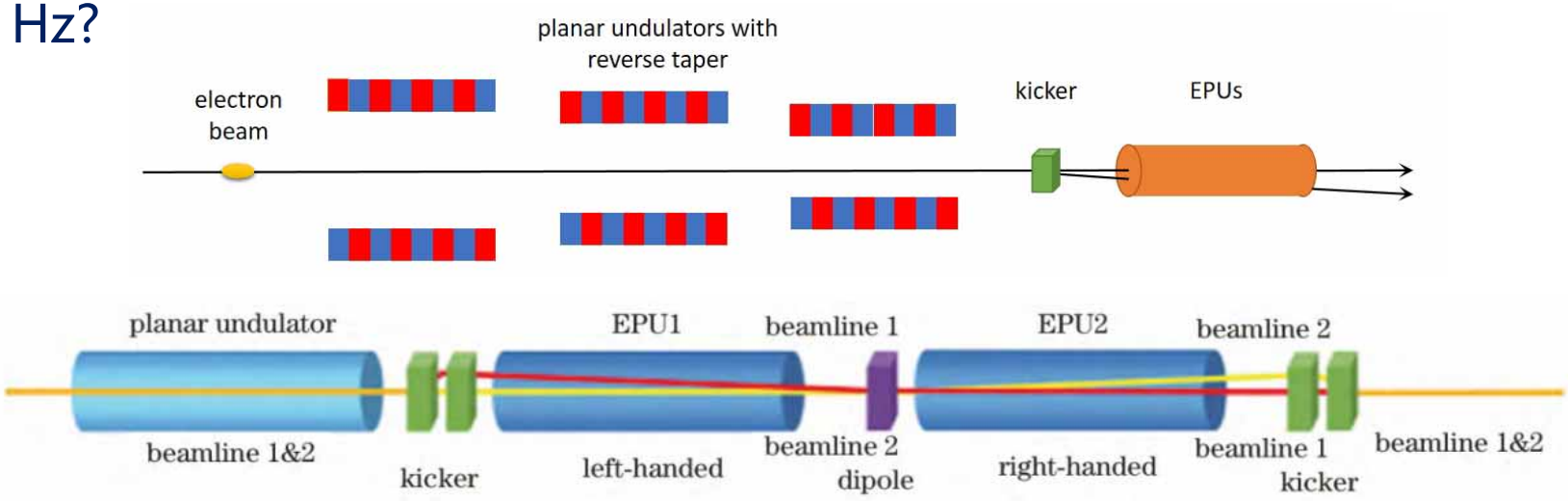


Parameter	Value
Beam energy	8 GeV
Slice energy spread	0.01%
Normalized emittance	0.5 μm·rad
Charge	100 pC
Peak current	1500 A

Rapid polarization switch

- Circular polarization
  - Helical radiator(APPLE-type/Delta undulators)
- Methods of polarization switch
  - Mechanical switching(APPLE-type) (higher repetition?)
  - Kicker, reverse tapered undulator & APPLE-type undulators
  - Kickers , reverse tapered undulator & APPLE-type undulators
  - Mega Hz?

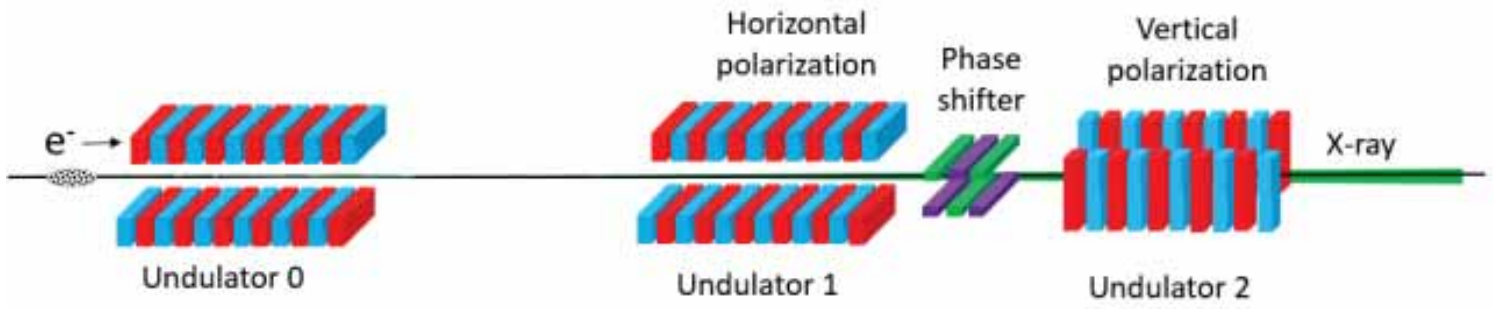




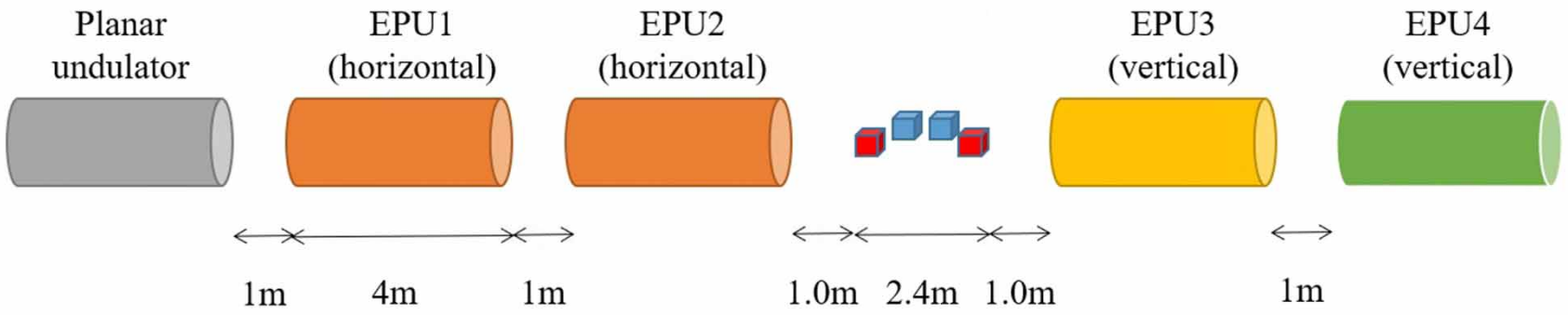
Rapid polarization switch

Scheme for high-repetition-rate polarization switch

Crossed planar undulators



4-EPU section



Helical → planar

Lower polarization purity but higher repetition(phase & intensity differences)

Avoid saturation, beam profile control, slightly detuned, SASE→seeded if possible

Special phase shifter

Rapid polarization switch

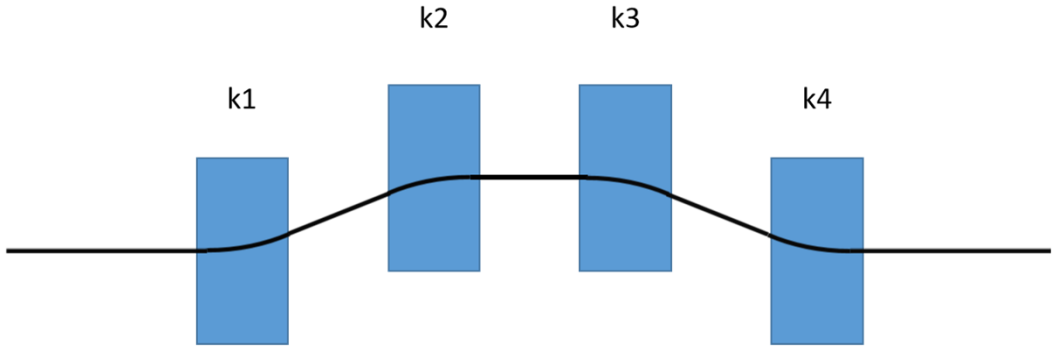
Bunch-by-bunch phase shifter

Consist of 4 kickers, placed like a chicane

Adjustable frequency and amplitude

Relatively long(~2.5m)

Offer phase shift more than π in the whole wavelength range



Kicker Parameters

Parameter	Value
Beam energy	8 GeV
Max frequency	500 kHz
Working mode	bunch by bunch
Effective length	300 mm
Deflection angle	25 −60 μrad

Rapid polarization switch

FEL simulation (low photon energy)

Polarization calculated by S parameters

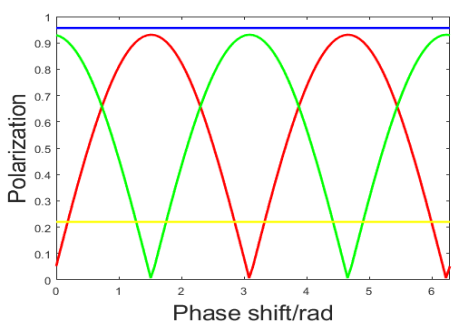
Observation 100m downstream the EPUs

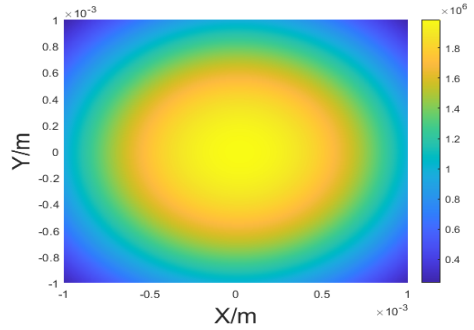
Polarization degree over 90%/85%

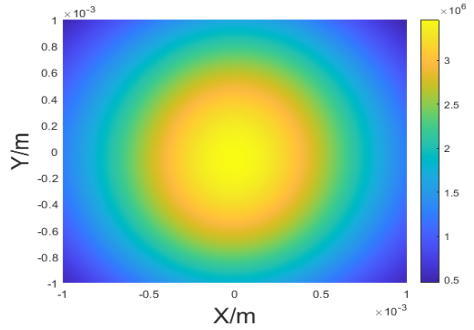
Horizontal: 2

Vertical: 1

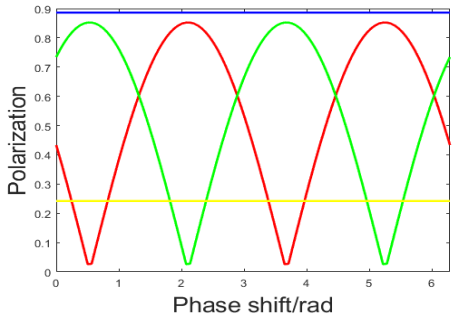
$$\vec{\mathbb{S}} = \begin{pmatrix} \left\langle E_x^{0\,2} \right\rangle + \left\langle E_y^{0\,2} \right\rangle \\ \left\langle E_x^{0\,2} \right\rangle - \left\langle E_y^{0\,2} \right\rangle \\ 2\left\langle E_x^0 E_y^0 \cos\left(\phi_x(t) - \phi_y(t)\right) \right\rangle \\ 2\left\langle E_x^0 E_y^0 \sin\left(\phi_x(t) - \phi_y(t)\right) \right\rangle \end{pmatrix}$$

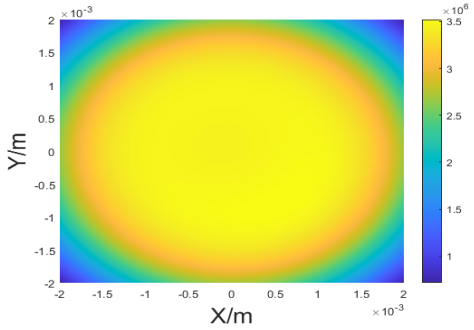


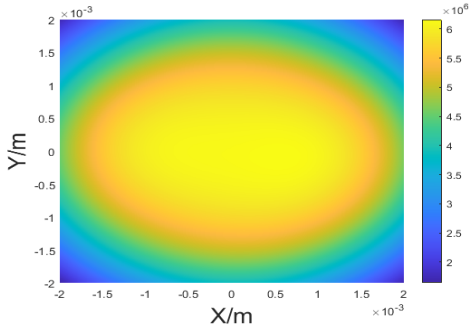




1.2keV







510eV

Rapid polarization switch

FEL simulation (high photon energy,3keV)

2+1: below 80%

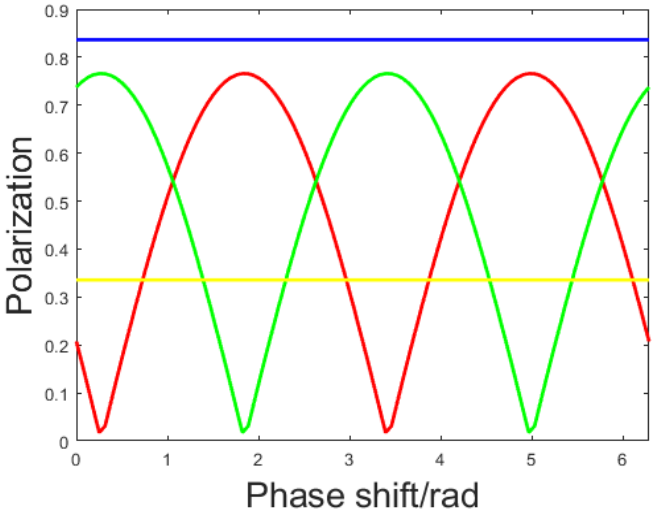
Relatively large differences in phase and intensity

2+2: around 90%

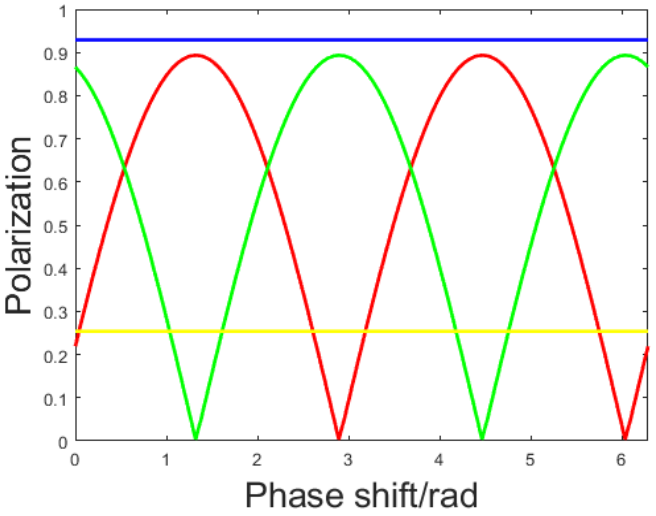
Shot noise? 3% in polarization

Observation spot? hardly affects (60-100m downstream)

Phase shifter length? slight in a small range(over 80% from 2.1m-2.7m)



1 vertical



2 vertical

Fully Coherent Femtosecond X-Ray FEL

Principle

Kicked transversely to get a time-related transverse tilt

Transversely limited seeding laser

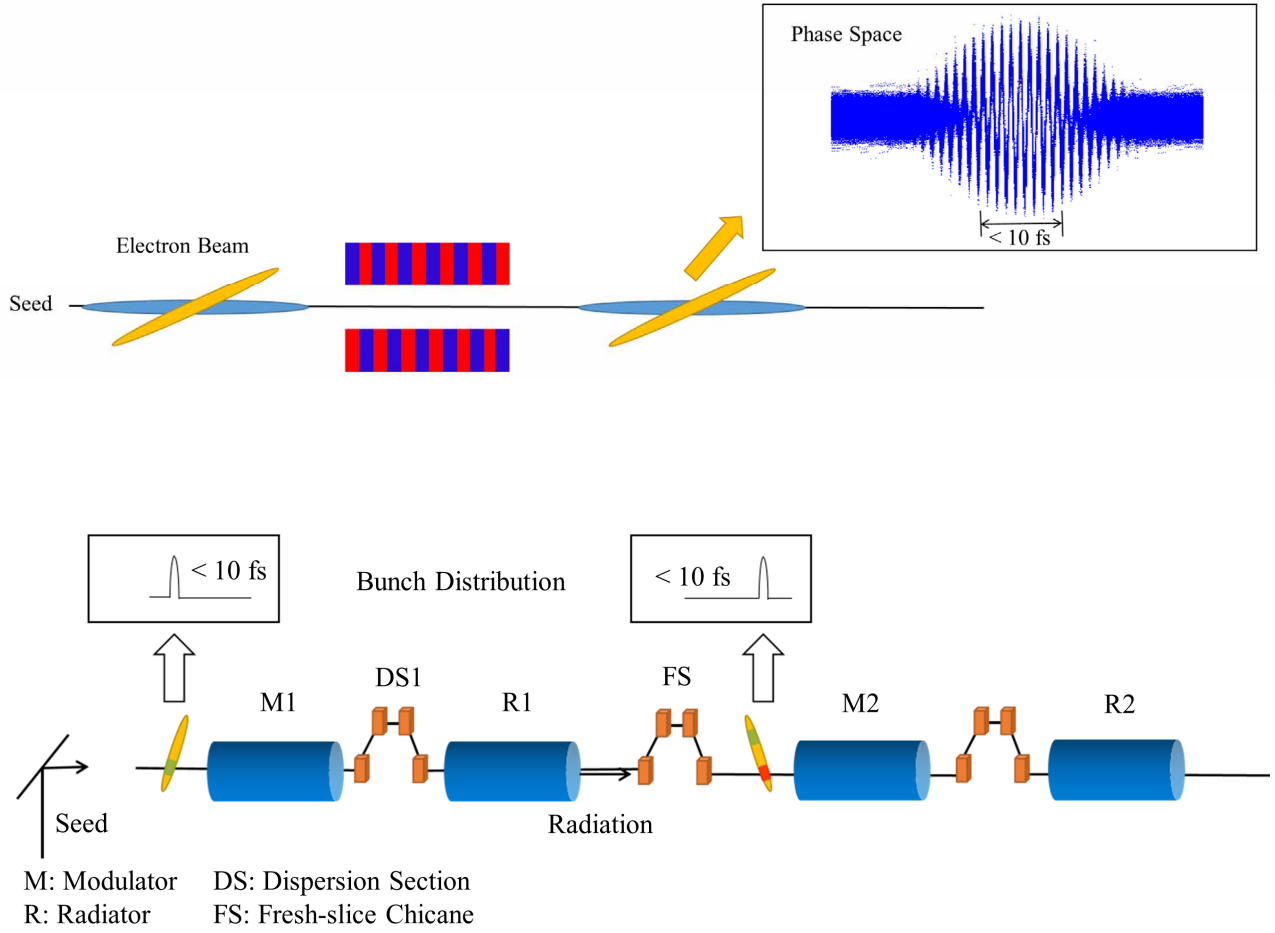
Transverse restrains → longitudinal restrains

Harmonic lasing: even shorter

Cascaded HGHG: beam tail modulates beam head

EEHG: same part modulated twice

EPU harmonic lasing: shorter&double color&double polarization



Fully Coherent Femtosecond X-Ray FEL

FEL simulation

45th harmonics

Wavelength: 5.9 nm

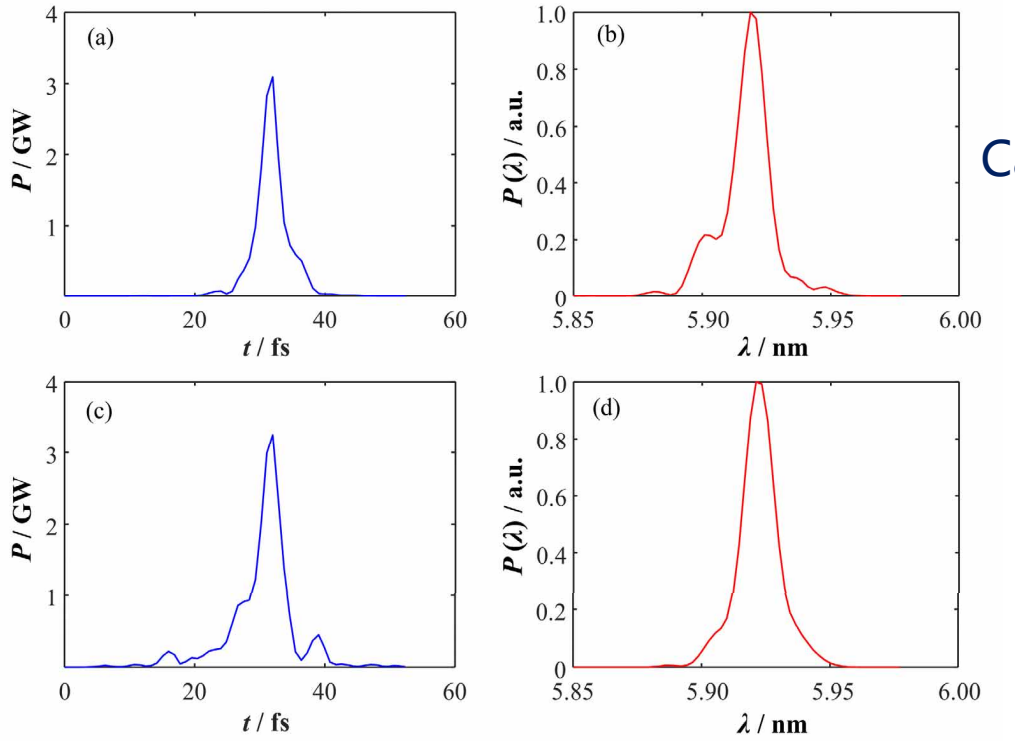
Peak power: over 3 GW

Pulse duration:

3.3 fs for cascaded HGHG

3.7 fs for EEHG

Similar to the theory



Cascaded HGHG

EEHG

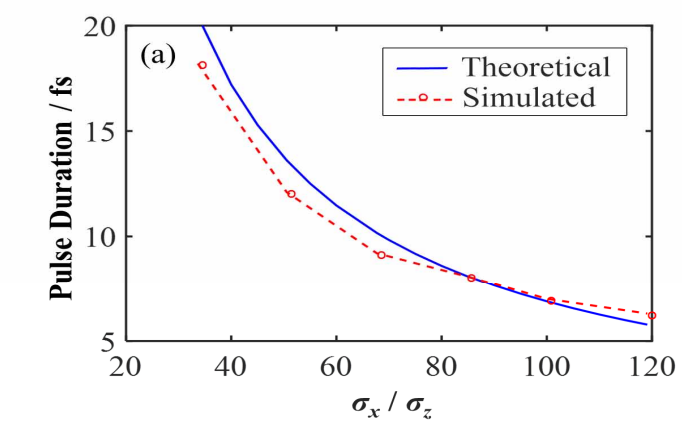
Fully Coherent Femtosecond X-Ray FEL

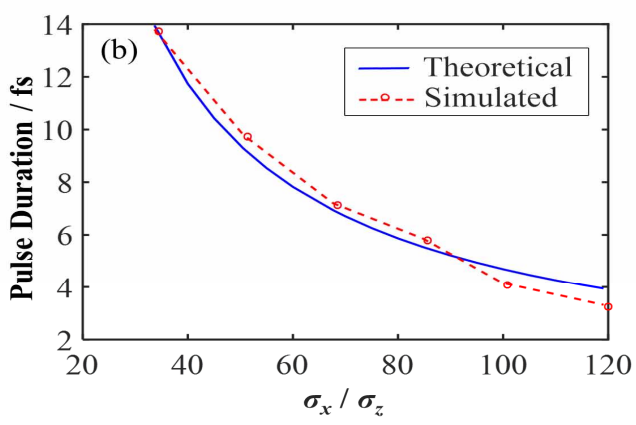
FEL simulation

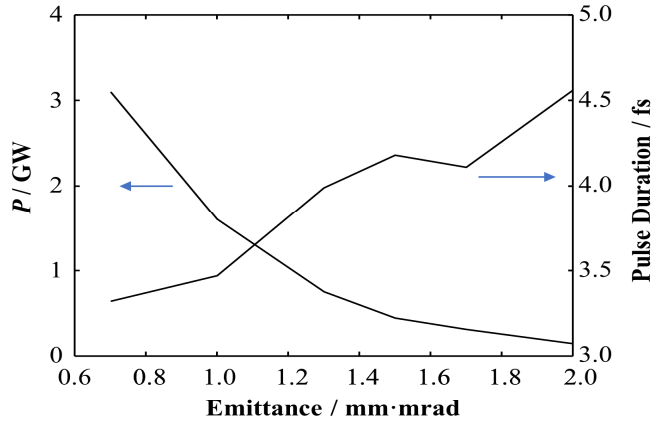
Pulse duration vs transverse slope

Radiation quality vs emittance

Pulse duration







9th harmonic

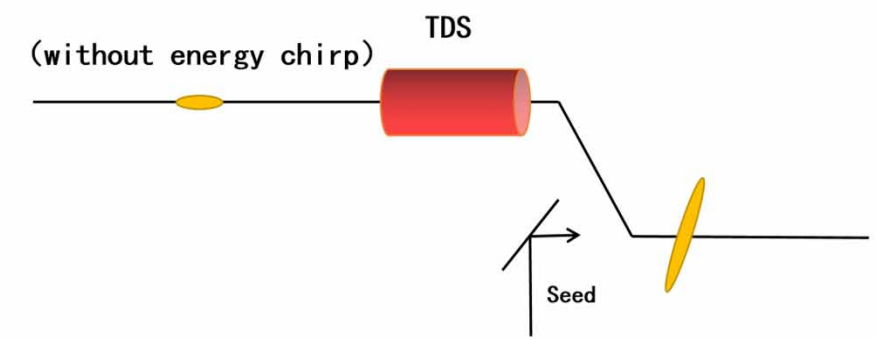
45th harmonic

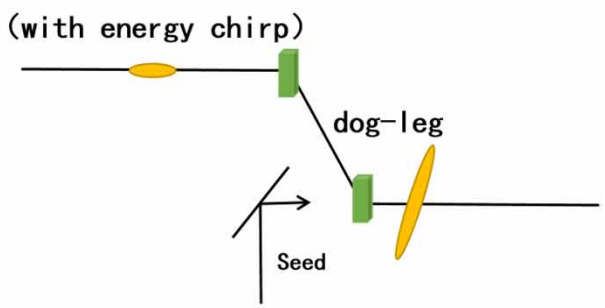
Fully Coherent Femtosecond X-Ray FEL

FEL simulation

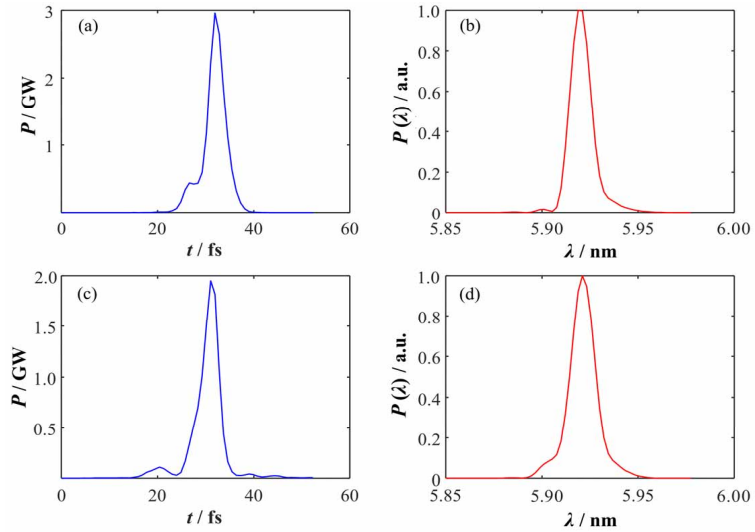
Beam with energy chirp

Beam position jitter

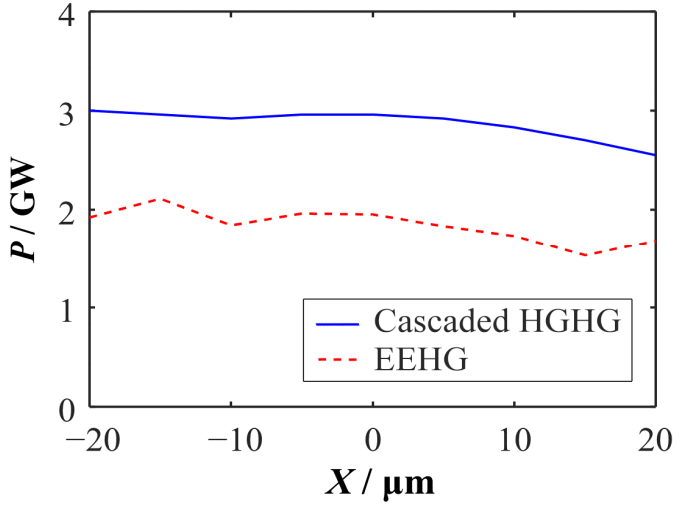




Energy chirp



Horizontal jitter



Fully Coherent Femtosecond X-Ray FEL

FEL simulation

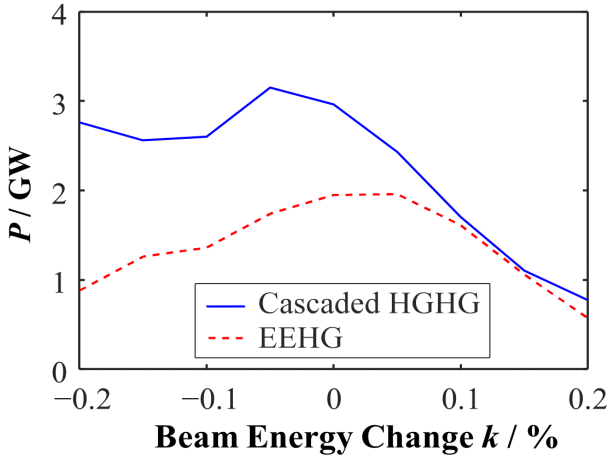
Beam energy jitter

Wavelength: 3 nm

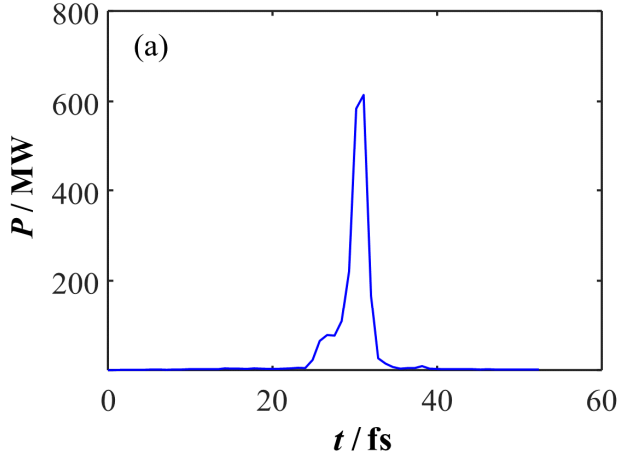
Peak power: over 600 MW

Pulse duration: around 2 fs

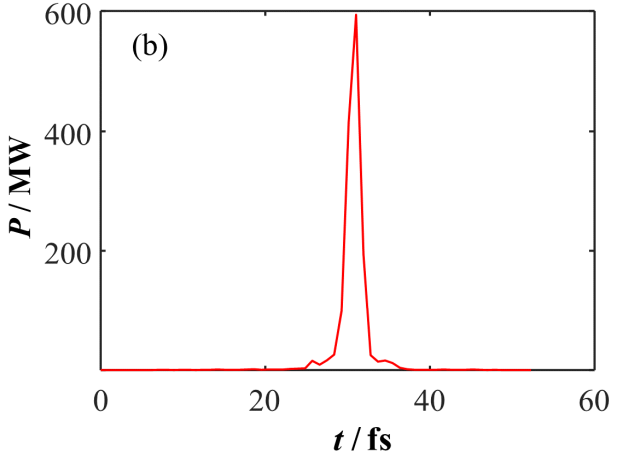
Beam energy jitter



90th harmonic (circular polarization)



EEHG



Cascaded HGHG

Summary

- Pulse-by-pulse polarization switch over 85% polarization degree under SASE mode.
- Femtosecond FEL pulse under EEHG/cascaded HGHG mode.
- Both linearly and circularly polarized femtosecond FEL.
- A series of jitter analysis.

THANK YOU FOR LISTENING