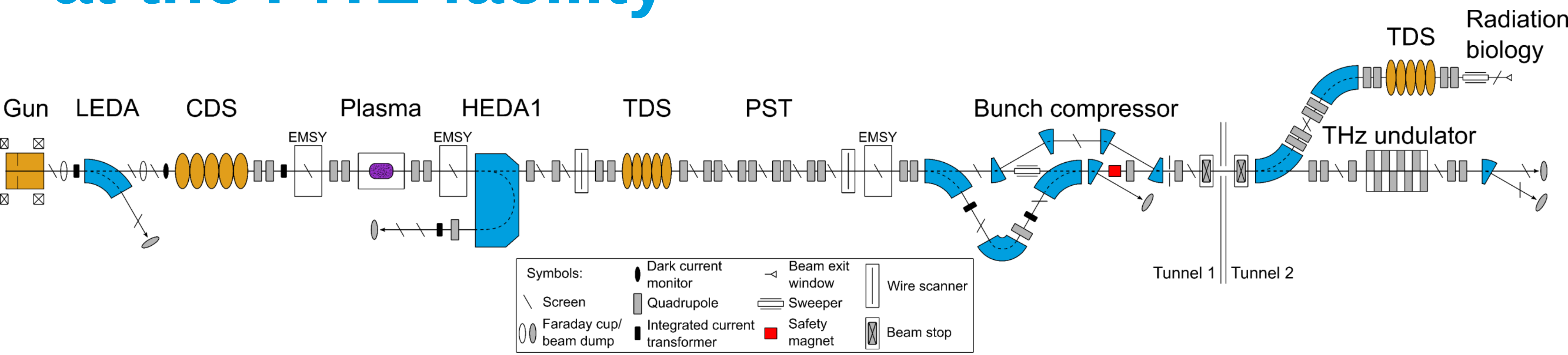
Summary and outlook of a superradiant THz FEL source at the PITZ facility



Natthawut Chaisueb,

PPS seminar, DESY, Zeuthen

Work tasks

UR and Superradiant radiation

1. Parameter space by SPECTRA
   a) Benchmark of SPECTRA code and analytical calculation
   b) Effects of transverse emittance and energy spread
   c) Limitation of coherent part of undulator radiation
   d) Tunable THz undulator radiation at PITZ
   e) Collecting efficiency at different observed positions
   f) Manipulation on electron bunch length, bunch charge and pulse energy

2. Pulse energy calculation from S2E simulated beam
   a) S2E simulated beam at full compression (A. Lueangaramwong)
   b) Electron beam form factor from different beam profiles
   c) Pulse energy of superradiant radiation

3. Impact of energy chirp by OCELOT

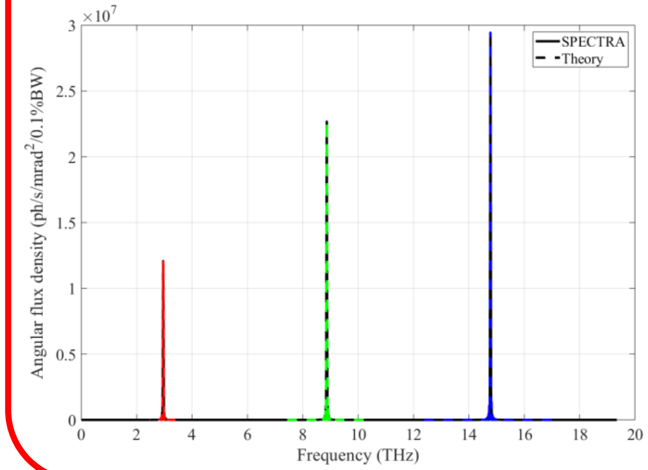
4. Influence of narrow undulator chamber
   a) Temporal profile of superradiant radiation
   b) Characteristics of transverse photon profile

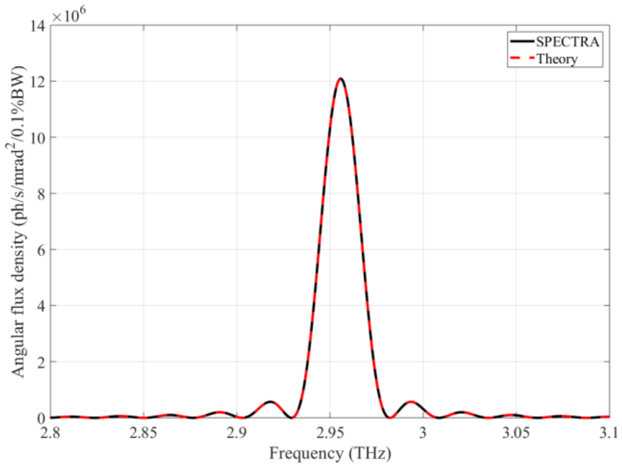
5. Experiments and S2E simulations

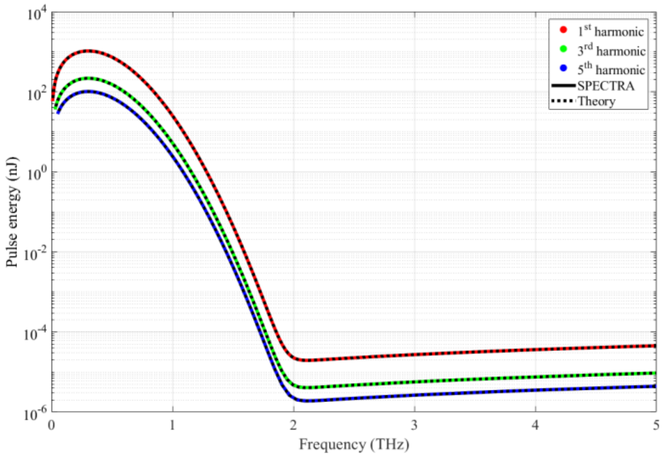
Proceeding!!!

1. Parameter space by SPECTRA

a) Benchmark of SPECTRA code and analytical calculation

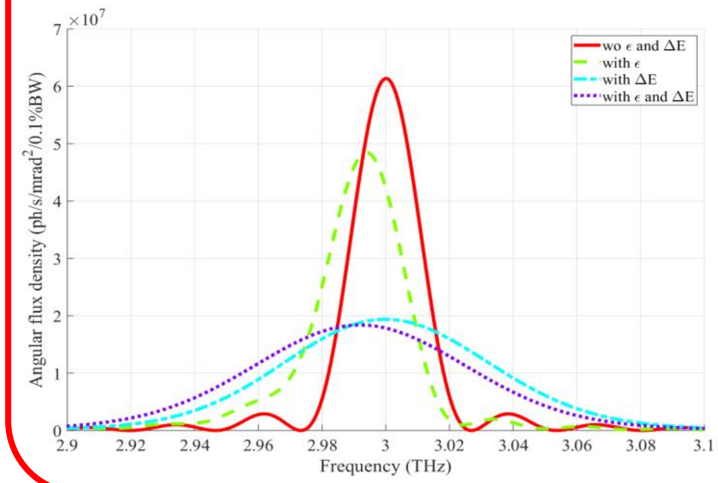


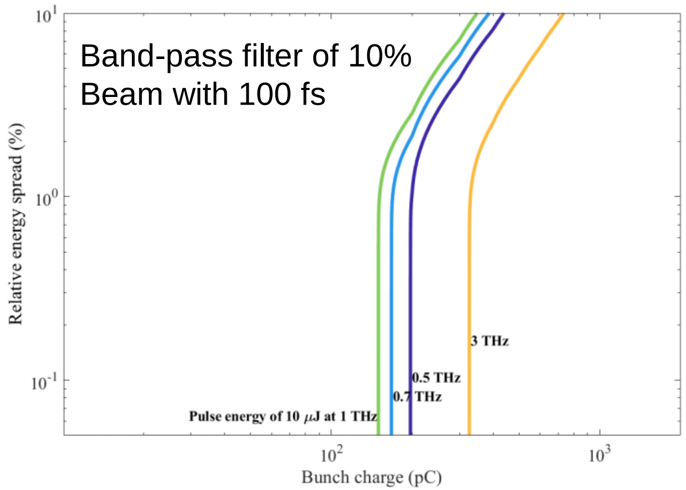




- The results in term of angular flux density and pulse energy from SPECTRA code is equivalent to theory of superradiant undulator radiation.

b) Effects of transverse emittance and energy spread

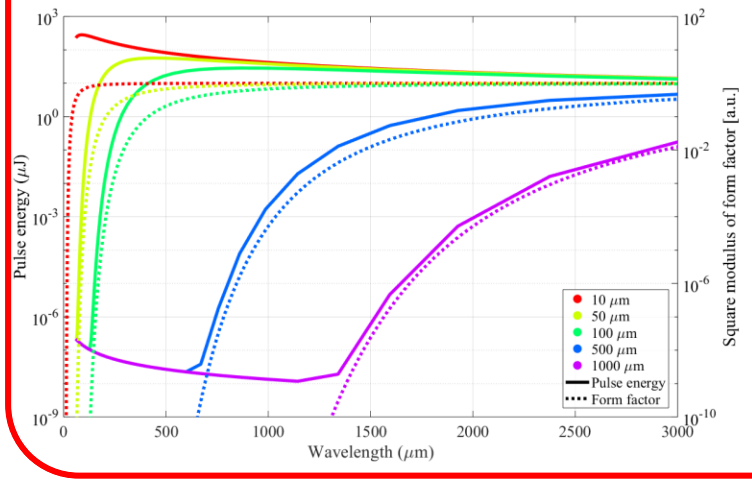




- Transverse emittance leads to slight decrease of the radiation intensity.
- While energy spread plays significant role in superradiant undulator radiation and causes a spectral broadening.
- Pulse energy starts decreasing when relative energy spread is higher than 1% for band-pass filter of 10%. (referred to PITZ beam properties)

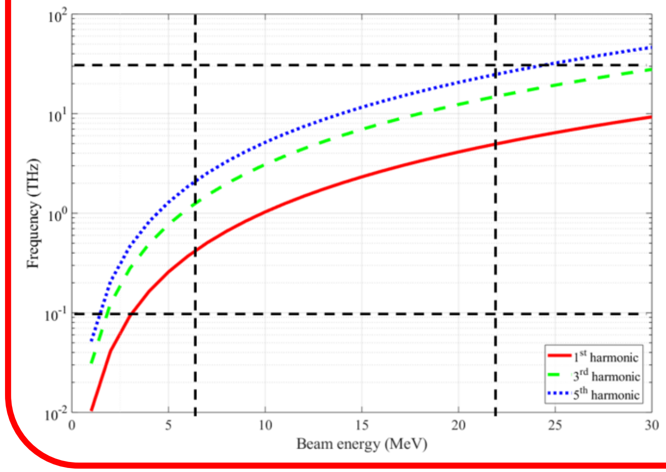
1. Parameter space by SPECTRA (2)

c) Limitation of coherent part of undulator radiation



- The pulse energy and form factor drop at wavelength shorter than their bunch length.
- This shows clearly the difference between incoherent and coherent radiation.

d) Tunable THz undulator radiation at PITZ

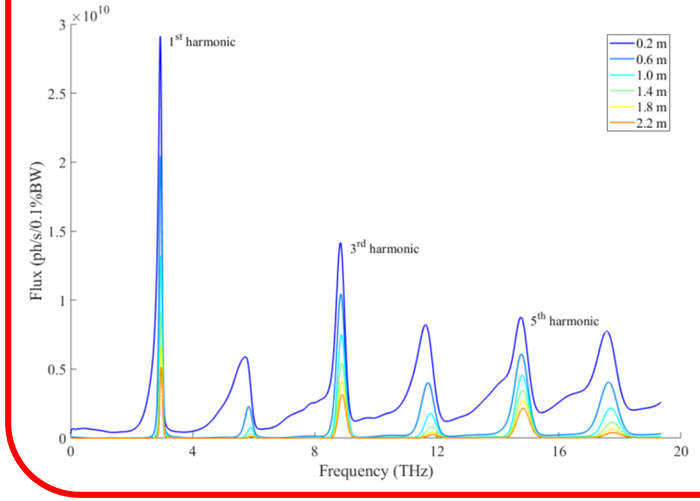


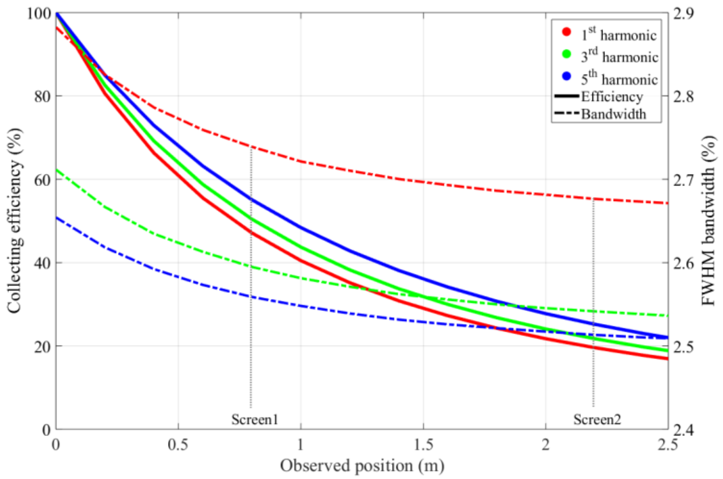
1st harmonic: 0.5 – 5 THz

3rd harmonic: 1.5 – 15 THz

5th harmonic: 2.5 – 25 THz

e) Collecting efficiency at different observed positions

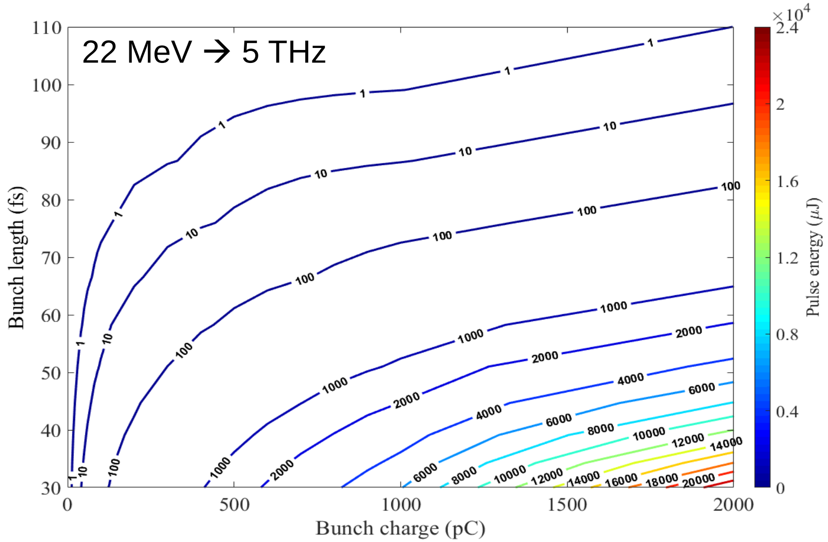




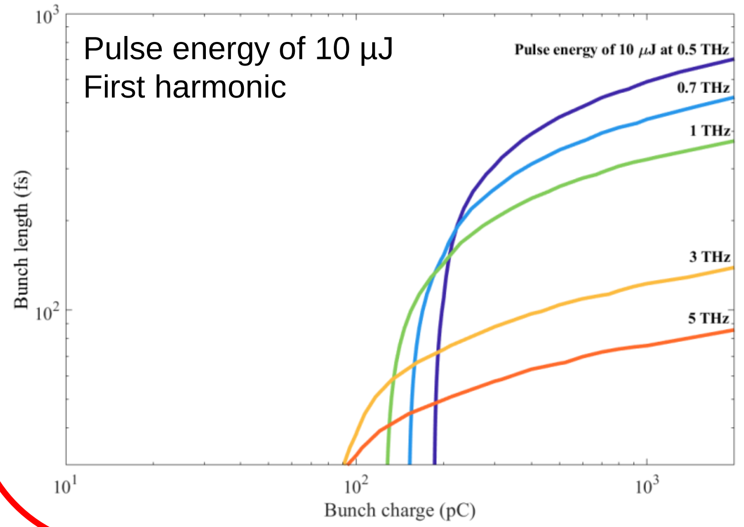
- The collecting efficiency shows that the radiation intensity can be reached around 70% and 55 % at screen positions of 0.6 m and 2.2 m, respectively compared to that at the end of the undulator.
- FWHM bandwidth at positions far from the undulator exit is narrower due to lower intensity.

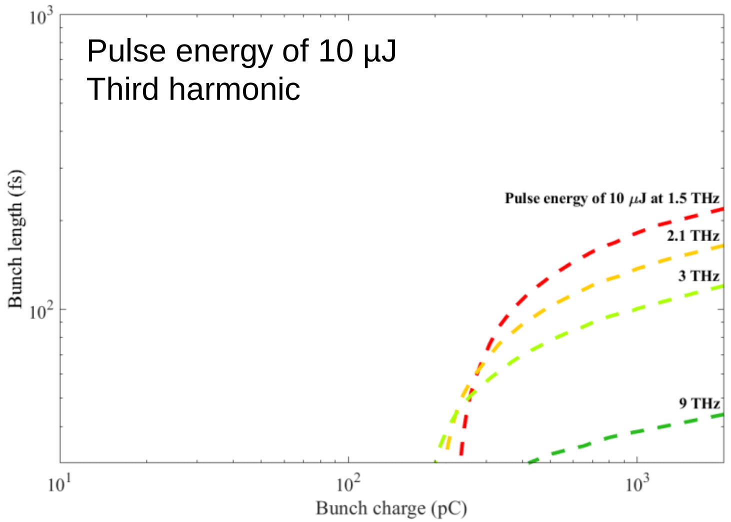
1. Parameter space by SPECTRA (3)

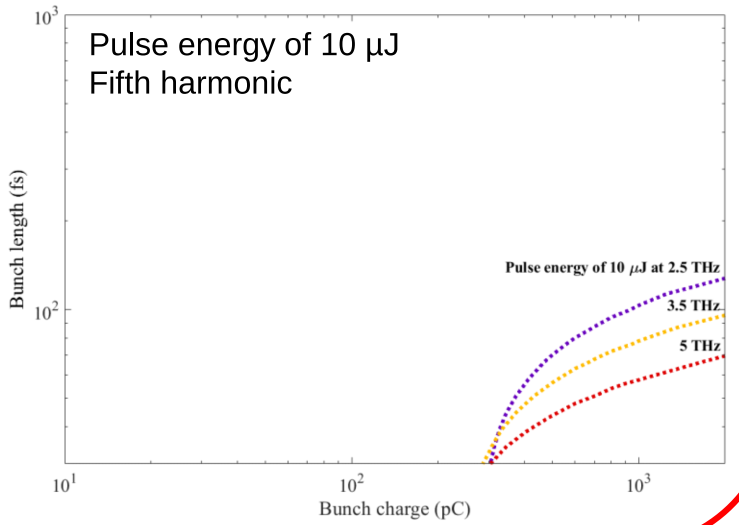
f) Manipulation on electron bunch length, bunch charge and pulse energy



- Bunch length can be manipulated by bunch charge to get desired pulse energy. That is longer bunch length requires higher bunch charge.
- In PITZ case, THz frequency or wavelength can be tuned by only beam energy. Therefore, the low-energy beam should be considered because it can have longer bunch length than that for high-energy beam to get high pulse energy.
- The pulse energy of 10 μJ at frequency range of 0.5 – 5 THz and 5 – 9 THz can be achieved at 1st and 3rd harmonics, respectively for electron beam energies of 7 – 22 MeV.

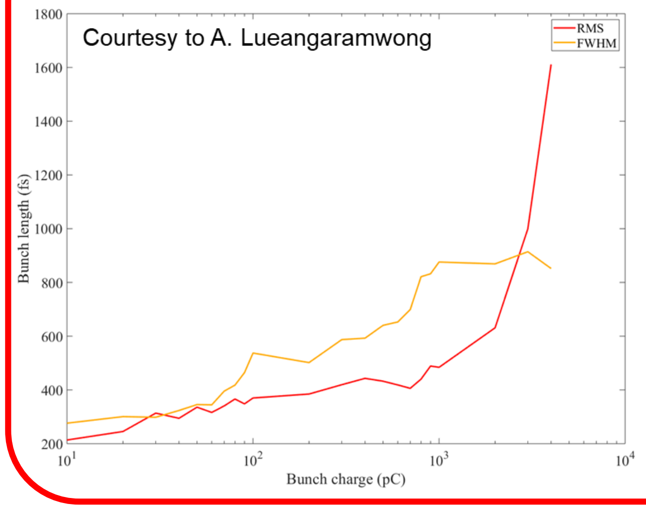






2. Pulse energy calculation from S2E simulated beam

a) S2E simulated beam at full compression

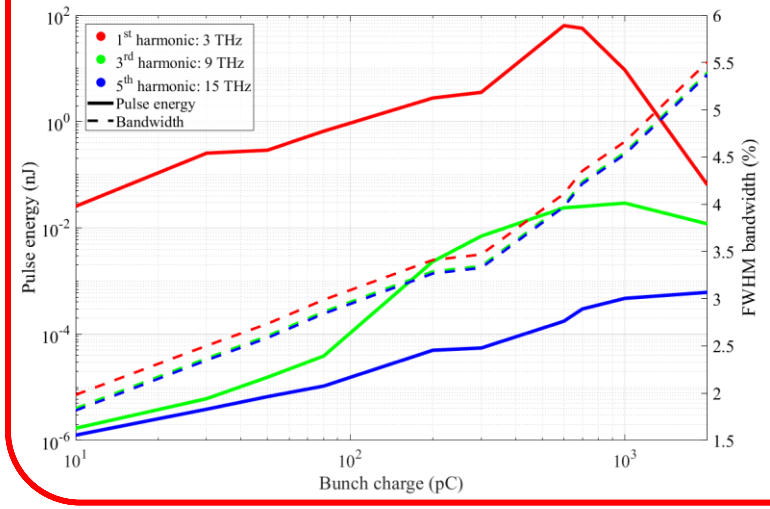


(A. Lueangaramwong)

Beam energy = ~17 MeV
Frequency = 3 THz

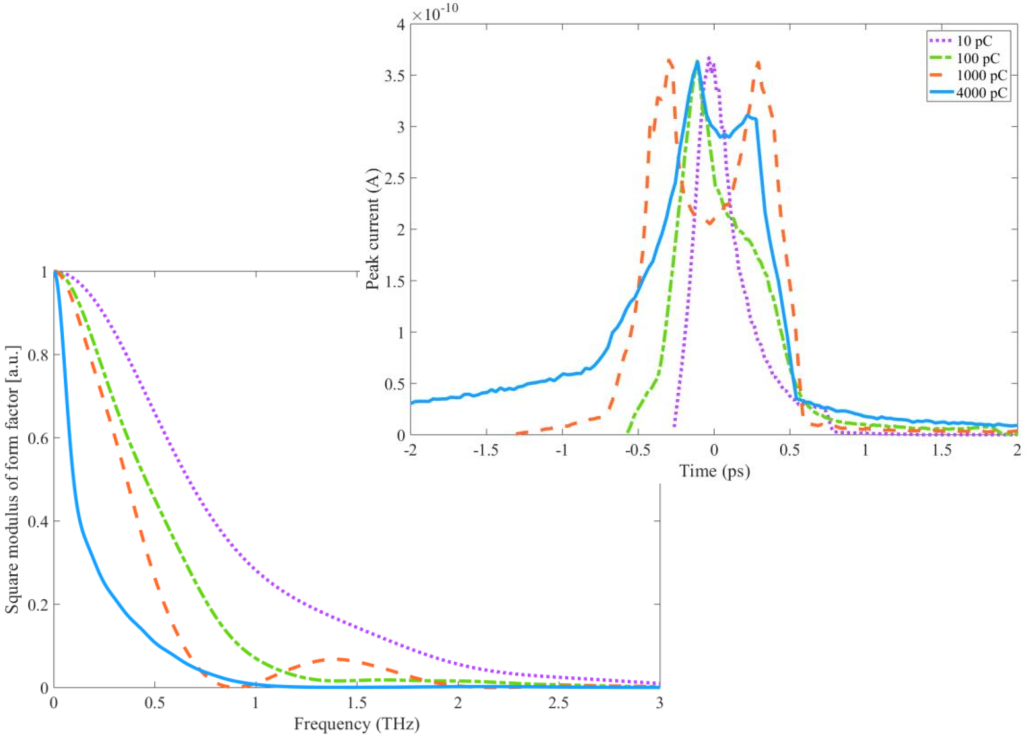
Anusorn optimized booster phases to get beam distributions with shortest rms bunch length at each bunch charge.

c) Pulse energy of superradiant radiation



- The pulse energy calculated from S2E simulated beam is in the order of sub-nJ to 100 nJ for 1st harmonic.
- To get higher pulse energy, bunch length should be shorter.

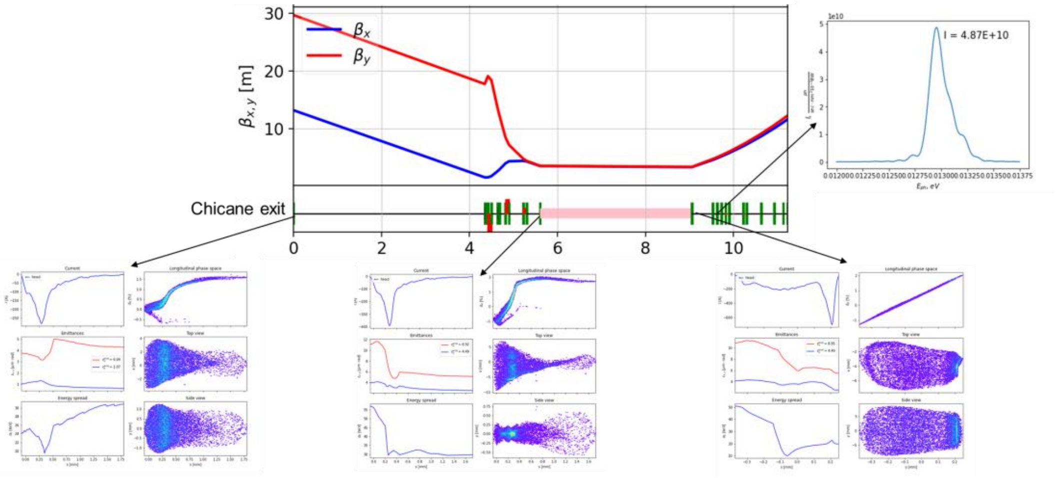
b) Electron beam form factor from different beam profiles



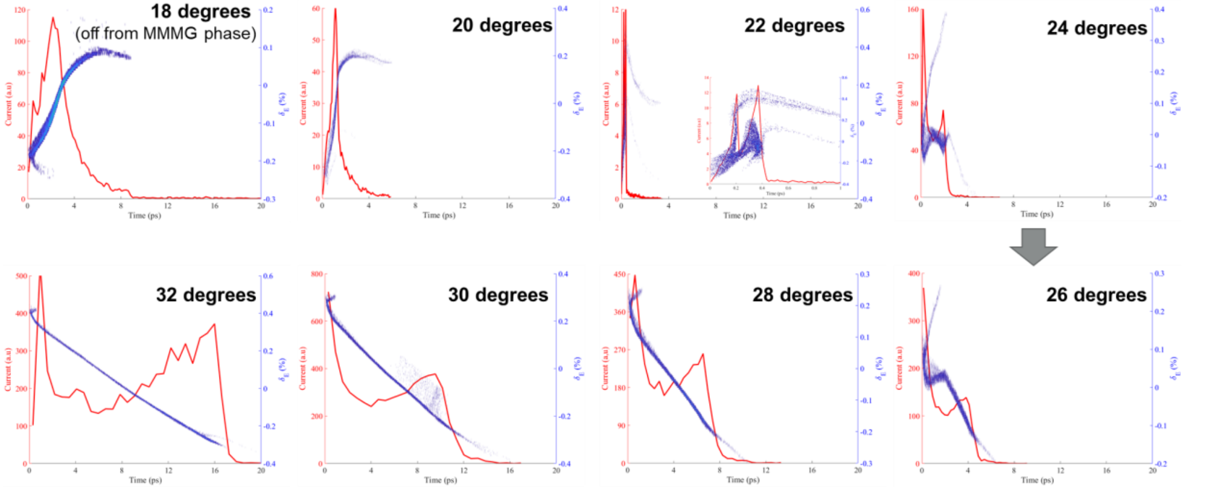
- The form factors for different bunch charges were calculated from the Fourier transform of longitudinal beam profile.
- The coherent part of shorter bunch length covers in broader frequency.

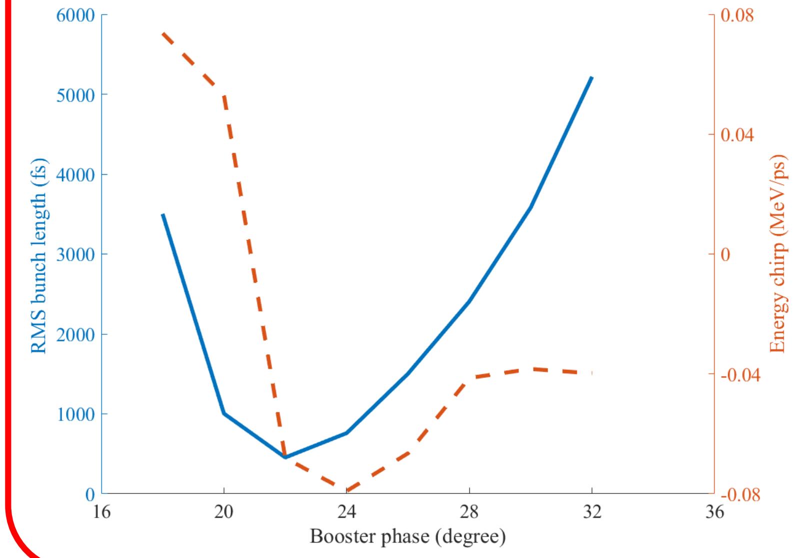
3. Impact of energy chirp by OCELOT

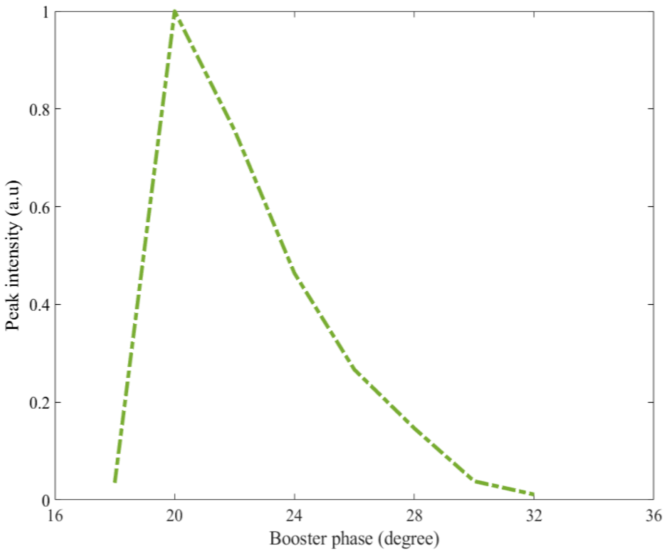
Beam transportation from chicane exit to LCLS undulator



Beam profiles at undulator entrance for different booster phases







- The result shows that shortest bunch length does not provide highest intensity because of negative energy chirp and electron beam dynamic changs along the undulator.
- For positive energy chirp, shorter bunch length gets higher peak intensity.
- Therefore, high peak intensity of the superradiant undulator radiation can be reached for short beam with positive energy chirp.

4. Influence of narrow undulator chamber by …proceeding…

a) Write own MATLAB script

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Undulator radiation in a waveguide

Gianluca Geloni*, Evgeni Saldin, Evgeni Schneidmiller, Mikhail Yurkov

Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

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How?

- They perform preparatory to the problem of optimizing the radiation transport system after the undulator.
- They solved the field equation with a tensor Green's function technique based on paraxial and resonance approximation.
- The electric field was found as a superposition of the waveguide modes.

What?

- They developed a theory of undulator radiation with near-field expression, when the presence of the vacuum-pipe affects radiation properties.
- They exemplified it in the case of the infrared undulator beamline at FLASH.

Why?

- Since the THz radiation diffraction size exceeds the vacuum-chamber dimensions, characterization of infrared radiation must be performed accounting for the presence of a waveguide.
- Wavelengths in the order of 200 mm
- A 4 m-long undulator
- A radiation diffraction size of order of a centimeter
- A circular pipe with radius R = 1.8 cm

b) Use WARP code suggested by Xiangkun

5. Experiments and S2E simulations …proceeding…

Measurement program: Measurements of bunch length vs laser pulse length and booster phase

Estimated number of shifts required: 5 – 6 shifts

Brief description of the experiment: Short electron bunch length is a key for superradient THz radiation. This program aims to find shortest bunch length by tuning laser pulse length and booster phase.

Expected results: Temporal profile, transverse emittance, bunch length vs laser pulse length vs booster phase

Initial parameters for the experiment:

Photocathode laser:	Pharos
Temporal profile:	Gaussian, 0.2 - 1 ps FWHM with step of 0.2 ps
BSA size:	1.5 mm
Maximum number of pulses:	2-3 pulses for TDS related measurements
Electron beam	
Bunch charge:	500 pC at Low.FC1
RF Gun	
RF power in the cavity/Beam momentum at LEDA:	Momentum ~6.2 MeV/c at MMMG
RF phase:	MMMG
Booster	
RF power in the cavity/Beam momentum at HEDA1:	17 MeV/c at MMMG
RF phase:	Phase set point 0 - 80 degree with step of 10 degrees wrt MMMG (70 - 80 degree with step of 2 degrees wrt MMMG)

Thank you