

HXRSS simulations

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Beam dynamics meeting, 09.06.2020

European XFEL

HXRSS simulation status

Input for SASE2 HXRSS simulation (up to now used from Guangyao's simulation for SASE1)

Simulated working points

	100 pC	250 pC	Reminder: experimentally we have only tried 14 GeV, 250 pC with 8 keV and 9 keV
3 keV	Yes, with 8 GeV beam (by me)	No	
9 keV	No	Yes, with 17.5 GeV beam (by Vitali)	O. Chubar et al. J. (2016). J. Synchrotron Rad. 23, 410-424.
14.4 keV	Yes, with 17.5 GeV beam (by me)	No	

European XFEL S. Liu et al. PRAB 22.6 (2019):060704.

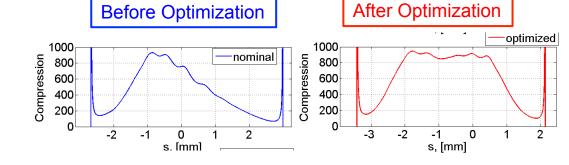
Title of the presentation

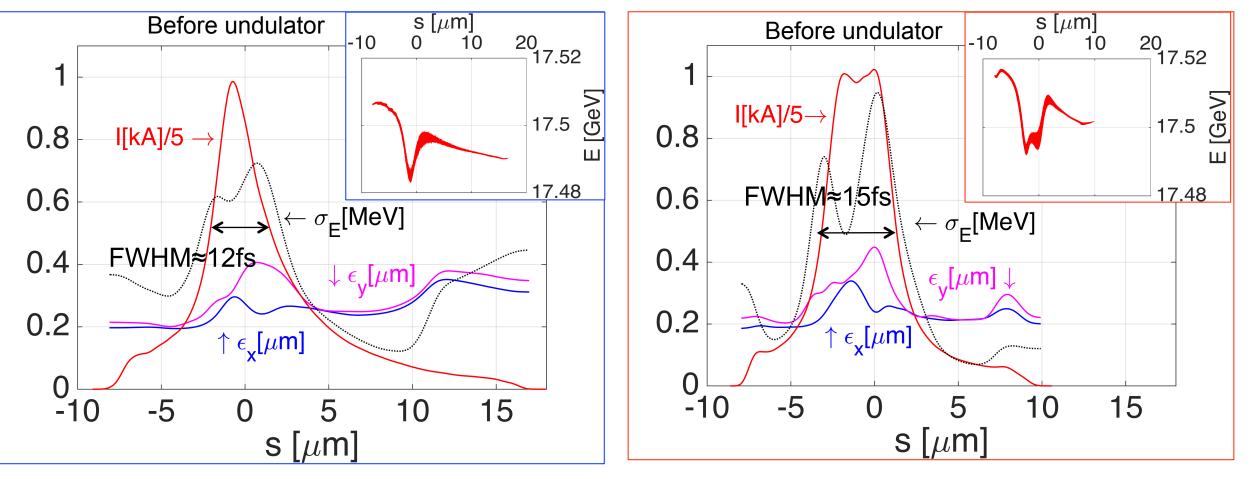
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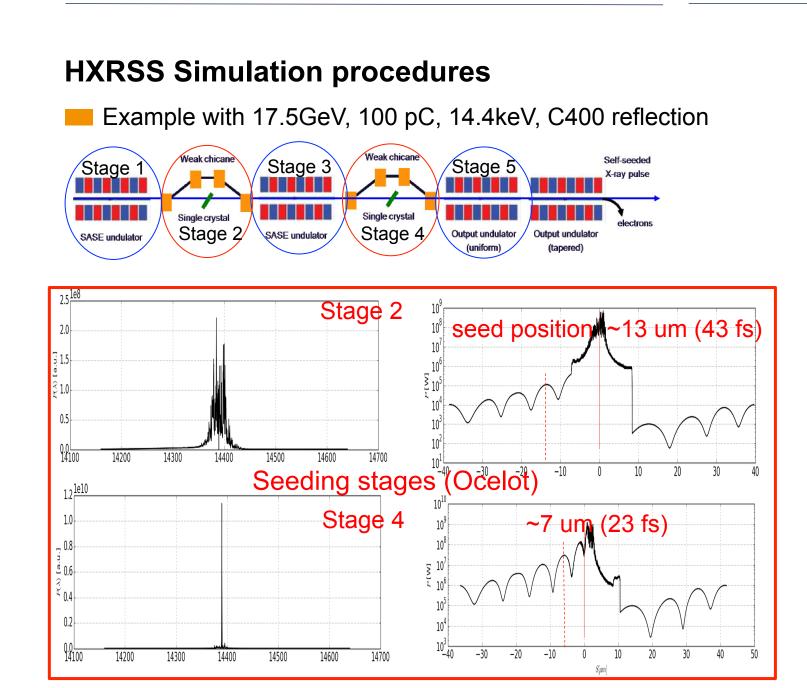
100 pC input

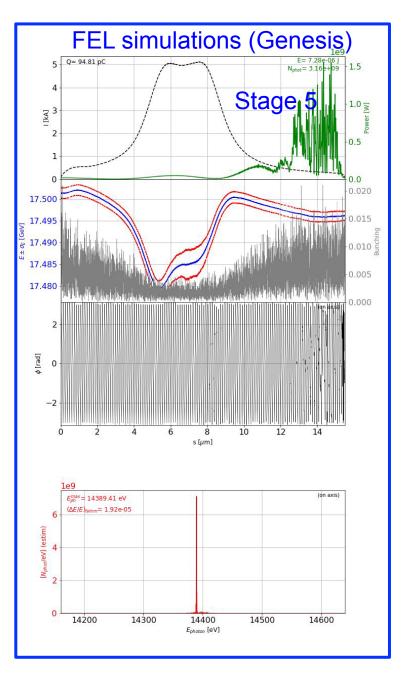
Originally from Guangyao

Optimization done in 2017 -> used in HXRSS simulations









250 pC input Beam dynamics simulation for EXFEL for different bunch charge cases Q=0.25nC From Guangyao (2013) -> used in the old HXRSSsimulations From Igor (2018) Measured at B2D (2020) before undulator 1.7512 × 10 before undulator 1.751 I[kA]/ 21 Beam Dynamics at the European XFEL up to SASE4/5 Igor Zagorodnov, 06.12.2018 0.8 Beam dynamics for 250 pC, 5 kA main linac 0.6 riments 38.4fs projected x-emittance growth by 100% SASE2 ~ projected y-emittance growth by 90% 0.4 ε [µm] ш [µm $\sigma_{\rm F}[{\rm MeV}]$ 0.2 Current Longitudinal phase space Longitudinal phase space Current 0.0 0.0 4000 4000 [%] 8 -0.1 ₹ -20 -15 -10 15 20 25 30 -5 0 10 5 -0.1 25 30 2000 1.4 2000 s [µm] FWHM: ~50 fs⊶ -0.2 Emittances Top view Emittances Top view $\varepsilon_x^{proj} = 0.5 \mu m \cdot rad, \varepsilon_v^{proj} = 1.6 \mu m \cdot rad$ 0.6 0.6 $\varepsilon_x^{proj} = 0.8$ $\epsilon e^{\text{proj}} = 1.34$ 0. 0.02 0.5 [m] 0.5 $\epsilon_v^{\text{proj}} = 1.26$ $\epsilon_{\nu}^{proj} = 1.37$ 0.0 0.00 Â. 0.4 A 0.4 -0.1-0.02 0.3 0.3 Side view Energy spread Energy spread Side view current profile [kA] 1000 1000 0.1 0.05 FWHM: ~45 fs or [keV] 500 500 0.0 0.00 Mar. 2020 -0.1-0.05 2 A -0.015 -0.010 -0.005 0.000 0.005 0.010 -0.015 -0.010 -0.005 0.000 0.005 0.010 -0.015 -0.010 -0.005 0.000 0.005 0.010 -0.015 -0.010 -0.005 0.000 0.005 0.010 s [mm] s [mm] s [mm] s [mm] EUIUPEAII AFEL

Z

σ∈ [keV]

100

150 200

0 50

longitudinal [fs]

-150 -100 -50

17.5 GeV, 250 pC, 9 keV, C400 reflection

*Chubar, O., Geloni, G., Kocharyan, V., Madsen, A., Saldin, E., Serkez, S., Shvyd'ko, Y. and Sutter, J. (2016). J. Synchrotron Rad. 23, 410-424.

Stage 2/ Stage 4 SASE undulator Output undulato Output undulator SASE undulator (uniform) (tapered) t [fs] -133 -100 -67 -33 33 Stage 1 (5 undulators) 375 Stage 3 (5 undulators) 375 4.5x10¹² 300 1.5x101 300 ['∩' 3.0x10¹² []) []) []) []) []) []) []) P [MW] 225-P(E) [A.U.] [MW] d 1.0x10¹⁴ ~ 1 uJ 150-5.0x1012 75 75-(e) (f) (a) (b)0.0 -2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0 -40 -30 -20 -10 20 -0 10 30 40 Stage 2 Stage 4.0x1014 250 4x10 0 V12x10 t [fs] 250 4x10¹ 200 200 MW 150 Q 100 P(E) [A.U.] 7.5x10 3x101 P [MW] Ma 20 -30 20 70 120 170 \$0.00 150 E-Eo [meV] 2x101 100 50 1x10¹² \$ [µm] (d 50 (h)-10 10 20 30 -40 -30 -20 -0 40 0.0 -2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5

Output from 5 undulators is around 1uJ

Seeding position is at \sim 100 fs (in commissioning we were at \sim 20 fs delay)!

Bunch length matters -> longer the initial SASE pulse, the larger the delay before the first bump European XFEL



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Self-seeded

K-ray pulse

electrons

Neak chican

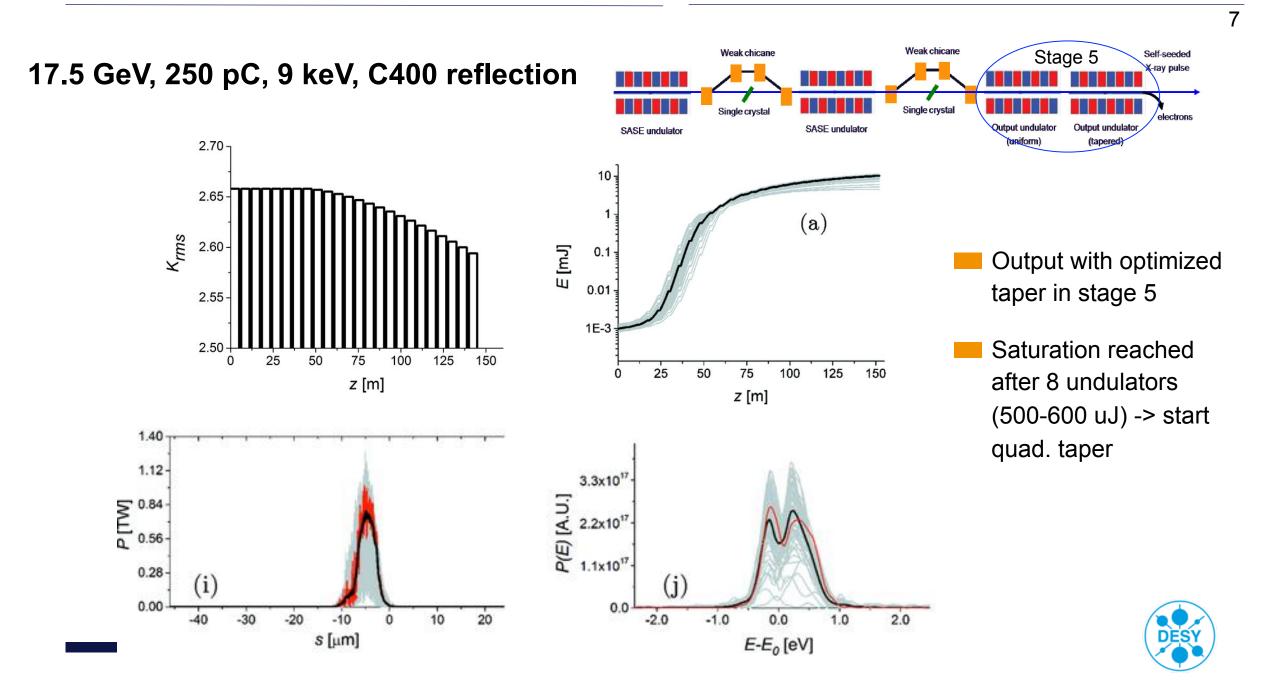
Single crystal

Weak chica

Single crystal

Stage

Stage 3



Summary

- Simulations showed that several uJ level of SASE input is enough for seeding, however transverse overlap between e- and seed after chicane is crucial to get saturation!
- Position of the first bump of monochromatic wake (delay for e- beam) depends on photon pulse length (lasing window)
 - bunch length can be measured by TDS BC2 and lasing window by DD scan -> should be documented!
 - delay scan VS seed signal (in a good seeding condition) can be performed to find the optimum delay position
 - previous success of self-seeding (up to 200 uJ) with a delay of ~20 fs indicates a very short lasing window (~10 fs? with 250 pC beam)
 - I in the case of **long bunch** (and long lasing window, e.g. > 25 fs as in Mar. 2020), **longer delay** should be scanned
- **250 pC, 9 keV case in simulation**: saturation in stage 5 is around 500 uJ (8 undulators) and above mJ can be reached with quadratic taper



Discussions and future plans

- Get new input beam from Igor/Segey with "realistic" profile (as close as possible to the TDS measurements)
 can we do s2e simulations based on the TDS measurements?
 - can we measure the increase of projected emittance (using wire scanners) after switchyard and compare with Igor's simulation?
 - Start with 14GeV, 250 pC, 9keV
 - from "above" we start with the newest s2e simulations by Igor for SASE2
 - from "below" we start with a simple Gaussian model, where we put our best guess of parameters (like lasing window, current, emittance, energy spread, chirp) from machine data.
 - I we keep on comparing with reality
- At first, we can keep the undulator ideal, then introduce other effects like launching, angle kicks in the undulator, misalignments and so on, also based on diagnostics.
 - Prepare a working point for 100 pC run?

