

# Hard X-ray Self-seeding operator training

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#### **Outlines**

Why Hard X-ray Self-seeding?

How it works?

- What is special at the European XFEL?
- How to set-up HXRSS? (single chicane case)
- How to tune HXRSS?
- What can happen during user run?
- How to switch back to SASE?



Important for upcoming 4 weeks of user delivery!

1,0x10<sup>12</sup>

5,0x10<sup>11</sup>

0,0 0,1496

P(ג.)[A.U.]

Why Hard X-ray self-seeding (HXRSS)?

EuXFEL DCM design

Shan Liu on behalf of the HXRSS team

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Si(111) Δλ/λ ~ 1.4e-4 Si(220) Δλ/λ ~ 6.1e-5 Si(511) Δλ/λ ~ 1.1e-5

#### 1500 Cryo-cooling, ACCM SASE spectrum Spectrum amplitude Shaft assm. Sine-arm 40 eV Monochromator at MID SASE undulator 9.24 9.16 9.22 Photon energy (keV) Courtesy of Anders Madsen X. Dong et al. Linear stag **1e-4 –1e-5 BW is required** for many coherent scattering experiments Monochromators reduce intensity and increase intensity fluctuations **Temporal coherence** of reflected beam varies from pulse to pulse Cryocooled Si monochromators cannot transmit more than ~ 50 mJ during MHz train (adiabatic heating) 0,1498 0,1502 0,1504 0.1506 0,1500 0,1508 Seed pulse can lock in phase different regions of the e-beam λ[nm] **External seeding not available** yet in hard X-ray range -> self-seeding European XFEL



\* G. Geloni, V. Kocharyan, E. Saldin (DESY 10-133)



increases SNR and share the heat load on crystal

no heat load issues

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#### **HIREX\*** diagnostic spectrometer



Shot-resolved spectra of pulsed X-ray beams at MHz rates

- Covers hard x-ray range 5 20keV
- **High resolving power** of up to 40,000 (resolution 0.2 eV at 8 keV)
- Energy calibration by changing crystal pitch
- Gotthard detector signal processing (especially for multi bunches) will be improved by upgrading to Gotthard-II)



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European XFEL
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#### Developed by Naresh Kujala

#### \* HIREX = HIgh REsolution hard X-ray



SASE requirements

SASE from U12 should be >10 uJ (ideally around 40-50 uJ)

>10 cells in U3 should contribute (at least cell 19-28) -> good orbit downstream is required

#### SASE tuning

- similar to standard SASE tuning but without quadratic taper
- open U3 to check U12 SASE level, optimize if needed
- add U3 cell by cell (or two cells at one time)
  - ▶ optimize orbit with air coils for this cell
  - ▶ if you have > 100 uJ with linear taper, open first cells in U12
  - ► save a golden orbit and a file after optimization is done



Seed with SASE switch on SA23 feedback switch on chicane HXRSS2 increase delay step by step up to 30 fs









European XFEL



#### Insert crystal

XFEL main task panel -> Photons -> Expert Panels-> SASE2-> HXRSS





#### Insert crystal

Crystal angle information on confluence page





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## How to set-up HXRSS? -- single chicane case

- Find seeded signal
  - XFEL main task panel -> Photons -> Spectrum-> pySpec SA2



Shan Liu on behalf of the HXRSS team scan direction 7 Seed signal Spectrum Contine 2.15:1 scan direction Seed signal Plane (here) (au)

- **Fine tune the delay** again (using Correlation2D function from PyHirex
- Manually change dt in the range of 18-40 fs while looking at the peak signal in PyHirex
- Find the delay for maximum peak signal





Shan Liu on behalf of the HXRSS team

#### How to tune HXRSS?

Larger delay can reduce the background, but seeding input is also lower





#### How to tune HXRSS?





# Set-up color 2/3 and adapt detune for U3 scan in several eV step



Shan Liu on behalf of the HXRSS team

SAS	SE2 Undulator Server		Print Undulator Taper
Cell Nr.	1 2 3 4 5 6 7 8 10 11 12 13 1	15 16 17 19 20 21 22 23 24 25 26 27 28 29 30 3	31 32 33 34 35 36 37 WAVELENGTHCONTROLSA2
Color Group		Delay	K Value Plote - ScatterView K Value P
Und. Gap PhaseShifter Gap PhaseShifter Gap Offset 3.5	13.8         13.9         13.8         13.9 <td< td=""><td>13.9         13.9         13.9         13.9         13.9         13.9         13.9         13.9         13.9         13.9         14.0         14.0         13.9         14.0         <th< td=""><td>Please try to avoid the global controls for standard operation!         Please try to avoid the global controls for standard operation!         Wave Length controls call           14.0         14.0         14.1         14.0         14.0         14.1         14.0           15.5         45.6         45.3         47.5         50.2         47.2         14.0         Global Controls         2.895         ////////////////////////////////////</td></th<></td></td<>	13.9         13.9         13.9         13.9         13.9         13.9         13.9         13.9         13.9         13.9         14.0         14.0         13.9         14.0 <th< td=""><td>Please try to avoid the global controls for standard operation!         Please try to avoid the global controls for standard operation!         Wave Length controls call           14.0         14.0         14.1         14.0         14.0         14.1         14.0           15.5         45.6         45.3         47.5         50.2         47.2         14.0         Global Controls         2.895         ////////////////////////////////////</td></th<>	Please try to avoid the global controls for standard operation!         Please try to avoid the global controls for standard operation!         Wave Length controls call           14.0         14.0         14.1         14.0         14.0         14.1         14.0           15.5         45.6         45.3         47.5         50.2         47.2         14.0         Global Controls         2.895         ////////////////////////////////////
k #λ			Color 1     12900.0     2.892-       Color 2     12790.0     2.891-       Color 3     12922.0     2.89-       Global     13000.0     2.89-
zoom \$.\$\$ up dowm reset	2.804 2.804 2.803 2.803 2.784 2.7888 2.7888 2.788 2.788 2.788 2.788 2.788 2.78	2785 2786 2785 2785 2784 2784 2784 2784 2784 2783 2783 2783 2783 2783 2783 2783 2783	T78         2776         2776         2776         2776         2776         2776         2776         2788         2.886-         2.886-         2.887-         2.
1.8		ell pumber	Z.882 account 2.882 2.881 detune K
Color 0	Color 1	Color 2	Color 3
All to max. gap All to park All close All stop	<sup>1</sup> <sup>2</sup>	bark <sup>2</sup>	û Û û û û û û û û û û û û û û û û
Undulators Quad Movers	Δk/k Taper         linear         8.99 ± / τ +         e-5/cell, power law         7.9 ± / τ +         e-5/cell,	Δk/k Taper linear 8.99 <sup>1</sup> / <sub>2</sub> e-5/cell, power law 34.0 <sup>-1</sup> / <sub>2</sub> e-5/cell,	Ak/k Taper linear         8.99 + e-5/cell, power law         3.5 + e-5/cell,         2.874 + e-5/cell,
GAP error	power taper starts after 32 - cells and uses exponent	2.00 - power taper starts after 16 - cells and uses exponent 2.00 -	power taper starts after 8 - cells and uses exponent 2.00 -



European XFEL

Set-up color 2/3 and adapt detune for U3
 scan in several eV step



Shan Liu on behalf of the HXRSS team







- Air coil optimization after the chicane, start with launching correctors for SA22 or SA23
- Send only 1 shot (Average over N bunches=1) to DOOCS (with DOOCS: Send Data checked)
- Using seeded peak signal from HIREX in Ocelot: XFEL.UTIL/DYNPROP/MISC/HIREX\_AMPL

vith data
Send Dat





- Air coil optimization after the chicane, start with launching correctors for SA22 or SA23
- Switch off the SA23 feedback before optimizations, keep SA2 feedback running
- Save golden orbit in SA23 feedback after optimizations





#### Phase shifter scans

- using seeded signal: XFEL.UTIL/DYNPROP/MISC/HIREX\_AMPL
- first for undulators downstream of chicane, then also for the upstream undulators
- if there's no contribution from one cell, optimize the orbit upstream of that cell again until it contributes





#### Ampl: 22.6 uJ, Offset: 438.6 uJ, defaultharmonic: 8.0, period for max amplitude: 8.195 +- 0.0 XFEL.UTIL/DYNPROP/MISC/HIREX\_AMPL : BPS.2404.SA2: Cell 34 Some contribution 520 500 480 440 SASE 420 400 380 360 340 phase shifter period feedback is off Save Data 2022\_09\_20\_11-01-10 Print to xfellog Print to file

#### How to tune HXRSS?

- Matching quads using ocelot
- Taper optimization -> increase of SNR (larger linear taper, earlier start of power taper)
  - Laser heater, compression
- Always **keep an eye on HIREX peak signal:** XFEL.UTIL/DYNPROP/MISC/HIREX\_AMPL
- Close more attenuators if peak signal > 3000

Display of	HIREX peak	signal	from pvS	Spec	
		3			A=2743m
• • • • •			Misc		
Avarage over N bunches     Cross-calibration with XGM			Logbook	Logbook with data	
Background control			Control	DOOCS. Send Data	
Take Background	v subtract background				Ľ
Show Background	Hide Average			Stop	
					Step

**European XFEL** 



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Solid At	tenuato	or							
Photon Energy			1290	)0 eV	12900.0	eV			
Desired Transmission		0.3	0.38 0.3800		00	Fir	nd Target	Pu	
Target Transmission		0.38	0.38221033			Мо	ve Target	CV	
Actual	Transmis	sion	0.	17599145					to
CVD Dia			iamond	amond			5	Silicon	
75um	150um	300um	600um	1.2mm	2.4mm	0.5mm	1mm	2mm	
$\bigcirc$	$\bigcirc$	$\bigcirc$	$\bigcirc$	$\bigcirc$	$\bigcirc$		$\bigcirc$	$\bigcirc$	Targe
			Open	Open	Open				OUT
 Close	Close	Close	Close	Close	Close	Close	Close	Close	IN
Setup	Setup	Setup	Setup	Setup	Setup	Setup	Setup	Setup	
74.0	72.1	69.2	62.8	76.5	74.6	71.0	64.3	72.7	
			Tem	peratures	s (°C)				

HIREX\_OUT

SOLIDATT

1 pulse

Out

HIREX\_STATUS

C110

Insert All CVD of SOLID

INSERTED

Machine parameters

nPulses 1

9001.1479 1426.5404

ove hirex IN with 1 pulse

1 pulse

Ep

#### What can happen during user run?

- Signal to noise ratio check
  - park crystal or detune the pitch angle
  - can also be used to check if seeding is still there when HIREX is off
- Intensity drop during delivery
  - fine tune compression
- optimize launch SA2 using adaptive feedback
- optimize launch SA23 using ocelot

Shan Liu d	n behalf of the HXRSS team	1
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Shan Liu on behalf of the HXRSS team



#### What can happen during user run?

- Energy scan tool
  - XFEL main task panel -> Photons -> Expert Panels-> SASE2-> Crystal set tool



		HXRSS GUI v0.9			
		Expert Settings			
		HXRSS Crystal Set Tool			
Photon Energy [eV]	9000.00		Display Map	ear Table Selection	
Select a configuratio	n from the table or click Dis	play Map.			
date	SA2 Co	lor 1 EPH Mono	2 PA	Mono 2 RA	
2022-03-28 13:02	8950.0	44.4	1.28		
2022-03-28 12:58	59 8950.0	45.995	1.28		
2022-03-28 12:36	37 8850.0	46.334	1.28		
		i.			
	c	Crystal Configuration Calculat	or		
Photon Energy [ev]	9000	Pitch Angle [	·] 50.1843		
Roll Angle [°]	1.280	Reflection:	[0, 0, 4]	Apply	
Crystal setpoint und	ated: nitch: 50 1843° and ro	ll·1 28°			
Calc Pitch Angle:	50.1843	Deriv [eV/deo	ı] -129.29		
Scan mode	Und. Photon Energy [e	ev] 9000.0	Motor temp:	38,60	
		Crivetal Statue			
		or yotar otatus	121		
	Мо	nochromator 1	Mono	chromator 2	
	Insert	Park	Insert	Park	
nserted/Parked:		parked		parked	
Pitch Angle:		30.000	49.484		
Roll Angle:		-0.9800	2	1.5800	
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Shan Liu on behalf of the HXRSS team

#### How to switch back to SASE?

- **Retract the crystals** (all of them) by set the X position to park
- **HIREX out** (close all the attenuators, and close Gotthard shutter)



- Set chicane delay to 0 and degauss the chicanes (to allow parallel operation in other beamlines, please insert the first vacuum valve in T1)
- Switch off the SA22 and SA23 feedback
- Use the photon energy switch tool to prepare a photon energy file from the file saved before HXRSS set-up and use seq. to change photon energy to apply the file settings
- Launch optimization using adaptive feedback if needed
- If SASE level is still not back to the file value
  - scan phase shifters near the two chicanes
  - use ocelot optimizer to optimize orbit near the two chicanes (using air coils)

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#### Thank you for your attention !



HXRSS confluence pages https://confluence.desy.de/display/XFELOp/HXRSS+set-up+procedure https://confluence.desy.de/display/HTUD/HXRSS+user+delivery+history