FLASH2020+ im Detail.

Johann Zemella

DESY Betriebsseminar 2020

Outline

Overview of the upcomming actions

Injector reconstruction works in detail

FLASH 1 plans

FLASH 2 plans

Reconstruction Work

Injector:

- Exchange of ACC2,3 in 2021
- Laser Heater in front of BC2.
- DBC2: shorter to get space for LH.
- UBC2: shorter
- BC3 will be a c-chicane
- DBC3: longer to get a better diagnostic station

FLASH 1

- HGHG/EEHG Seeded FEL down to 4nm at 1 MHz
- THz source
- DUMP will be kept as it is!

FLASH 2

- Undulator scheme for advanced lasing schemes.
- Two color lasing and atto second pulse generation
- Wavelength tuning range : SASE: 2.3-60 nm, HL: 1-2nm

Laser Heater Implementation in BC2.

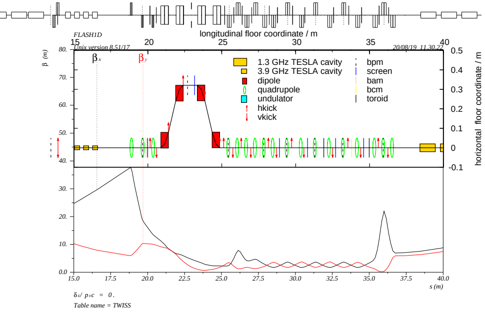
Required Lattice Modifications.

⇒ Free space for the laser heater:

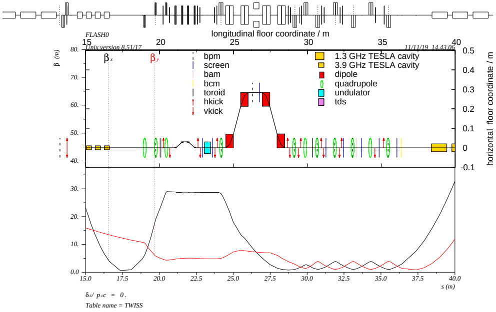
The matching section in DBC2 shortened

BC2 will be moved downstream.

Actual FLASH Lattice



New FLASH2020+ Lattice



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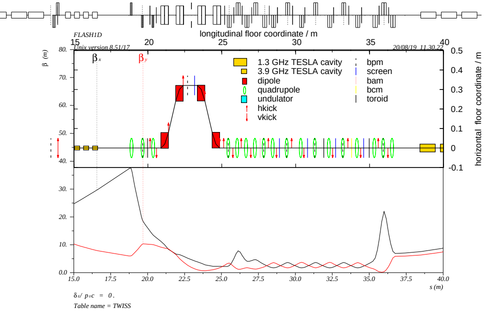

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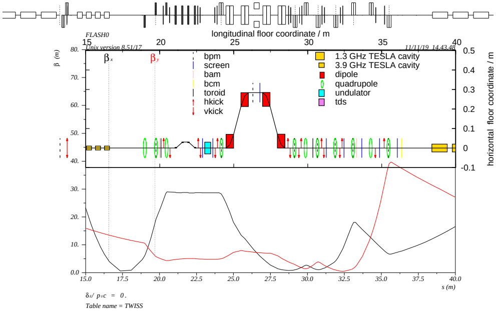

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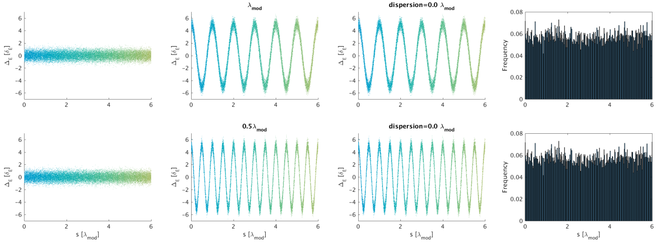

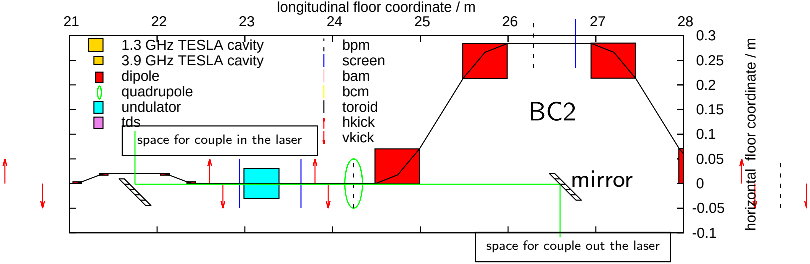

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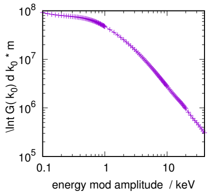
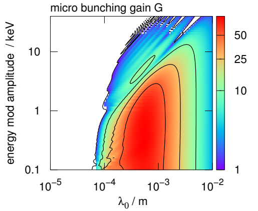
Linear Gain Model for 250 pC





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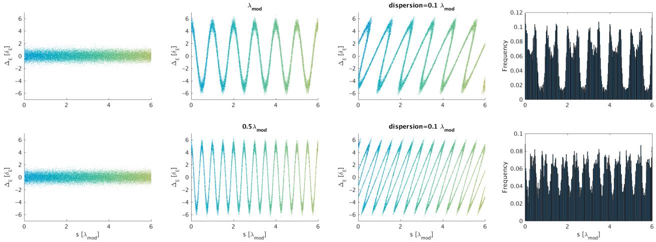

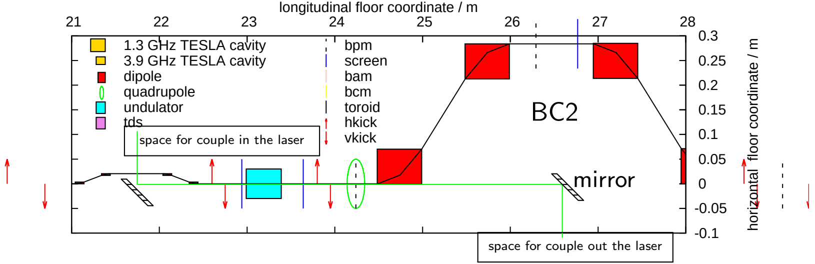

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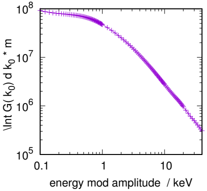

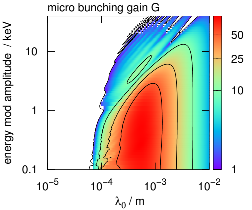

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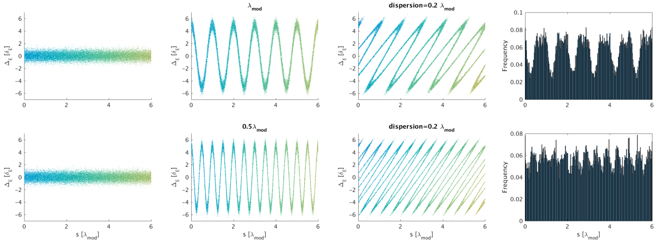

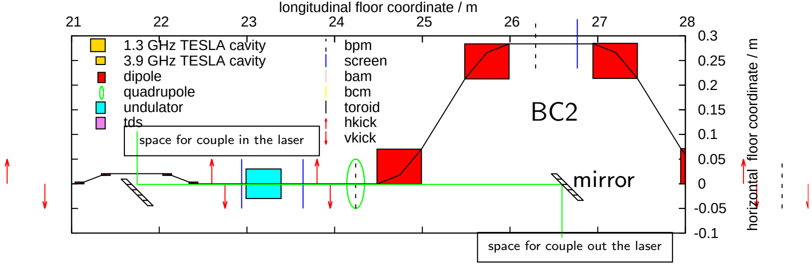

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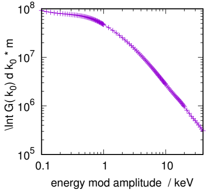

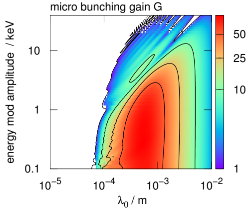

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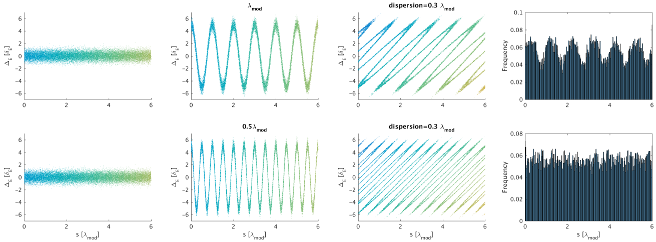

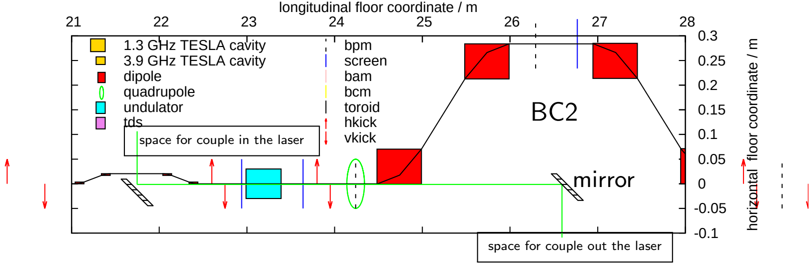

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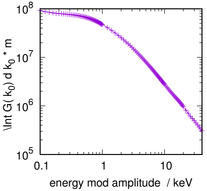

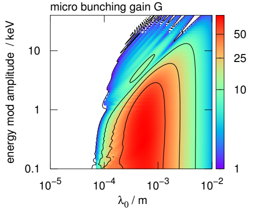

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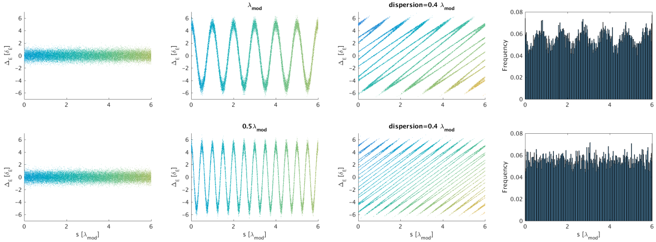

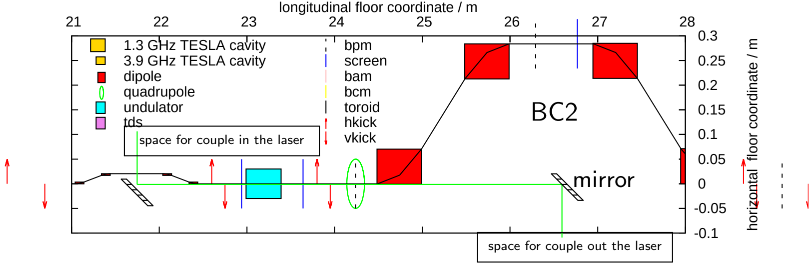

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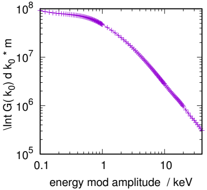

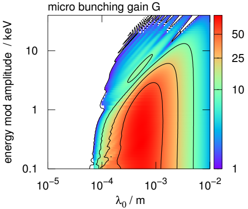

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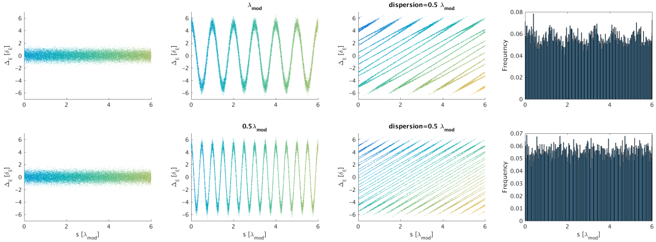

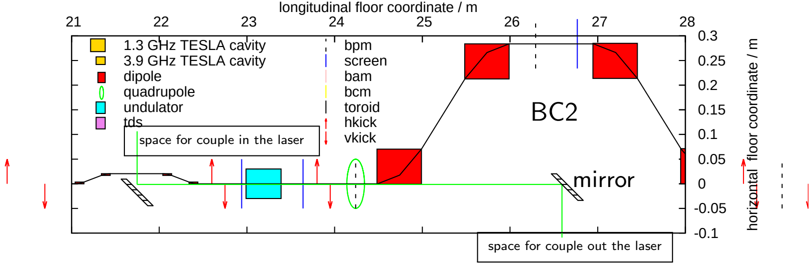

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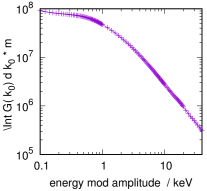

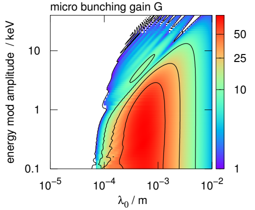

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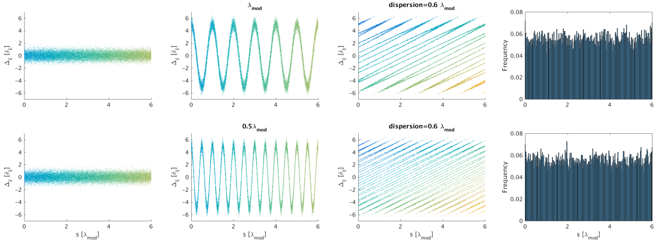

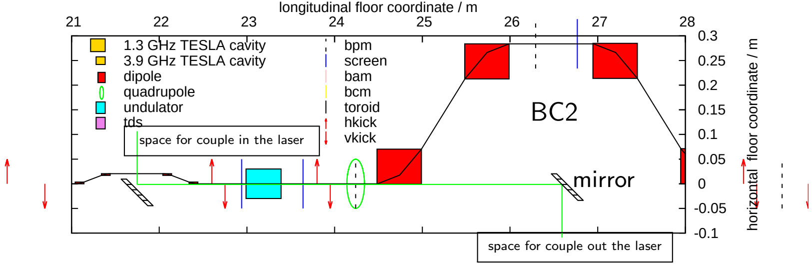

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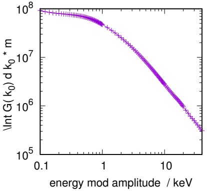

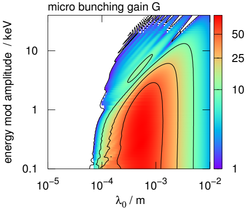

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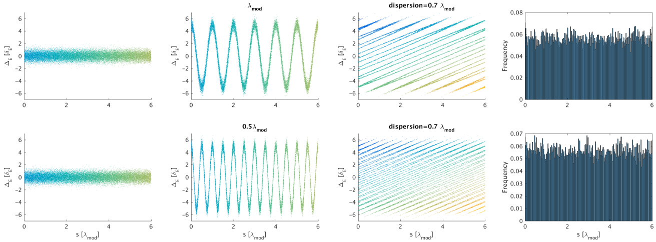

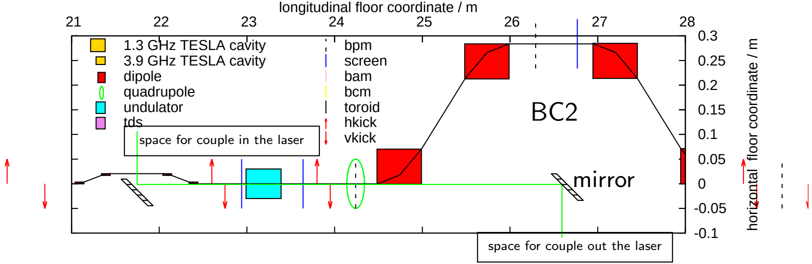

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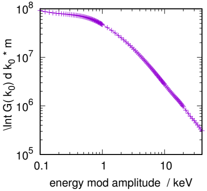

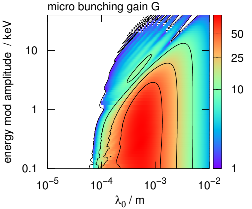

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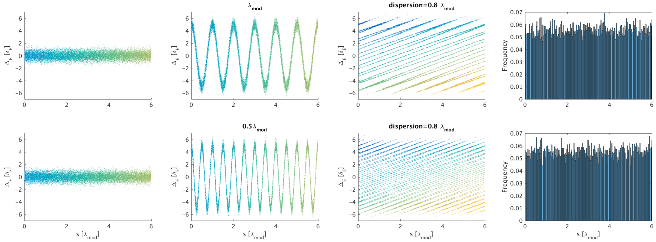

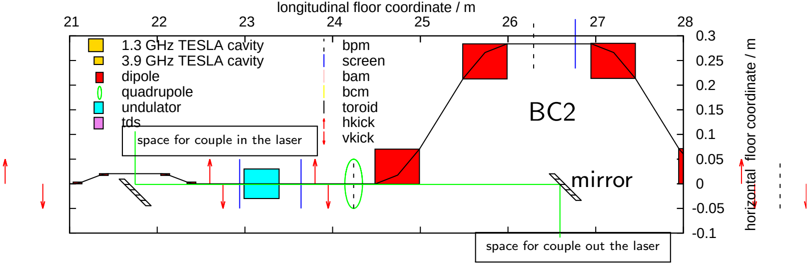

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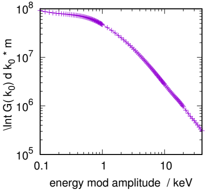

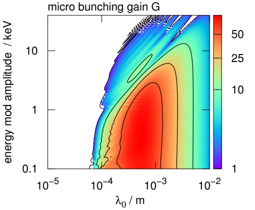

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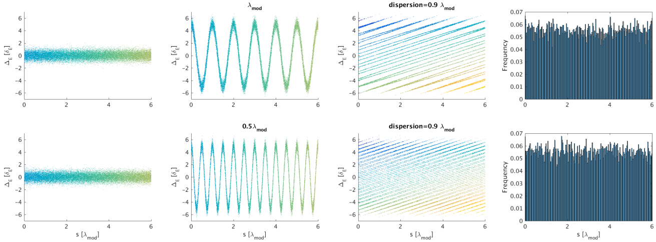

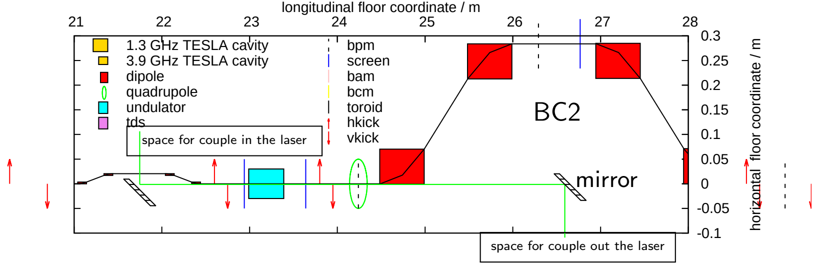

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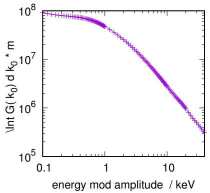

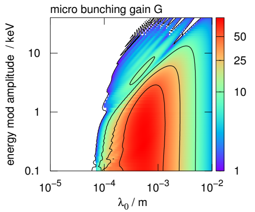

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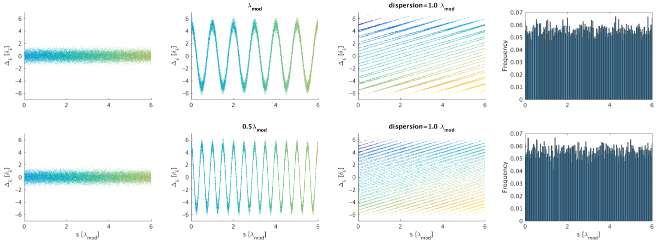

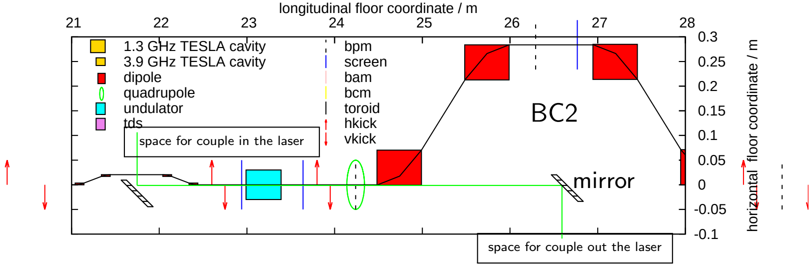

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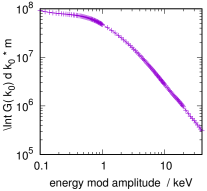
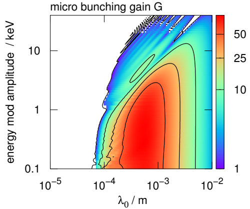
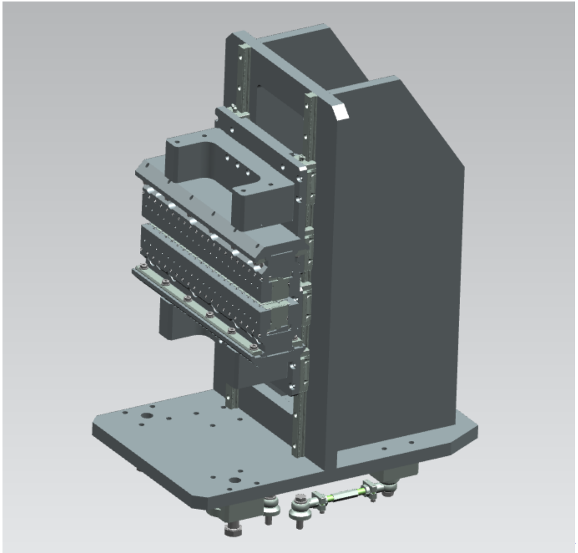




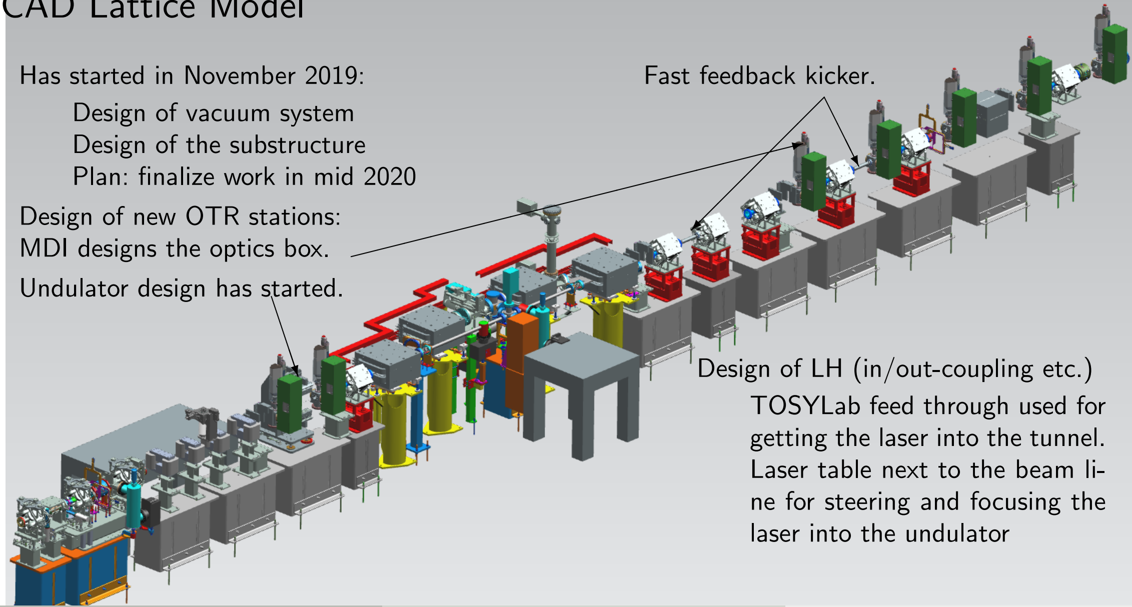
Undulator for the LH

With variable gap using permanent magnets

Length	400	mm
Period length	40	mm
# periods	10	
Minimum gap	15	mm
Undulator K	1.3	
Resonant wavelength	$\sim$500	nm



CAD Lattice Model



Has started in November 2019:

- Design of vacuum system
- Design of the substructure
- Plan: finalize work in mid 2020

Design of new OTR stations:
MDI designs the optics box.

Undulator design has started.

Fast feedback kicker.

Design of LH (in/out-coupling etc.)

- TOSYLab feed through used for getting the laser into the tunnel.
- Laser table next to the beam line for steering and focusing the laser into the undulator

Matching in DBC2

The FODO channel is now single powered, because a
matching optics and transport optics
is needed.

For the FODO optics: Phase advance between the 5 screens:

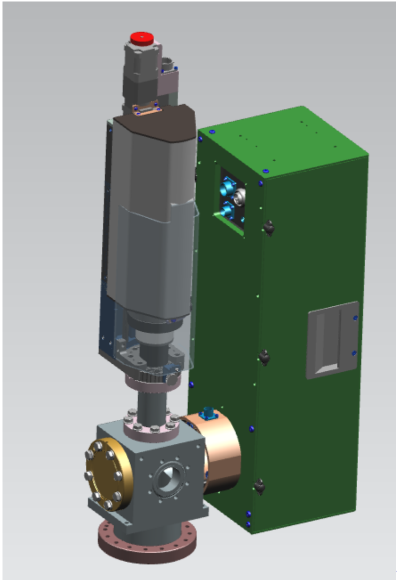
OTR	$1 \rightarrow 2$	$2 \rightarrow 3$	$3 \rightarrow 4$	$4 \rightarrow 5$	$1 \rightarrow 5$
plane	phase advance/ deg				
x:	23.5	50	23.5	50	147
y:	50	23.5	50	23.5	147

The OTR station will be a new design (similar to XFEL OTR-L).

No scintillator used to avoid charge saturation effects.

Beam size at screens: $\sim$ 50 um (beta function $\sim$ 2 m)
OTR resolution: $<$10um

The configuration allows also single and multi quadrupole scans.



BC3 Lattice changes

Shorten UBC3, remove OTR, add BAM.

Shorten BC3 from 14.5 m to 12 m.

Change from s- to c-chicane:

R56 then same for 5 deg (now 4.7 deg).

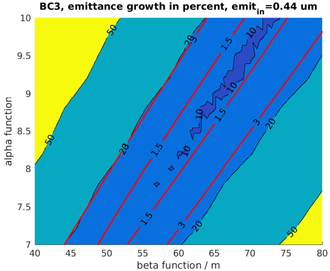
Quads and skew quads in the BC:

→ Correction of transverse-longitudinal correlations.

→ Deflecting angle is fixed and no straight passage possible.

Saved space in UBC3 and BC3 added to DBC3.

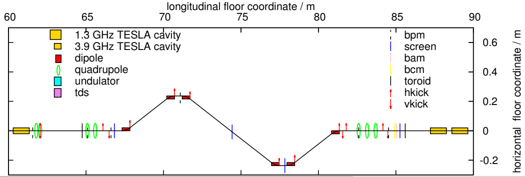
→ Building an electron optics diagnostic station at DBC3.



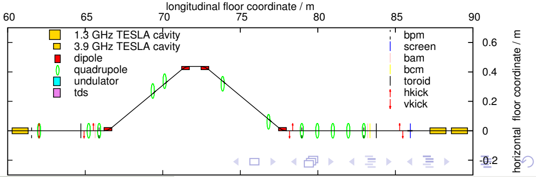
Twiss Parameters upstream of BC3

$\beta_{In} = 65\,\mathrm{m}, \alpha_{In} = 9$

actual



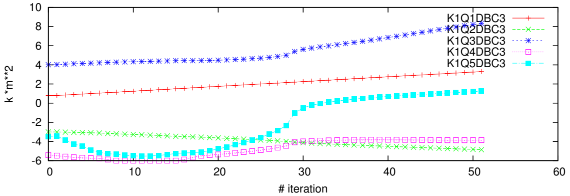
new

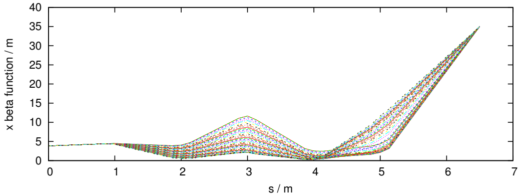


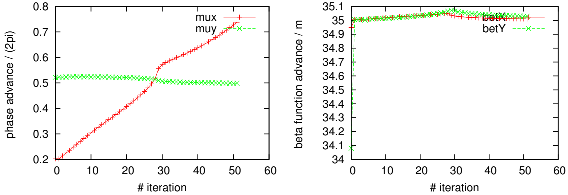
DBC3: Multi quadrupole scan

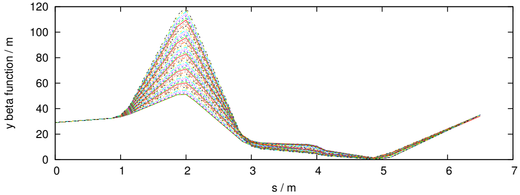
Design 1

- Beta function on screen well above resolution limit
- Phase advance in horizontal plane 180 deg
- Quadrupole ramping smooth and few directio
- Phase advance in vertical plane 160 deg









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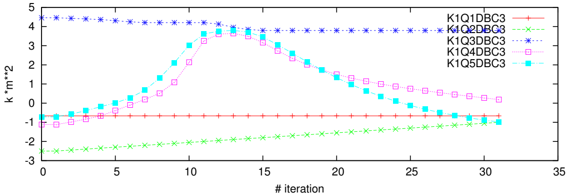
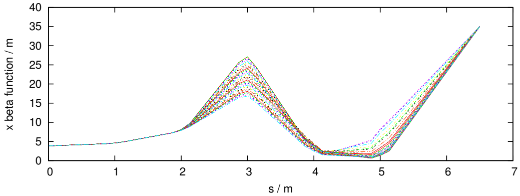
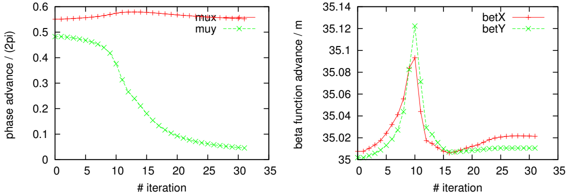
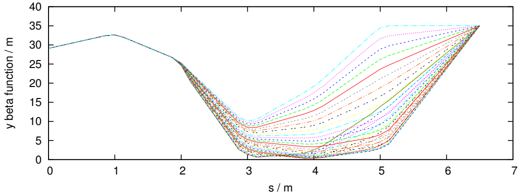


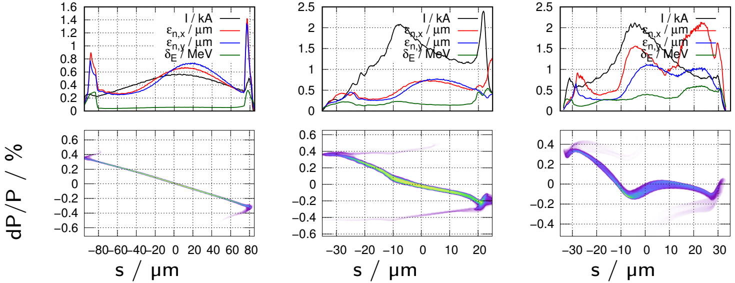






S2E for electrons

all 250 pC FL1 seeding FL2 w/ 3rd BC FL2 w/o 3rd BC



Charge	250 pC	
Module	V / MV	ϕ / deg
ACC1	150.32	8.52
ACC39	18.724	175.2
ACC23	399.36	17.90
ACC45	400	0.0
ACC67	400	0.0

q/pC	I_p/A	ε_p/μm	ε_s/μm	E_s/eV	C_1	C_2	C_3	C_{tot}
500	2000	1.4	0.80	230	4	8	2.5	80
250	2000	1.1	0.60	230	4	9	3.5	250
100	2000	1.0	0.35	250	4.5	10	5.6	300
20	1500	0.9	0.35	270	10	10	6.0	300

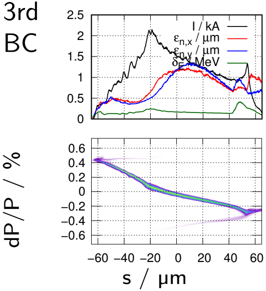
Simulated with XTrack including:

- 3D space charge
- CSR

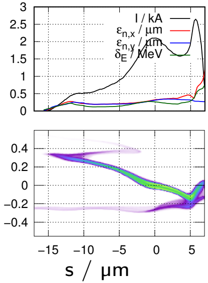
S2E for electrons

all with 3rd BC

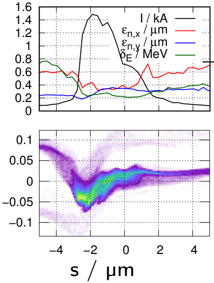
for FLASH2: 500 pC



for FLASH2: 100 pC



for FLASH2: 20 pC



Charge	500 pC	
Module	V / MV	ϕ / deg
ACC1	160.16	3.60
ACC39	20.756	163.1
ACC23	428.96	19.22
ACC45	400	0.0
ACC67	400	0.0

q/pC	I_p/A	ε_p/µm	ε_s/µm	E_s/eV	C_1	C_2	C_3	C_{tot}
500	2000	1.4	0.80	230	4	8	2.5	80
250	2000	1.1	0.60	230	4	9	3.5	250
100	2000	1.0	0.35	250	4.5	10	5.6	300
20	1500	0.9	0.35	270	10	10	6.0	300

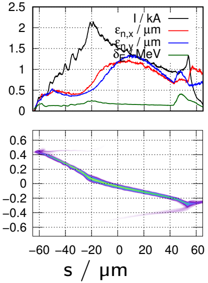
Simulated with XTrack including:

- 3D space charge
- CSR

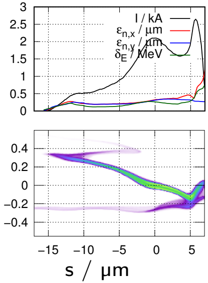
S2E for electrons

all with 3rd BC

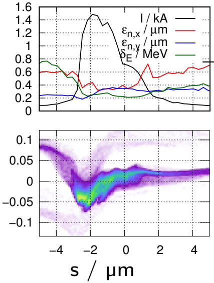
for FLASH2: 500 pC



for FLASH2: 100 pC



for FLASH2: 20 pC



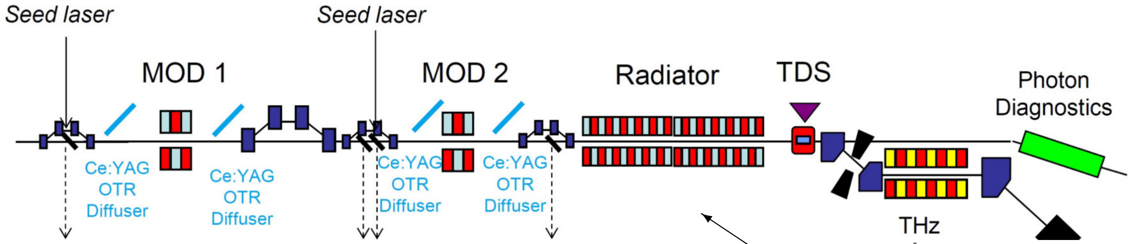
Charge Module	100 pC V / MV	 ϕ / deg
ACC1	150.32	1.99
ACC39	19.616	157.8
ACC23	396.16	16.46
ACC45	400	0.0
ACC67	400	0.0

q/pC	I_p/A	ε_p/µm	ε_s/µm	E_s/eV	C_1	C_2	C_3	C_{tot}
500	2000	1.4	0.80	230	4	8	2.5	80
250	2000	1.1	0.60	230	4	9	3.5	250
100	2000	1.0	0.35	250	4.5	10	5.6	300
20	1500	0.9	0.35	270	10	10	6.0	300

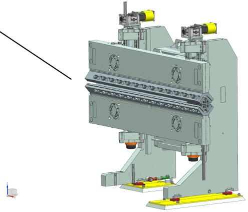
Simulated with XTrack including:

- 3D space charge
- CSR

FL1 scheme



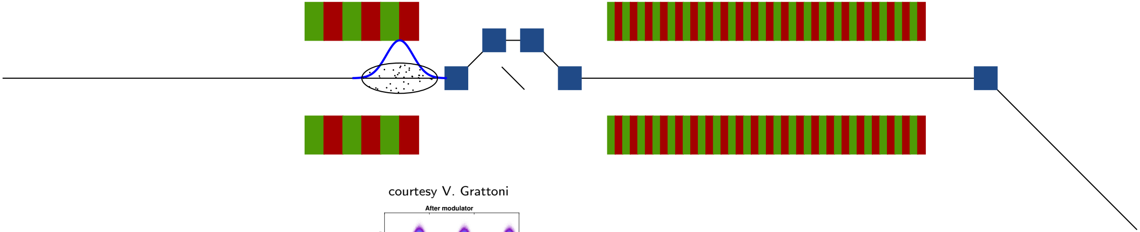
	FLASH1 (Seeded)	FLASH1 (SASE)	Unit
Wavelength range	4-60	4-60	nm
Pulse energy	$<$100	$<$1000	μJ
Pulse duration (FWHM)	30	5-200	fs
Spectral width	Fourier limited	0.5-2	%
# Pulses	10-5000	10-5000	s^{-1}



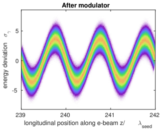
App

FL1 Schemes

HGHG

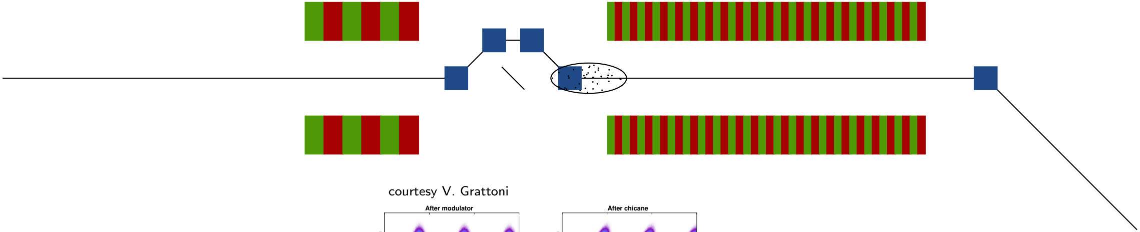


courtesy V. Grattoni

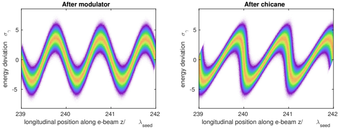


FL1 Schemes

HGHG

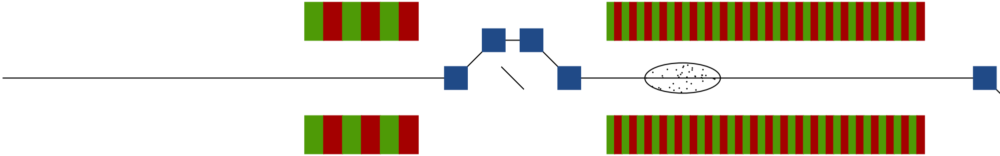


courtesy V. Grattoni

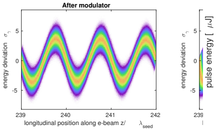


FL1 Schemes

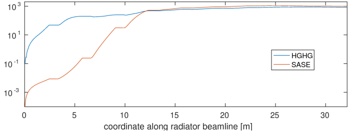
HGHG



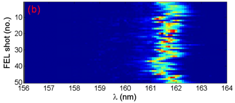
courtesy V. Grattoni



FLASH2020+ CDR

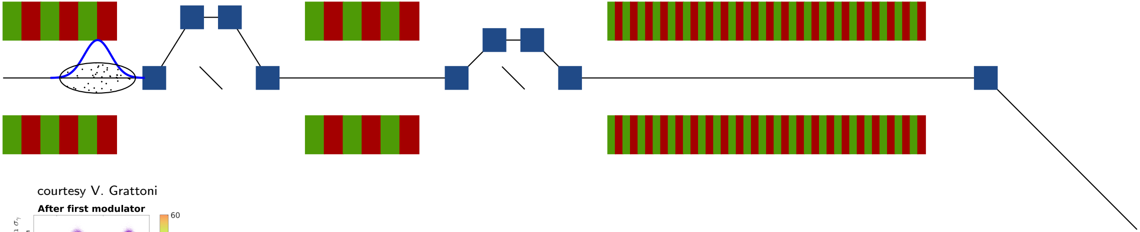


E. Hemsing, et al PRST-AB 17, 070702 (2014)

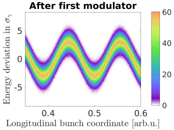


FL1 Schemes

EEHG

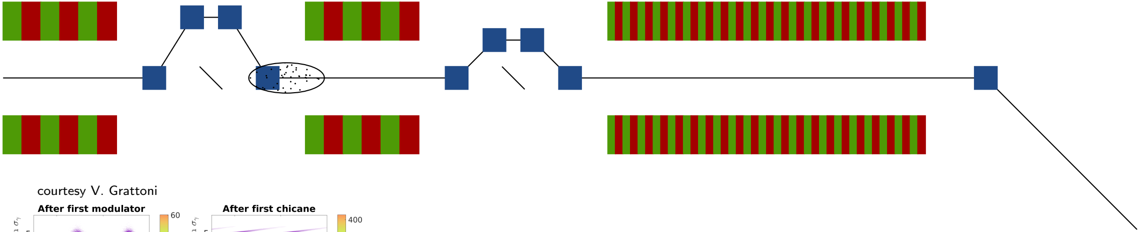


courtesy V. Grattoni

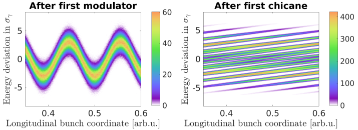


FL1 Schemes

EEHG

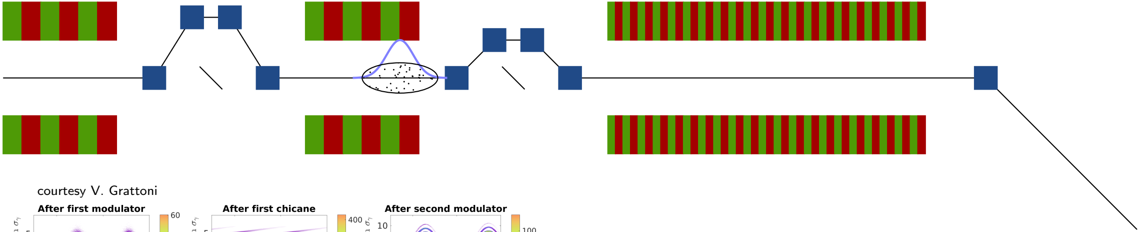


courtesy V. Grattoni

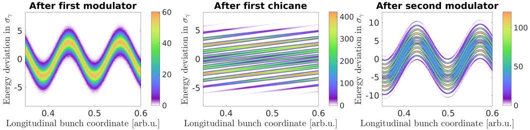


FL1 Schemes

EEHG

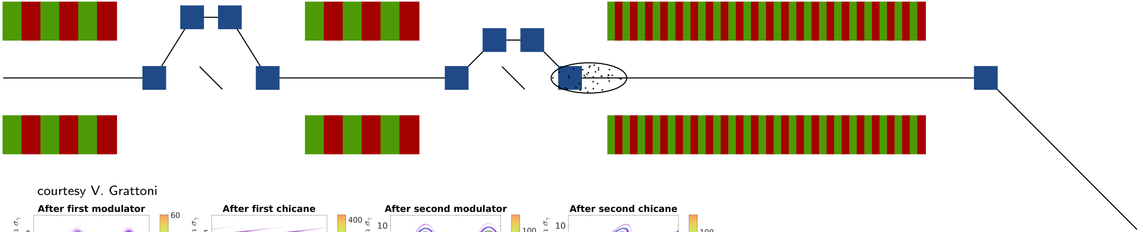


courtesy V. Grattoni

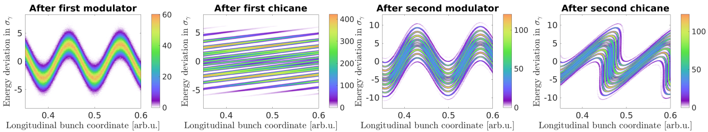


FL1 Schemes

EEHG

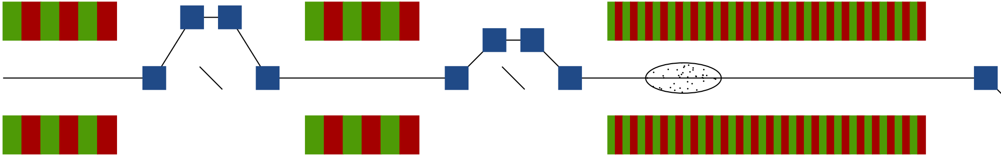


courtesy V. Grattoni

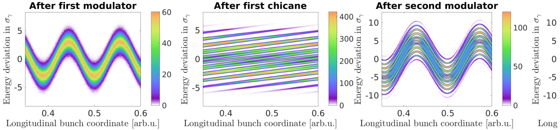


FL1 Schemes

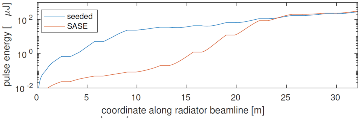
EEHG



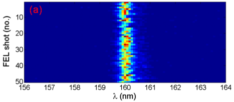
courtesy V. Grattoni



FLASH2020+ CDR

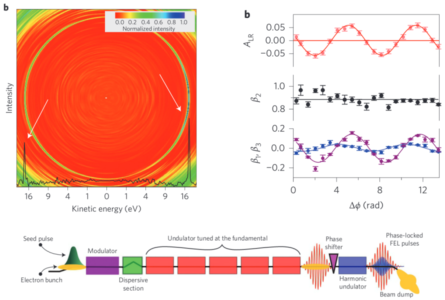


E. Hemsing, et al PRST-AB 17, 070702 (2014)



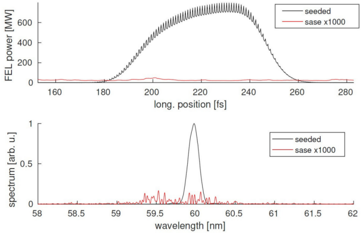
Benefits of the Schemes

	SASE	HGHG	EEHG
Longitudinal coherence	o	+	++
Transversal coherence	+	+	+
Control of FEL-pulse phase	–	+	+
FEL peak power	++	+	+
Wavelength range	++	o	+

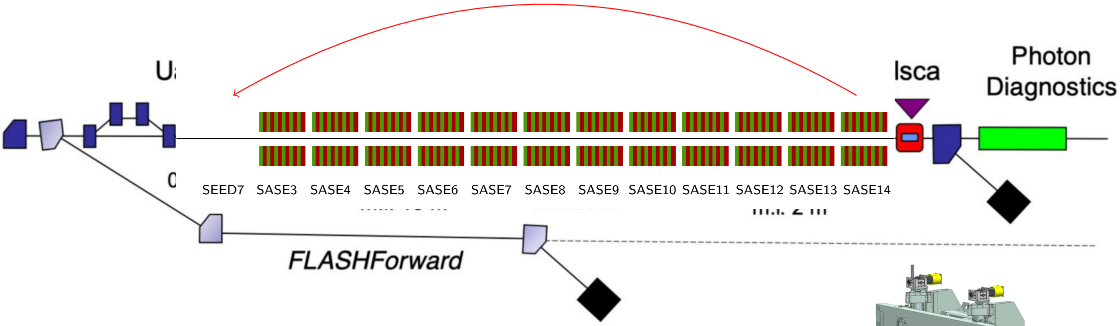


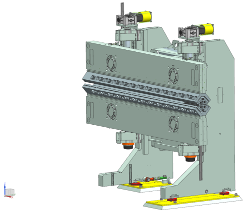
K. Prince, et al. Nat. Phot 10, 176–179 (2016)

Seeded-FEL vs. SASE-FEL for 60 nm



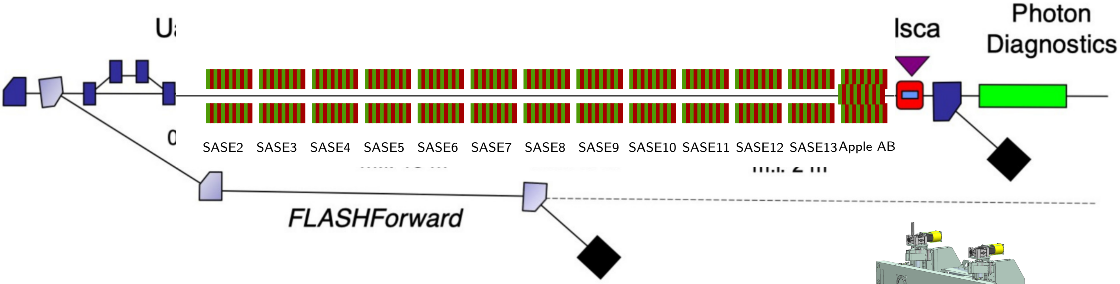
FL2 scheme

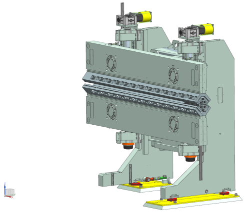




	FLASH2 (SASE)	Unit
Wavelength range	1.3-60	nm
Pulse energy	<1000	μJ
Pulse duration (FWHM)	0.1-200	fs
Spectral width	0.5-2	%
# Pulses	10-5000	s^{-1}

FL2 scheme





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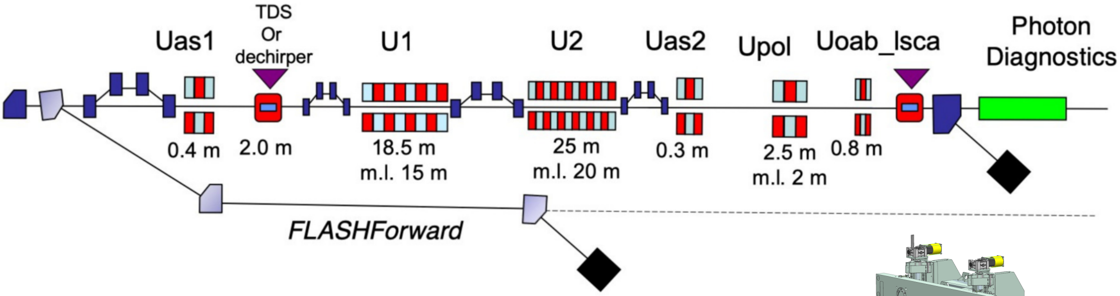
FL2 scheme



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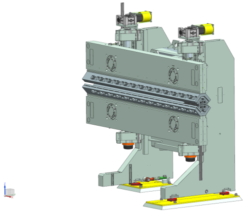


Schemes

Summary of CDR

lasing scheme	pulse energy / µJ	pulse duration / fs	wavelength / nm
SASE	< 1000	$10 - 500$	$2.3 - 60.$
harmonic lasing	< 1000	$10 - 500$	$1.0 - 2.0$
reverse taper with after burner	~ 10	$10 - 500$	$1.2 - 2.3$
frequency doubling	~ 1	$10 - 500$	$1.2 - 2.3$
two color lasing (1350 MeV)	~ 10	$10 - 500$	$4.0 - 18.5$
			$2.3 - 6.0$
two color lasing (750 MeV)	~ 10	$10 - 500$	$11. - 60.0$
			$7.0 - 20.$
optical after burner	~ 1	bunch duration	vis–NIR
longitudinal space charge amplifier	~ 0.1	possible< 1	VUV–X-ray
attosecond pulse generation	~ 0.1	> 0.2	> 3

A bunch of these values are estimates from experts!

Conclusion and Outlook

Injector:

- LH installation in BC2
- BC3 redesign to implement a diagnostic section
- Starting in 2021

FL1 FEL beam line:

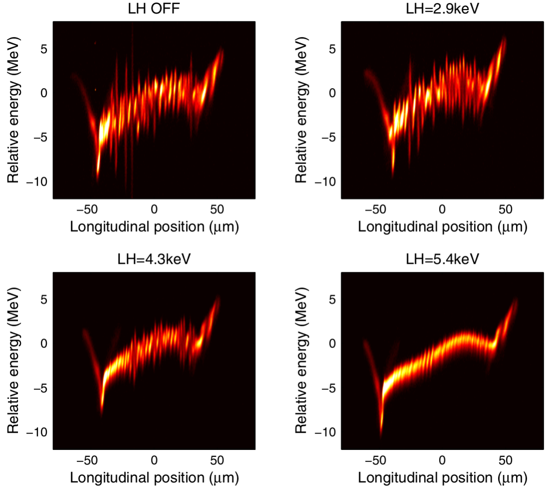
- Conversion to a seeded FEL beam line.
- Generating more stable (in energy and spectrum) and phase looked FEL pulses.
- Starting in 2023.

FL2 FEL beam line:

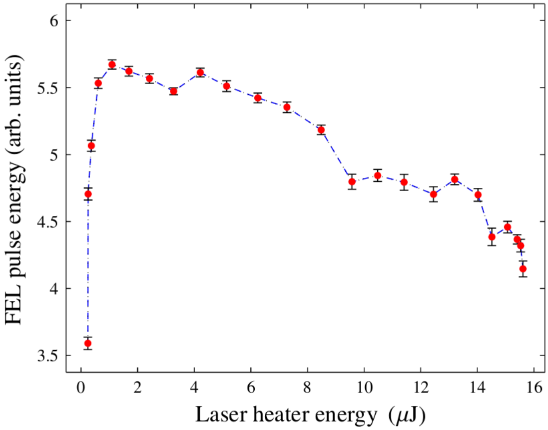
- Implementation of the after burner in 2021
- Undulator schemes more advanced to be able to generate ultra-short, two-color and high brightness pulses.
- Starting in 2023+x, x<10.

Backup

LH-Backup



Z. Huang, et al., PRSTAB 13,020703 (2010)



Ratner, et al., PRSTAB 18,030704 (2015)