



Center for the **A**dvancement of **N**atural
Discoveries using **L**ight **E**mission

Low Charge (< 20 pC) regime for SASE 1 undulator line at European XFEL

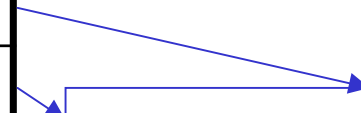
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Introduction

Beam Parameters	
Electron Energy	17.5 GeV
Bunch Charge	1 nC
Bunch Length (rms)	25 μm
Normalised emittance (rms)	1.4 mm mrad
Energy Spread (rms)	1.5 MeV
SASE 1 ($\lambda = 0.1 \text{ nm}$)	
Period	3.56 cm
K	3.3
Average beta	32 m
Total length	201.3 m



Decrease bunch charge from 1 nC to 20 pC



Simulations are performed for five different values of bunch rms length (1, 1.5, 2, 2.5 and 3 μm). For each value of bunch rms length emittance varies from 0.1 mm mrad to 0.3 mm mrad.

Simulation Results

SIMPLEX (steady-state)

- Design value (Bunch charge 1 nC)



Saturation Power 22.76 GW
Saturation Length 199.15 m

- Bunch charge 20 pC

$\sigma = 1 \mu\text{m}$

Emittance (mm mrad)	P_s [GW]	L_s [m]
0.1	56.83	77.54
0.14	49.19	85.93
0.18	43.69	95.56
0.22	39.68	99.77
0.26	36.24	105.91
0.3	33.51	116.29

$\sigma = 1.5 \mu\text{m}$

P_s [GW]	L_s [m]
31.95	83.57
27.87	96.38
24.76	107.44
22.32	116.47
20.52	122.71
18.91	134.98

$\sigma = 2 \mu\text{m}$

P_s [GW]	L_s [m]
21.18	92.03
18.47	105.52
16.44	116.68
14.78	124.95
13.61	138.54
12.63	135.59

Simulation Results

- Bunch charge 20 pC

$$\sigma = 2.5 \mu m$$

Emittance (mm mrad)	P_s [GW]	L_s [m]
0.1	15.44	99.98
0.14	13.39	114.71
0.18	11.89	120.53
0.22	10.81	129.13
0.26	9.93	141.65
0.3	9.15	145.28

$$\sigma = 3 \mu m$$

P_s [GW]	L_s [m]
11.78	106.51
10.26	117.22
9.17	134.56
8.29	142.97
7.56	149.25
6.95	153.67

The saturation power for this case can be comparable with design one for following values of bunch length and emittance:

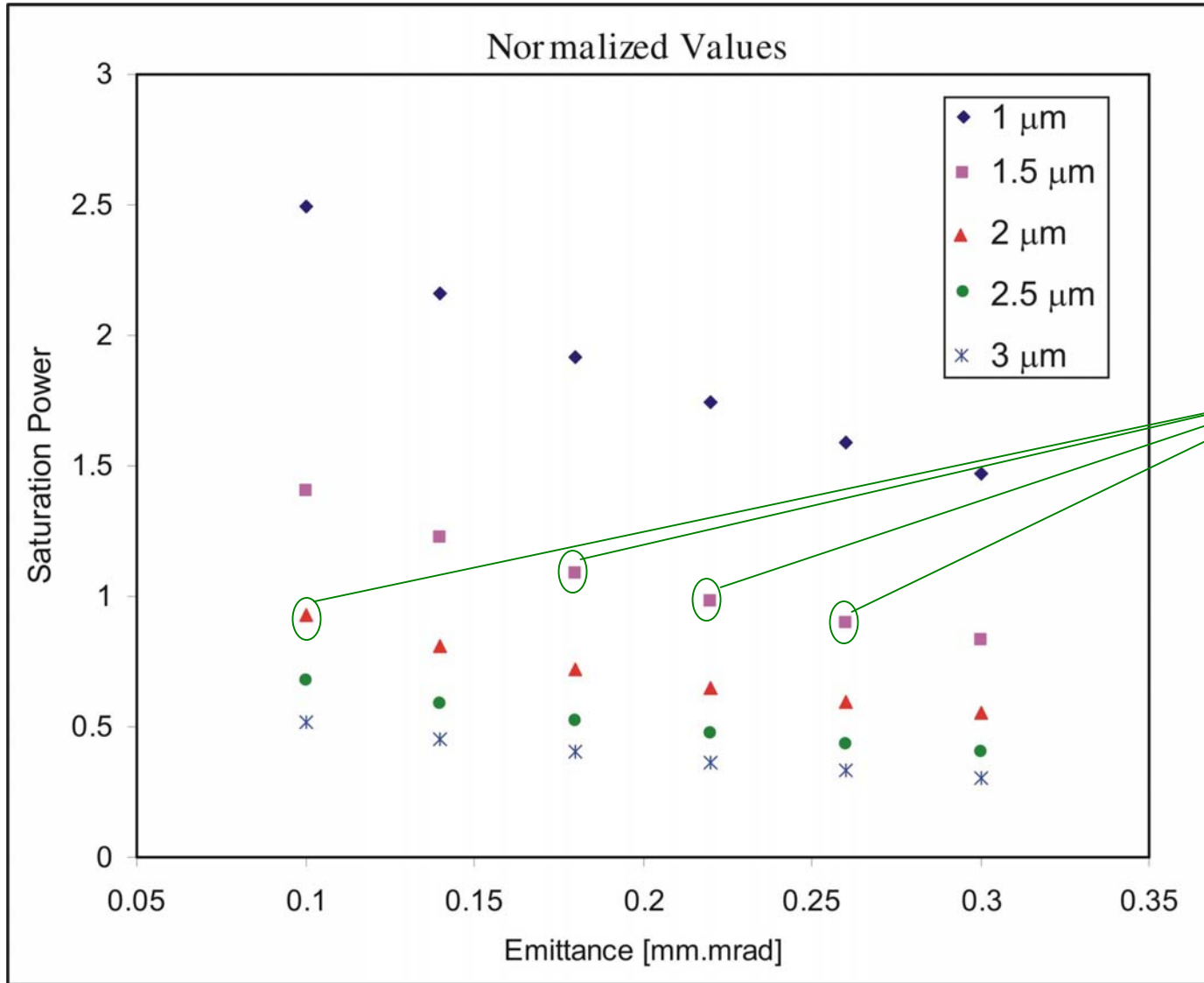
$$\sigma = 1.5 \mu m, \quad \varepsilon = 0.18 \text{ mm mrad}$$

$$\sigma = 1.5 \mu m, \quad \varepsilon = 0.22 \text{ mm mrad}$$

$$\sigma = 1.5 \mu m, \quad \varepsilon = 0.26 \text{ mm mrad}$$

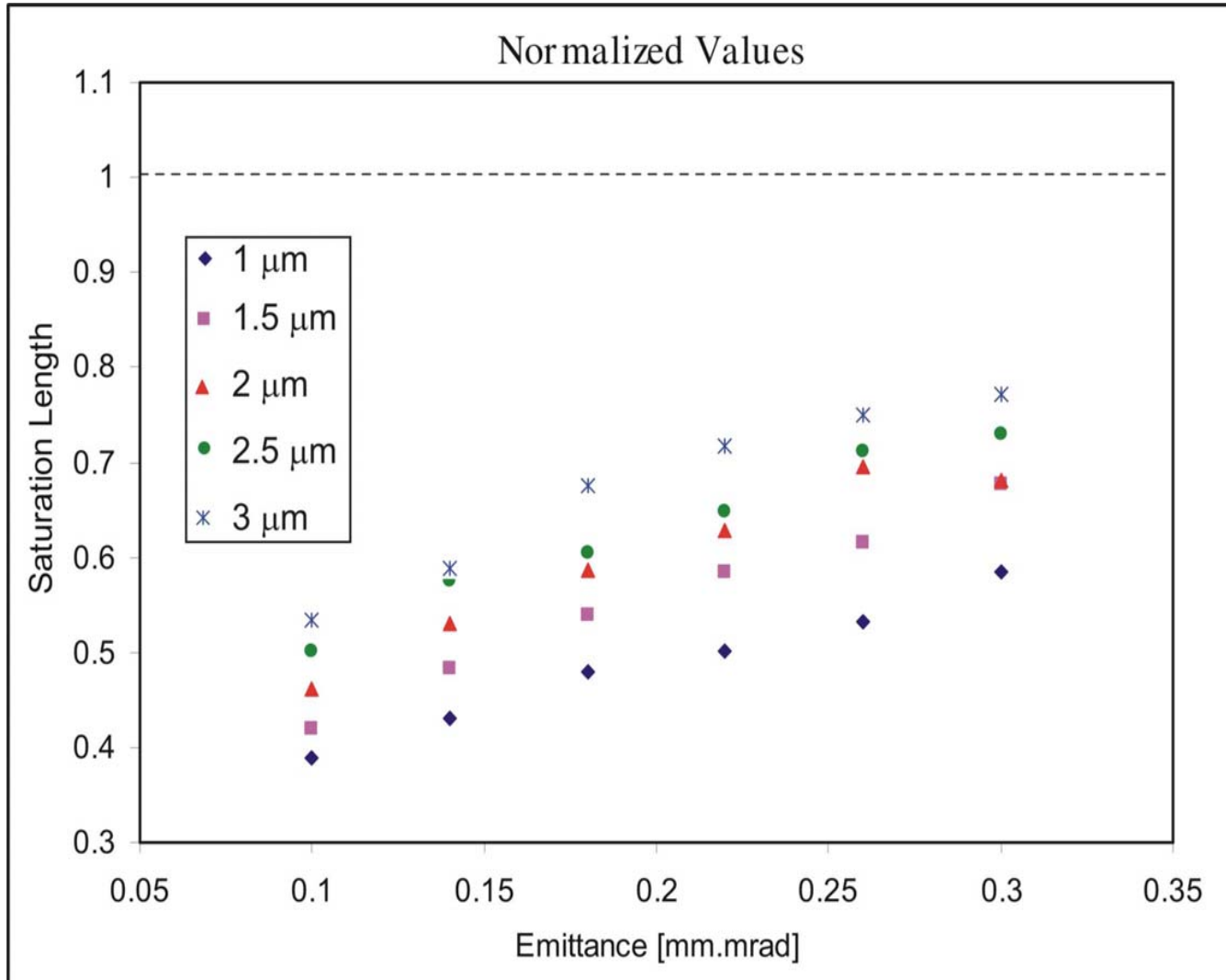
$$\sigma = 2 \mu m, \quad \varepsilon = 0.1 \text{ mm mrad}$$

Saturation Power



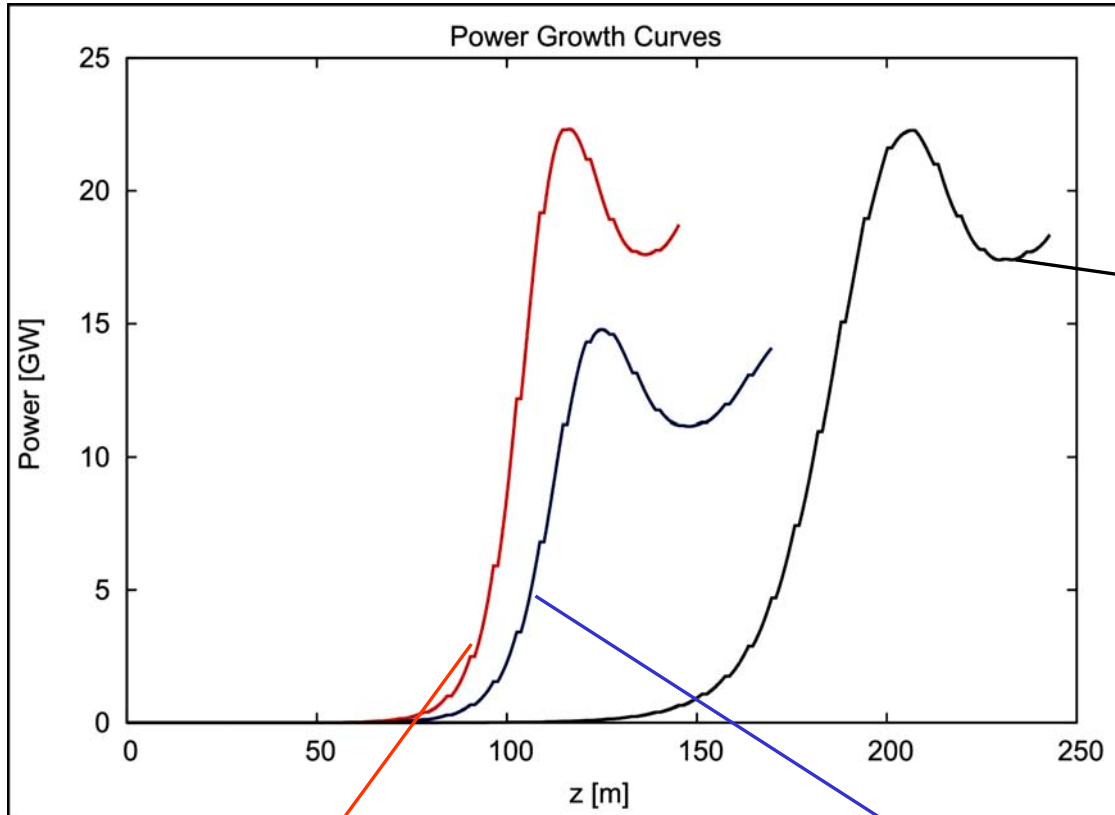
Close to design value

Saturation Length



The saturation length for this case is less than for the case with 1 nC bunch charge.

Power Growth Curves



Design

- Bunch charge 1 nC
- Emittance 1.4 mm mrad
- Bunch Length $25 \mu m$

- Bunch charge 20 pC
- Emittance 0.22 mm mrad
- Bunch Length $1.5 \mu m$

- Bunch charge 20 pC
- Emittance 0.22 mm mrad
- Bunch Length $2 \mu m$

CANDLE

Next Step

- Repeat simulations using SIMPLEX and GENESIS (time dependent)
- Investigate SASE FEL process for another range of beam parameters (such as bunch rms length, emittance, energy spread and etc.) and average beta functions.