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Compact

Compact Light WP2:
Soft X-Ray Free-Electron Laser

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First Midterm Review Meeting
Trieste, Italy - 19th June 2018

SUFEL
STOCKHOLM-UPPSALA CENTRE FOR
FREE ELECTRON LASER RESEARCH

Introduction

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Focus of Uppsala group within WP2:

- Study of **soft** x-ray case
- Task 2.1 – Specification of FEL output parameters based on user input
- Task 2.2 – Definition of FEL system & accelerator/undulator requirements

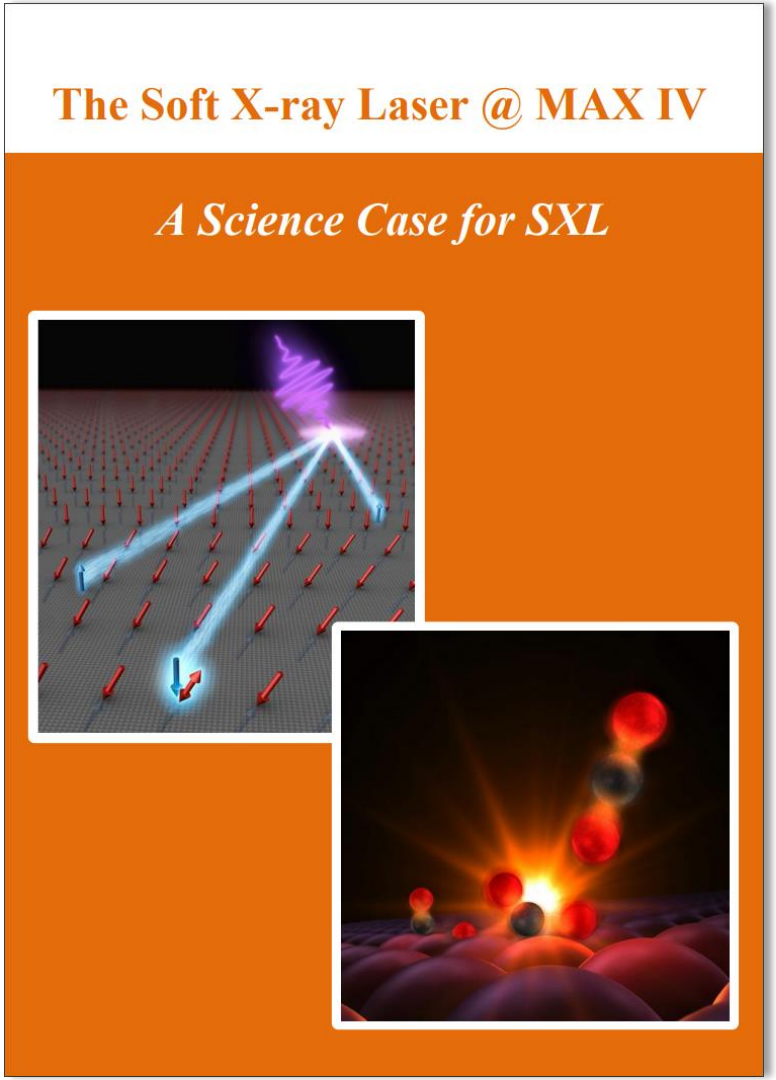
Synergy with other projects:

- **S**oft **X**-Ray **L**aser (SXL) at MAX IV Laboratory, Sweden
- **A**ttosecond **SI**ngle-Cycle **U**ndulator **L**ight (LUSIA)

In this presentation:

- User input on FEL output parameters
- Analytical estimation of FEL performance parameters
- Choice of λ_u & K for undulator
- First simulation results from GENESIS 1.3

User Input



- March 2016: Stockholm workshop to define the **science case** for a soft-x-ray FEL at MAX IV
- Report available for download at www.frielektronlaser.se
- General demands:

Wavelength	1 – 5 nm
Photon energy	0.25 – 1 keV
Pulse duration	1 – 50 fs
Repetition rate	10 – 100 Hz
Peak power	1 GW
Photons per pulse	10^{10} - 10^{12}
Peak brilliance	10^{30} – 10^{31} photons s^{-1} mm^{-2} $mrad^{-2}$ (0.1% BW)$^{-1}$

User Input – "Wish Lists"

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SXL Pink Beamline						
Photon energy [eV]	Pulse duration [fs]	Pulse energy [mJ]	Focused spot size [μm]	Mono-chromatic?	Resolving power $E/\Delta E$	Energy scanning?
250 – 1000	1	1	3	No	100	Yes
Polarization control?	Single-shot experiment?	Split and delay?	Two pulses (100 fs apart)?	Two colours (10 eV apart)?	Pump laser?	Wavelength regime of pump
Yes	Yes	Yes	Yes	Yes	Yes	THz, IR, optical UV, XUV

SXL Mono Beamline						
Photon energy [eV]	Pulse duration [fs]	Pulse energy [mJ]	Focused spot size [μm]	Mono-chromatic?	Resolving power $E/\Delta E$	Energy scanning?
250 – 1000	40	0.1	10 – 100	Yes	5000	Yes
Polarization control?	Single-shot experiment?	Split and delay?	Two pulses (100 fs apart)?	Two colours (10 eV apart)?	Pump laser?	Wavelength regime of pump
Yes	Yes	No	No	No	Yes	THz, IR, optical UV

Near-Term Actions

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- **Exchange of ideas with user community**
  - "Science @ FELs 2018" (25th – 27th June, Stockholm)
  - "Attosecond and FEL Sciences 2018" (2nd – 4th July, London)
  - Compact Light user meeting (date TBD, CERN)

- **Further simulation studies of soft x-ray FEL**
  - Baseline design – SASE operation mode
  - Production of attosecond light pulses
  - Harmonic-lasing self-seeding (HLSS) mode

- **Dissemination of results**
  - Peer-reviewed publication on compact soft-x-ray FEL design
    - in collaboration with Neil Thompson (Daresbury Laboratory)

FEL Performance Parameters

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- Examples of performance parameters:
  - Saturation length L_{sat}, saturation power P_{sat}, peak brilliance B
- Estimated using analytical tools:
  - M. Xie, *Nucl. Instr. Phys. Res. Sec. A* **445**, 59 (2000).
  - E. L. Saldin, E. A. Schneidmiller and M. V. Yurkov *New Journal of Physics* **12**, 035010 (2010).
- Examine dependence on undulator specifications
  - Period λ_u, parameter K
- Case study: MAX IV linac (designed to drive a soft x-ray FEL)

Electron energy	3 GeV
Relative energy spread	1 x 10^{-4}
Peak current	1.4 kA
Normalized emittance	0.4 mm mrad
Average of β function	5 m

Analytical Estimation

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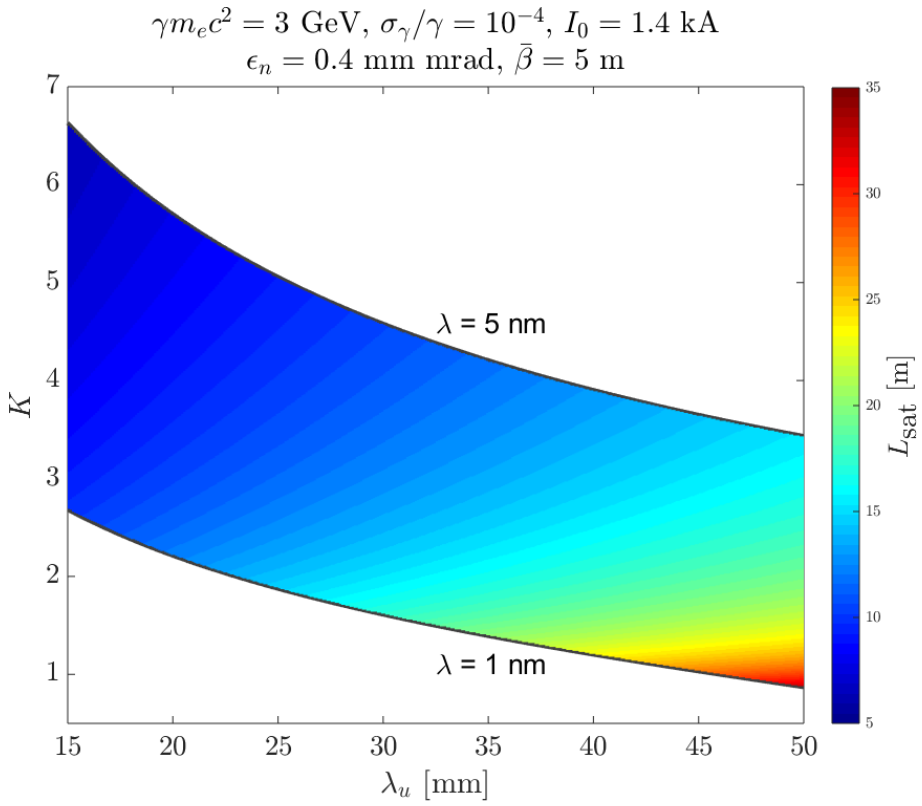
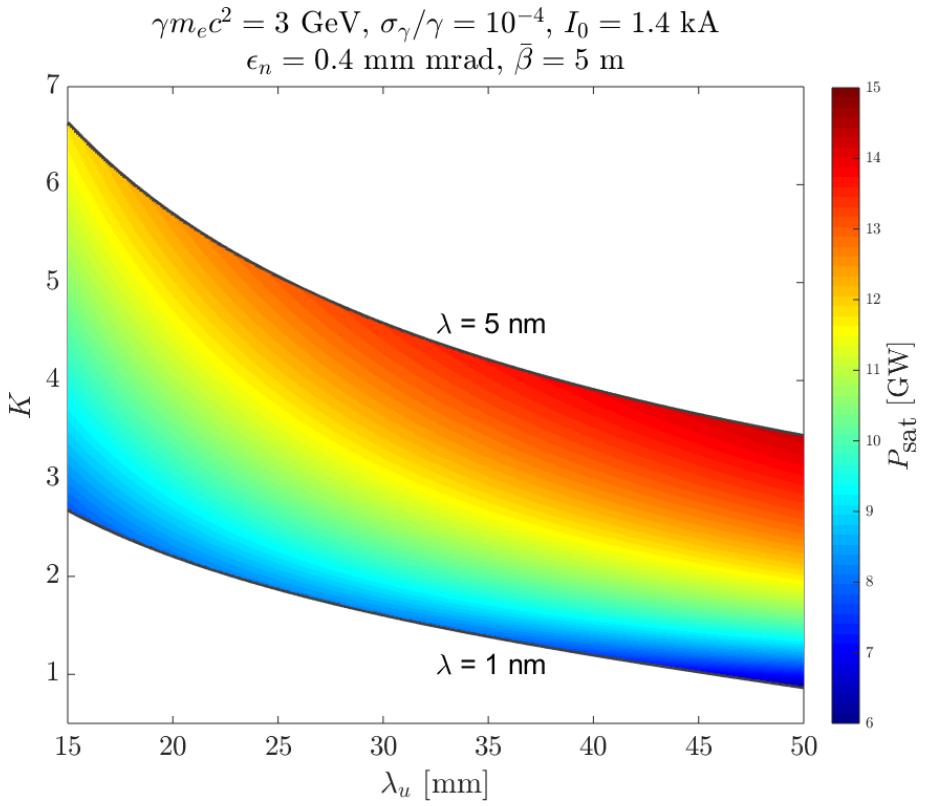
Saturation length



Saturation power



Analytical Estimation

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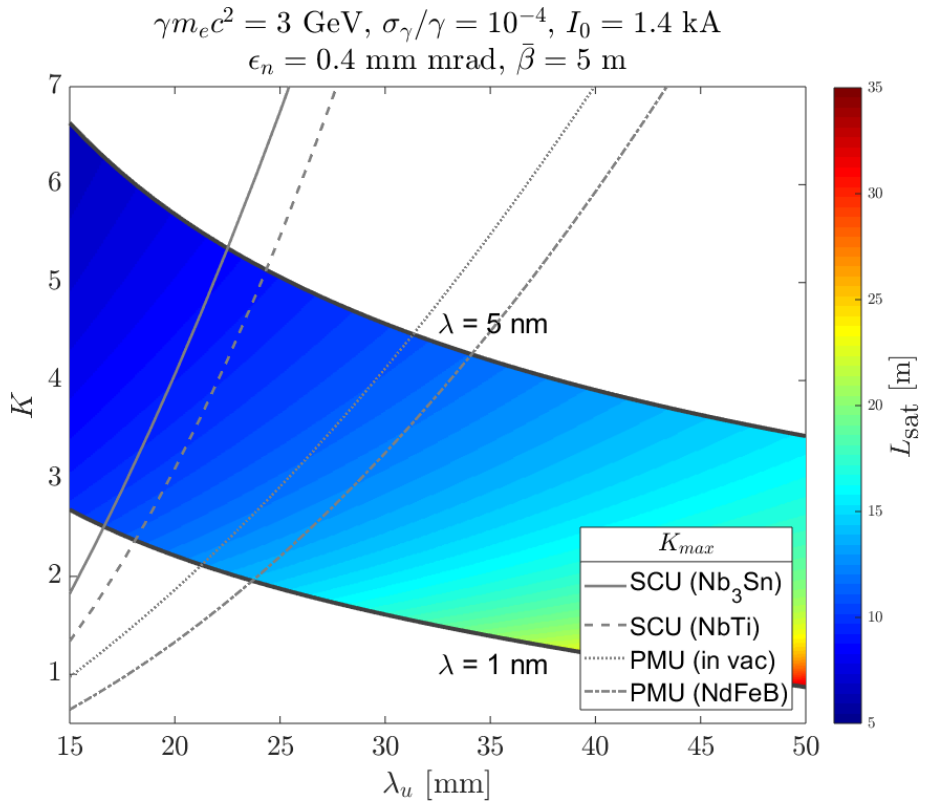
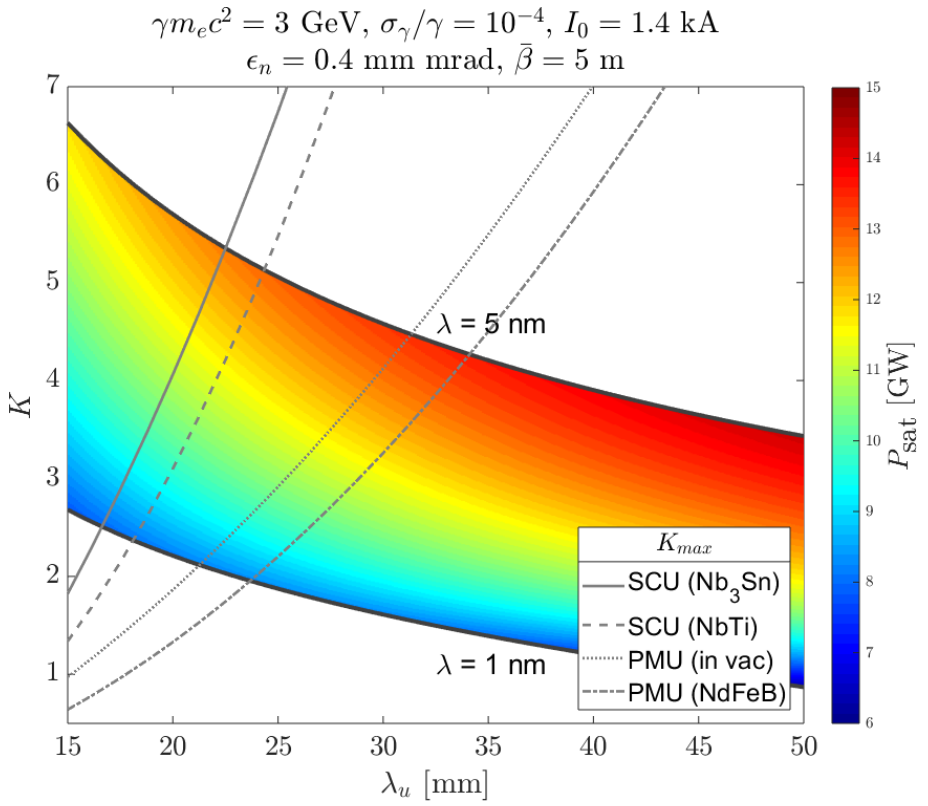
Saturation length



Saturation power



K_{max} curves assume a minimum gap of 7.5 mm (5.7 mm for in-vacuum undulators), and are extrapolated from data presented by Paul Emma at the SCU R&D Review of SLAC in 2014.

Analytical Estimation

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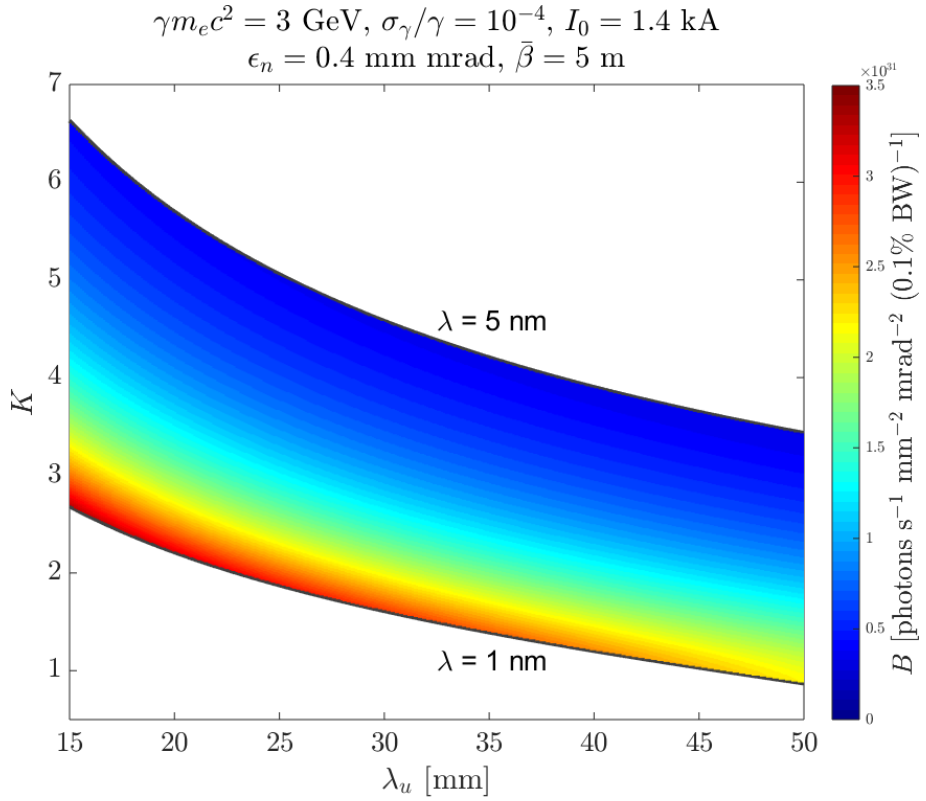
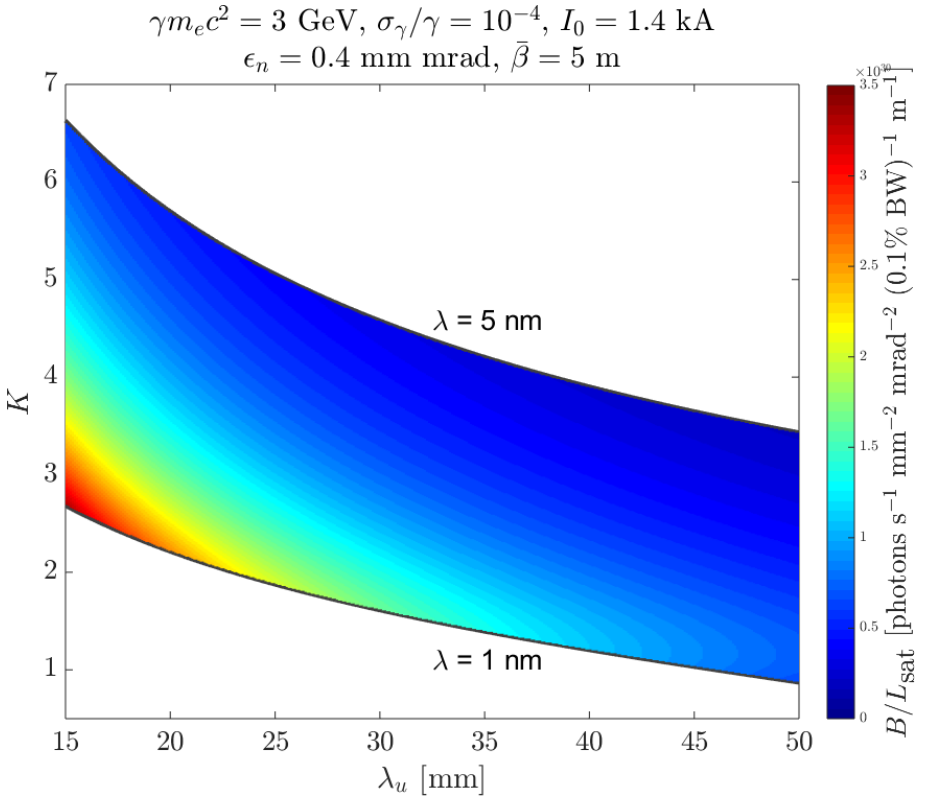
Peak brilliance



Peak brilliance per saturation length



Analytical Estimation

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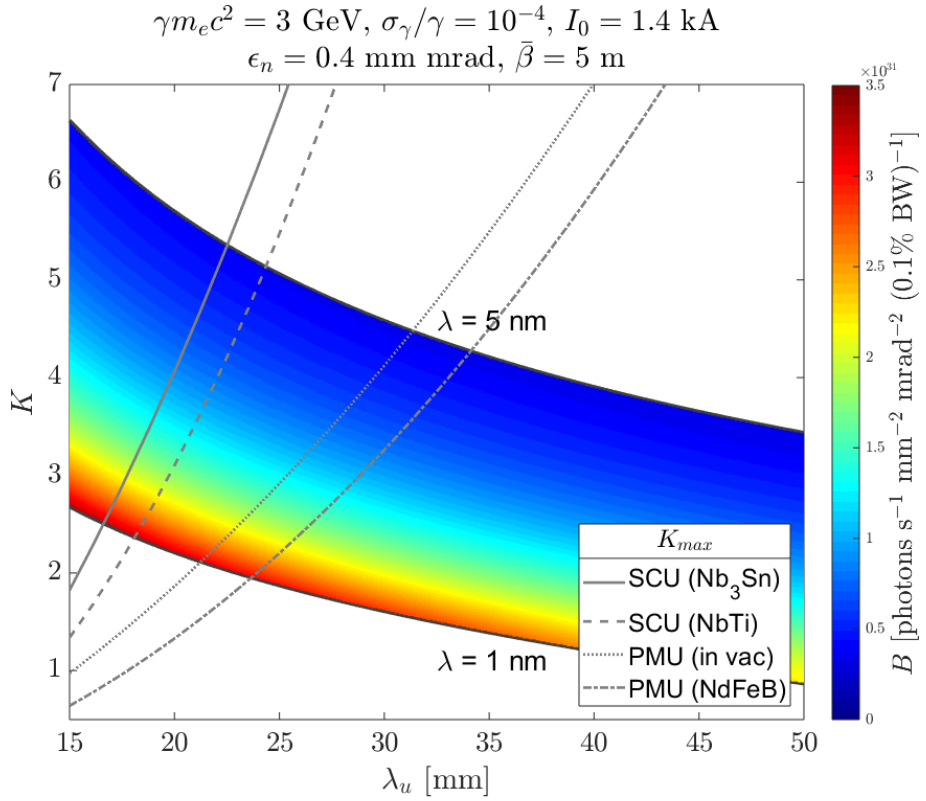
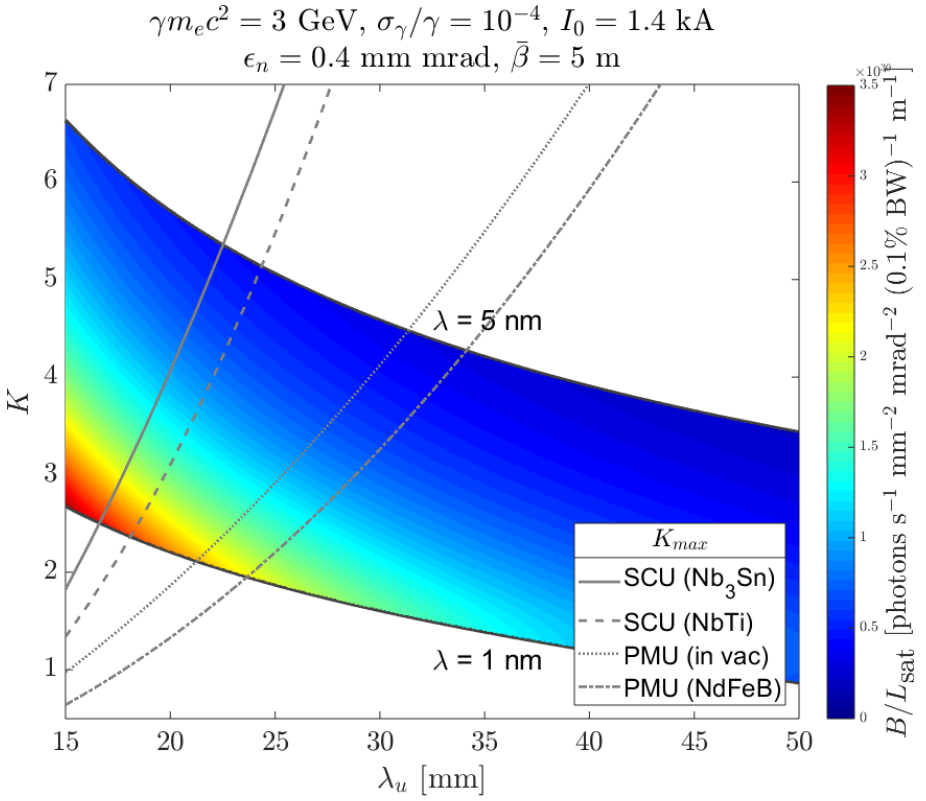
Peak brilliance



Peak brilliance per saturation length



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Numerical Simulation

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- Using the simulation code GENESIS 1.3
- 3D and time-dependent simulation
- Self-amplified spontaneous emission (SASE): 99 shots
- Results in reasonable agreement with analytical estimates
- Simulated operation point:

Radiation wavelength	1 nm
Undulator period	15 mm
K parameter	2.68
Undulator module length	2.7 m
Break section length	0.6 m
RMS length of electron bunch	9 μm

Numerical Simulation

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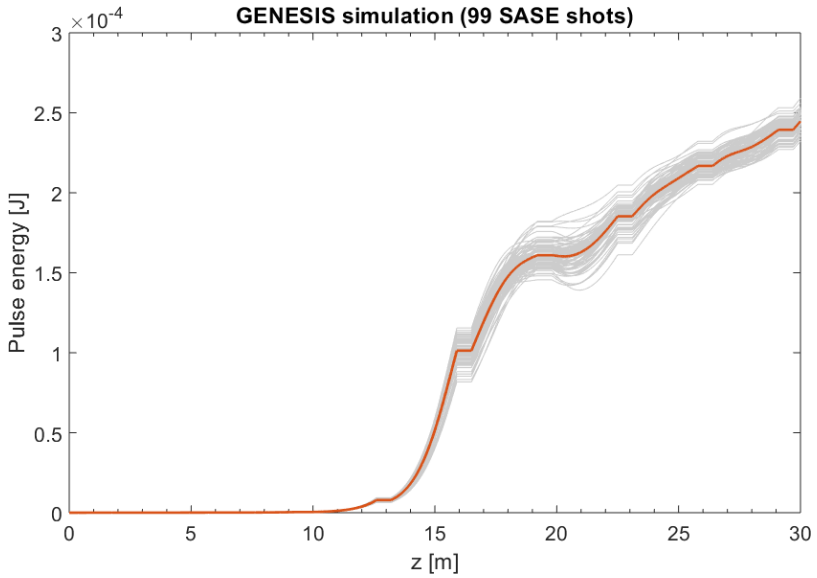

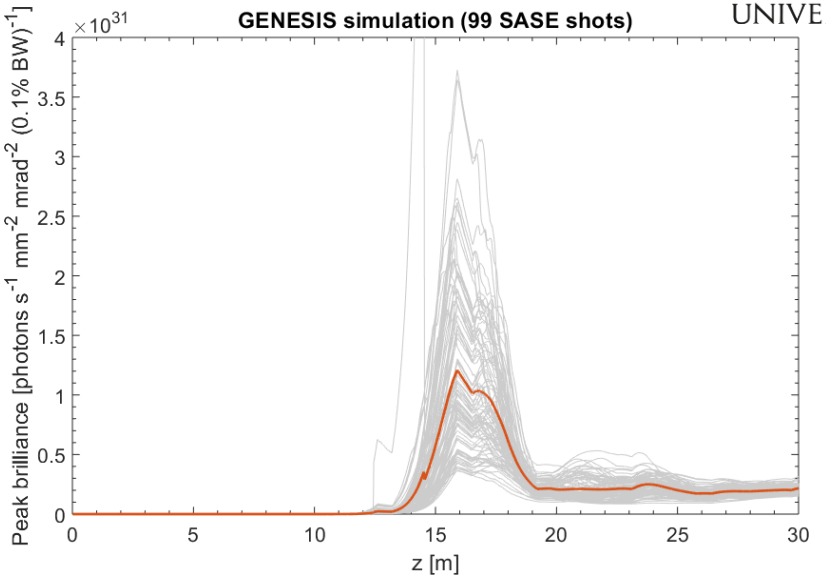

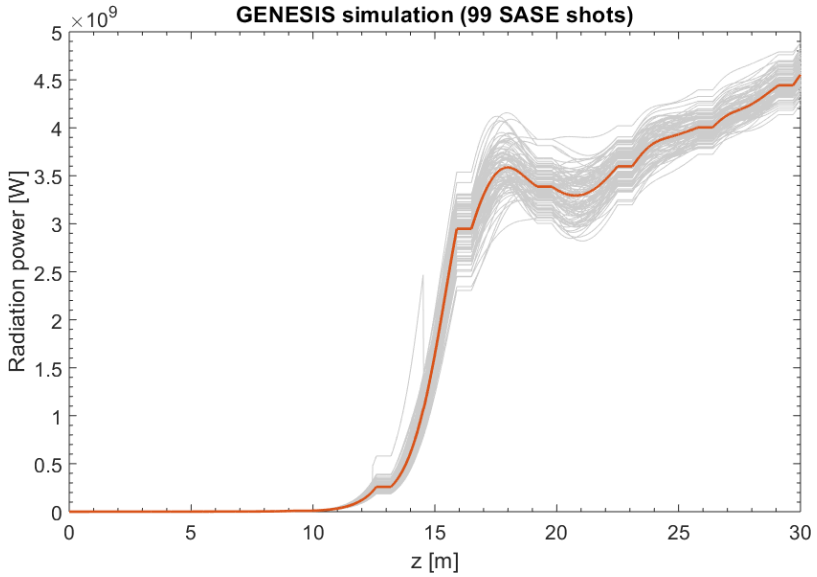

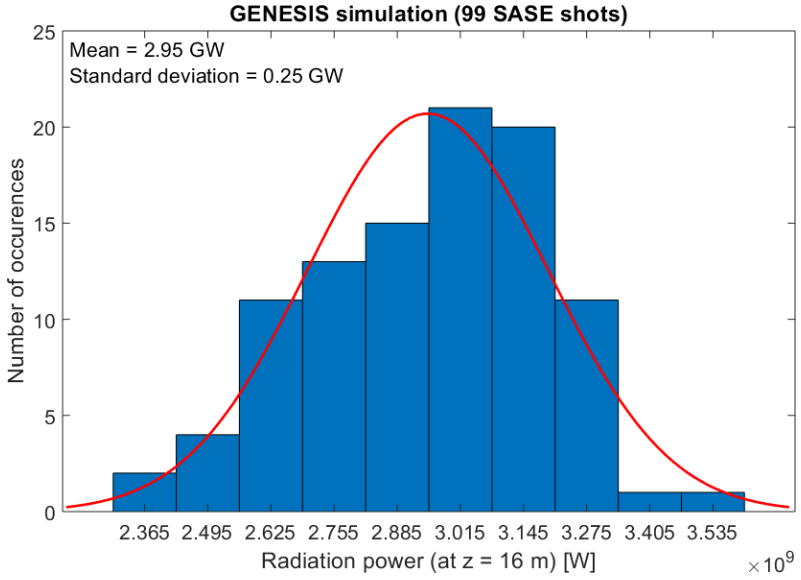

Acknowledgement

- Compact Light consortium
  - Funded by the European Union's Horizon 2020 programme
  - Grant agreement no. 777431
- Swedish Research Council (VR)
  - Project no. 2016-04593
- Royal Swedish Academy of Sciences (KVA)
  - Project no. PH2018-0037
- Stockholm-Uppsala Centre for Free-Electron Laser Research (SUFEL)