AKBP 9.3

Case Study for 100 µm SASE FEL Based on PITZ Accelerator for Pump-Probe Experiment at the European XFEL

Start-to-End Simulations

Outline

- Introduction
- Beam Optimization
- Beam Transport
- Simulation of FEL Radiation
- Summary & Outlook

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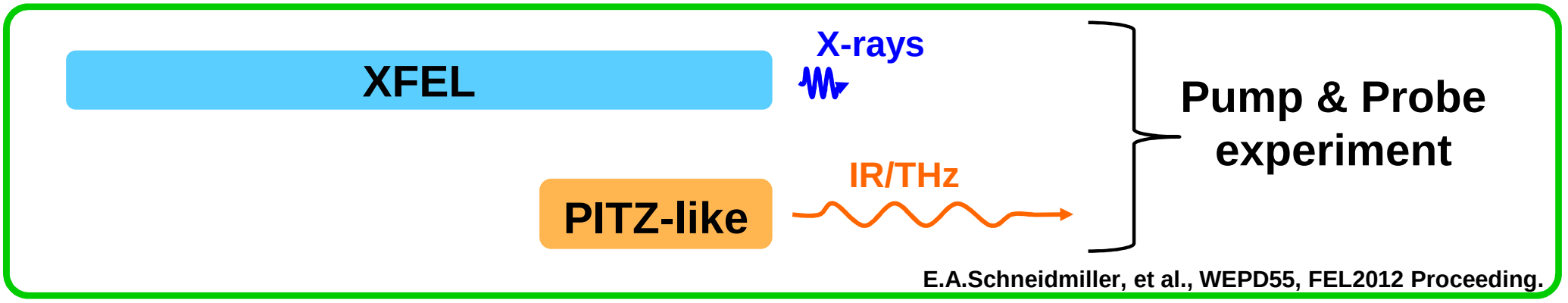
DESY

Introduction: IR/THz source Project at PITZ



E.A.Schneidmiller, et al., WEPD55, FEL2012 Proceeding.

Aims of development IR/THz sources at PITZ

- Prototype facility for an IR/THz source for pump and probe experiments planned at the European XFEL.
- Electron beam diagnostics from the radiation properties.
- Development of the experimental setup and testing of radiation diagnostics devices.

Studies for 2 types of radiation:

- High gain FEL
- Coherent Transition Radiation (CTR)

Proceedings concerning this project:

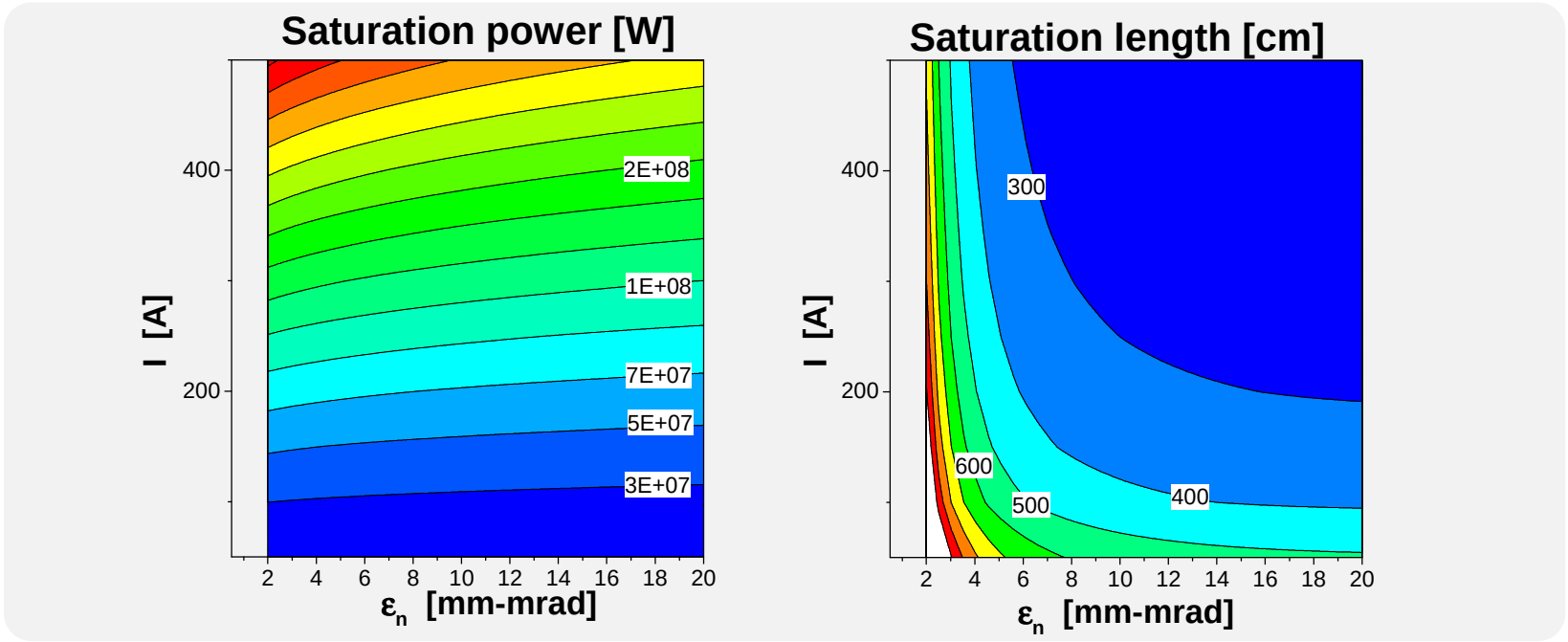
- E.Schneidmiller et al., in Proc. FEL2012 Conf. (WEPD55), Nara, Japan, 2012.
- P.Boonpornprasert et al., in Proc. FEL2014 Conf. (MOP055), Basel, Switzerland, 2014.

Introduction: Overview of FEL parameter space

The calculations have been performed with code FAST (Calculated by M.Yurkov & E. Schneidmiller).

Generate SASE FEL radiation wavelength of 100 μm using:

- Helical undulator with period length of 40 mm
- Electron beam with 15 MeV/c momentum, 4 nC bunch charge, ~2 mm rms bunch length

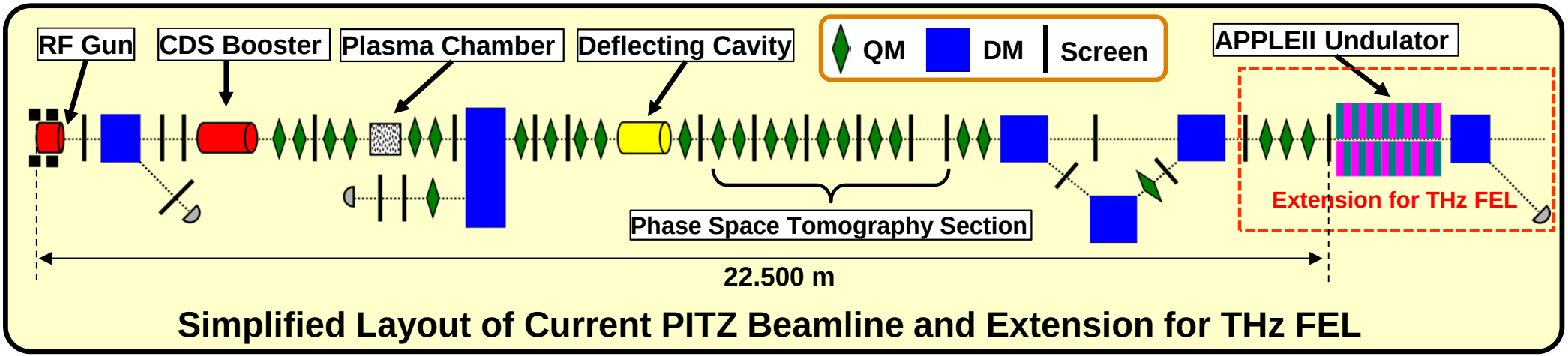


- **Transverse normalized emittance (ε_n) has almost no impact on saturation power.**
- **Higher ε_n ➔ shorter saturation length.**

Introduction: PITZ Overview

Main Goals - **Develop, test and optimization of high brightness electron beams sources**

- **Commissioning and optimizing RF guns for the European XFEL**

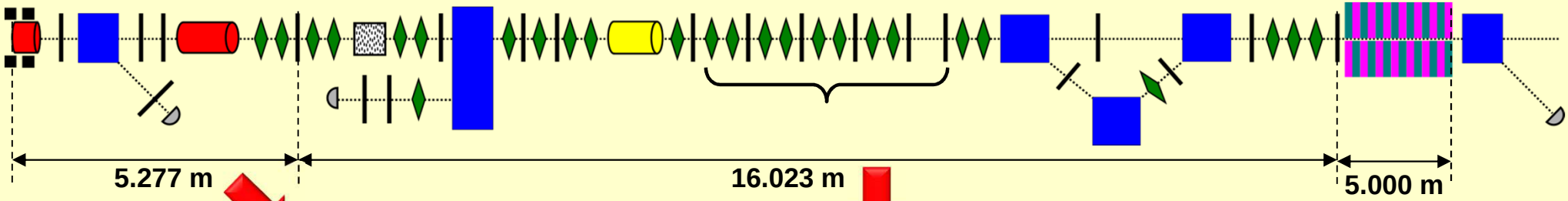


Simplified Layout of Current PITZ Beamline and Extension for THz FEL

- RF photoelectron gun solenoids (~7 MeV/c)
- Cut Disk Structure (CDS) booster (~25 MeV/c)
- UV photocathode laser
  - Cylindrical pulse shape (Gaussian, flat-top).
  - 3D-ellipsoidal pulse shape
- Electron beam diagnostics stations

Bunch charge of Few pC … 4 nC

Introduction: Working Step for S2E Simulations



1. Beam Optimization

- Tool: ASTRA
- Z = 0 to 5.277 m

Input Parameters for ASTRA	
laser pulse shape	Flattop
laser temporal time	21.5 ps
rms laser spot size	1.25 mm
Bunch charge	4 nC

- Final beam momentum ~15 MeV/c
- Optimize gun phase*, booster phase*, main solenoid current for compromising between

High peak current ⟷ **Low energy spread**

*Relative to maximum mean momentum gain (MMMG) phase

2. Beam Transport

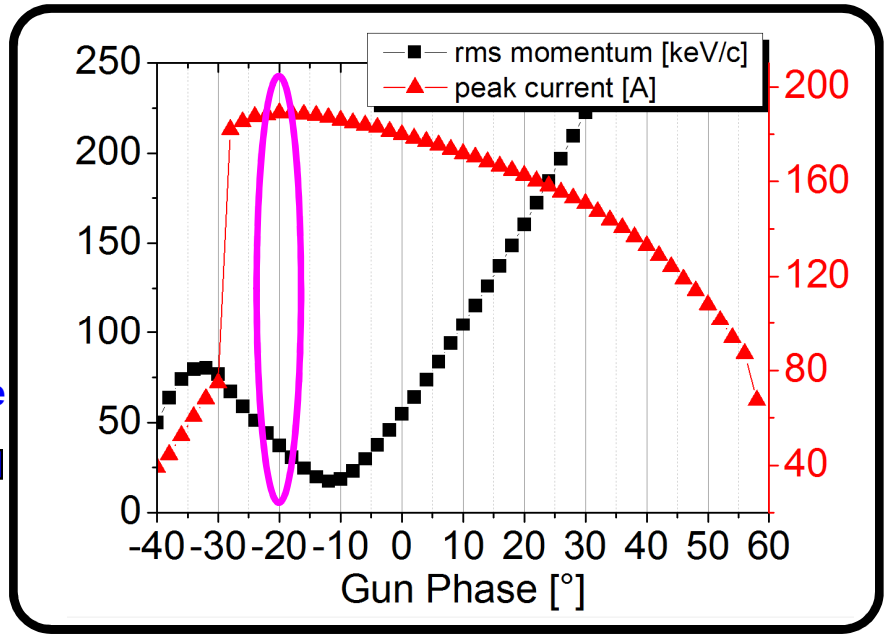
- Tools: ASTRA, MADX, SC Software (developed by HZB)
- Z = 5.277 to 22.500 m (16.023 m length)
- Transport strategy:
  - Transverse rms size is limited to 6 mm.
  - Symmetric transverse emittances and beam sizes at the undulator entrance.

3. FEL Simulation

- Tool: GENESIS 1.3
  - Time-dependent mode, space-charge calculation included, no seeded power
- Helical undulator , 40 mm period length
- Resonance wavelength of 100 µm

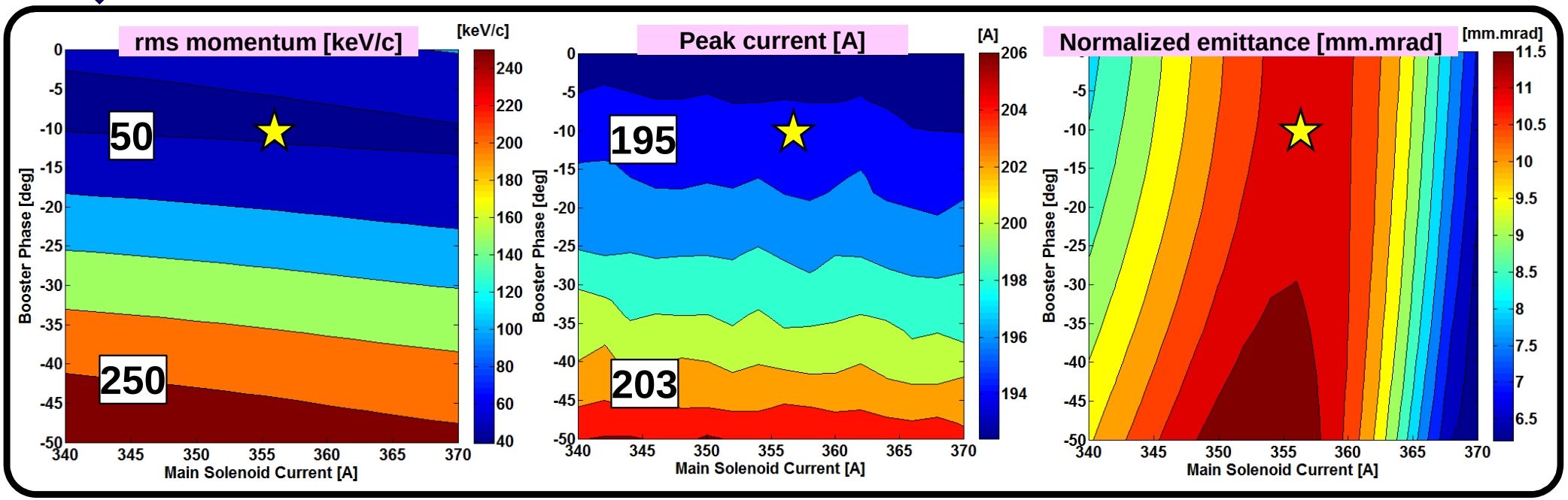
Optimization of Gun Phase, Booster Phase and Main Solenoid Current

Fixed gun phase to -20°

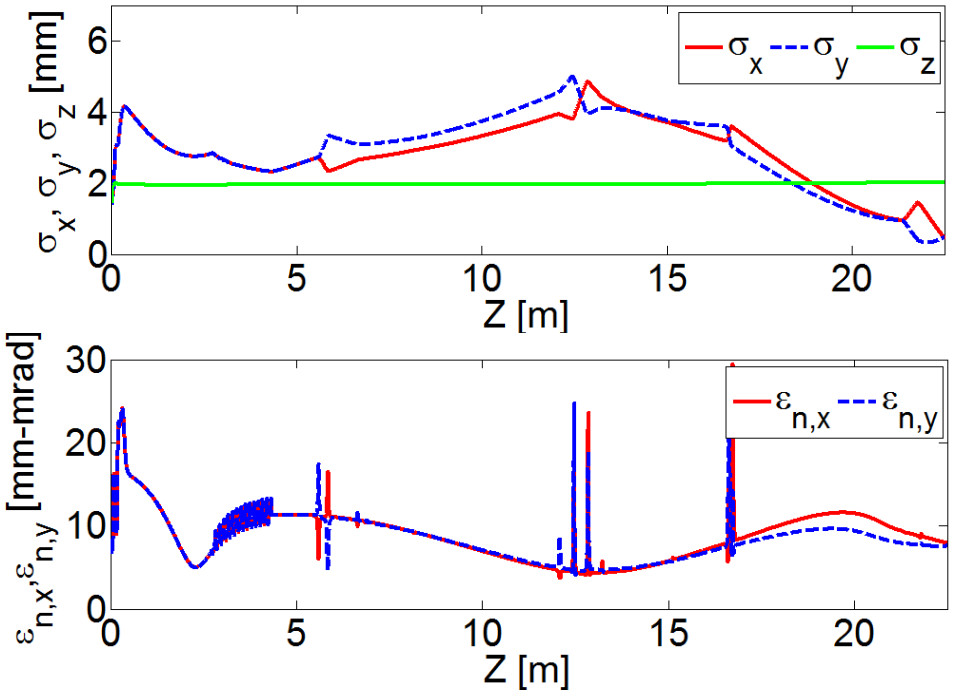


The optimized parameters are:

- **Gun phase = -20°**
- **Booster phase = -10°**
- **Main solenoid current = 356 A**

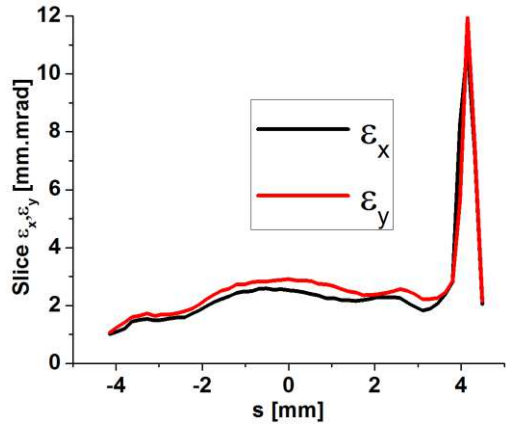


Beam Transport to the Undulator Entrance

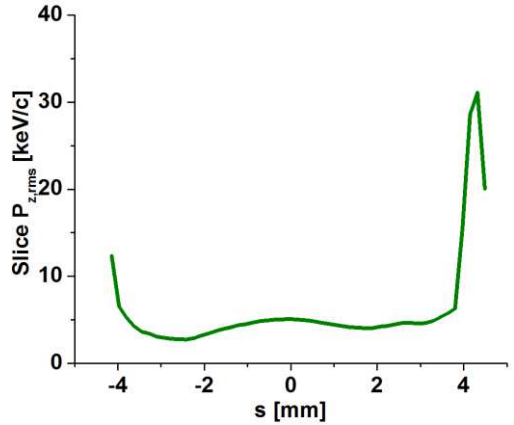


Parameters	Value
σx [mm]	0.475
σy [mm]	0.481
σz [mm]	2.022
$\varepsilon_{n,x}$ [mm.mrad]	7.917
$\varepsilon_{n,y}$ [mm.mrad]	7.599
Peak current [A]	199.3
$P_{z,rms}$ [keV/c]	134.736

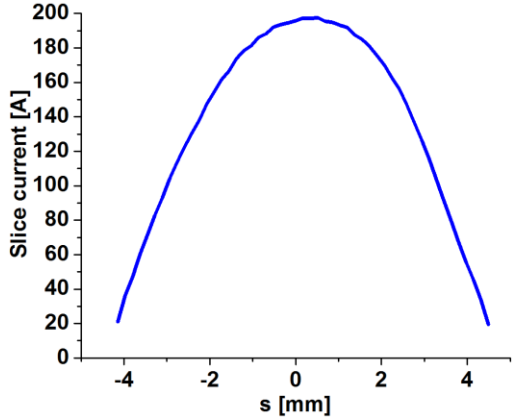
Slice emittance



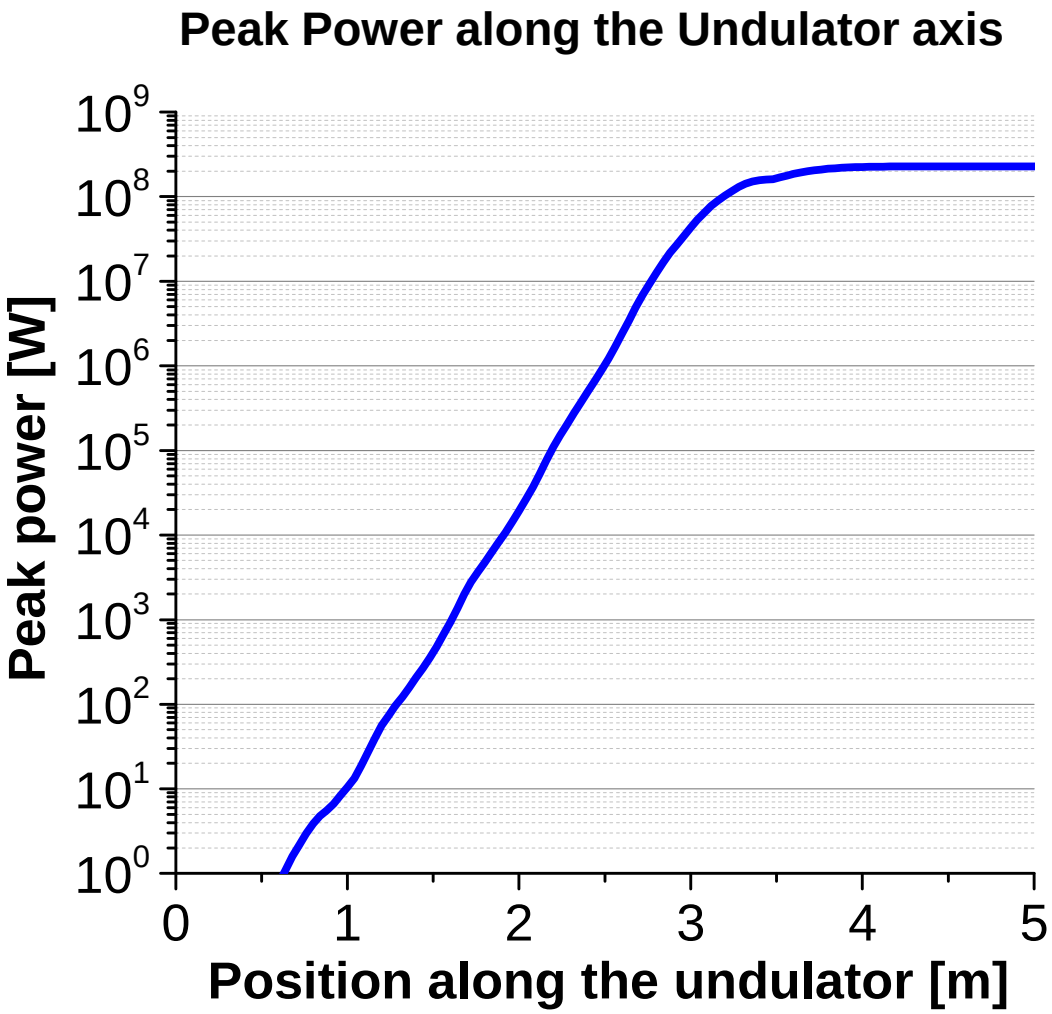
Slice rms momentum

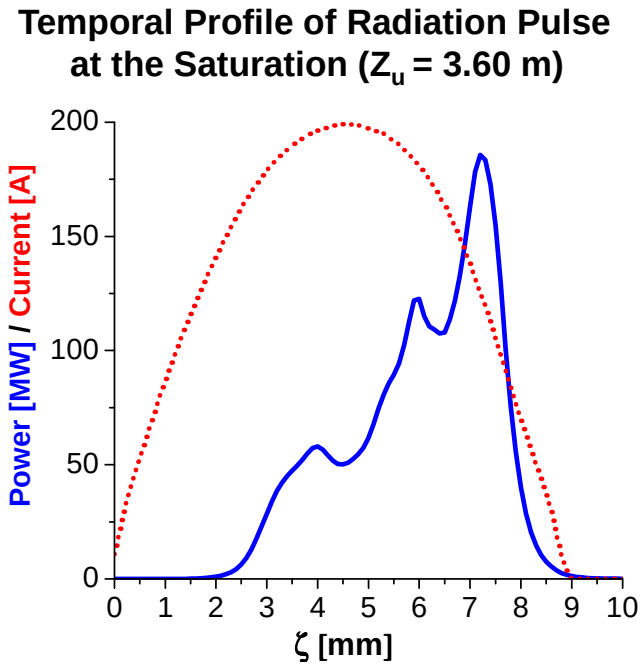


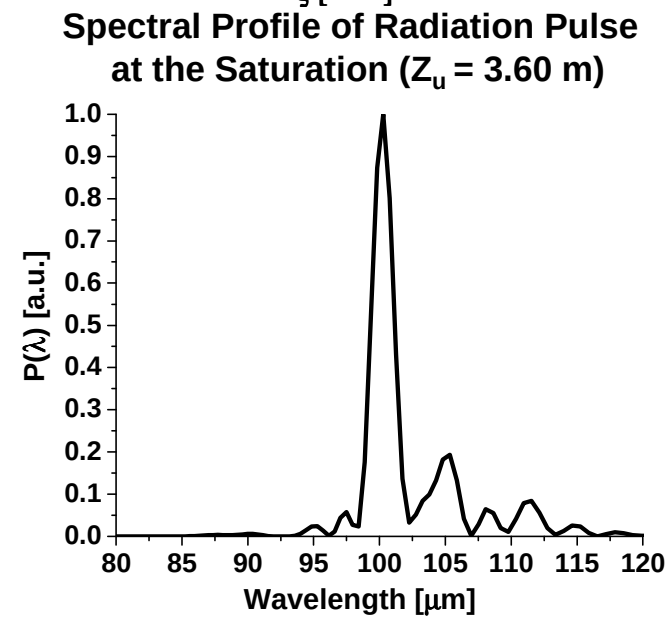
Slice current



Results of FEL Simulation for Radiation Wavelength of 100 µm







Saturation length (Z_u) is 3.60 m.

Peak power at saturation is 186 MW .

Summary and Outlook

Summary

- S2E simulation of the SASE FEL for 100 µm with actual PITZ beamline was performed.
- The results show that a radiation peak power of ~180 MW and a narrow bandwidth below 5% are achievable.

Outlook

- Improve beam transport strategy.
- Perform start-to-end simulation with 3D-ellipsoidal cathode laser, Planar undulator.

Other Talks from PITZ:

AKBP3.9	Igor Isaev	➔ RF Field simulations
AKBP7.5	Gaurav Pathak	➔ Gas density measurement
AKBP9.5	Georgios Kourkafas	➔ Electron beam matching
AKBP14.1	James Good	➔ 3D ellipsoidal laser system

Thanks for your attentions!

Backup Slides

Experimental Demonstration of 4nC Bunch Charge Generation at PITZ

11.01.2009 16:41 MK, H.-J.G **Laser on VC2, old BSA=1.9mm**