

Simulations of the IR/THz Options at PITZ (High-gain FEL and CTR)

Outline

- ▶ Introduction
- ▶ Simulations of High-gain FEL (SASE)
- ▶ Simulation of CTR
- ▶ Summary & Outlook

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**7th Market of Accelerator Ideas
DESY, Hamburg
1.09.2015**

Photo Injector Test Facility at DESY, Zeuthen site (PITZ)

↓ Considering

Development of “Intense and wide wavelength range” IR/THz source at PITZ

↓ Motivations & Goals



Pump & Probe experiment

PITZ is an ideal machine for development of the prototype IR/THz source

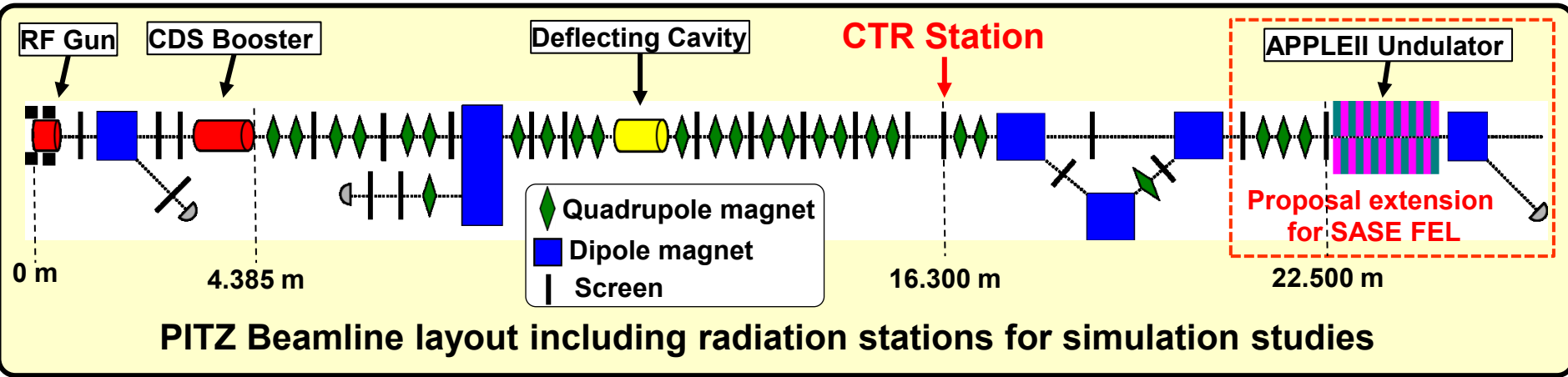
(Reference: E.A.Schneidmiller et al., WEPD55, FEL2012 conf.)

- ▶ Photon diagnostics
- ▶ Radiation based e-bunch diagnostics
- ▶ Service for light users

- Case studies of radiation generation produced by the PITZ electron beam
- ▶ SASE FEL
 - ▶ Coherent Transition Radiation (CTR)

Works in This Presentation

Preliminary Start-to-End (S2E) simulations for SASE FEL and CTR



- ▶ Photocathode RF Gun
- ▶ Cut Disk Structure (CDS) Booster
- ▶ UV photocathode laser
 - Cylindrical pulse shape (Gaussian, flat-top).
 - 3D-ellipsoidal pulse shape
- ▶ Electron beam diagnostics stations
- ▶ **Radiation stations for simulations studies**
 - **CTR station**
 - **Extension for SASE FEL**

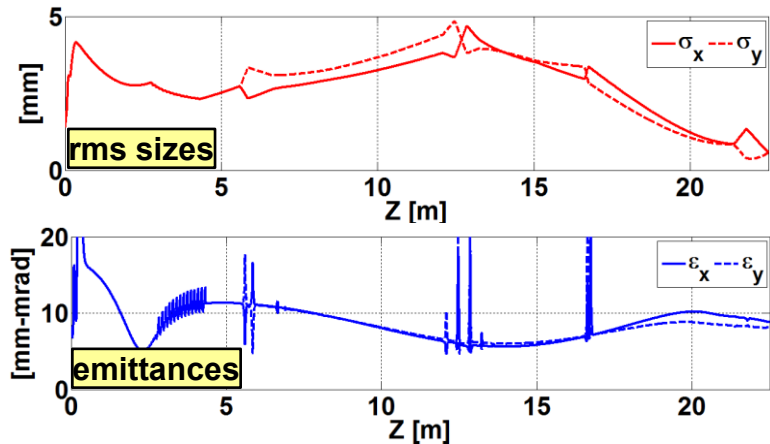
Key Parameters	
Laser temporal length	2 - 20 ps FWHM
Bunch charge	few pC ... 4 nC
Maximum mean momentum $\langle P_z \rangle$	~22 MeV/c

- ▶ **Simulation Tool: ASTRA code**
- ▶ **Goals of the beam transport:**
 - $\langle P_z \rangle \sim 15 \text{ MeV/c}$ at the undulator entrance
 - Symmetric transverse beam sizes and emittances at the undulator entrance

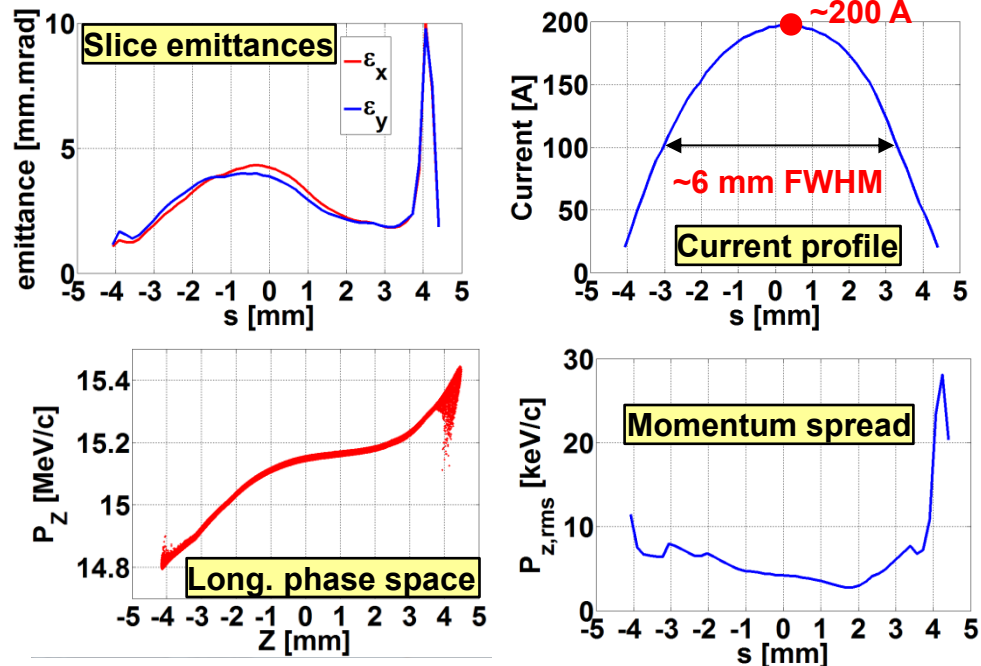
Input for ASTRA

Laser pulse shape	Flattop
Laser temporal length	20 ps FWHM
Rms laser spot size	1.25 mm
Bunch charge	4 nC
Z _{start} to Z _{end}	0 (cathode) to 22.500 m
Gun peak E-field	60 MV/m
Booster peak E-field	10 MV/m (for $\langle P_z \rangle \sim 15 \text{ MeV/c}$)
Gun phase	Optimized for: <i>High peak current</i> <i>Low energy spread</i>
Booster phase	
Solenoid fields	

Evolutions of transverse beam sizes and emittances

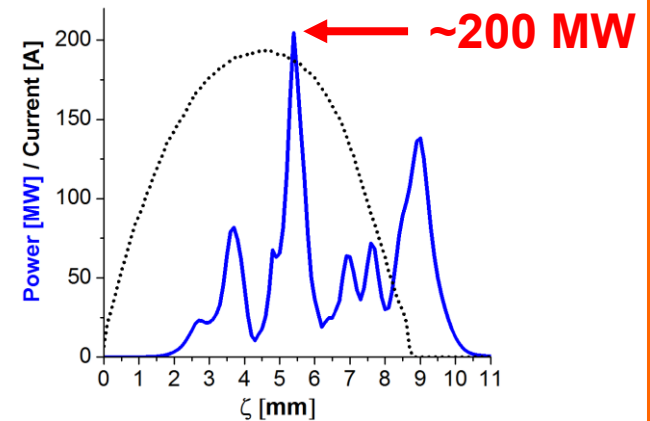


The longitudinal profiles at undulator entrance

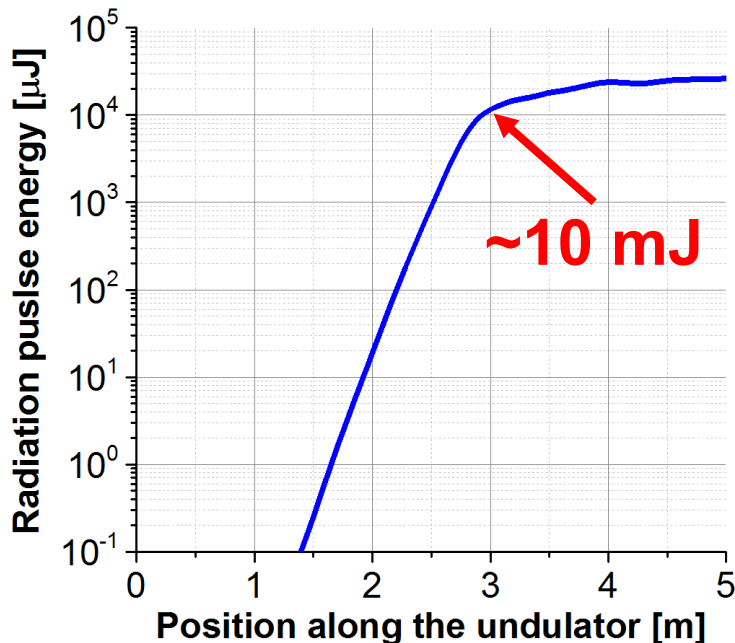


- ▶ **GENESIS 1.3 code (Version 2)** was used for numerical calculations of SASE FEL
- ▶ **Input for GENESIS:**
 - Time-dependent mode, space-charge effect included.
 - Helical undulator with **period length of 40 mm**
 - SASE FEL, **Radiation wavelength of 100 μm (3 THz)**

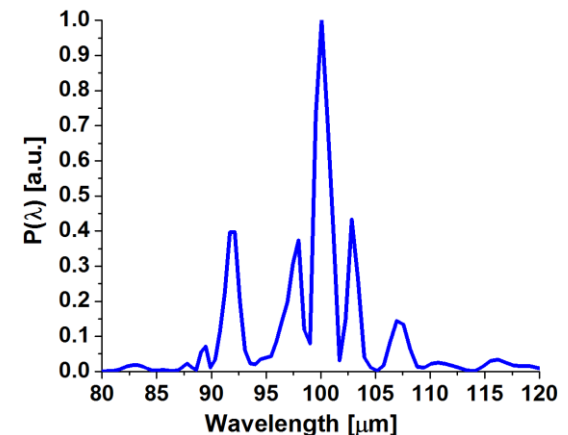
Temporal profile of radiation pulse at the saturation



Energy in the radiation pulse as a function of Undulator length



Spectral profile of radiation pulse at the saturation



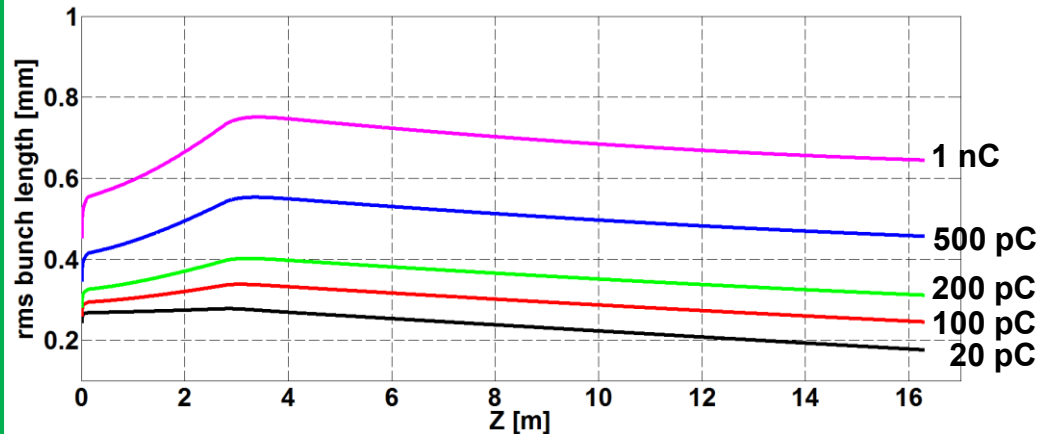
- ▶ Simulation Tool: ASTRA code
- ▶ The bunch compressed by velocity bunching in the booster.
- ▶ Minimum $\langle P_z \rangle$ is limited to ~ 15 MeV/c to prevent too big emission angle ($\theta \propto 1/\gamma$)

Input Parameters for ASTRA

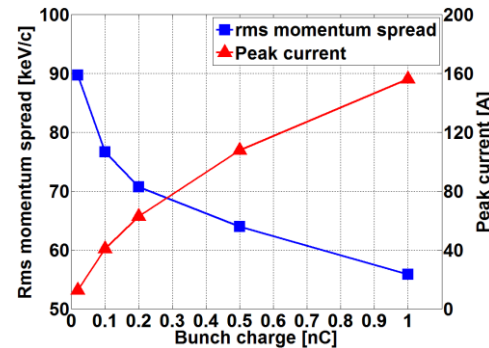
Laser pulse shape	Gaussian
Laser temporal time	2.43 ps (FWHM)
Rms laser spot size	1 mm
Bunch charge	20 pC to 1 nC
Z_{start} to Z_{end}	0 (cathode) to 16.30 m
Gun peak field	60 MV/m
Booster peak field	18 MV/m
Gun phase*	0°
Booster phase*	-60°

*with respect to maximum momentum gain phase

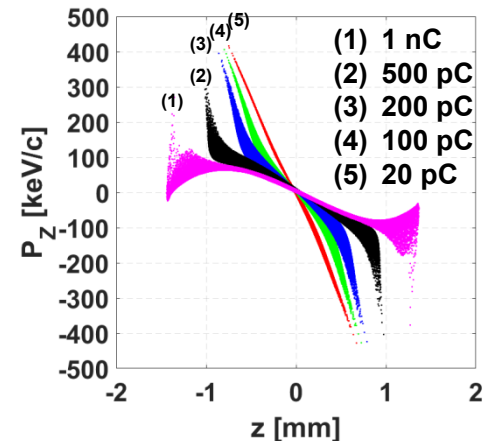
Evolutions of simulated rms bunch length



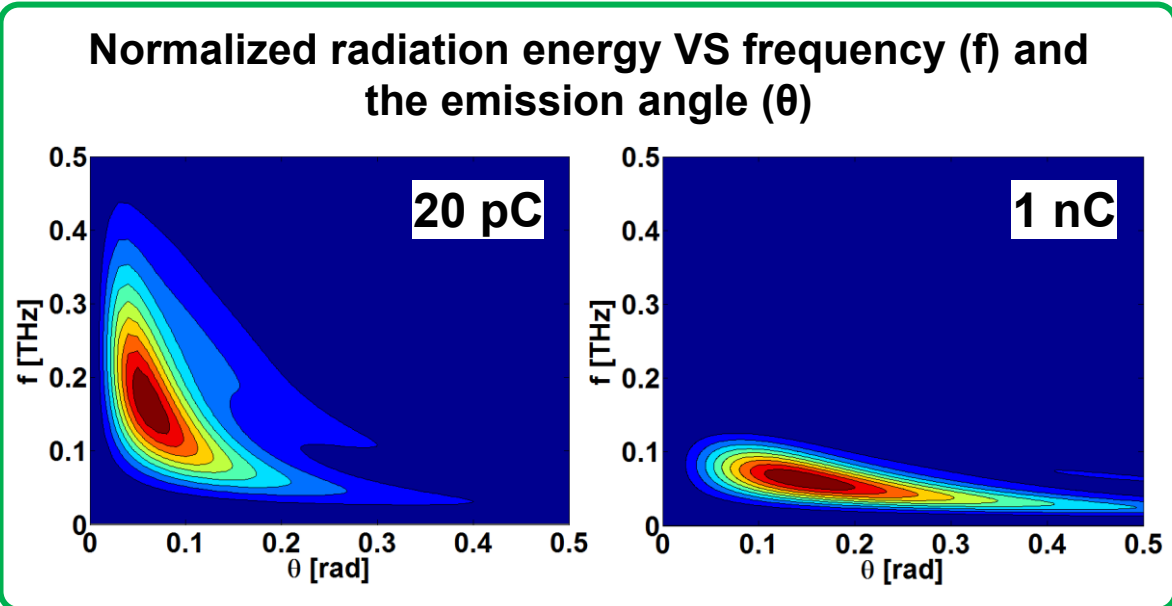
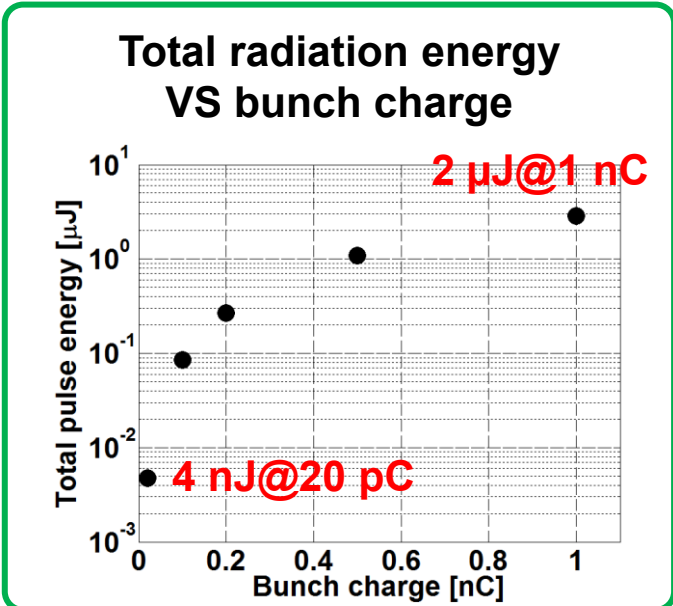
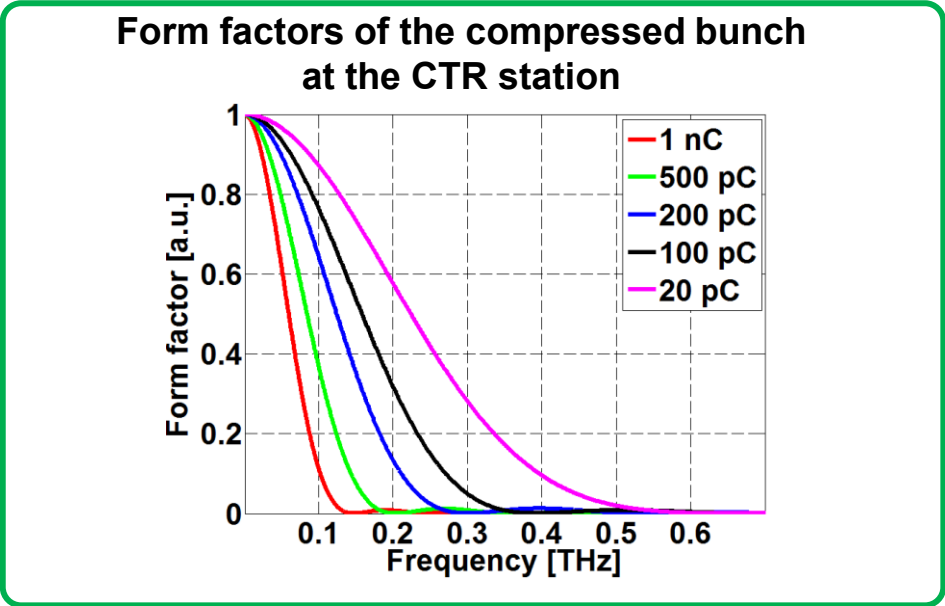
Rms momentum spread and peak current VS bunch charges at the CTR station



Long. phase spaces at the CTR station



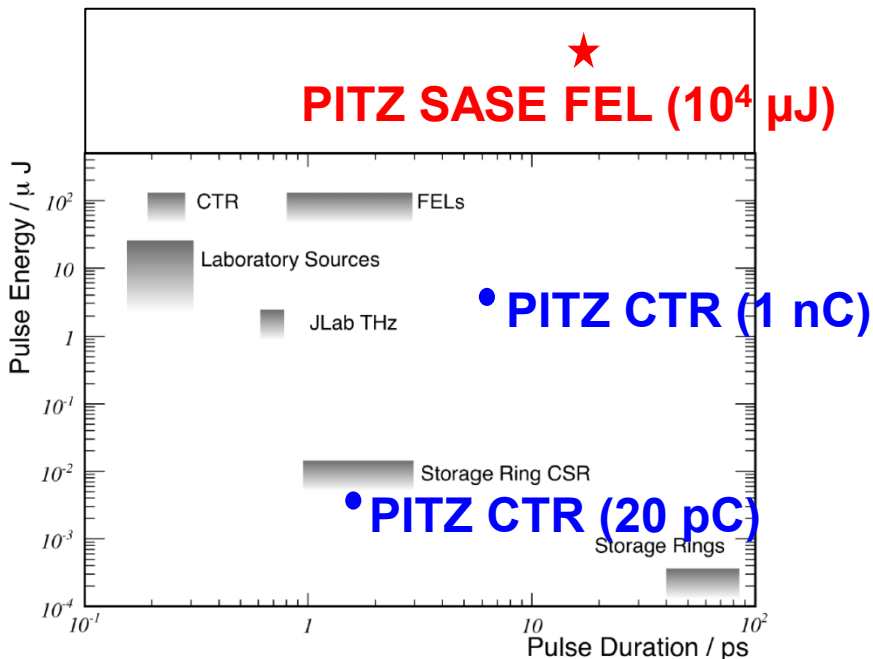
- ▶ CTR calculations were performed by using **Generalized Ginzburg-Frank Formula** [Casalbuoni et al., TESLA 2005-15].
- ▶ **Assumptions and input:**
 - Perfect conductor and **circular screen with radius of 15 mm.**
 - Backward radiation, far-field regime calculation
 - **E-beam with radius of 0.5 mm** is normal incident to the screen.



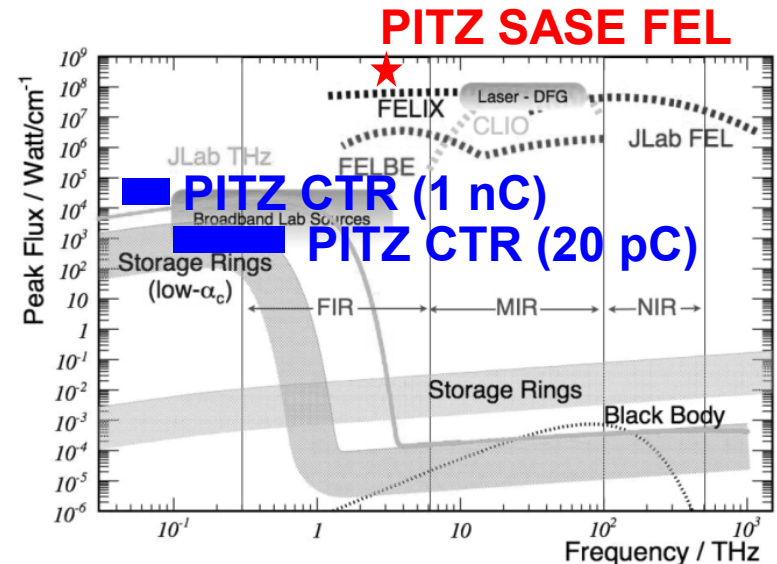
- ▶ Preliminary S2E simulations for the SASE FEL and the CTR using the PITZ accelerator were studied.

Comparison to the other IR/THz sources (the radiation from the PITZ sources are just estimation)

Pulse energy VS FWHM of the generating bunch for the various sources



Spectral peak power density VS frequency



Reference: Anke-Susanne Müller, Rev. Accl. Sci. Tech., 03, 165 (2010)

- ▶ **Plan to be implemented in the simulations studies:**
 - **SASE FEL:** Planar undulator
 - **CTR:** an oblique screen, near-field regime
 - Bunch compression using the HEDA2 section
 - Radiation transport
- ▶ **The CTR experiment is foreseen to take place in 2016**
- ▶ **We are seeking for:**
 - Planar/helical undulator with period length of **~40 mm** and **K ~ 1-2**
 - Bunch compressor

PITZ Team



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Thank you for your attentions!