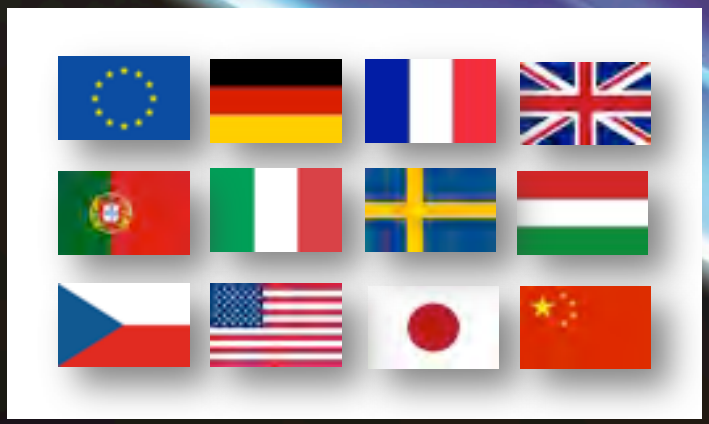
EUROPEAN PLASMA RESEARCH ACCELERATOR WITH EXCELLENCE IN APPLICATIONS

WP6 : FEL Pilot Application

M. E. Couprie



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Tasks, Milestones, Deliverables

Horizon 2020

Tasks

WP6.1 : Coordination and Communication (SOLEIL, ENEA)
WP6.2 : FEL baseline cases (SOLEIL, ENEA, CNRS-LOA, UHH, Lille Univ.)
WP6.3 : Undulator and technological development of equipments (SOLEIL, UHH, INFN, DESY, STFC)
WP6.4 : Towards scientific applications (SOLEIL, ENEA, STFC, DESY)
WP6.5 : Operational model (SOLEIL, DESY, INFN)

Milestones

MS4 : Electron beam baseline parameter for FEL application (SOLEIL) M6, published on intranet, DONE
MS5 : State-of-the-art of short period undulator (SOLEIL) M7, Activity report, DONE
MS17 : Models and scaling laws for plasma FEL dynamics (SOLEIL) M 20, Activity report

Deliverables

D6.1 : Report on state-of-the-art of short period undulators, Report, Public, M12-DONE
D6.2 : Models, scaling laws plasma FEL dynamics, Report, Public, M24
D6.3 : Diagnostic requirements and technical approaches, Report, Public, M24
D6.4 : Specific magnetic elements, Report, Public, M32
D6.5 : FEL Scientific user workshop, Report, Public, M48

WP6 - Hiring and personnel

WP6 effort

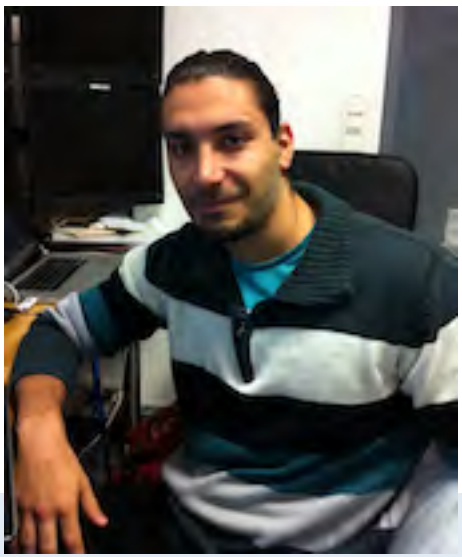
CNRS-LOA (4) : 24 months : Francesco Massimo started the 4/1/16, LPA CALDER -PIC simulations (1 GeV case) so far (shock injection), joint calculation time request to GENCI, and FEL calculations

SOLEIL (8) : 24 months (not 30) :

- part time Igor Andriyash (starting June 2016) : development of the CHIMERA code, FEL simulations
- part time Amin Ghaith (starting Oct. 2016) : undulator calculation
- part time Eléonore Roussel (starting April 2017)

ENEA (11) : 36 months : FEL simulations

UHH (14) : 24 months : starting Jan. 2017, (FEL simulations, cryo undulator) for 2 years



MS4 : Electron beam baseline parameter for FEL application

MS4 (8 p) : Prospective cases

- 1-1.5 GeV case, starting with one stage, 0.1 % energy spread, 1 mm.mrad emittance. Advanced beam manipulation to prepare the electron beam for the undulator section is advised. This can relax the requirements on the plasma acceleration stage.

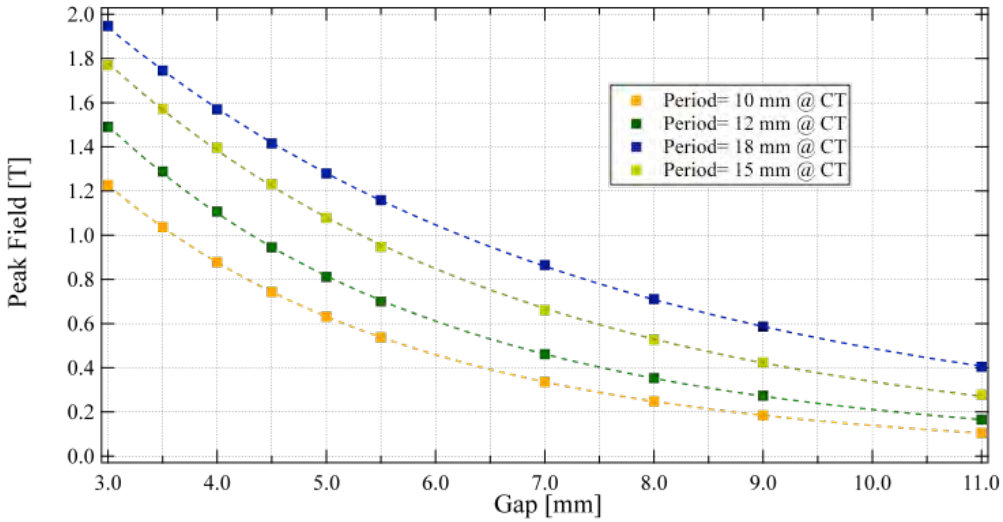
- 3 GeV case , 0.1 % energy spread, 1 mm.mrad emittance

- 5 GeV case, 0.1 % energy spread, 1 mm.mrad emittance

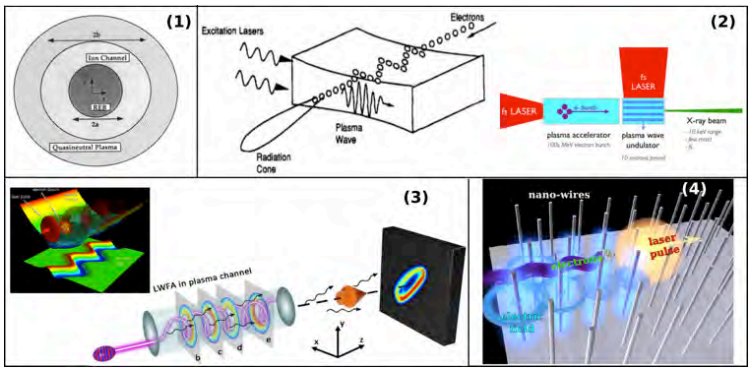
The targeted current value (or charge) has still to be investigated. From these three series of data, one could define reasonable LPA parameter specification for the FEL application, providing the requirements to the other WP.

MS5 / D1 : State-of-the-art of short period undulator (27 p.)

Development and state-of-the-art of cryogenic undulators



Advances on novel undulators (bi-harmonic undulators, sub-mm period undulators, plasma undulators)



Progress on superconducting undulators

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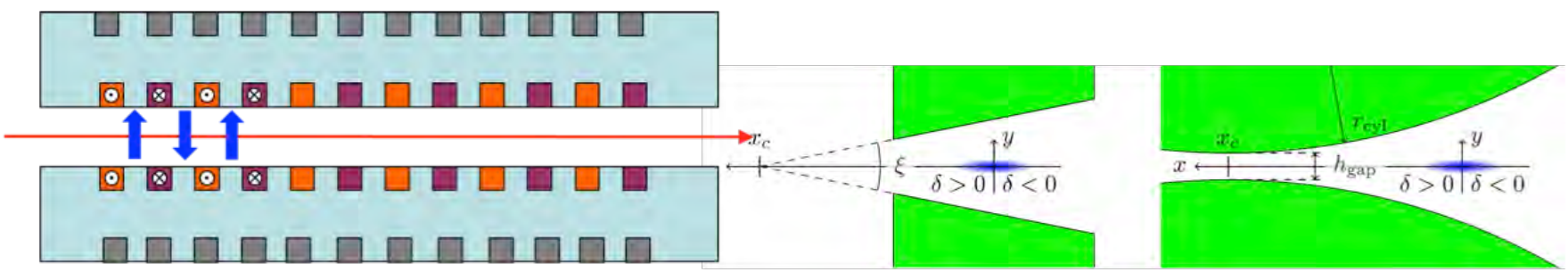
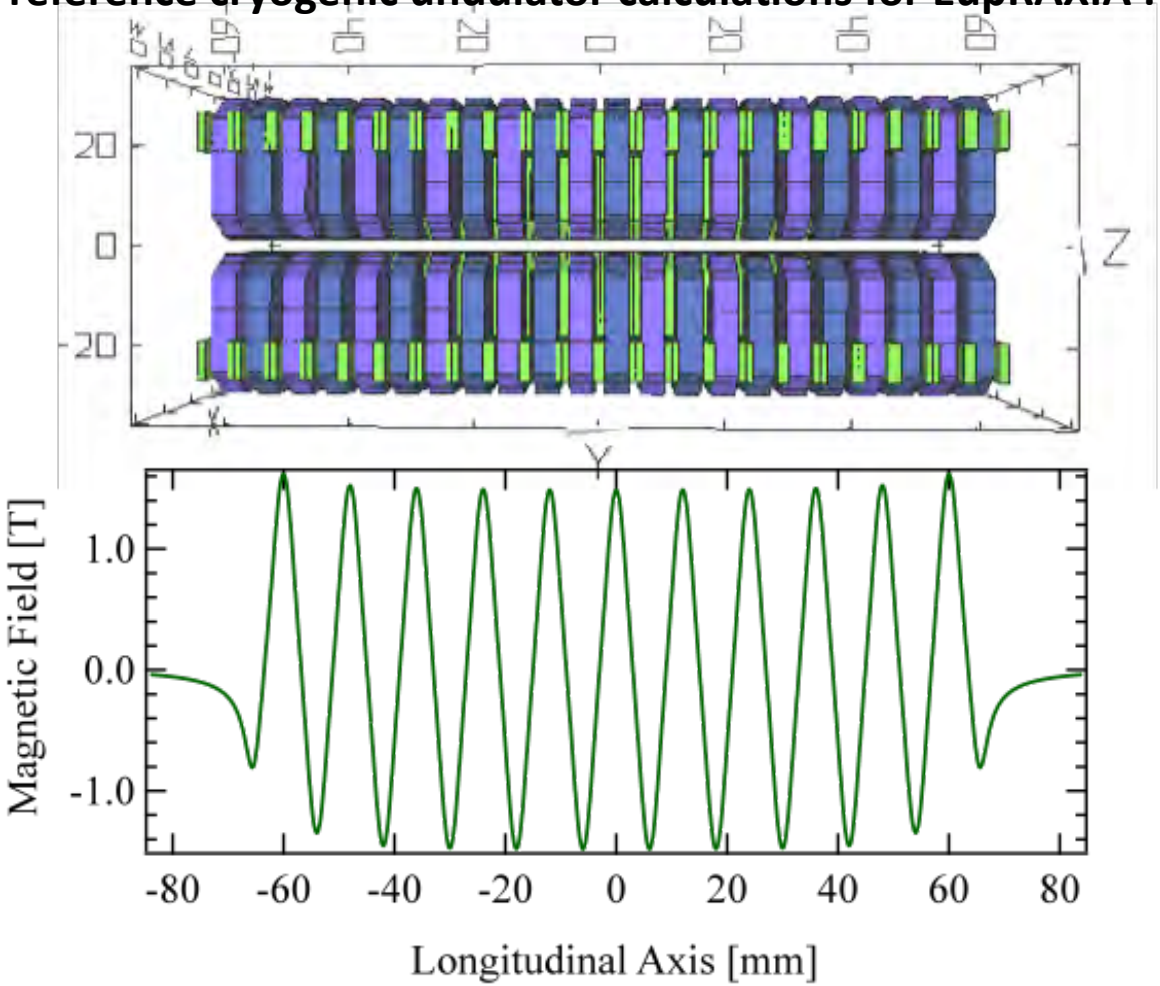


Transverse Gradient Undulators

MS5 / D1 : State-of-the-art of short period undulator

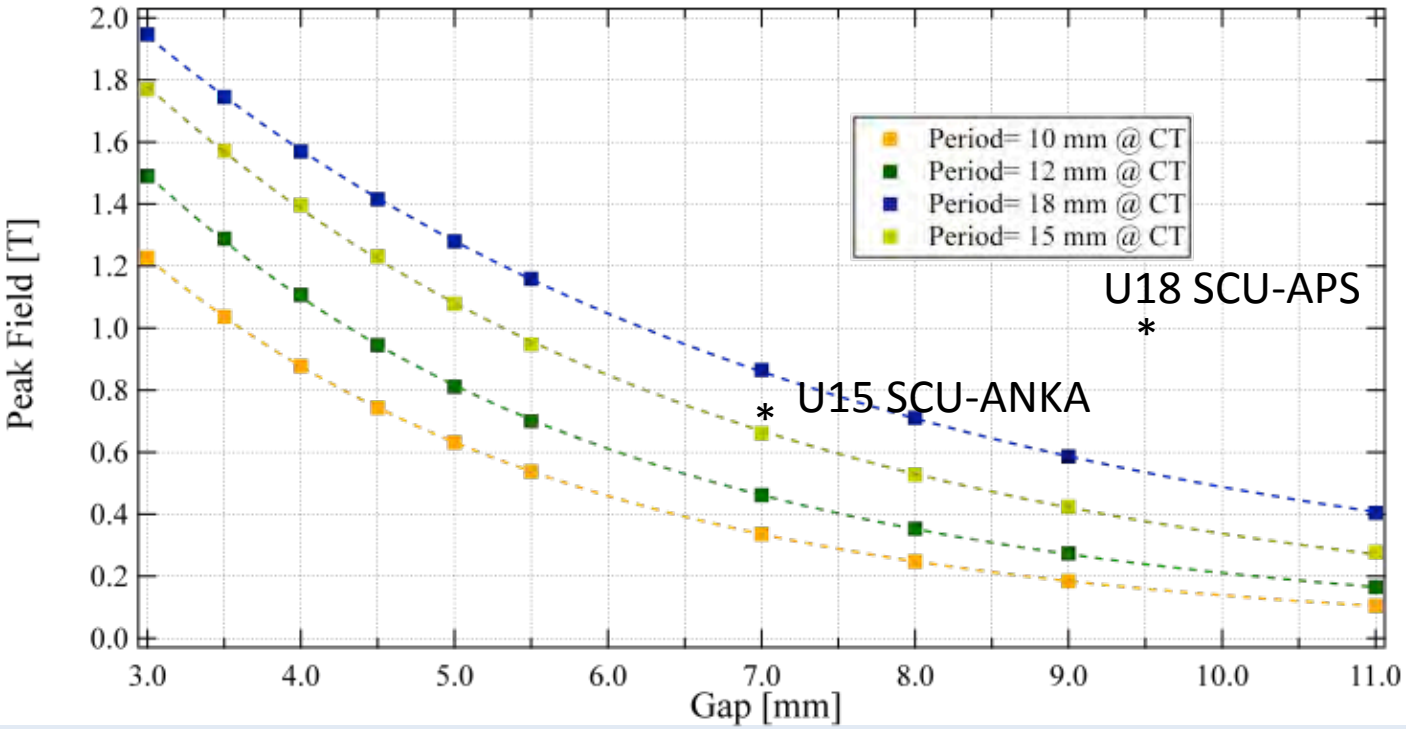
A reference cryogenic undulator calculations for EupRAXIA : U12, K = 1.19



RADIA model of a cryogenic undulator of 12 mm period: remanent field of 1.57 T, dimensions (x, z, s) : half-poles : 56x1x26 mm3 , magnets : 50x4x30 mm3 b) magnetic field for 3 mm gap

MS5 / D1 : State-of-the-art of short period undulator

Comparison with superconducting undulators



Changes in the parameter list

Doc. Identifier:
Del. 1.2 Date: 20. October 2016
FEL and undulator requirements for 1 GeV electron beam

Undulator type	-	in vacuum	T_{room}, cryo, supra cond.	
Radiation wavelength	λ	~ 4 nm	1 nm	10 nm
Brightness	B	tbd	tbd	
Peak brilliance	b	tbd	tbd	
Pulse length (FWHM)	τ_γ	5 fs	35 fs	10 fs
Pierce parameter	ρ	$> \sigma_{E,S}/E$	$> \sigma_E/E$	
Undulator period	λ_u	15 mm	15 mm	25 mm
Undulator parameter (peak)	K	0.872	1	3
Length of undulator section	L_u	1.995 m	2 m	3 m
Number of undulator sections	N_u	10	5	20
Undulator gap	g	2 - 5 mm, variable	2 -5 mm, variable	

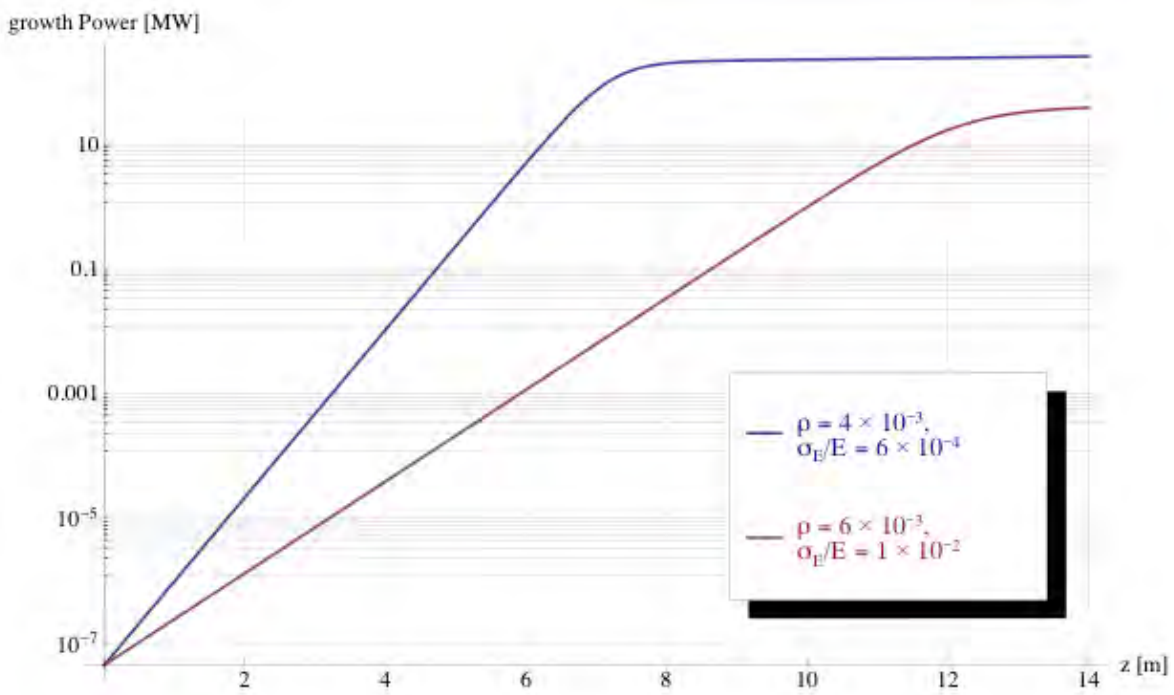
12 mm, cryo, K = 1.19, segments by 3 m

! Undulator length limited by slippage !!!

M17-D6.2 :FEL modelling

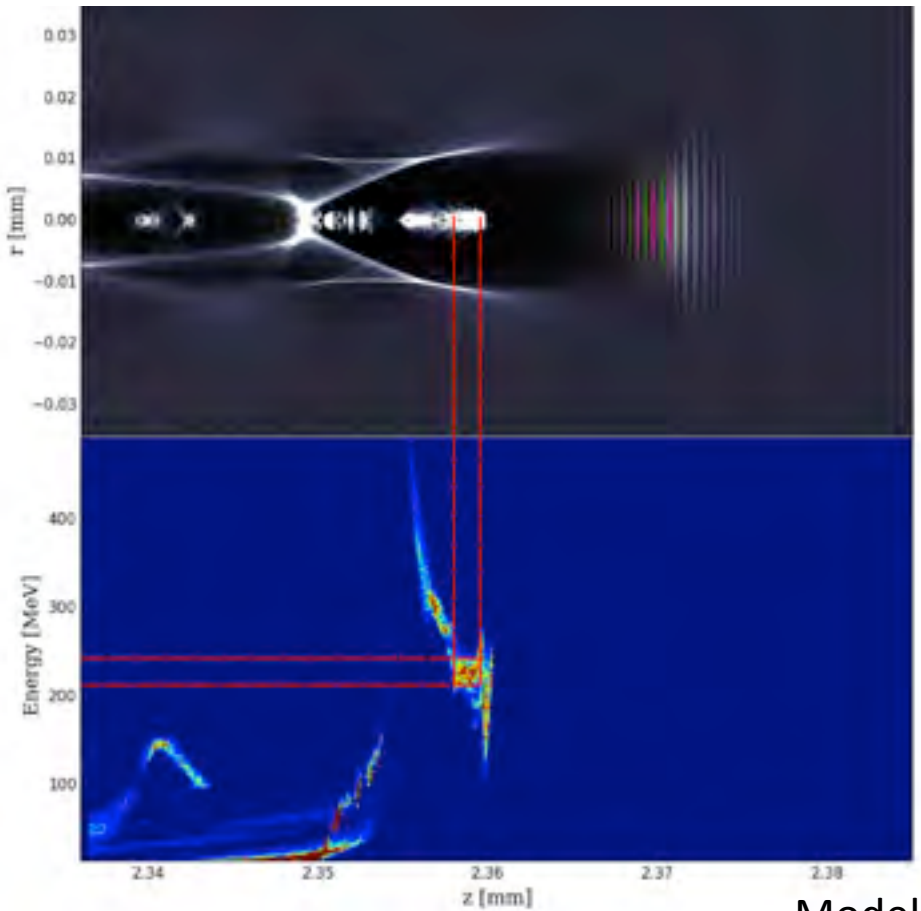
FEL modeling tools available (as presented in Pisa meeting) :

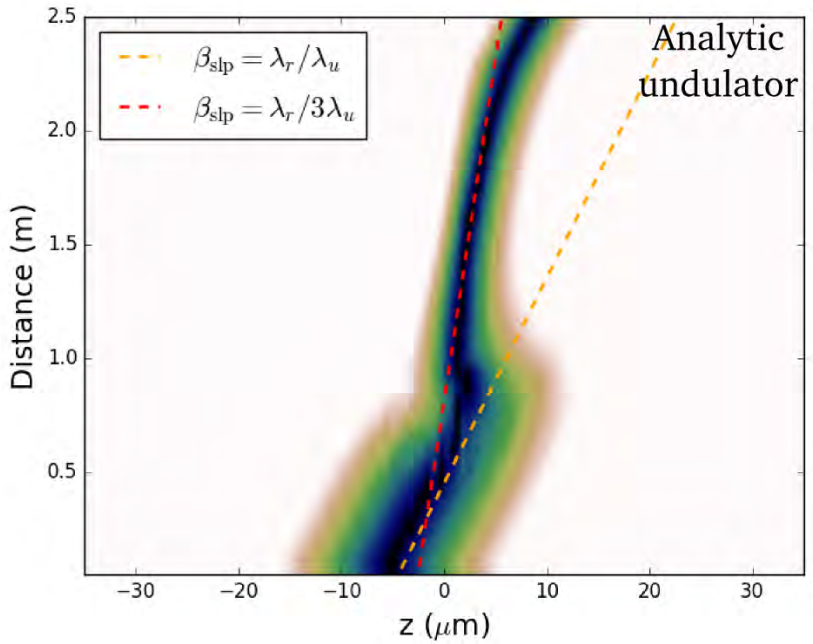
- Virtual Laboratory and Computor Aided Design for Free Electron Lasers outline and simulations (G. Dattoli, F. Nguyen et al.), Then, simulations in different cases : PROMETEO, GENESIS, CHIMERA (I. Andriyash), PUFFIN ...



M17-D6.2 :FEL modelling

FEL modeling tools under development (I. Andriyash, SOLEIL) : CHIMERA code including LPA and FEL





Modelling : I. Andriyash

M17-D6.2 :FEL modelling

How to do it? how it affects the other e. beam parameters?

Total energy spread (RMS)	σ_E/E	1%	1%	
Slice energy spread (RMS)	$\sigma_{E,S}/E$	0.1 %	0.1 %	
Transverse normalized emittance	$\varepsilon_{N,x}$, $\varepsilon_{N,y}$	1 mm mrad	1 mm mrad	
Transverse norm. slice emittance	$\varepsilon_{N,x,S}$, $\varepsilon_{N,y,S}$	tbd	tbd	
Slice length	z_s	tbd	tbd	
Alpha function	α_x, α_y	0	0	
Beta function	β_x, β_y	5 m	5 m	
Transverse beam size (RMS)	σ_x , σ_y	50 µm	50 µm	
Transverse divergence (RMS)	$\sigma_{x'}$, $\sigma_{y'}$	10 µrad	10 µrad	
Pointing stability (RMS)	$\sigma_{<x'>}$, $\sigma_{<y'>}$	100 µrad	100 µrad	
Energy stability (RMS)	δ_E/E	5%	1%	10%
Charge stability (RMS)	δ_Q/Q	5%	1%	10%
Bunch length stability (RMS)	δ_τ/τ	5%	1%	10%
Emittance stability (RMS)	$\delta_{\varepsilon N}/\varepsilon_N$	5%	1%	10%

For reference : 2.10^{-4} in FERMI in energy stability, <% on the charge ...

5% should be reduced to 1 % at least !!!!!

Outlook & AOB

Next to be done : FEL calculations

- Direct FEL configuration : need of better electron beam parameters => WP2, WP3 request

- 1 GeV case
extrapolation of the test experiment configurations (WP11) to 1 GeV (COXINEL ..)
start to end simulation with Francesco's simulation
evaluate the differences between a parameter set and a distribution
reference parameters of EuPRAXIA at 1 GeV : electron beam manipulation required (WP5)

- Relaible scaling LPA parameters for FEL optimisation (Analytical approach) : REQUEST TO WP2-3 : => guide for parameter range before systematic measurement

- REQUEST TO WP2-3 :set of 6D-distribution for our baseline cases (even if deviations, at least in Energy) : : started for the moment with one calculation by F. Massimo (WP6)

- REQUEST TO WP2-3 : systematic electron simulated / experimental data comparison, (especially simulatenous existing measured data in one single experiment) : what can we reach now for an FEL on paper ? what can e expect in the future?