EUROPEAN PLASMA RESEARCH ACCELERATOR WITH EXCELLENCE IN APPLICATIONS

WP6 : FEL Pilot Application

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 653782.

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

MS4 (8 p) : Electron beam baseline parameter for FEL application , 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

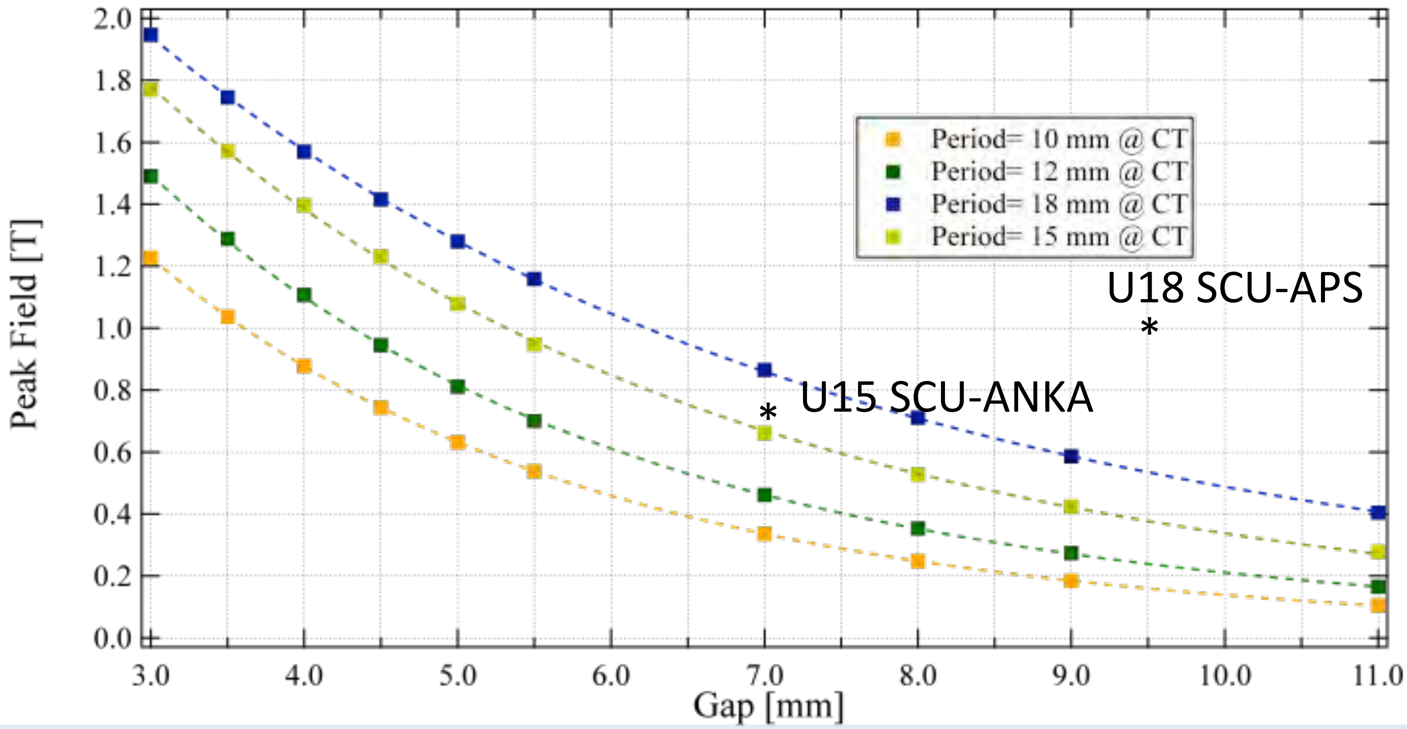
Targeted current value (or charge) still to be investigated.

MS17 : Models and scaling laws for plasma FEL dynamics
FEL modeling tools available :
- 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 ...

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

- Development and state-of-the-art of cryogenic undulators
- Progress on superconducting undulators
- Advances on novel undulators (bi-harmonic undulators, sub-mm period undulators, plasma undulators)
- Transverse Gradient Undulators

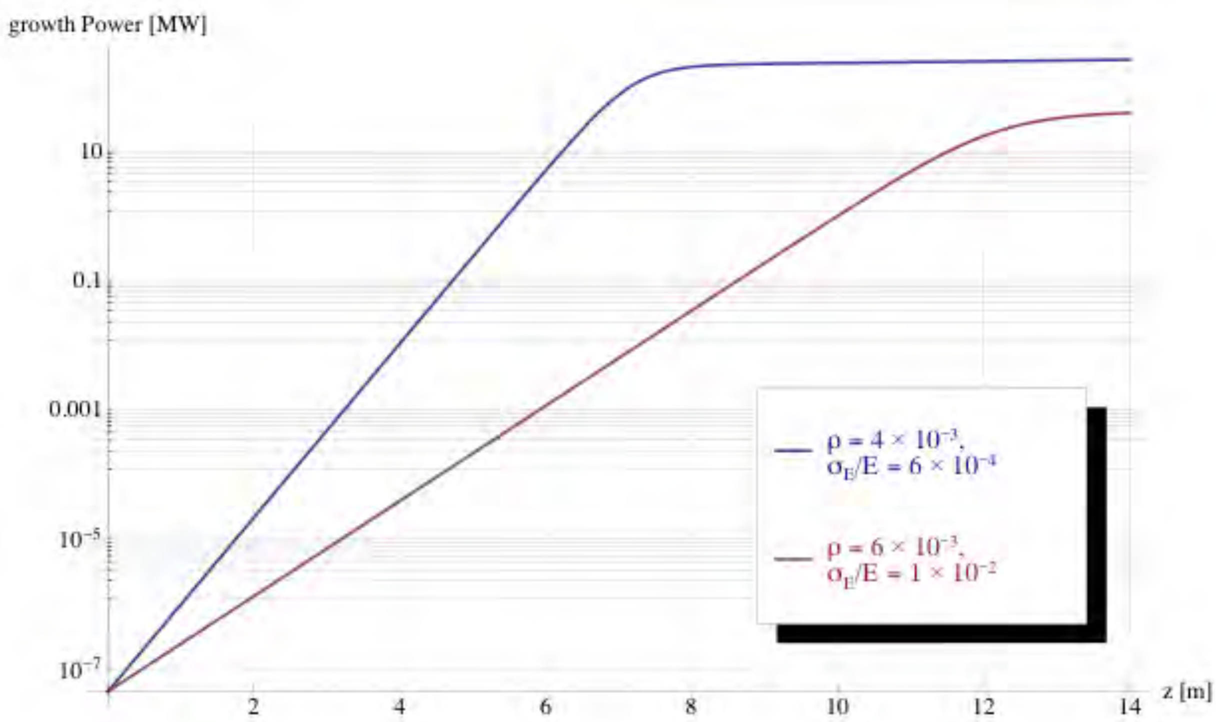
Since then, improvements of the magnet grades factor 1.7 / 1.57



A reference cryogenic undulator calculations for EupRAXIA : U12, K = 1.19@3 mm gap

MS5 / D2 : FEL scaling laws

- Report under progress (ENEA main contribution)



Horizon 2020

Discussion SOLEIL / ENEA (January)

- direct injection of the beam into undulator, beam manupulations (demixing chicane, TGU)
- principal challenges of TGU schemes: account for the higher terms in the transverse field dependence indicates significant beam degradation.
- Modeling of TGU undulator and implementations considered on SOLEIL
- Discussion of LPA scaling laws
- Discussion of undulator review

Discussion : WP6 : M. E. Couprie, I. Andriyash (SOLEIL) / WP5 : A. Chancé (CEA) (March)

Discussion on the focusing optics and demixing chicane design, the undulator choice etc....

REQUEST TO WP2-3 : LPA scaling laws

=> Analytical approach : Relaible scaling LPA parameters for FEL optimisation :

=> guide for parameter range before systematic measurement

- 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 one expect in the future?

first 1 GeV case to be sent

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 !!!

Changes in the parameter list

To be modified, see WP5

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 and request to other WP

Step 1 : Analysis of LPA based FEL scaling laws

- study the gereralised scaling laws : guide for optimization, need of LPA scaling laws
- apply to examples of exitanting data (measured/ simulated)
- extropolate parameter sets of existing LPA based FEL test experiments (cf WP11)

• Parametric FEL modeling for straightforward use of LPA 1GeV beam: optimal beta function of the beam, and amplification suppression with energy spread...
• Comparison with analytical framework
• Discuss with WP5 the focusing optics and demixing chicane design.

Step 2 : FEL calculation based with set of beam parameter @ 1 GeV

- Direct FEL configuration : calculated electron beam parameters => to be sent (WP5, A. Chancé)

Step 3 : S2E FEL calculation @1 GeV

- REQUEST TO WP2-3 :set of 6D-distribution for our baseline cases + to WP5 for transport and beam manpulation: start first with one simulation by F. Massimo (WP6)

Step 4 : Look at the design of the particular equipment required for the transport line for the S2E FEL calculation @1 GeV cases

publications, proceedings and conference

On EuPRAXIA fees, or with acknwoledgments to EuPRAXIA

Publications

- F. Massimo, S. Atzeni, A. Marocchino, Comparisons of time explicit hybrid kinetic-fluid code Architect for Plasma Wakefield Acceleration with a full PIC code, J. Comput. Phys. 327 (2016) 841
- F. Massimo, A. F. Lifschitz, C. Thaury and V. Malka, Numerical studies of density transition injection in laser wakefield acceleration, Plasma Phys. Control. Fusion 59 (2017) 085004

Conference participation

- F. Massimo, Forum ILP (Aussois, France, 12-17 March 2017), poster: Numerical Studies of Density Transition Injection in Laser Wakefield Acceleration
- F. Massimo, Erice School-Workshop "Trends in Free Electron Laser Physics" (Erice, Italy, 17-23 May 2016), oral: Numerical methods for FEL-oriented plasma accelerators