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Grant Agr. 777431

WP5 – Overview Report

Federico Nguyen – ENEA
On behalf of the WP5 Study Group

1st XLS-CompactLight Annual Meeting – Barcelona, December 11th 2018

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WP5 – Organization and items

Particip.	P. M. Undulators	S.C. Undulators	Beam Dynamics (Opt. & Match.)	Exotic Undulators (RF, Laser, Plasma)	Magn. Measurem. & Cost+Risk	Advanced FEL schemes (Multicolour, Polar.)
ENEA						
KYMA	R. Geometrante					
CERN						
USTR						
STFC						H.M.C. Cortes
KIT		A. Bernhard				
PSI					T. Schmidt	
ANSTO				D. Zhu		
Au-IAT			Z. Nergiz			
ALBA						

- Structure designed to have the available expertise covering the requested tasks: undulator technologies, beam interacting within the undulator sections, FEL properties and more advanced schemes
- Since last June in Trieste, two major efforts requested to our WP5:
  1. Provide parameter tables matching the proposed XLS FEL features – WP2
  2. Provide order of magnitude costs of the undulator system – WP7

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Focus on the hard X-ray case: our choice

Undulator parameters	
undulator period	1.3 cm
undulator gap	3 mm
deflection parameter (RMS)	1.17
Bunch parameters	
beam energy	9 GeV
pulse duration (FWHM)	7.5 fs
bunch charge	75 pC
peak current	9 kA
norm. emittance	0.12 mm×mrad
energy spread	0.01 %
Potential reach	
FEL wavelength ($\hbar\omega$)	0.05 nm (25 keV)
N_γ/pulse	2.5×10^{11}
E_{FEL}/pulse	1 mJ
saturation length	25 m

$$\epsilon[mm \times mrad] < \frac{\gamma\lambda_r}{4\pi}$$

$$\varepsilon[mm \times mrad] \approx \frac{2}{3}\sqrt{Q[nC]}$$

Hard to reach for 1 mJ energy/ pulse with much lower charge or much higher emittance

Hard to achieve much lower emittance with such a charge

Bottom line: this is our choice, but feel free to use other values at your convenience and risk!

Focus on the soft X-ray case: not frozen at all

Undulator parameters	
undulator period	~~1.7 cm~~
undulator gap	~~3 mm~~
deflection parameter (RMS)	1.9
Bunch parameters	
beam energy	4 GeV
pulse duration (FWHM)	10 fs
bunch charge	20 pC
peak current	1.9 kA
norm. emittance	0.12 mm×mrad
energy spread	0.01 %
Potential reach	
FEL wavelength ($\hbar\omega$)	0.66 nm (1.9 keV)
N_γ/pulse	5.6×10^{11}
E_{FEL}/pulse	0.2 mJ
saturation length	21 m

Please, do not stick with these undulator small values: proper multicolour operations yet to prove!

Variable polarisation & Two Colours operations strongly challenge these parameters:

a dedicated WP5 effort run by H. M. Castaneda Cortes (see his talk), D. Dunning, is meant to study the feasibility of these operations in terms of both undulator configurations and beam lines

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Comprehensive undulator cost analysis

Compact

planar: hard x-ray

		out of vac	in-vac	CPMU
Performance: K (λ/gap)	15 / 4 mm			
	10 / 3 mm			
Design				
Fabrication by Lab				
Magnetarray				
Support				
Drive System / Controls				
Vacuum System				
Optimization				
Fabrication by Company				
Installation / Infrastructure				
Commisssioning				
Operation / Maintenance	10 years			
price / m [€]				
total price [€] / saturation length [m]				

See T. Schmidt's talk for the version with filled entries plus considerations

EPU: soft x-ray

		APPLE II	DELTA	APPLE III	in vac
Performance: K (λ/gap)	40 / 7 mm				
	20 / 5 mm				
Design					
Fabrication by Lab					
Magnetarray					
Support					
Drive System / Controls					
Vacuum System					
Optimization					
Fabrication by Company					
Installation / Infrastructure					
Commisssioning					
Operation / Maintenance	10 years				
price / m [€]					
total price [€]/ saturation length [m]					

Bottom line: cost indications are given. Downselection of technologies based on cost is beyond the WP5 mandate: focus on physics solutions!

The compactness challenge

- A specific task for "exotic" novel concept undulators, eventually promising small size insertion devices, even if with low TRL (see talk from G. Dattoli)
- Big effort from A. Cross, L. Zhang (Strathclyde) & D. Zhu (ANSTO), see their contribution in Agenda
- The bunch features are demanding in terms of bunch current density and emittance, but definitely rewarding!

Undulator parameters	
undulator period	0.44 cm
deflection parameter (RMS)	0.36
Bunch parameters	
beam energy	6 GeV
peak current	5 kA
norm. emittance	0.08 mm×mrad
energy spread	0.01 %
Potential reach	
FEL wavelength ($\hbar\omega$)	0.018 nm (69 keV)
N_γ/pulse	1.3×10^{10}
E_{FEL}/pulse	5 mJ
saturation length	28 m

Preliminary

WP5 at this meeting

WP5 Activity Report and Discussion				
10:15	10:55	10'	Overview of WP5	Federico Nguyen (ENEA)
		10'	Undulators Cost Matrix	Thomas Schmidt (PSI)
		10'	PM Undulators	Jordi Marcos (ALBA-CELLS)
		10'	SC Undulators	Julian Gethmann (KIT)
Coffee Break & Meeting Photo				
11:25	12:00	10'	Microwave Undulators	Liang Zhangh (USTR)
		10'	Undulators for soft X-rays schemes	Hector M. C. Cortes (STFC)
		10'	Study of wakefields in undulators	Avni Aksoy (UA-IAT)
		5'	Discussion	All

And then starting 2019 with a rush towards the Undulator Technology Survey deliverable document

WP5 deliverables roadmap

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D5.1	Technologies for the CompactLight undulator	16 - ENEA	Report	Public	18
D5.2	Conceptual Design Report of the undulator	16 - ENEA	Report	Public	36

Description of deliverables

D5.1: A report comparing the different technologies for the undulator, as an input for WP2, (R, PU, M18).
D5.2: Design Report of the undulator to be included in the main deliverable of CompactLight, (R, PU, M36).

D5.1 : Technologies for the CompactLight undulator [18]

Review report comparing the different technologies for the CompactLight undulator.

D5.2 : Conceptual Design Report of the undulator [36]

Design Report of the undulator to be included in the main deliverable of CompactLight

Please, stay FEL-tuned

WP4	D4.2	D15	RF power unit	Design report	CERN	Report	Public	31 Dec 2020	Pending	
WP4	D4.3	D16	RF unit design and fabrication procedure	Report on RF	CERN	Report	Public	31 Dec 2020	Pending	
WP5	D5.1	D7	Technologies for the CompactLight undulator	Review report	ENEA	Report	Public	30 Jun 2019	Pending	
WP5	D5.2	D17	Conceptual Design Report of the undulator	Design Report	ENEA	Report	Public	31 Dec 2020	Pending	
WP6	D6.1	D8	Computer codes for the facility design	Review report	UA-IAT	Report	Public	30 Jun 2019	Pending	
WP6	D6.2	D18	Start to end facility simulations	Final report o	UA-IAT	Report	Public	31 Dec 2020	Pending	

WP5 – Indico page & contacts

XLS - WP5 - Undulators and light production

December 2018

- 05 Dec 8th WP5 Meeting NEW

November 2018

- 08 Nov 7th WP5 Meeting

September 2018

- 26 Sep 6th WP5 Meeting

May 2018

- 30 May 5th WP5 Meeting

April 2018

- 18 Apr 4th WP5 Meeting

March 2018

- 14 Mar 3rd WP5 Meeting

If you are interested or wish to contribute, please join!

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https://indico.cern.ch/category/9782/

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Compact

Thank you!

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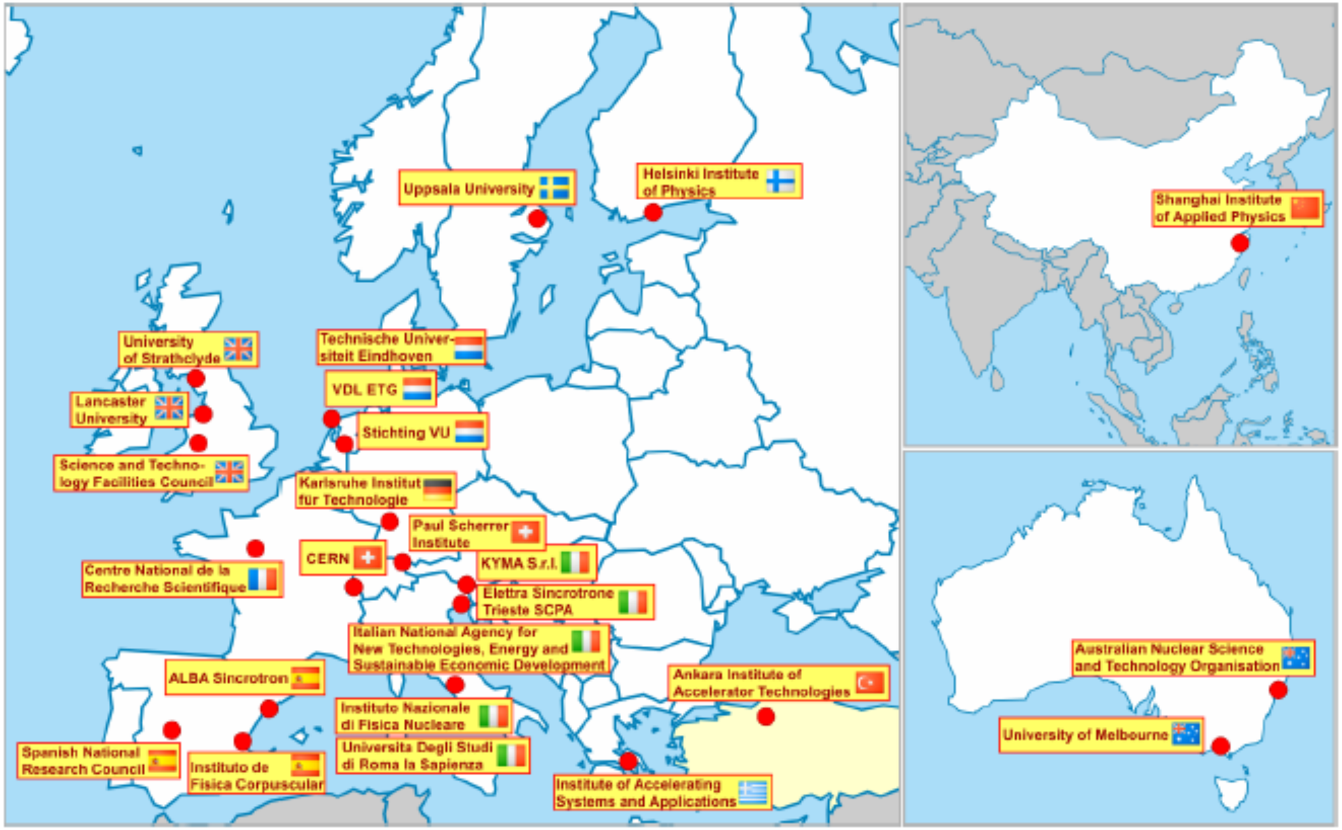

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Focus on the Hard X-rays: the Kim-Pellegrini limit

Undulator parameters	
undulator period	1.3 cm
undulator gap	3 mm
deflection parameter (RMS)	1.17
Bunch parameters	
beam energy	9 GeV
pulse duration (FWHM)	10 fs
bunch charge	75 pC
peak current	7 kA
norm. emittance	0.07 mm×mrad
energy spread	0.01 %
Potential reach	
FEL wavelength ($\hbar\omega$)	0.05 nm (25 keV)
N_γ/pulse	2.7×10^{11}
E_{FEL}/pulse	1.06 mJ
saturation length	23 m

So far, so good… but while the ε_n fulfills Kim-Pellegrini limit,

It is not consistent with the ε_n scaling as a function of the bunch charge

$$\varepsilon[mm \times mrad] \approx \frac{2}{3}\sqrt{Q[nC]}$$

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Focus on the Hard X-rays: emittance vs. charge

Compact

Undulator parameters	
undulator period	1.3 cm
undulator gap	3 mm
deflection parameter (RMS)	1.17
Bunch parameters	
beam energy	9 GeV
pulse duration (FWHM)	5 fs
bunch charge	75 pC
peak current	14 kA
norm. emittance	0.18 mm×mrad
energy spread	0.01 %
Potential reach	
FEL wavelength ($\hbar\omega$)	0.05 nm (25 keV)
N_γ/pulse	2.5×10^{11}
E_{FEL}/pulse	1 mJ
saturation length	25 m

Now, the emittance scaling growth with charge is fulfilled, but much larger than the Kim-Pellegrini limit

I_{peak} (peak power) is really huge a value