WP2 Introduction

11th December 2018, ALBA, Barcelona

Jim Clarke, STFC Daresbury Laboratory

WP2 FEL Science Requirements and Facility Design

- **Task 2.1 -** FEL user scientists and potential users will provide specification for the Hard X-ray FEL output parameters (in terms of wavelength range, pulse energy, polarisation, beam structure, pulse duration, synchronisation to external laser, etc.).

- **Deliverable 2.1** - A report summarising the requests from the users and defining the performance specifications for the FEL, **(31/12/18).**

- **Task Leader – Vitaliy Goryashko, Uppsala University**
  - **Vitaliy will provide a report from the User Meeting that was held in November**

- **Agreeing the FEL specification this week is a key outcome from this meeting**

WP2 FEL Science Requirements and Facility Design

- **Task 2.2 -** The outcome of the previous task will be used by FEL experts (working closely with WP3, 4, & 5) to define the FEL system, with the accelerator and undulator requirements that are needed to achieve the specification (electron energy, bunch charge, peak current, emittance, energy spread, period, field strength, etc.). Then the task will identify and choose the most appropriate technical solutions considering cost, technical risk and performance. *The other WPs make recommendations for all the technical solutions which are then agreed within this task.*

- **Deliverable 2.2** - A report summarising the FEL design, with the accelerator and undulator requirements to achieve the specification, i.e. electron energy, bunch charge, peak current, emittance, energy spread, undulator parameters, etc., **(31/12/19).**

- **Task Leader – Simone DiMitri, Sincrotrone Trieste**
  - **Simone will talk about the process of selecting the technical solutions in the year ahead**

WP2 FEL Science Requirements and Facility Design

- **Task 2.3 –** Engineers, accelerator physicists, undulator and RF experts will receive machine specification from FEL experts and will then design a user facility capable of achieving these requirements. Regular contact and iterations between the FEL experts, engineers, accelerator and undulator designers will be essential to achieve an optimised design. The Hard X-ray FEL ***conceptual design report*** will also include options for Soft Xray FEL and Compton Source. *WP2 has responsibility to ensure facility design is self consistent.*
- **Deliverable 2.3** - The conceptual design report for a Hard X-ray FEL facility, including cost estimates, with options for Soft X-ray FEL and Compton Source, **(31/12/20).**

- **Task Leader – Neil Thompson, STFC Daresbury Laboratory**
  - **Neil will talk about planning for the CDR**

REMINDER: Compact Light FEL Preliminary Specification

Two informal meetings were held with leading proposers of UK XFEL

- All of them are experienced users of LCLS, and other FEL user facilities, including European XFEL now
- CompactLight proposal stated that “we will develop a hard X-ray FEL design tailored to the UK user specifications”

General comments from UK users

- **If UK XFEL is not world leading then why would anyone want to use it?**
- **We will all just go to the best facility for our research whatever country it is in**
- **We can’t justify funding UK XFEL unless it has unique capabilities, enabling science that is not possible on other FELs**

- A preliminary set of parameters were discussed in Trieste based on this input

REMINDER: CompactLight Preliminary Specification Notes

250 eV – to cover the carbon K edge

25 keV – requested by group studying extreme materials

Pulse duration – 100as isolated pulses have definite science need identified (atomic and molecular physics), *case for shorter pulses than 100as to be determined*

Pulse duration – 50 fs not a definite requirement, *just a typical number*

Pulse energy – 1mJ at 25keV highly desired by extreme materials, *higher welcome* but may not be realistic

Repetition rate – 100Hz at 25keV (high power lasers are combined in experiment and they only have low repetiton rate)

Repetition rate – 1000Hz or greater *highly desirable* for the soft X-ray, 250eV to 2keV

Two colour output is required – see slide

Two pulse output required with time separation of pulses set by the FEL between -20fs and +40fs. Larger time separations will be achieved within the beamline (split and delay)

Polarization – variable, selectable below 2 keV.

Polarization – above 2keV *to be determined.*

We are not expected to cover this photon range with one beamline

There is a natural beamline breakpoint at ~2keV where gratings are replaced by crystals

REMINDER: CompactLight Preliminary Specification

The table below separates the FEL output requirements into the two regimes of operation (soft/hard x-ray) to show which parameters are required in combination.

	Soft x-ray	Hard x-ray
Photon energy [keV] (min-max)	0.25 - 2	2 - 25
Wavelength [nm] (max-min)	5 - 0.6	0.6 - 0.05
Repetition rate [Hz]	1000	100
Maximum pulse energy [mJ]	Not specified	1 (at 25 keV, less at other energies?)
Number of photons	Not specified	2.5 x 10^{11} at 25 keV
Pulse duration [fs]	0.1 – 50	
Polarisation	Variable, selectable	Not specified
Two-colour pulses: time separation [fs]	-20 -> +40	
Two-colour pulses: photon energy variation (max. of E2/E1)	2 (270-530eV), 1.2 for the rest of the range	1.1

REMINDER: CompactLight Preliminary Specification Proposal

	LCLS	SACLA	PSI ARAMIS	LCLS-II HXR	PAL XFEL HXR	EUXFEL HXR	CompactLight
Min Photon Energy (keV)	0.27	5	1.8	1.03	2.06	3.1	0.25
Max Photon Energy (keV)	12.4	15.5	12.4	25	20.6	25	25
Max Pulse Energy (uJ)	6000	250	150				1000
Pulse Duration (fs)	2 - 100	20 - 30	20				0.1 - 50
Pulses/s	120	60	100	120	60	27000	100 to 1000
Beam Energy (GeV)	15	8.5	5.8	15	10	17.5	TBD

IOP Publishing Reports on Progress in Physics
Rep. Prog. Phys. 80 (2017) 115901 (73pp) https://doi.org/10.1088/1361-6633/aa7cca

Review

Short-wavelength free-electron laser sources and science: a review*

E A Seddon[1,2,3], J A Clarke[1,3], D J Dunning[1,3], C Masciovecchio[4], C J Milne[5], F Parmigiani[4,6,7], D Rugg[8], J C H Spence[9], N R Thompson[1,3], K Ueda[10], S M Vinko[11], J S Wark[11] and W Wurth[12]

ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development

Focus on the hard X-ray case: our choice

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)	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

Stay in the middle!

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 round up values at your convenience and risk!

ENEA
Italian National Agency for New Technologies, Energy and Sustainable Economic Development

Focus on the soft X-ray case: our choice

Compact

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

Small increase in E_{beam} allows to reach for 0.6 nm (2 keV) comfortably

Emittance stays well between Pellegrini's and Di Mitri's limits

Variable polarization & Two Colours operations require careful feasibility studies with these undulator parameters, in particular at small period:

H. M. Castaneda Cortes is tackling this issue in WP5 and is greatly acknowledged

Please, stay FEL-tuned

Other Interactions with Users

- Representatives of CompactLight were at Science@FELs Conference in Stockholm and interacted with potential users
- Representatives of CompactLight were at the Attosecond and FEL Science Conference in London and interacted with potential users
- A dedicated CompactLight User Meeting was held at CERN in Nov 2018
- A questionnaire has been developed and sent to ~50 users.

Funded by the
European Union

Compact

Thank you!

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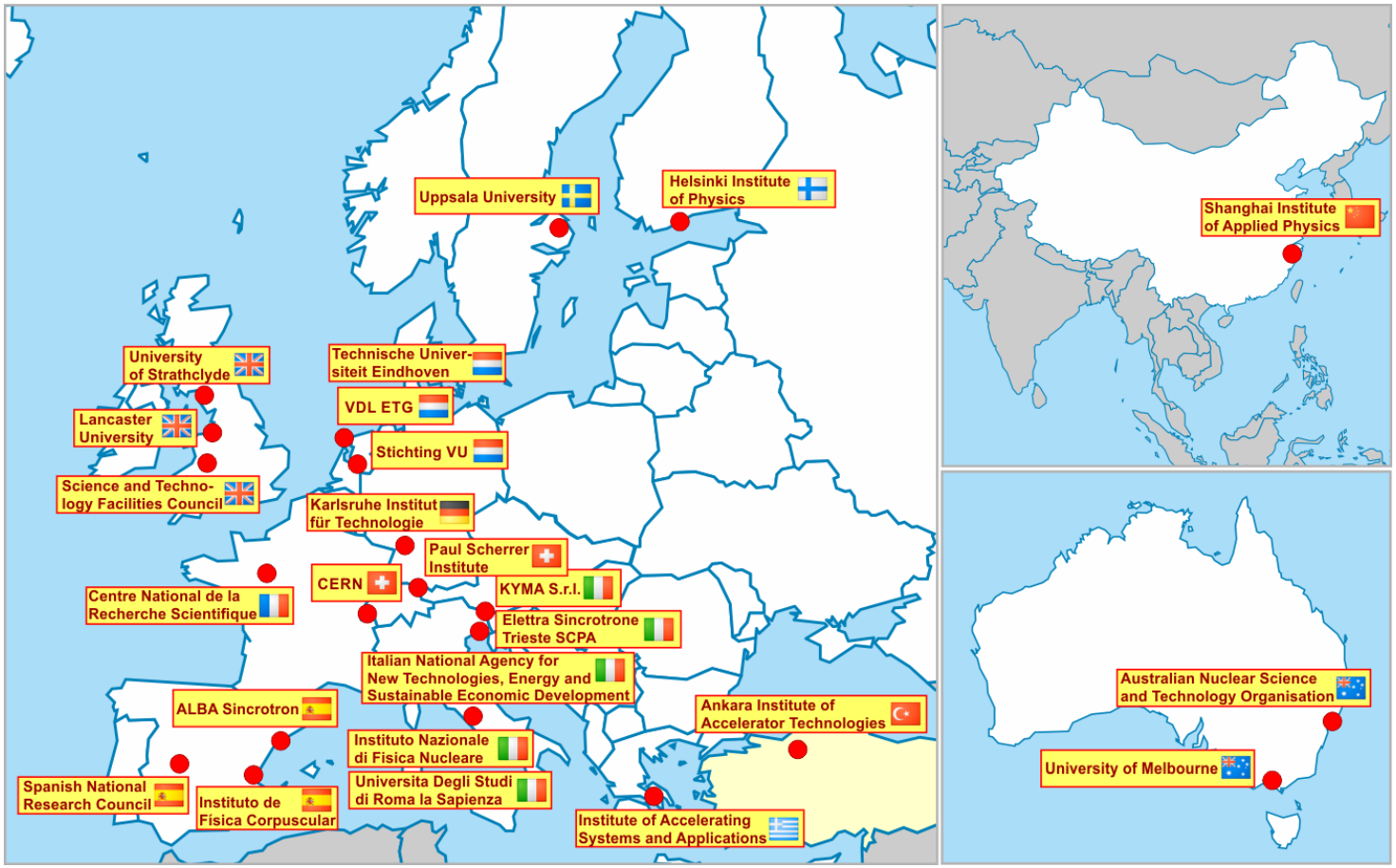

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