Presentation of the Conceptual Design Report for the Soft X-ray Laser@MAX IV (SXL)

SEPTEMBER 28, 2021

Today

- Introduction & Science Case highlights
- The Conceptual Design Report
- Discussion

MAX IV

SUFEL STOCKHOLM-UPPSALA CENTRE FOR FREE ELECTRON LASER RESEARCH

LUND UNIVERSITY

LLC LUND LASER CENTRE

Stockholm University

KTH VETENSKAP OCH KONST

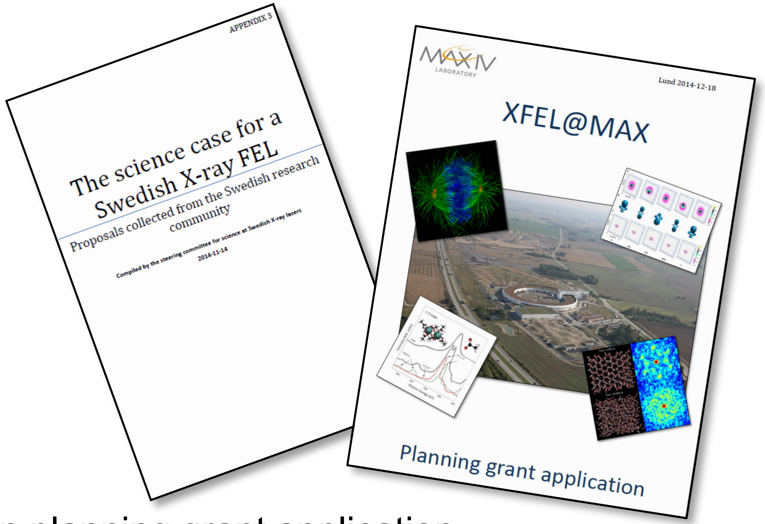
UPPSALA UNIVERSITET

What is SXL ?

- An **initiative** by the user community that requests enhanced capabilities to deliver coherent ultra-short pulses in the soft X-ray range.
- A **Free Electron Laser source** in the soft X-ray (1-5 nm) wavelength range driven by the MAX IV 3 GeV LINAC.
- **SXL Main features** (from CDR):

Electron beam energy	3 GeV
Charge per bunch	10 – 100 pC
Wavelength range	1 – 5 nm
Photon pulse duration (FWHM)	0.8 – 26 fs
Photon energy per pulse	0.015 – 1.5 mJ
Maximum repetition rate	100 Hz
Maximum peak brightness	4×10^{33} photons/s/mm^2/mrad^2/0.1%BW
Full polarization control with Apple-X undulators.	
Extensive range of pump lasers, from IR to XUV.	
Two-pulse/Two-colour, delays from few fs to few tens of ns	
Prepared for future expansions: Echo-Enabled Harmonic Generation, High Brightness SASE, Self-Seeding	

The SXL initiative



- **December 2011:** Agreement to collaborate on a scientific case for a hard X-ray FEL (MAX IV, FEL Centre Stockholm-Uppsala, Lund Laser Centre and Uppsala University)
- **May 2012:** Startup meeting @ VR, steering committee formed
- **2012-2014:** 3 user workshops, discussions, collection of proposals for science case
- **Fall 2014:** 49 proposals collected from the Swedish science community, used as appendix in planning grant application
- **Spring 2015:** KAW offered 50% funding, but required co-funding from founders
- **Summer/fall 2015:** Nobel Symposium on FELs, Soft X-ray initiative presented at MAX IV UM, Working group for SXL formed

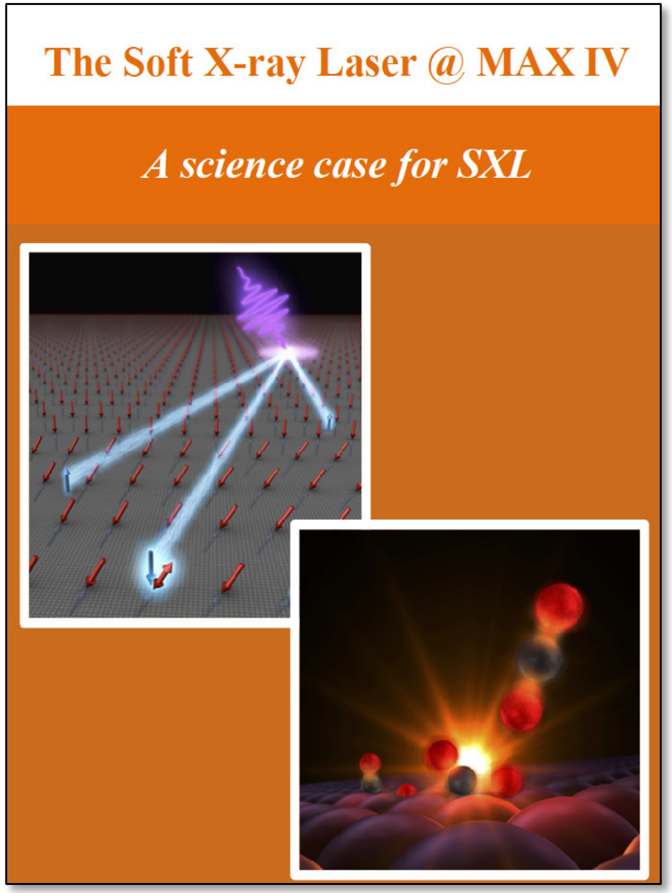
Anders Nilsson,	Stockholm University	Chair, Chemistry
Stefano Bonetti,	Stockholm University	Co-chair, Condensed Matter
Henrik Öström,	Stockholm University	Chemistry
Michael Odelius,	Stockholm University	Chemistry
Mats Larsson,	Stockholm University	AMO Science
Oscar Tjernberg,	KTH	Condensed Matter
Jonas Sellberg	KTH	Life Science
Jan Erik Rubensson,	Uppsala University	Novel Spectroscopy
Vitaliy Goryashko	Uppsala University	Accelerator Science
Raimund Feifel,	Gothenburg University	AMO Science
Per Johnsson,	Lund University	AMO Science
Sverker Werin,	Lund University	Accelerator Science
Francesca Curbis	Lund University	Accelerator Science
Jesper Andersen	MAXIV	Observer

Workshop 21-23 of March 2016

AlbaNova University Center, Stockholm - Goal to define the Science Case for SXL

- 139 registered participants, 129 attended
- 100 Swedish scientists took part
- Top soft X-ray laser scientists were invited
- Lectures, break-out groups, discussions

The SXL Science Case report from 2016



Three unique opportunities:

I. ***A spectrally broad pumping range*** *with potential for attosecond temporal resolution and strong single-cycle THz pulses.*

II. ***Unique detection schemes*** *using nonlinear effects to enhance the cross section for resonant inelastic X-ray scattering (RIXS).*

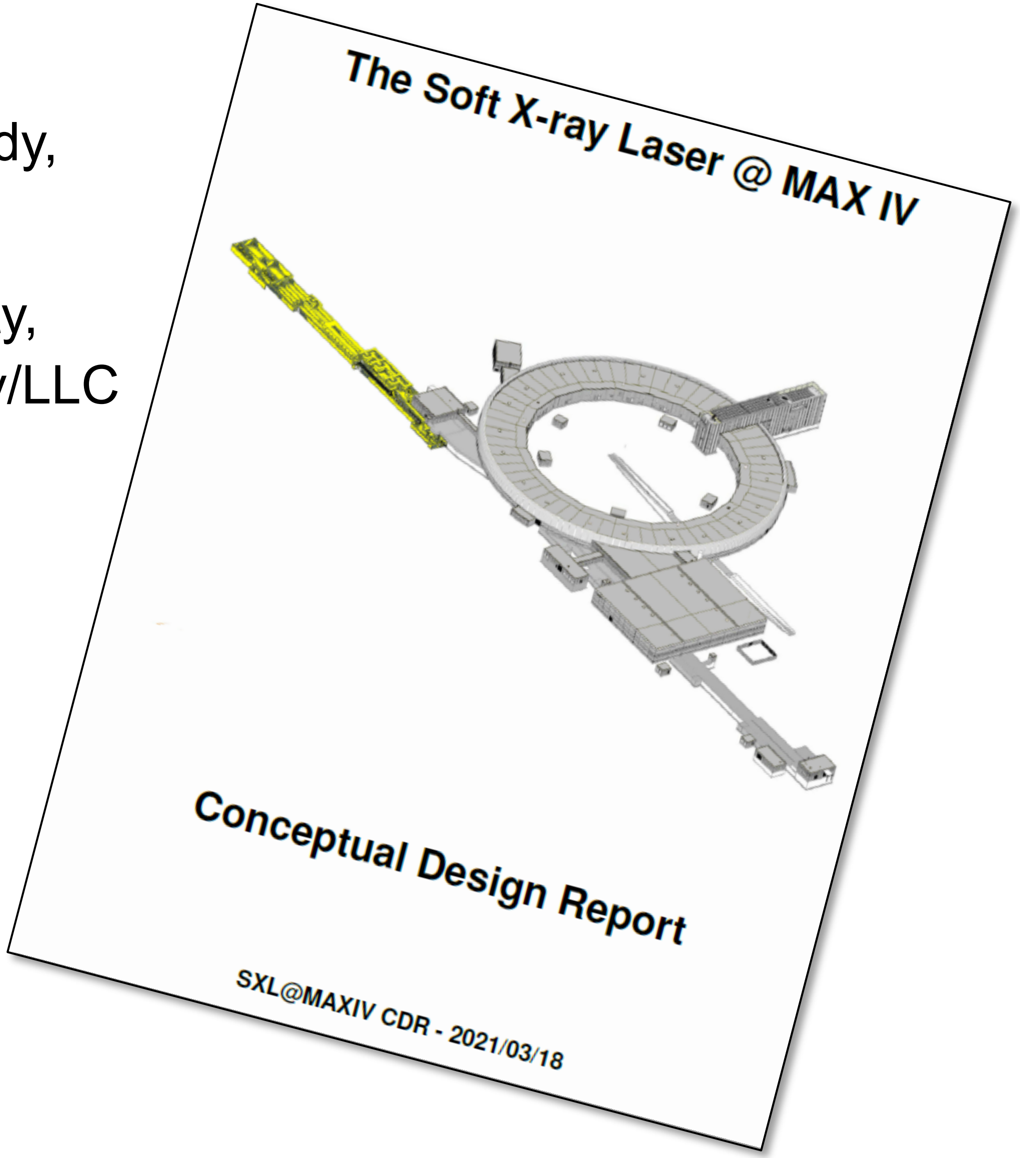
III. *A capacity that, through the* ***synergies with other beamlines at MAX IV****, creates a unique platform for imaging and spectroscopy*

https://indico.maxiv.lu.se/event/141/material/paper/0.pdf

The SXL Conceptual Design Study

- **2016:** Linac pre-study => Green light!
- **2017:** Application to KAW for a Conceptual Design Study, approved in October
- **Joint project:** Stockholm University, Uppsala University, Royal Institute of Technology (SUFEL), Lund University/LLC and MAX IV Laboratory
- March 2018 - March 2021
- Partial funding by the Wallenberg foundation
- Project deliverable: **Conceptual Design Report**

Knut och Alice Wallenbergs Stiftelse


The Soft X-ray Laser @ MAX IV

Conceptual Design Report

SXL@MAXIV CDR - 2021/03/18

Science case overview

AMO Science
- Ultrafast charge and structural dynamics
- Nonlinear X-ray AMO

Condensed Matter Physics
- Ultrafast magnetism: watching spins move in time and space
- Correlated systems - Superconductors
- Correlated systems - Multiferroics
- Structure and dynamics of liquids and glasses
- Semiconductor nanostructure dynamics: Dopants and interfaces
- Sub-femtosecond opportunities in condensed matter

Chemistry
- Photochemistry
- Heterogeneous catalysis
- Electrochemistry
- Photovoltaics

Life Science
- Coherent diffractive imaging of living cells and other intrinsically heterogeneous biological building blocks
- Fluctuation-based X-ray scattering of conformational changes in protein solutions
- Energy conversion involving non-adiabatic dynamics probed by ultrafast X-ray spectroscopy

Theory Support for New Experiments
- Methods development

Science case: Key experiments (2019)

AMO Science

- Ult
- No

AMO – From charge migration to charge transfer

Condensed Matter Physics

- Ultrafast magnetism: watching spins move in time and space
- Correlated systems - Superconductors
- Co
- Str ses
- Semiconductor nanostructure dynamics: Dopants and interfaces
- Sub-femtosecond opportunities in condensed matter

CondMat – Control emergent order in quantum materials

Chemistry

- Pho
- Het
- Elec
- Photovoltaics

Chemistry - Heterogeneous Catalysis, probing Transition States in Surface Reactions

Life Science

- Coherent diffractive imaging of living cells and other intrinsically heterogeneous biological building blocks
- Fluc ional cha
- Energy conversion involving non-adiabatic dynamics probed by ultrafast X-ray spectroscopy

Life Science – Fluctuation Based X-ray Scattering

Theory Support for New Experiments

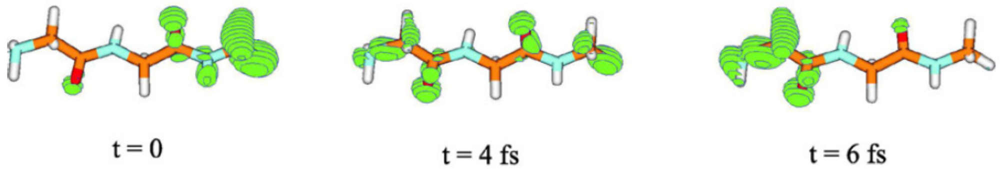
- Methods development

AMO – From charge migration to charge transfer

Coherent electron dynamics are ultimately responsible for the outcome of chemical processes

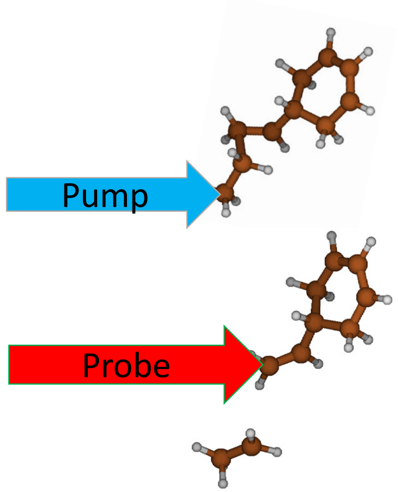
Ultrafast inner-valence ionization → ***Atto- to femtosecond charge migration*** *driven by electron correlation* → *Structural changes driven by average electronic potential* → ***Femto- to picosecond charge transfer*** *mediated by the structural dynamics*

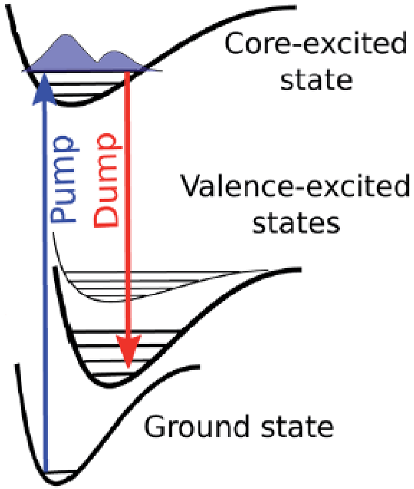
The availability of **intense few to sub-femtosecond**, **two-color**, pulses in the VUV, XUV and SXR regimes will open up completely unexplored territory for the understanding and control of these processes



Examples:

- Site-specific pump-probe schemes
- Stimulated RIXS
- Time-resolved, broadband, transient absorption

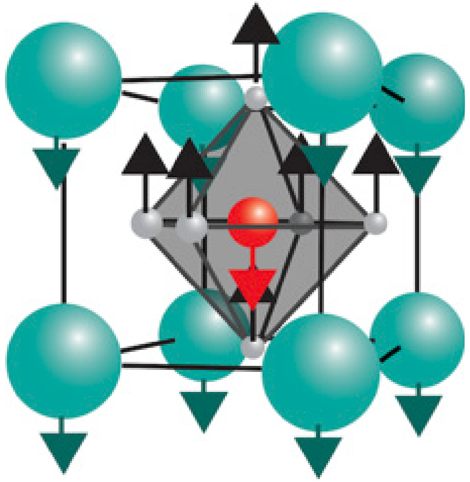




A. I. Kuleff, et al., *Chem. Phys.* **414**, 100 (2013)

V. Kimberg *et al.*, *Struct. Dyn.* **3**, 3 (2016)

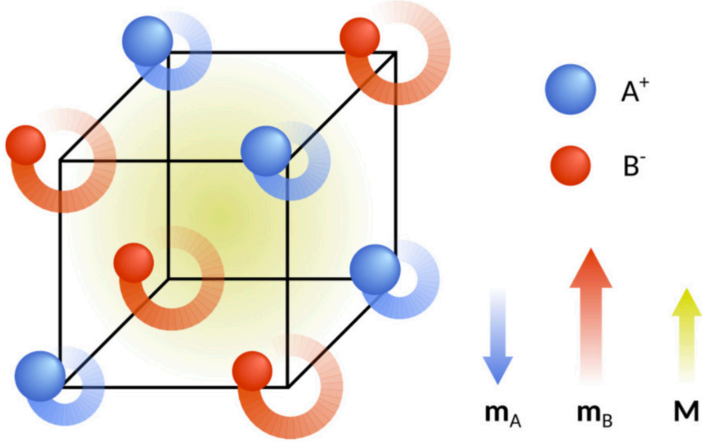
CondMat – Control emergent order in quantum materials



- Terahertz & mid-IR: resonant, heat-free excitation of low-energy excitations (phonons)
- Quantum materials show emergent orders depending on atomic, charge or spin order

M. Kozina et al. *THz phonon up-conversion in SrTiO3, Nature Physics* **15**, 387–392 (2019)

- Example: make material magnetic by pumping phonons with THz light, probe with XMCD
- **General idea:**
  - Create and control new emergent order with low-energy photons
  - probe it spectroscopically with variable polarization with SXL!

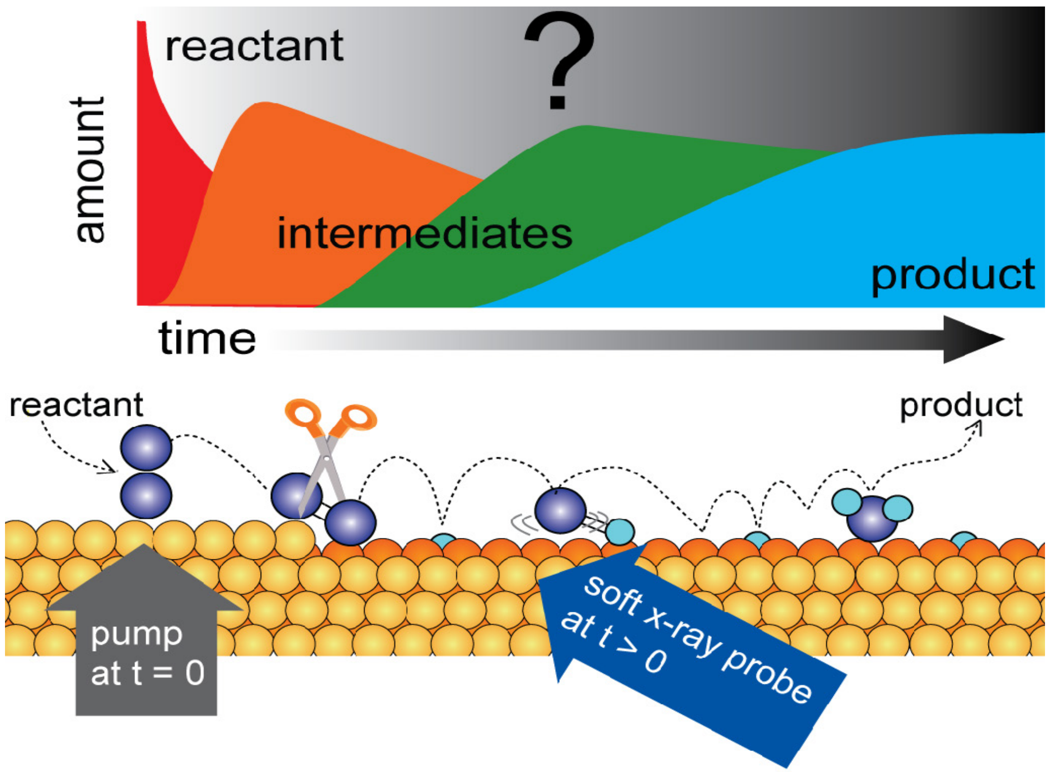


D. M. Jurachek, et al. *Dynamical multiferroicity, Phys. Rev. Mat.* **1**, 014401 (2017)

Goal: Create new phases of matter with ***dynamics*** as material design parameter

Chemistry - Heterogeneous Catalysis

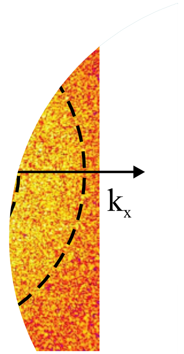
- Understanding reaction mechanism and dynamics

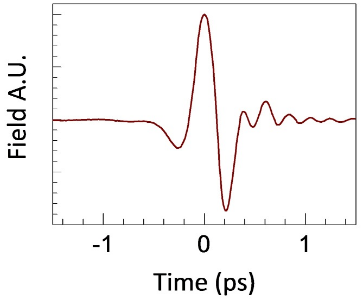


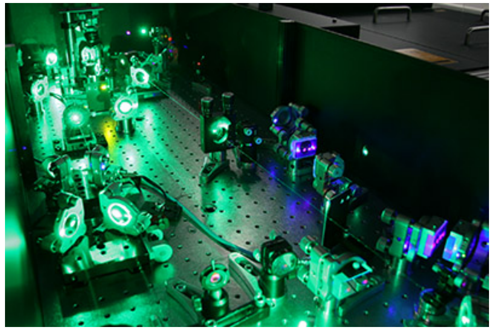
- Nuclear dynamics
  What are the transition states and intermediates in surface reactions? Electronic structure?
  What are the relevant dynamical processes?
- Electron dynamics
  Energy flow? Non-adiabatic processes?

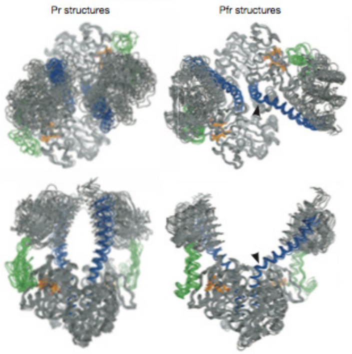
Life Science – Fluctuation Based X-ray Scattering

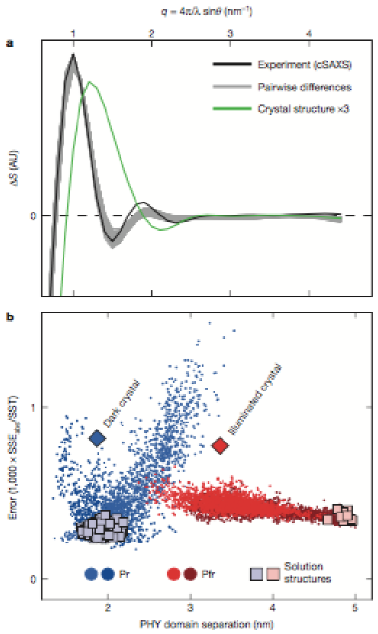
- Use correlations in coherent diffraction patterns to probe conformational changes in solution
- Utilize unique capabilities at SXL combined with THz pump or other state-of-the-art pump lasers from LLC
- Requires a reproducible system that can be synchronized with a trigger
  - Phytochrome photosensors good proof-of-principle











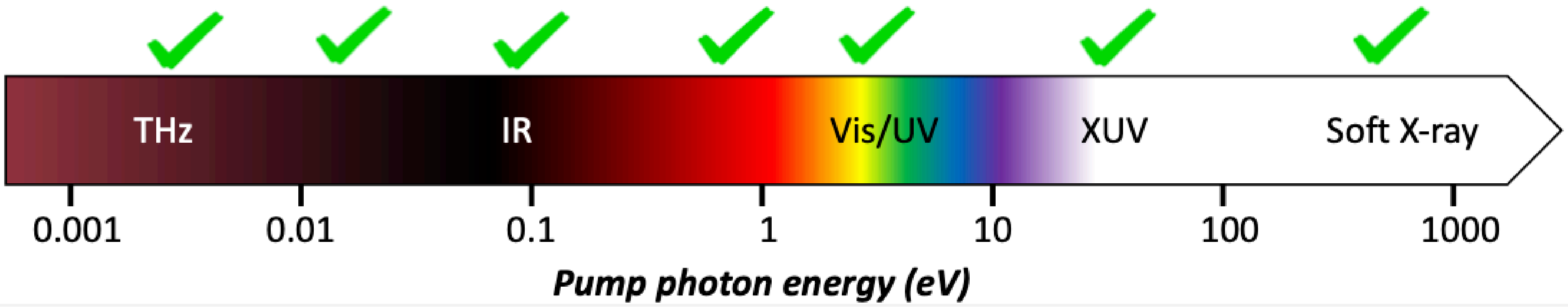
H. Takala *et al.*, *Nature* **509**, 245–248 (2014)

A. V. Martin, *IUCrJ* **4**, 24–36 (2017)

Required FEL parameters for key experiments

	Parameter	AMO	CondMat	Chemistry	Life Science
Single pulse operation	Wavelength (nm)	1 – 5	1 – 5	1 – 5	1 – 5
	Pulse energy (uJ)	0.1 – 0.2	2 – 4	2 – 4	1000
	Photons per pulse	$5 \cdot 10^8 – 5 \cdot 10^9$	$10^{10} – 10^{11}$	$10^{10} – 10^{11}$	10^{12}
	Photon per pulse / mm^2	$6 \cdot 10^{14} – 6 \cdot 10^{15}$		$1 \cdot 10^{13} – 2 \cdot 10^{14}$	$2 \cdot 10^{18}$
	Pulse duration FWHM (fs)	1-2	30 – 50	3 – 50	50
	Polarization	Linear	Variable	Horizontal + vertical	Linear
Two pulse operation	Pulse energy separation (eV)	10 (250-550 eV) 5 (550-1000 eV)		0-135 (250-550 eV)	0
	Pulse time separation (fs)	-100 - +1000		-100 - +1000	10^6-10^{12}

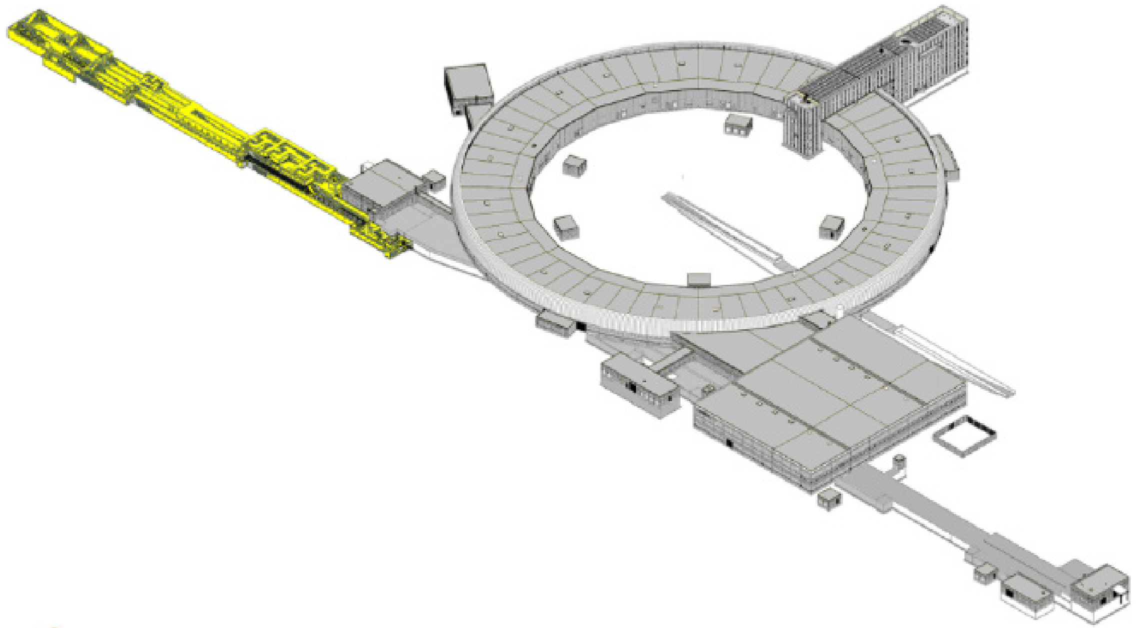
	Parameter	AMO	Chemistry	Cond. Matt.	Life Science
Single pulse operation	Wavelength (nm)	✓	✓	✓	✓
	Pulse energy (uJ)	✓	✓	✓	✓
	Photons per pulse	✓	✓	✓	✓
	Photon per pulse / mm^2	✓	✓	✓	✓
	Pulse duration FWHM (fs)	✓	✓	✓	✓
	Polarization	✓	✓	✓	✓
Two-pulse operation	Pulse energy separation (eV)	✓	⚑	✓	✓
	Pulse time separation (fs)	⚑	⚑	✓	⚑



Main messages in CDR

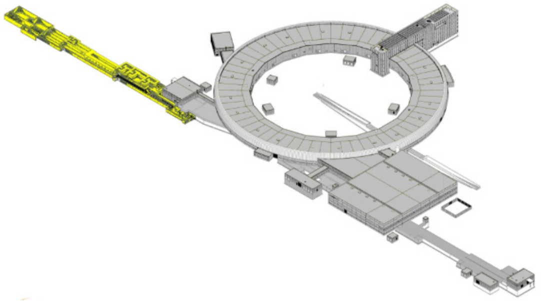
- SXL expected to be a state-of-the-art FEL for pump-probe measurements if built within 5 years
  - *Wide range of pump options, 100 Hz repetition rate, full polarization control*
- All single x-ray pulse experiments envisioned in Science Case available in Phase 1
  - *Novel experiments in all scientific areas, note time-resolved RIXS in AMO and imaging in Cond. Matt. and Life Science*
- State-of-the-art two-pulse operation in Phase 2
  - *Some two-pulse experiments available already in Phase 1*

The Soft X-ray Laser @ MAX IV



Conceptual Design Report

SXL in a nutshell

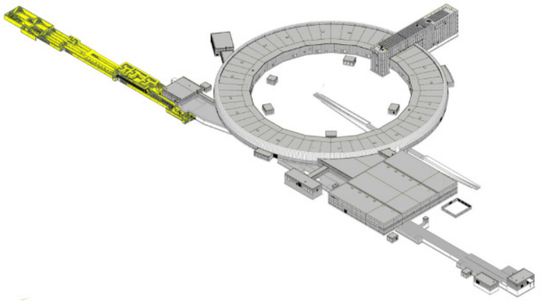


- SXL is a science and user driven initiative
  - *The Swedish user community has requested increases capabilities to explore ultrafast science in the soft X-ray range in a variety of fields.*

- The SXL design provides competitive performance that enables unique science opportunities.
  - *The SXL specialty will be very short pulses with excellent stability and two-pulse two-colour schemes.*

- SXL capitalizes on the existing infrastructure to open research opportunities that are not possible at any other beamline at MAX IV.
  - *The already operating MAX IV linac is well suited as an FEL driver and only relatively minor changes are required.*

The SXL CDR Project



SXL CDR Steering Group

Pedro Tavares, Anders Nilsson, Mats Larsson

Advisory Committee

Ingolf Lindau (chair)

Sven Reiche, Simone Dimitri,

Zhirong Huang, Luc Patthey, Wilfried Wurth

CDR Work Packages

WP1: Science Case
Anders Nilsson

WP2: Accelerator
Sara Thorin

WP3:FEL
Francesca Curbis

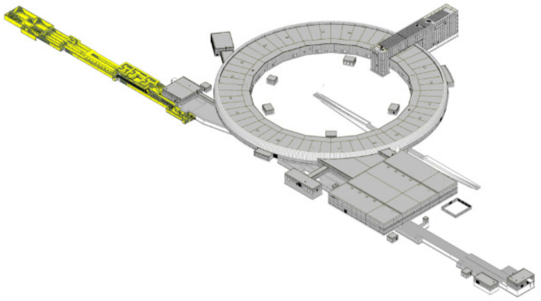
WP4:ID
Hamed Tarawneh

WP5: Beamline
Peter Salén
Vitaliy Goryashko

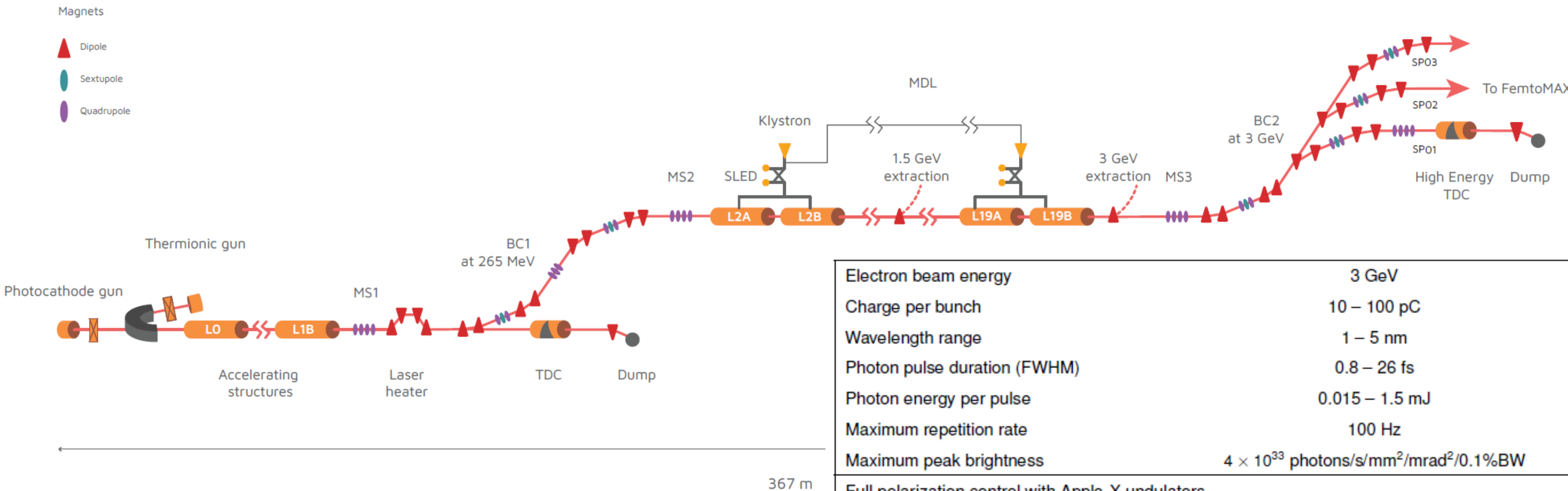
WP6: Exp.Station
Jonas Sellberg, Stefano Bonetti, Per Eng-Johnsson

WP7: Infrastructure
Jonas Modéer

Overview



Existing



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Maximum repetition rate	100 Hz
Maximum peak brightness	4×10^{33} photons/s/mm^2/mrad^2/0.1%BW

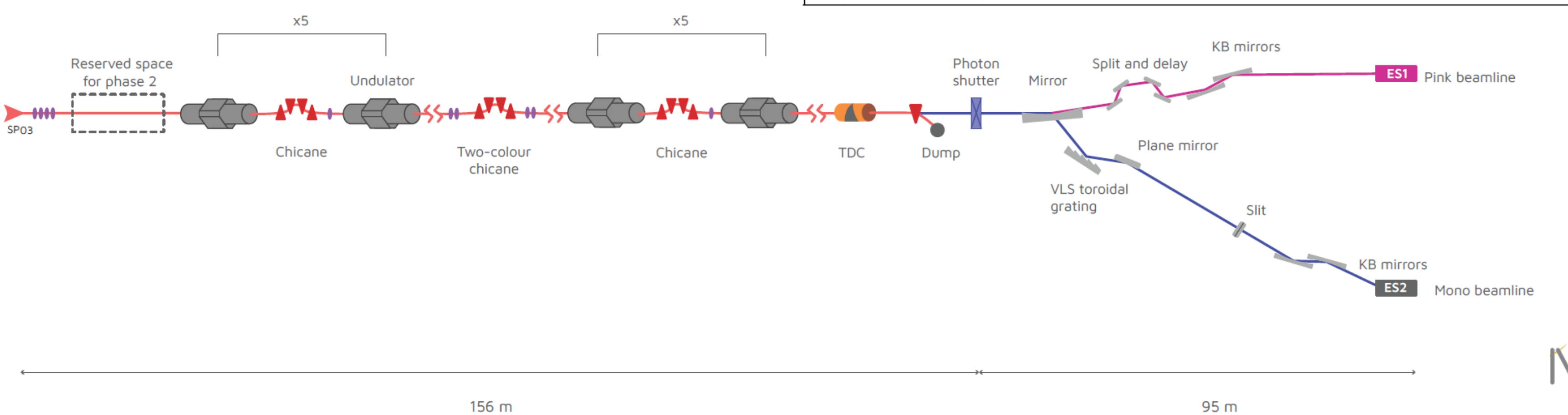
Full polarization control with Apple-X undulators.

Extensive range of pump lasers, from IR to XUV.

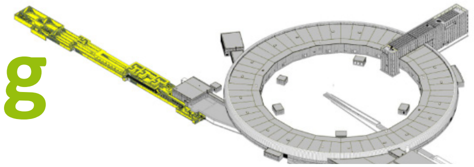
Two-pulse/Two-colour, delays from few fs to few tens of ns

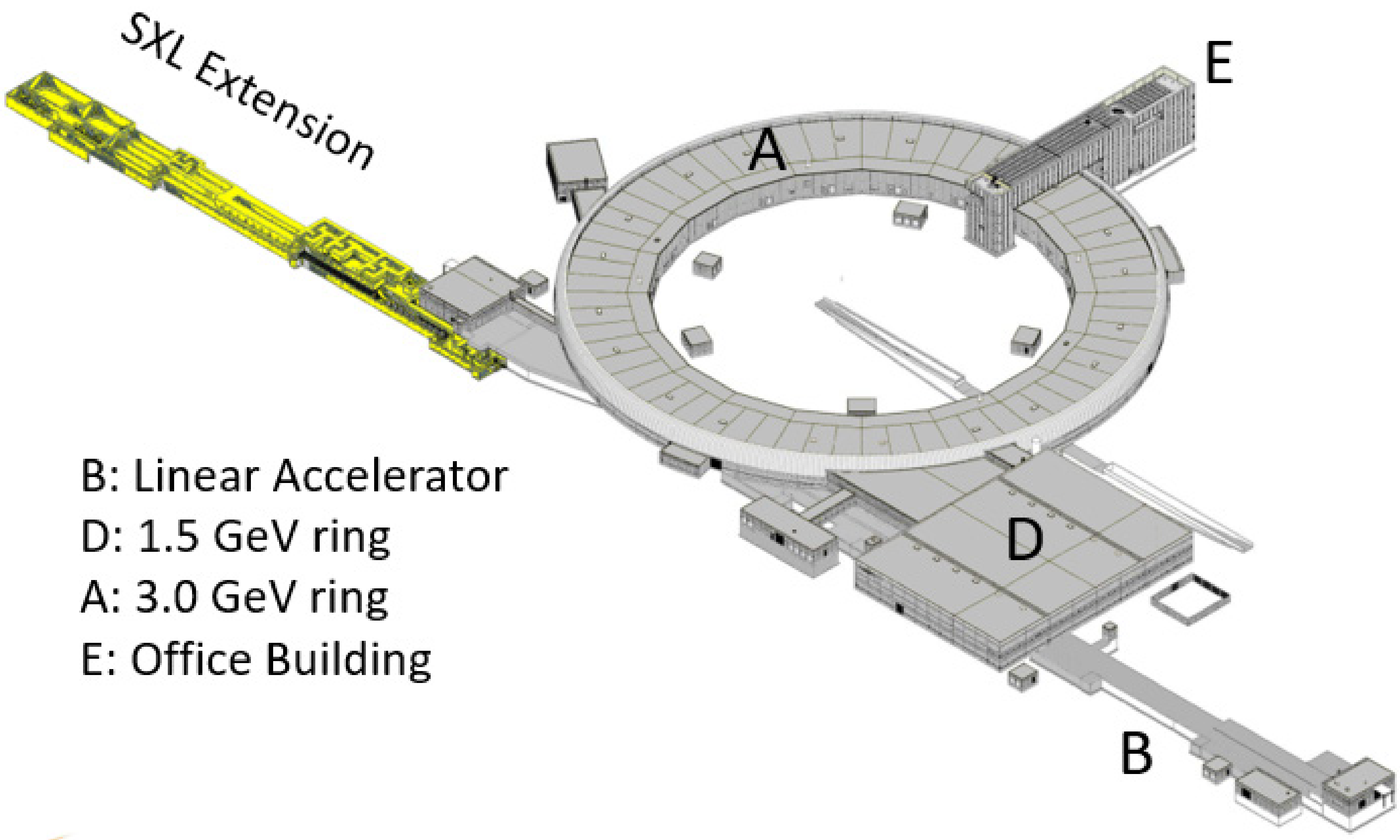
Prepared for future expansions: Echo-Enabled Harmonic Generation, High Brightness SASE, Self-Seeding

Expansion



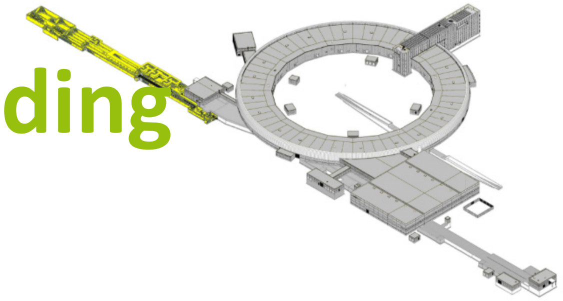
Infrastructure – Extension building

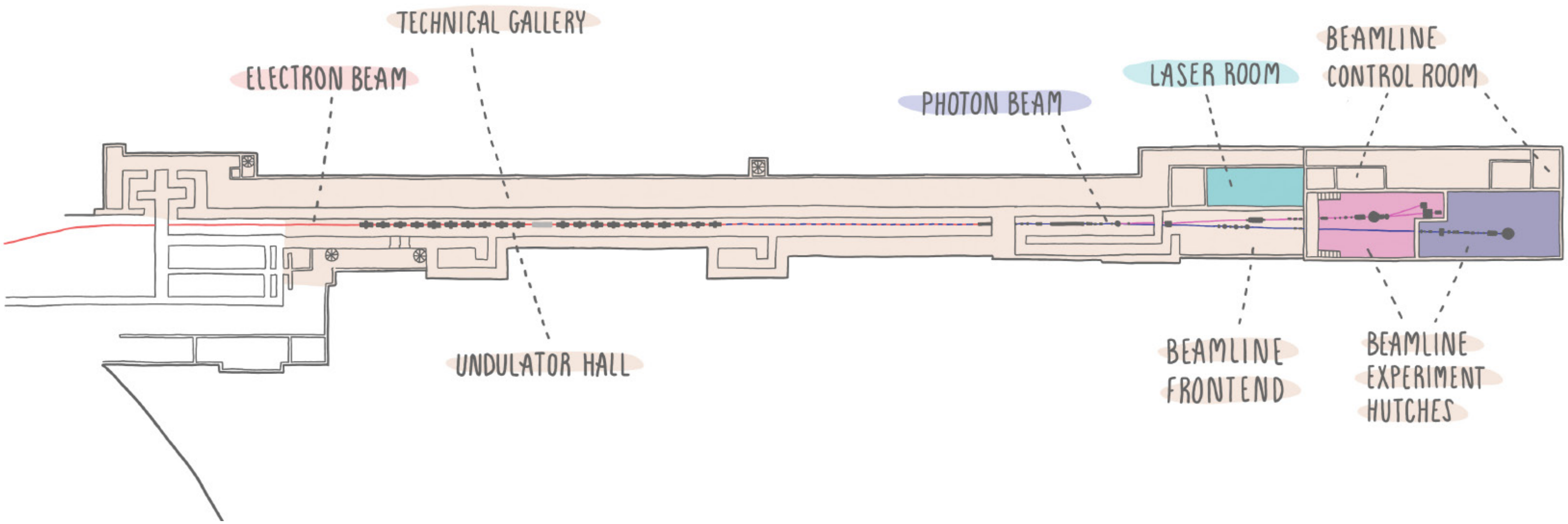


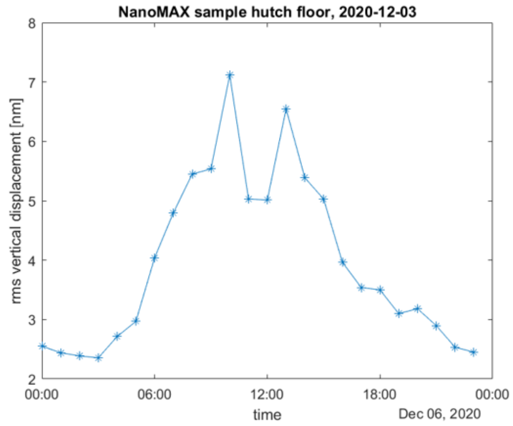


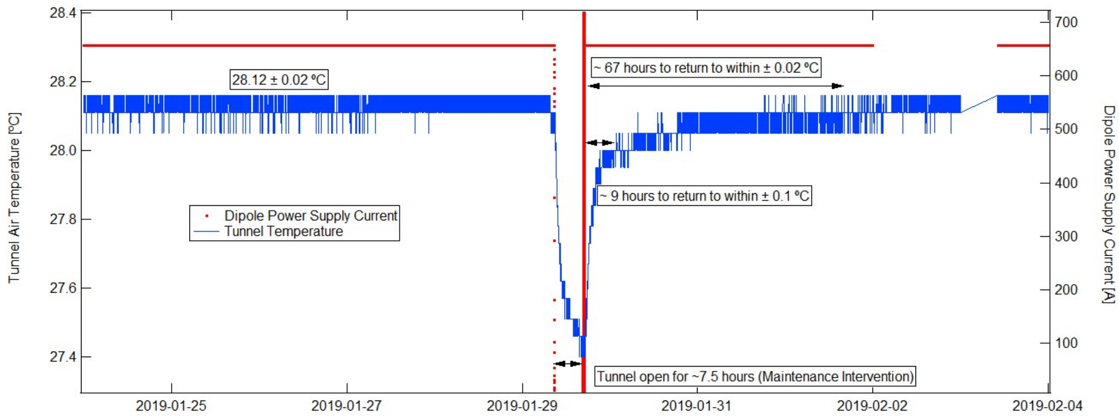
B: Linear Accelerator
D: 1.5 GeV ring
A: 3.0 GeV ring
E: Office Building

Infrastructure – Extension Building

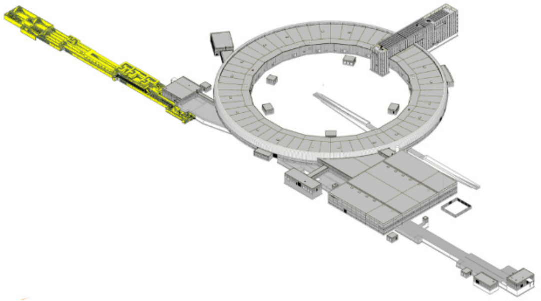








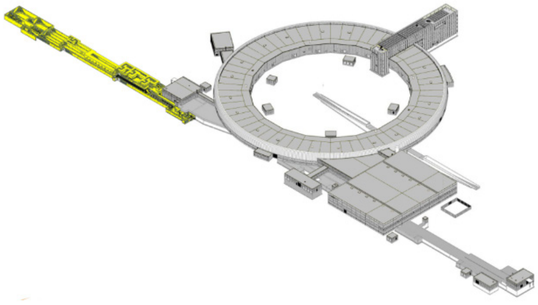
The building Extension



- The Building Extension lies entirely within the MAX IV Campus.
  - Total area ~4000 m^2 ~ 10% of existing area

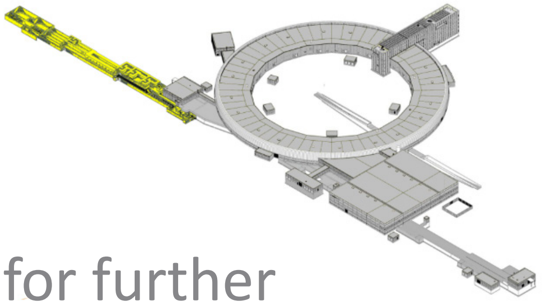
- A cost-effective building design that
  - *Minimizes the interference with regular user operations at MAX IV.*
  - *Maintains the same high floor stability requirements used for the existing MAX IV.*
  - *Incorporates enough space to allow for SXL phase 2 features such as echo, de-chirper, seeding.*
  - *Keeps the possibility of installing an extension of the linear accelerator to 5-6 GeV, which is needed for driving a future hard X-ray FEL.*

SXL Phase 1



- Accelerator
  - 3 GeV, 100 Hz
  - Mode 1a: 100 pC, 18 fs fwhm, -0.56 MeV/fs
  - Mode 1b: 10 pC, 1.8 fs fwhm, -4.5 MeV/fs
- FEL
  - SASE, 1 – 5 nm, Tapering, Optical Klystron
  - Apple X Undulators with Full Polarization Control
  - Photon pulse: 0.8 – 26 fs (fwhm), 0.015 – 1.5 mJ, up to 4×10^{33} $ph/s/mm^2/mrad^2/0.1\%BW$
  - Two-pulse two-colour
    - Split undulator scheme: 10 fs ~ 1 ps
    - Separate RF buckets: 330 ps ~ 50 ns
- Beamline
  - Pink + Mono beamlines + Two open ports
  - Pump laser systems (THz to XUV). HHG for the pink beamline.
  - CAMP type + Surface Science End-stations

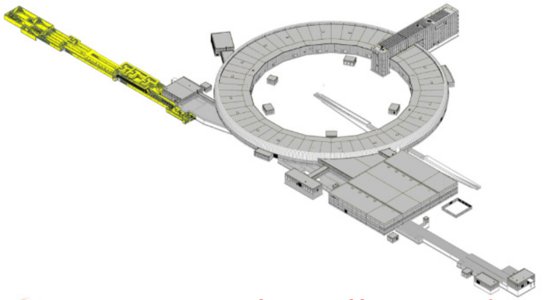
SXL Phase 2



The SXL design includes enough flexibility to allow for further improvements beyond its intended initial performance envelope.

- Laser Heater
- Two-pulse two colour requiring split & delay for negative delays
- Echo Enabled Harmonic Generation
- De-chirped beam (Accelerator Mode 2)
- High Brightness SASE
- Self-Seeding
- Atto-s pulses
- HHG to the monochromatic beamline
- Angular-streaking for ultra-high resolution arrival-time monitor

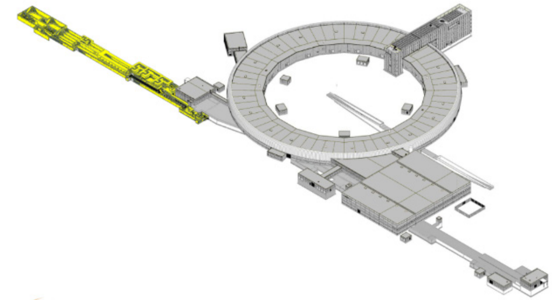
SXL in the international context

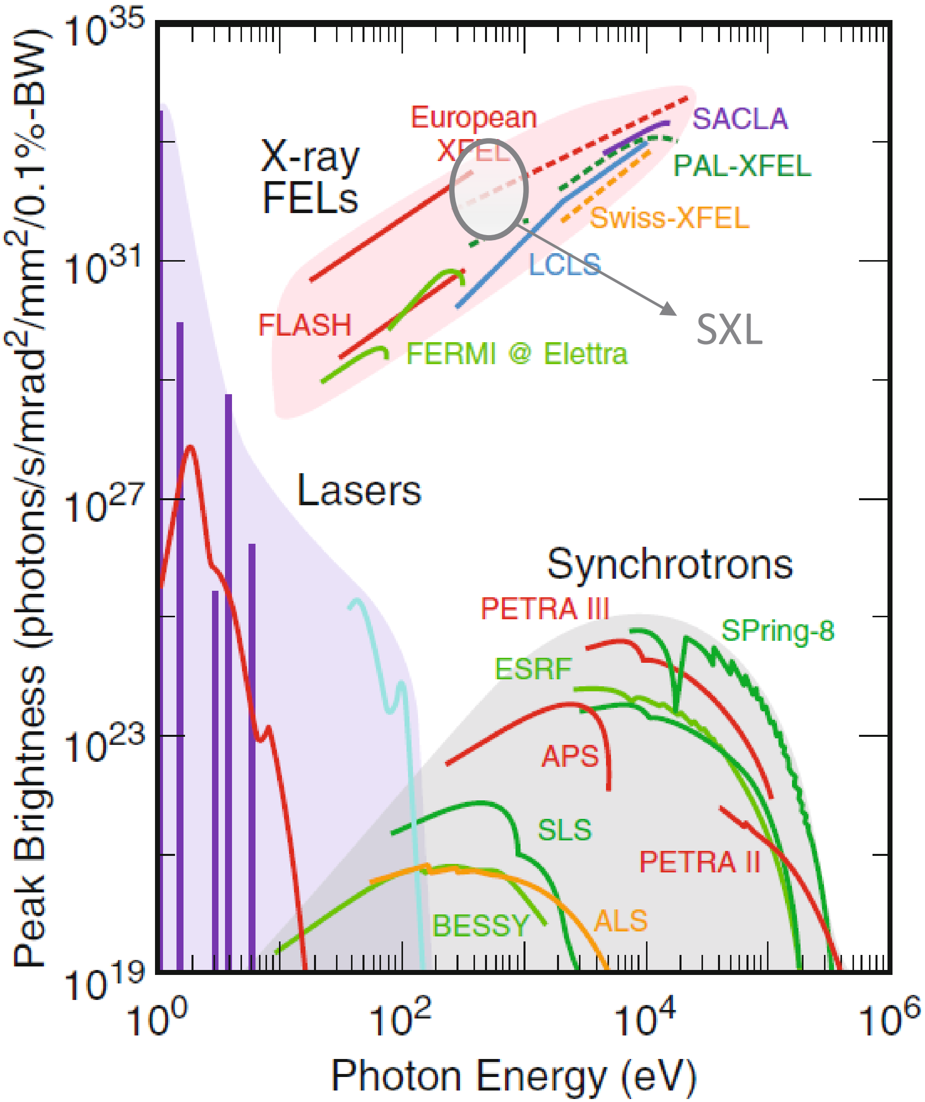


Data adapted from X-ray FEL Science: The International Perspective by Massimo Altarelli, London 2019

Facility	SXL	Swiss FEL	Fermi	FLASH	SXFEL Shanghai	XFEL	PAL	LCLS I	LCLS II	SACLA
Max electron Energy [GeV]	3.0	5.9	1.5	1.25	1.6	17.5	10	14.3	14.3	8.5
Wavelength range [nm]	1 5	0.1 7	4 100	4 90	1.2 12	0.05 4.7	0.08 6	0.1 4.4	0.05 4.7	0.06 0.3
Photons/pulse	$8x10^{10}$ $4x10^{13}$	10^{13}	10^{13} 10^{14}	$3x10^{13}$	10^{11} 10^{13}	10^{12}	10^{11} 10^{12}	10^{13}	10^{12} 10^{13}	$4x10^{11}$
Peak Brilliance [$ph/s/mm^2/mrad^2/0.1\%BW$]	10^{32} $4x10^{33}$	10^{33}	10^{31}	10^{31}		$5x10^{33}$	10^{33}	10^{33}	$2x10^{31}$	10^{33}
Rep. Rate [Hz]	100	100	10 50	5000	10 50	27000	60	120	10^6	60

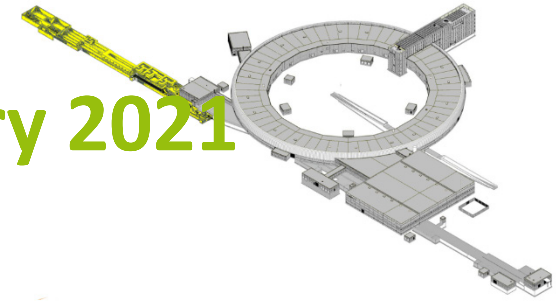
SXL in the international context





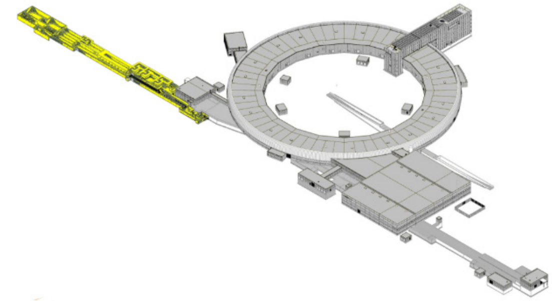
Plot from:
X-Ray Free Electron Lasers and Their Applications
By Sébastien Boutet and Makina Yabashi
In: "X-Ray Free Electron Lasers", Springer 2018.

4th SXL CDR SAC Meeting February 2021



- **Committee Members**
  - Simone Di Mitri, Elettra and Univ. of Trieste
  - Zhirong Huang, SLAC
  - Ingolf Lindau (Chair), SLAC and LU
  - Luc Patthey, PSI
  - Sven Reiche, PSI
- **Main Conclusions**
  - The SAC congratulates (the) team for a very well executed CDR. The document fulfils high international standard.
  - The FEL parameters for SXL Phase-1 map very well in the scientific case. The SAC considers the SXL scientific case to be very solid
  - The SAC identifies the present project reaching the last state-of-the-art FEL developments, which definitely allow further science developments for the next decade, to be addressed in the TDR.

Knut och Alice Wallenbergs Stiftelse



UPPSALA UNIVERSITET

MAX IV

SUFEL

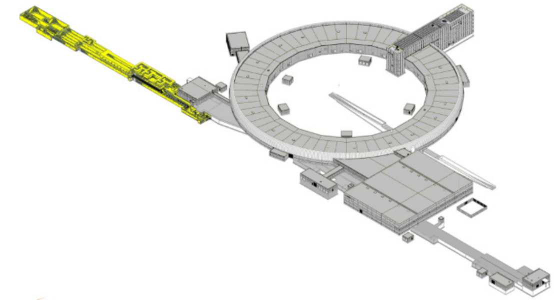
STOCKHOLM-UPPSALA CENTRE FOR FREE ELECTRON LASER RESEARCH

Stockholm University

KTH VETENSKAP OCH KONST

LUND UNIVERSITY

LLC LUND LASER CENTRE



Acknowledgements

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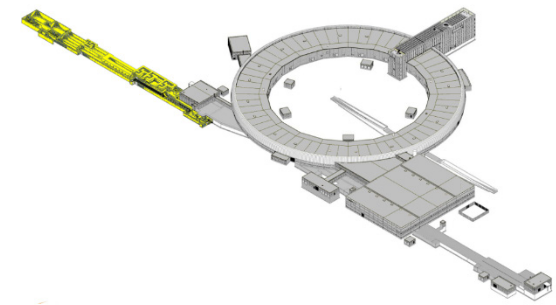
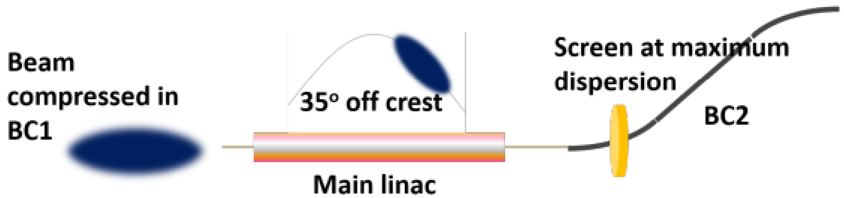
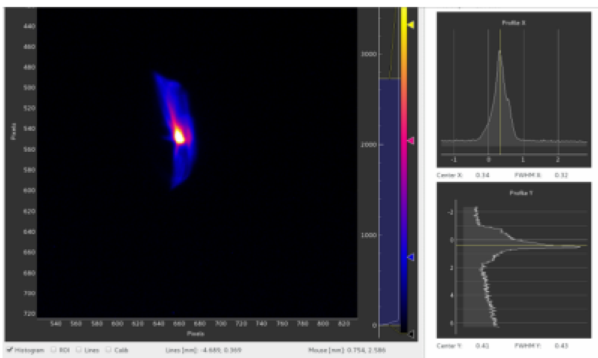
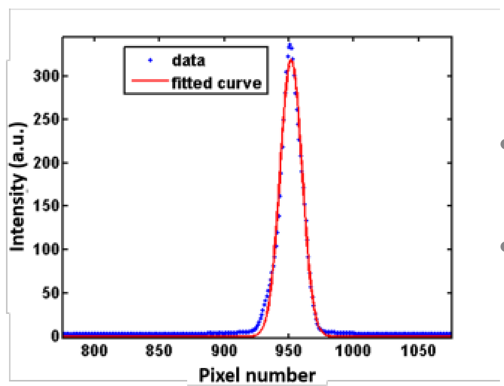
SXL Accelerator



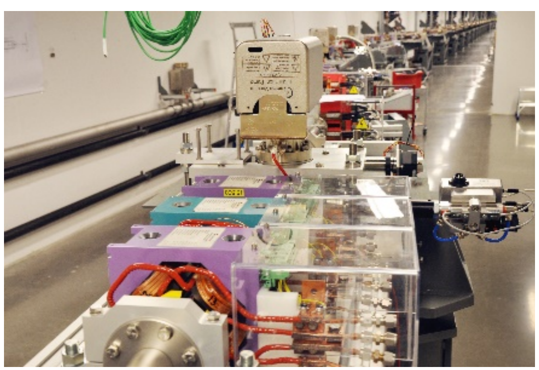






Already operating MAX IV linac

- provides the electron beam energy, bunch charge and compression capability required to satisfy the SXL demands
- bunches shorter than 20 fs rms demonstrated
- rms energy jitter at BC2 measured to be ≈ $1 \times 10{-}4$ corresponding to rms arrival time jitter of 10 fs



September 2021

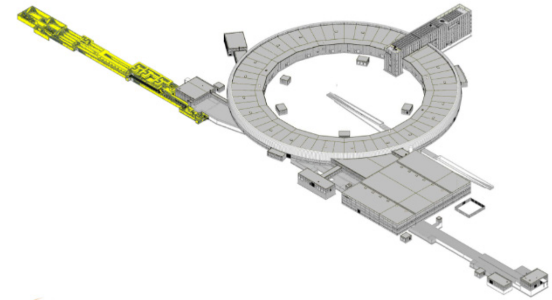
Pre-existing linac - benefits

- Linac improvements ~10% of the total SXL budget.
A new linac ~ double the cost of the whole SXL project.

- Time, takes almost a year to install and commission a linac

- Experience, know how
- Issues already discovered and solved.
- Operations team established and experienced.

SXL Accelerator

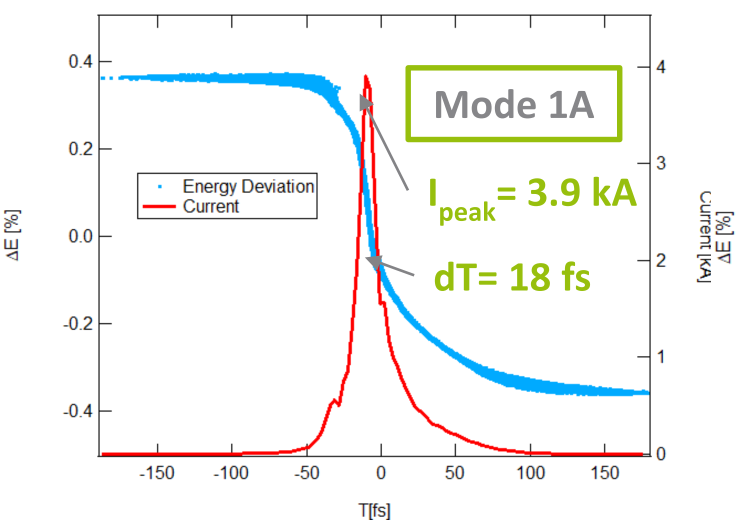


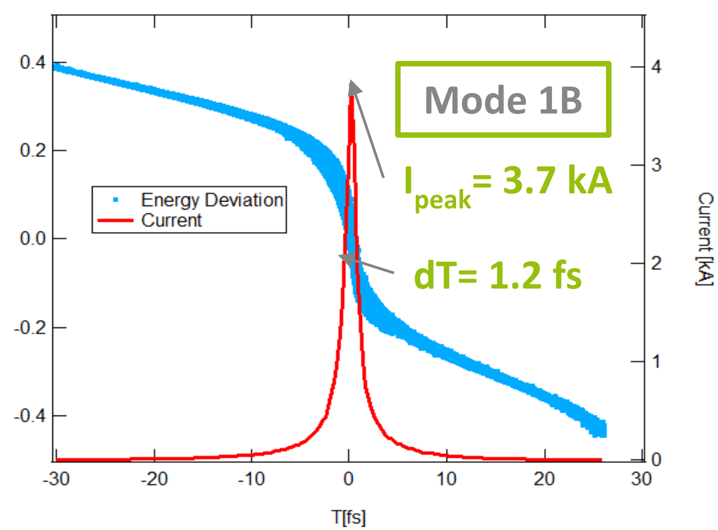
SXL Stability

Arrival time sensitivity and jitter tolerances		1A			1B		
Parameter	RMS Tolerance	Sensitivity	Jitter		Sensitivity	Jitter	
			RMS	FWHM		RMS	FWHM
Gun Laser Arrival Time	0.01 ps	35.7 fs/ps	0.1 fs	0.84 fs	11.8 fs/ps	0.12 fs	0.3 fs
Gun Charge	1 %	0.6 fs/%	0.6 fs	1.4 fs	0.09 fs/%	0.09 fs	0.2 fs
RF phase	0.01 deg	676 fs/deg	6.76 fs	15.9 fs	312 fs/deg	3.1 fs	7.3 fs
Modulator HV	0.001 %	740 fs/%	0.7 fs	1.7 fs	161 fs/%	0.16 fs	0.4 fs
BC dipole current	0.01 %	3 fs/%	0.0 fs	0.1 fs	0.1 fs/%	0.001 fs	0.003 fs
TOTAL Jitter			**6.8 fs**	**16.1 fs**		**3.1 fs**	**7.4 fs**

- Arrival time jitter – a challenge! But not impossible.
- Passive stabilization scheme (magic angle, wake chirp), reduces the influence of klystron modulator voltage jitter and phase jitter.

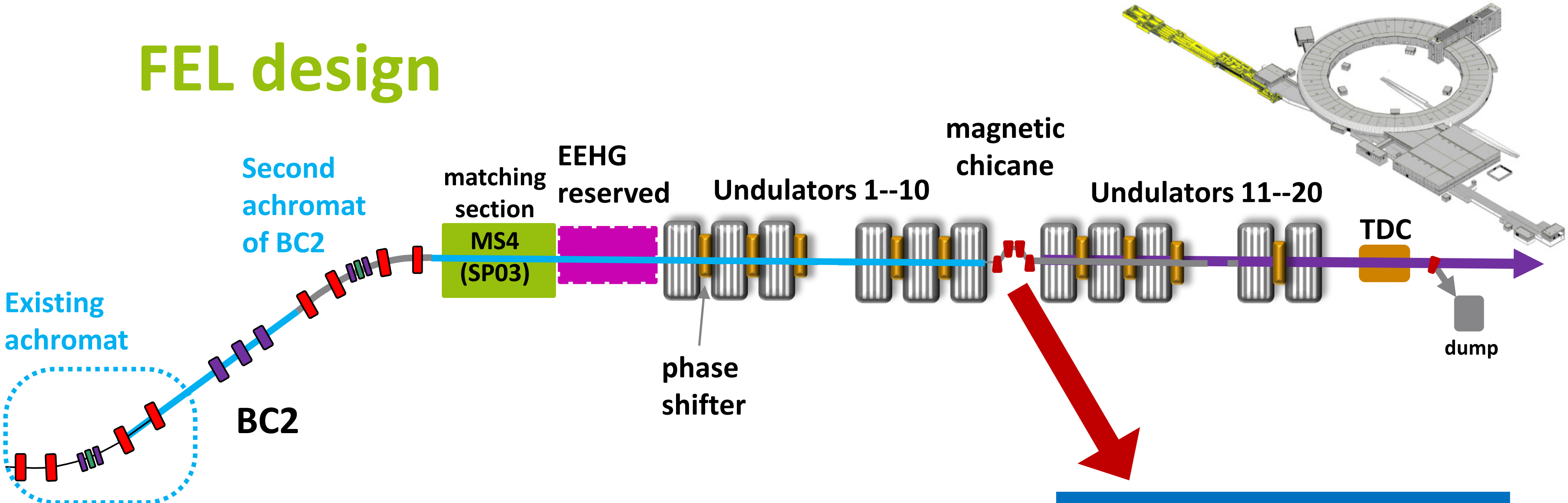
Short Pulses for SXL



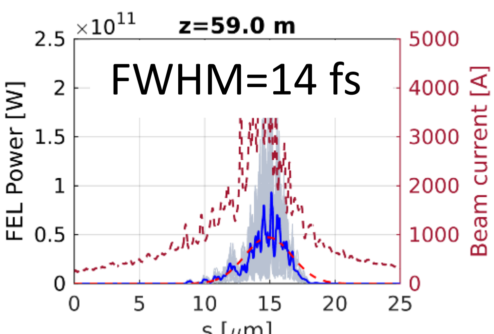


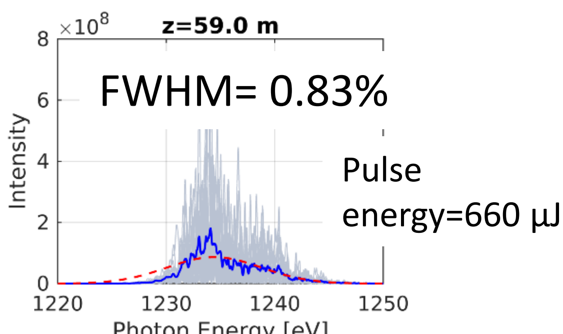
- Bunch compression scheme capable of producing ultrashort pulses
- Passive linearisation done with T566 using magnets

FEL design

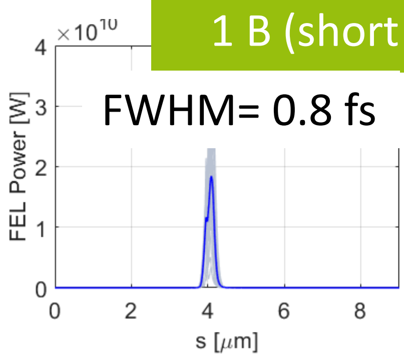


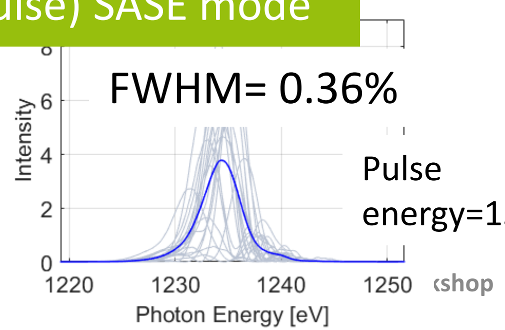
1 A (long pulse) SASE with tapering



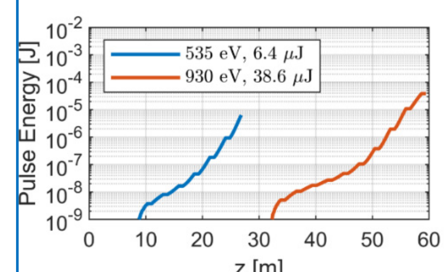


1 B (short pulse) SASE mode





Two pulses two colours

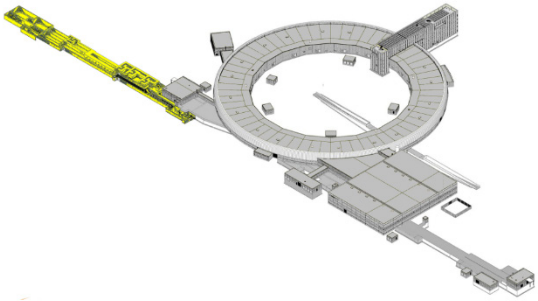


K-edges
C+O (285–535) eV
C+N (285–400) eV
N+O (400–535) eV
L-edges
O+Mn (535–640) eV
O+Cu (535–930) eV
O+Co (535–780) eV
Co+Cu (780–930) eV

Delays 2nd pulse: +10fs – 1ps

Possible jumps of 330ps

Development of FEL design



- Phase 1 @start-up
  - Fulfils the users’ requirements
  - SASE mode with long and short pulses
  - Full polarization control
  - Full tunability 1—5 nm
  - Double pulses with variable delay and wavelength

- Phase 2 – will be improved with YOUR input!
  - Bandwidth reduction
  - Longitudinal coherence enhancement
  - Improved stability
  - More 2 colour options (combination of wavelengths/intensity ratios/delays…)
  - Shorter pulses

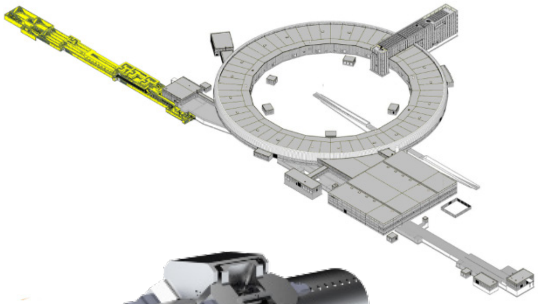
Seeding
Echo EHG
HB-SASE
Self-seeding

Backup
Table with performance

	1A				1B		
	SASE	SASE + taper	SASE	SASE + taper	SASE		
Wavelength	1	1	5	5	1	5	nm
Active length (without breaks)	26	40	14	30	20	12	m
Total length (with breaks)	42	59	20	45	29	17	m
Undulator taper?	No	Yes	No	Yes	No	No	—
Pulse energy	130	660	220	1500	15	20	µJ
Power	14	50	36	56	15	12	GW
Number of photons per pulse	6.60E+11	3.3E+12	5.5E+12	3.8E+13	7.6E+10	5.0E+11	—
Pulse duration (FWHM)	9.3	14	5.2	26	0.8	1.2	fs
Pulse bandwidth (FWHM)	0.5	0.8	0.7	1.2	0.36	0.8	%
Virtual source location, x and y	-5.3, -4.8	-10, -9.9	-1.5,-1.9	-8.7, -8.8	-2.7, -2.9	-1.7, -1.4	m
Virtual source size (2sigma), x and y	50.7, 45.4	57, 54	49.6, 48.3	149, 145	25.1, 28.4	43.6, 37.8	um
Virtual source divergence, x and y	9.7, 8.7	8.5, 8.1	42.8, 36.0	32, 32	16.0, 13.7	51.2, 62.9	urad
M^2, x and y	1.5, 1.3	1.5, 1.4	1.3, 1.1	3.0, 2.9	1.26, 1.22	1.4, 1.5	—

MAX IV

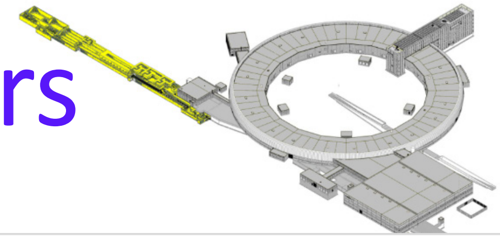
SXL Undulator



- Compact design based on APPLE X type with 2 m magnetic length, 40 mm period length with minimum gap of 8 mm and full polarization control fulfilling the required photon energy range of 250 -1000 eV.
- Conceptual magnetic and mechanical design of undulator. Definition of procedures for assembly, magnetic and mechanical measurement, tuning, fiducialization and alignment.
- Undulator budget estimate and preliminary BOM is in place.
- Mass production scenarios based on collaboration with qualified industrial partner(s) is foreseen. Prototyping is key in knowledge transfer.
- Development of pulsed wire system suitable for magnetic measurement of closed structure such as APPLE X undulator.
- A full-scale undulator prototype has been funded (50% MAX IV & 50% EU via LEAPS-INNOV initiative). The project started April 2021 with timeline of 24-30 months. Potentially to be tested with e-beam at FemtoMAX beamline.

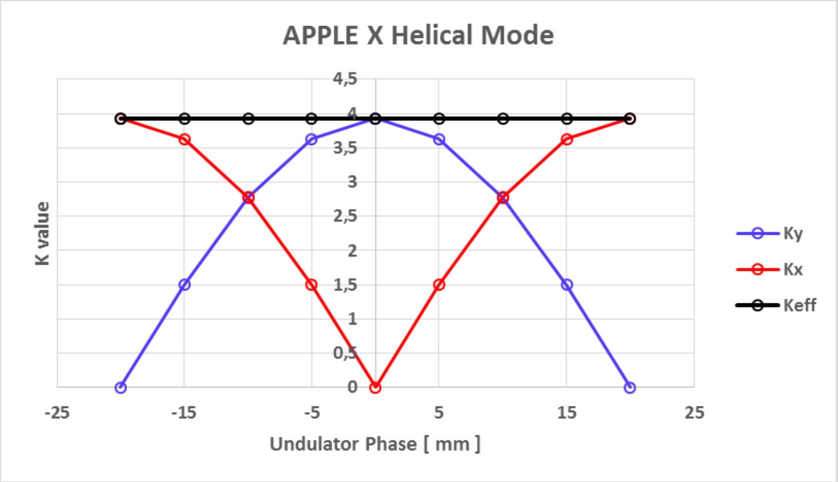
Procurement of magnet blocks and undulator parts started June 2021.

SXL Undulator Parameters

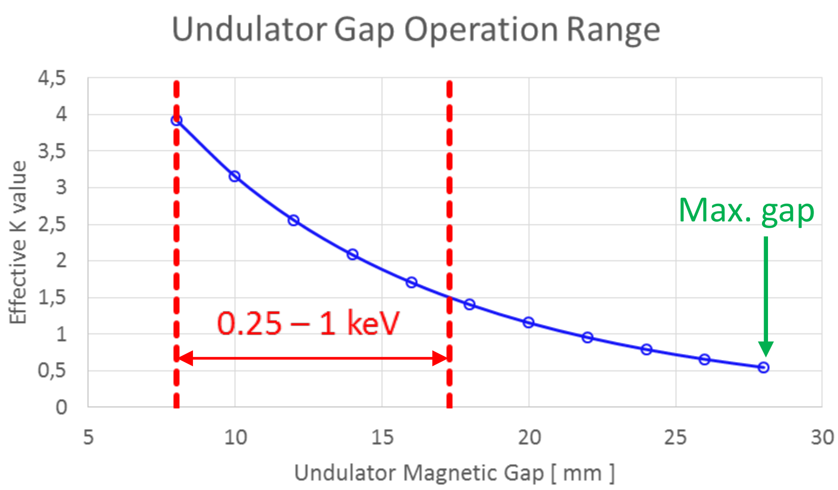


SXL Undulator design is based on compact APPLE X type.

1) Full polarization control in helical mode only (inclined polarization is possible too).
2) Possibility to create gradient as extra feature.

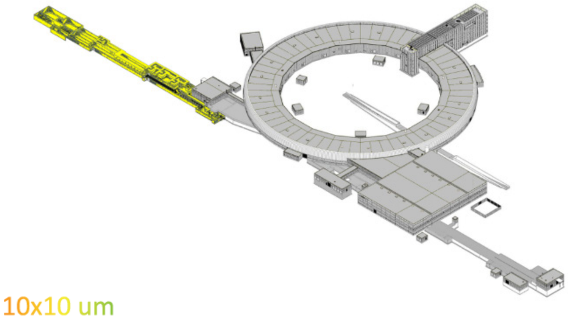


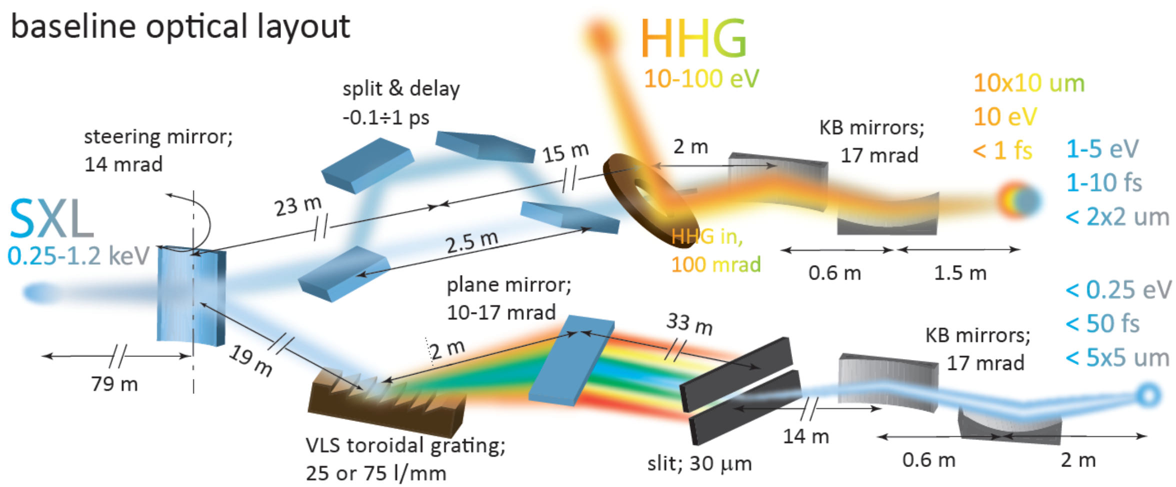
SXL Compact APPLE X Undulator Parameters	
Magnet type	SmCo (B_r=1.12 T)
Period Length	40 mm
Photon energy range	0.25 – 1 keV
Magnetic gap range	8.0 – 17.3 mm
Effective K range	3.9 – 1.51
Max. gap / min. eff. K	28 mm / 0.55
Undulator magnetic length	2 m



MAX IV

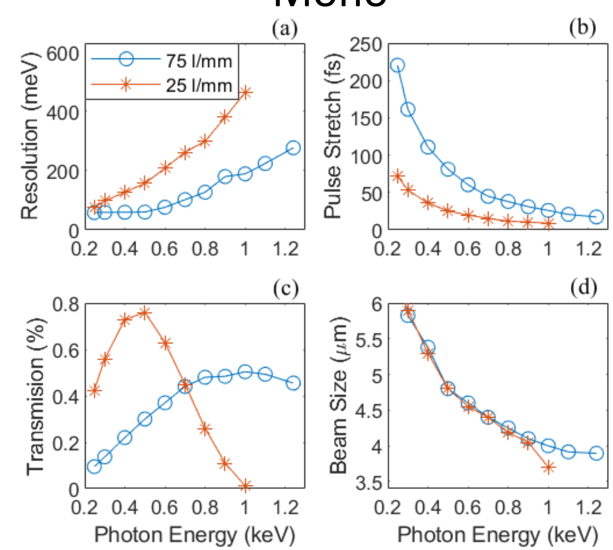
Photon Beamlines



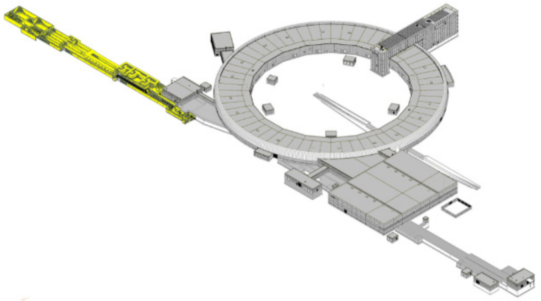


Parameter	Pink	
Grating	-	-
Wavelength (nm)	1	5
Photon energy (eV)	1240	248
Transmission (%)	72	60
Pulse energy (μJ)	475	900
Photons/pulse $\times 10^{10}$	240	2300
Beam size ($\mu m \times \mu m$)	0.82×1.1	2.1×2.9
Pulse stretching (fs)	-	-
Resolution (meV)	-	-

Mono



Main Messages in the CDR



- **Versatile,** supports many types of experimental modes

  - split-delay capability

  - HHG pump capability

  - variable spot size at the sample

  - intermediate focus or expanding beam option

- **State of the art output parameters**

  - pink: um FWHM spot size at the sample

  - mono: combines high transmission, temporal and spectral resolution over 1-5 nm

- **Diagnostics setup for efficient online characterization**

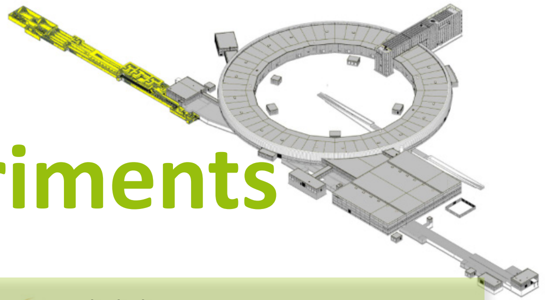
  - mainly gas based diagnostics

  - temporal and spectral diagnostics placed after sample (pink beamline)

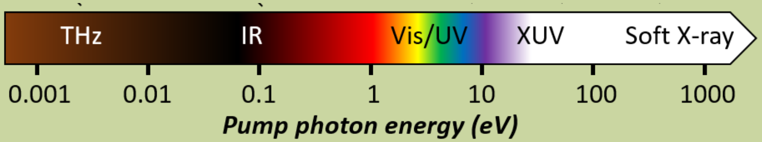
  - VUV (HHG) and X-ray diagnostics

MAX IV

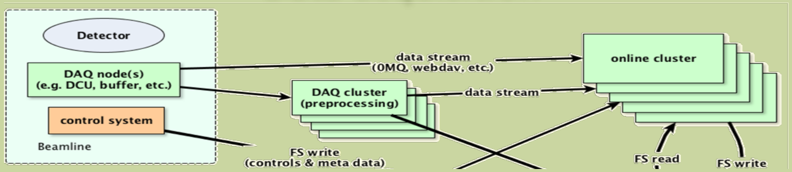
Beam delivery and user experiments

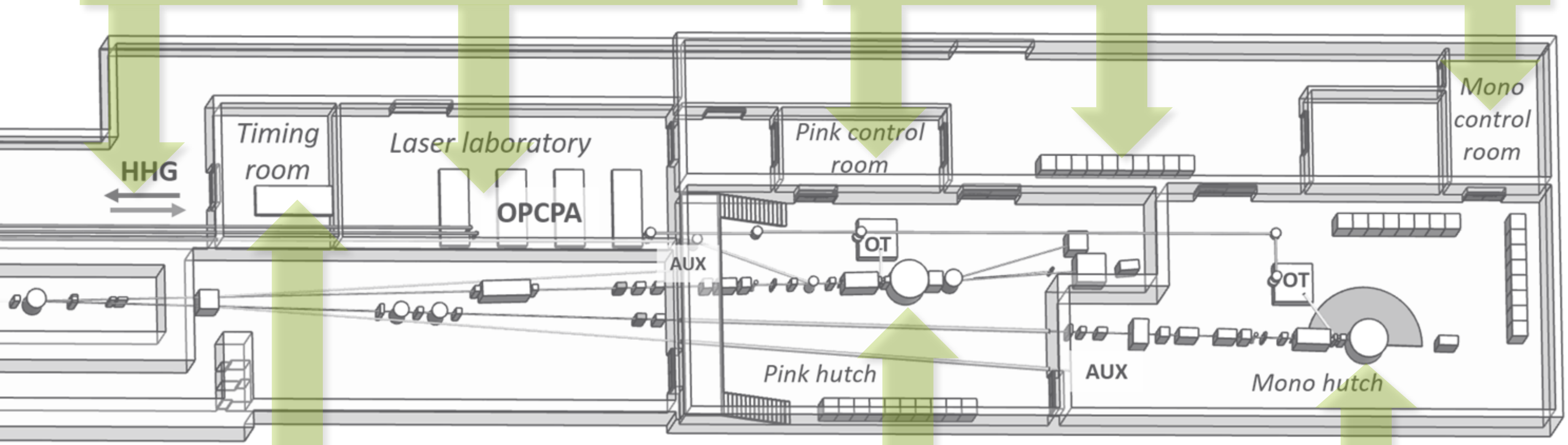


Pump-probe infrastructure

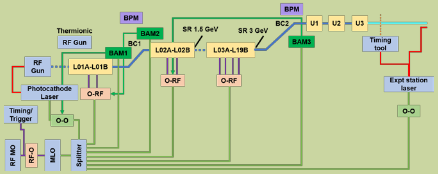


Data acquisition

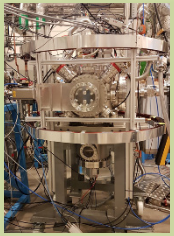


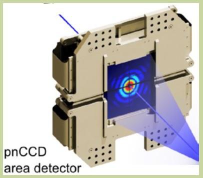


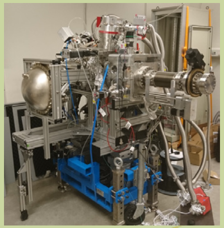
Timing and synchronization



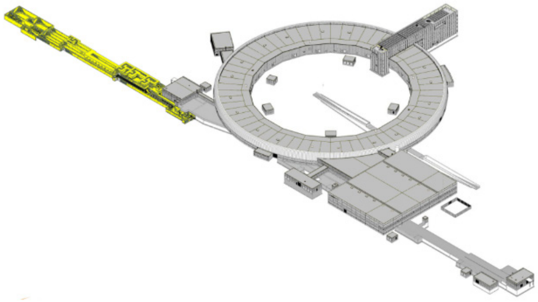
Endstation concept





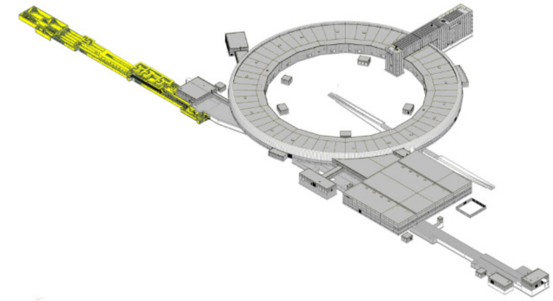


Main messages in the CDR



- Ultrafast pump and probe possibilities for users in a wide wavelength range
  - *Careful planning of infrastructure for primary and secondary sources*
  - *Modular endstation concept combining in-house endstations, user endstations and open ports for development work*
- Well-tested approach for timing and synchronization
  - *Based on commercial all-optical solutions already successfully implemented at other facilities*
- Data acquisition and detection building on existing solutions
  - *Based on existing MAX IV infrastructure for maximum integration and minimum troubleshooting*
  - *Use of commercially available detector technology*

Acknowledgements



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Beyond the CDR

- **October 6**
  Proposal for SXL to the *needs inventory of research infrastructure of national interest**

- **October 28, 09:00-13:00**
  MAX IV User Meeting satellite on ***Ultrafast x-ray science using SXL at MAX IV***
  https://www.maxiv.lu.se/users/user-meetings/ultrafast-x-ray-science-at-max-iv/
  Speakers: Nora Berrah, Steve Johnson, Jon Marangos, Daniela Rupp, Pedro Fernandes Tavares

- **November 18**
  Expression of Intent for SXL to MAX IV

- **Summer 2022**
  Science case workshop