Soft X-ray Laser (SXL) @ MAX IV

Peter Salén

SUFEL

STOCKHOLM-UPPSALA CENTRE FOR FREE ELECTRON LASER RESEARCH

Previous research

- **PhD 2007:** Femtosecond studies of photodissociation and relaxation processes of molecules in liquid phase

- **Employed SUFEL 2007-2017:**

  Research at, and development of, FELs.

  - LCLS - Studies of double-core holes

  - FELIX - New method for obtaining IR-spectra

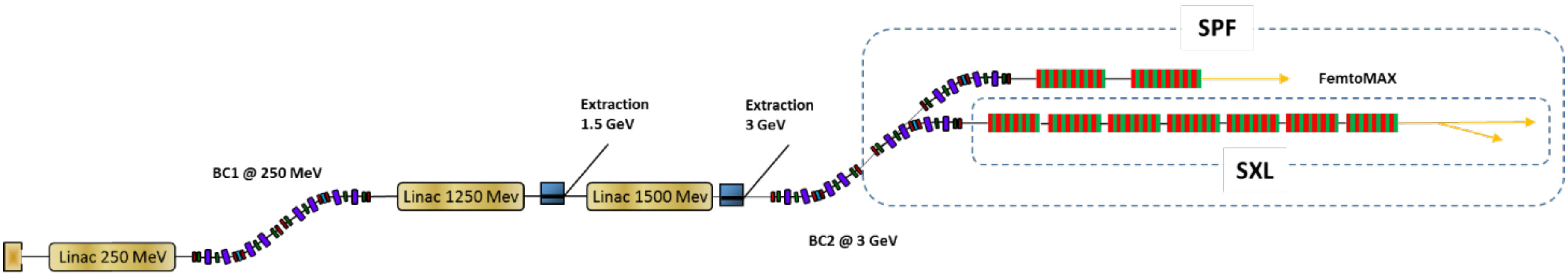
  - Seeding projects at FLASH (ORS, HGHG)

  - Development of THz FEL

  - Single-cycle attosecond source

  - SXL @ MAX IV

SXL @ MAX IV

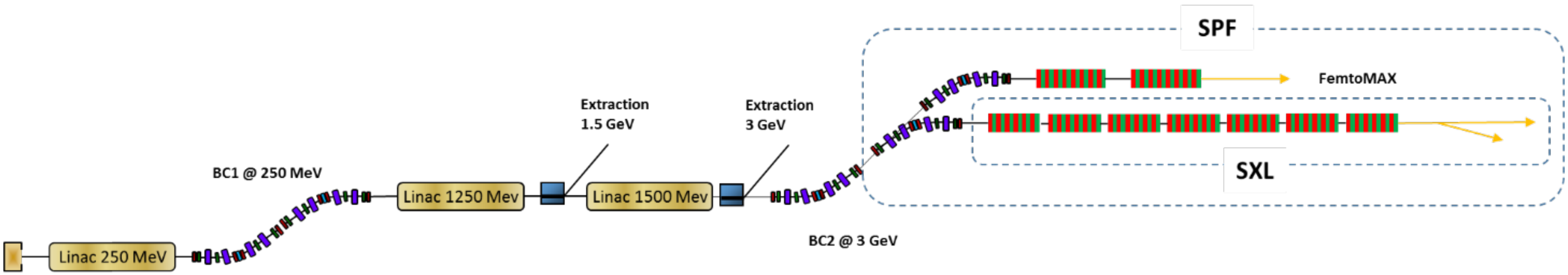


Stockholm University
Uppsala University
Lund University
MAX IV
KTH, GU

SUFEL

SXL @ MAX IV

FemtoMAX: 1.8-20 keV



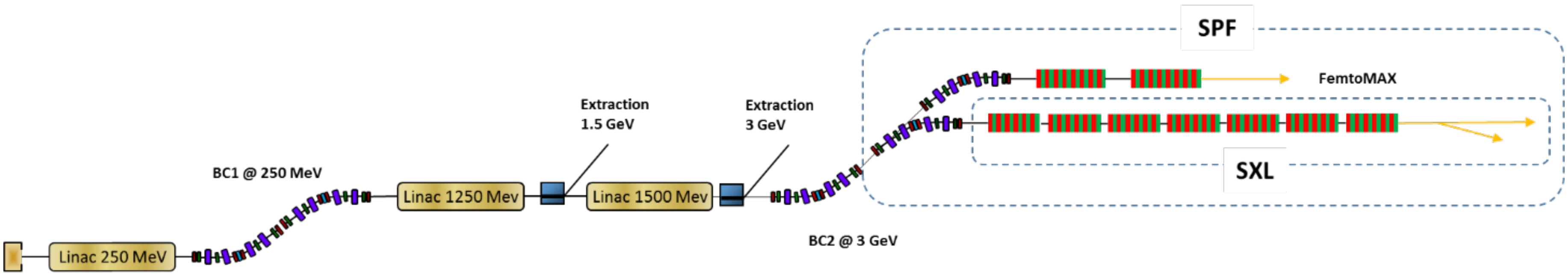
SXL parameters

Wavelength	1 nm	5 nm
Photon energy	1 keV	0.25 keV
e-Energy	3 GeV	1.5 GeV
Photon power (peak)	(GW)	(GW)
Photons/pulse	(10^{12})	(10^{12})
Pulse length (RMS)	10 fs	10 fs
Rep. rate	100 Hz	100 Hz

Features

- SASE baseline design.
- A broad range of pump-possibilities for pump-probe experiments from day one.
- Two-pulse and two-color options will be developed at an early stage.
- Seeding schemes, attosecond pulses and THz upgrades are envisioned at a second stage.

SXL @ MAX IV

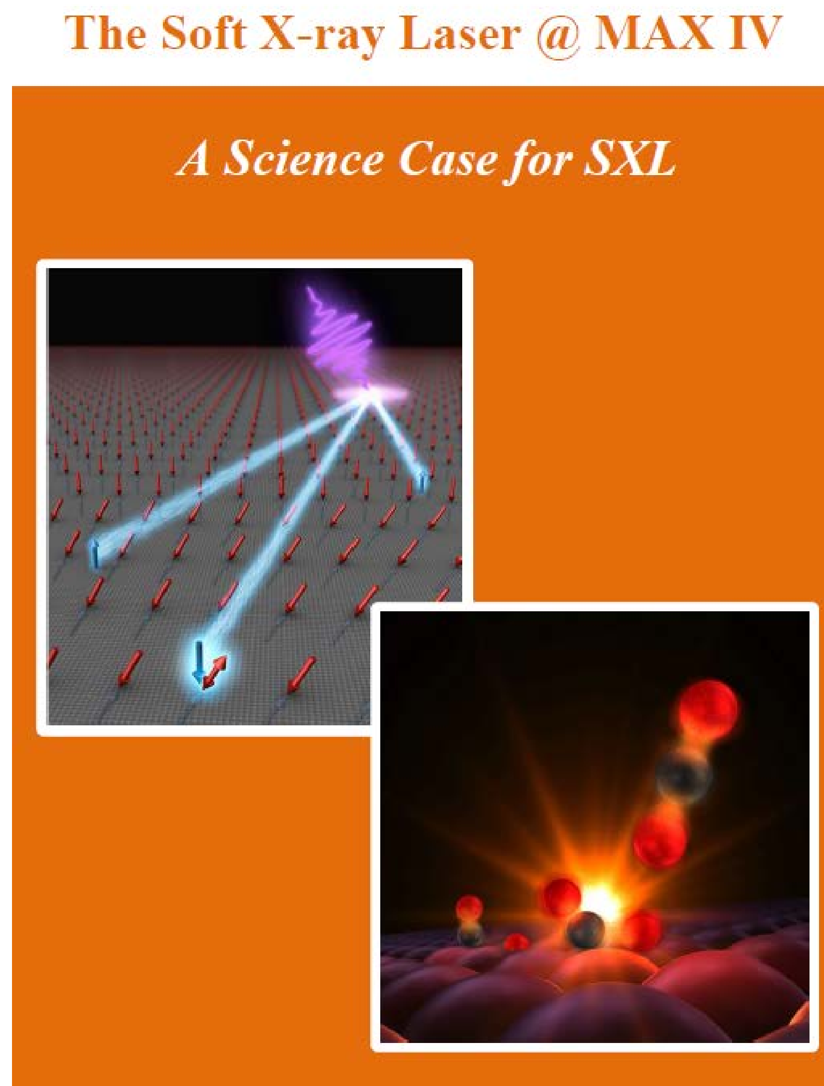


	Period (year)
Science Case	2015-2016
Conceptual Design Study	2017-2018
Construction	2019-2022

SXL @ MAX IV – Science Case

Workshop March 2016

-> Science Case document



www.frielektronlaser.se

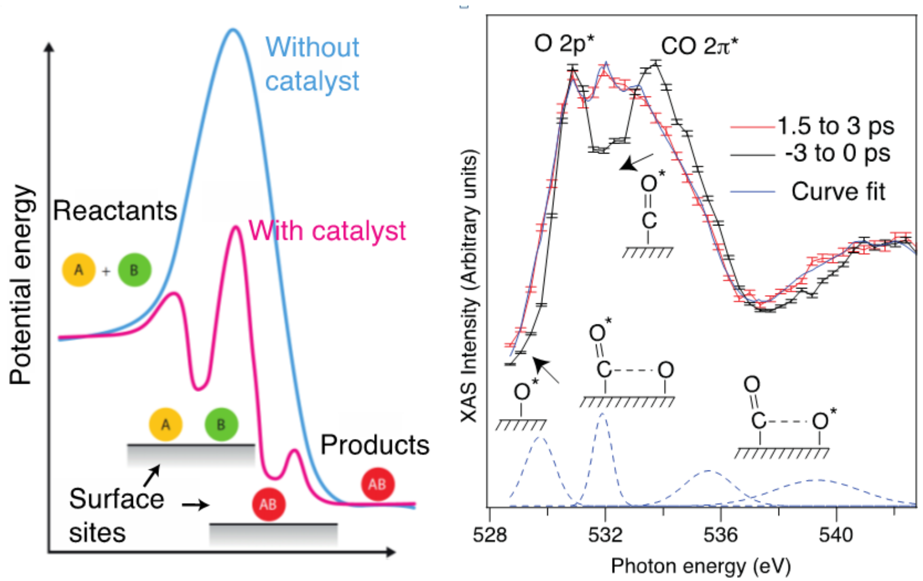
Science Case - Chemistry

Catalysis

To develop sustainable energy sources

Understand catalytic reaction mechanisms

Transition state is the key

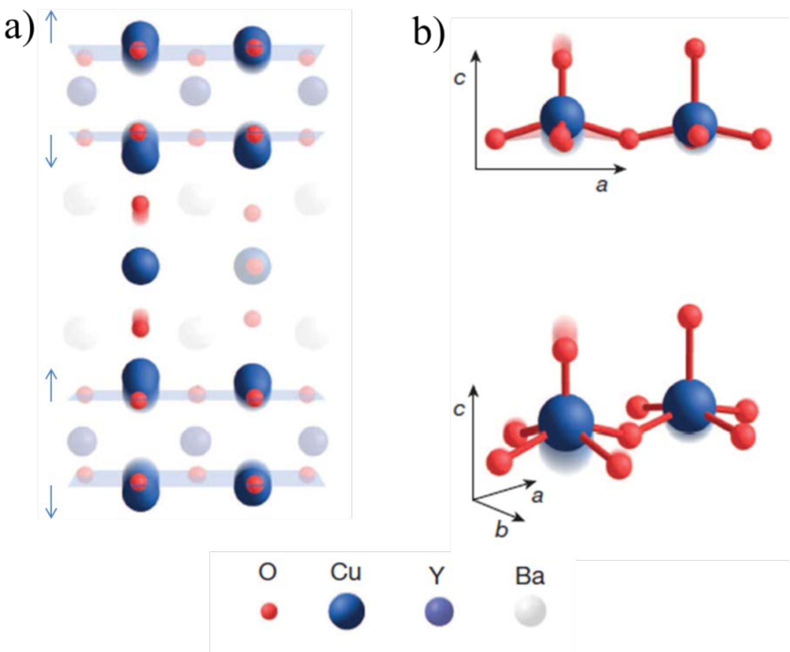


H. Öström et al. Science **347**, 978 (2015)

SXL provides broad range of pumping possibilities combined with core-level probing

Science Case – Condensed Matter

Superconductivity



IR-THz pump induce SC properties

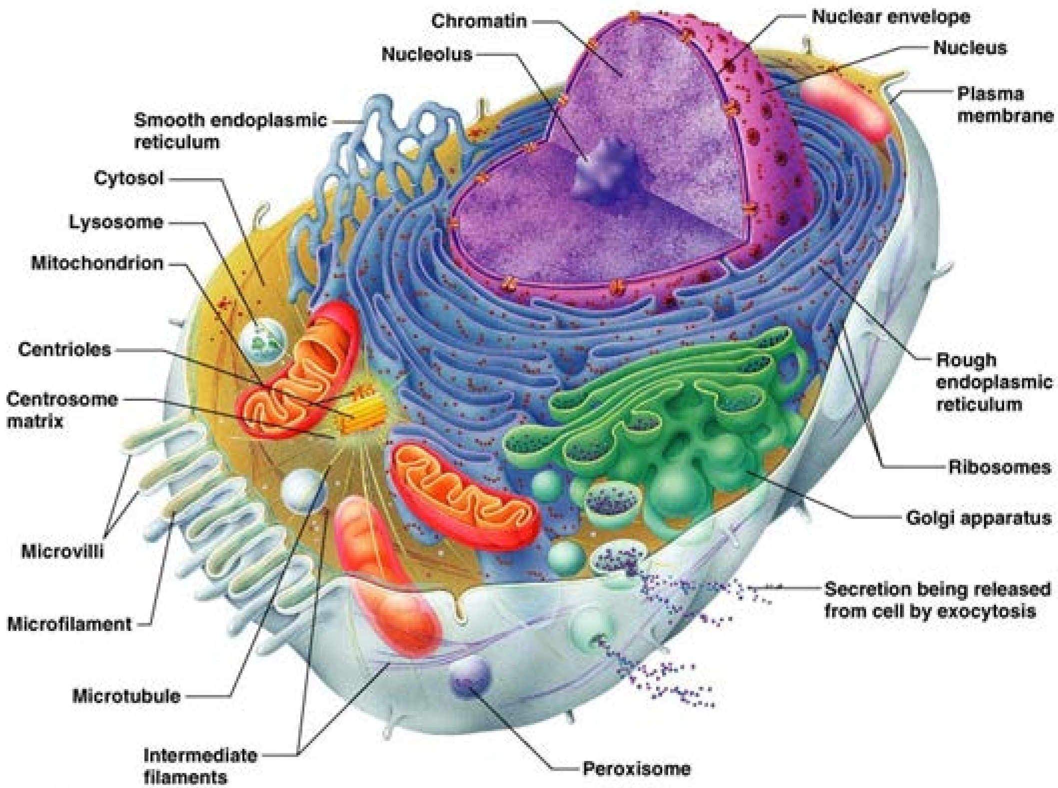
X-ray scattering => lattice structure

New insights from SXL using SAXS resonantly at O K-edge?

R. Mankowsky *et al.*, Nature **516**, 71 (2014)

Science Case – Life Science

Imaging living cells



"Human Anatomy & Physiology" E. N. Marieb, Pearson Eduction (2004)

Conceptual Design Study

KAW funding application for CDS 22.7 MSEK

KAW: 10.5 MSEK
Co-funding: 12.2 MSEK (SUFEL, MAX IV, LU)

Human resources: 15 MSEK
(Accelerator and FEL work)

Hardware: 7.7 MSEK
(Transverse deflecting cavity, low emittance gun)

The Soft X-ray Laser @ MAX IV

Funding Application for a
Conceptual Design Study

Stockholm University
Uppsala University
Lund University
MAX IV

Conceptual Design Study

Work packages

Work package	Description
1	Organisation
2	Science
3	Accelerator
4	FEL
5	Beamline
6	End stations
7	Budget
8	Infrastructure

Conceptual Design Study

Investigate required linac properties and upgrades

Linac parameters

Energy	3 GeV
Energy spread	<0.05% + chirp
RF frequency	3 GHz
Rep. rate	1-100 Hz
Bunch length	10-500 fs
Charge per bunch	20-200 pC
Normalised emittance	<1 um

Pre-study of linac's suitability as FEL driver performed in fall 2016 => <u>No show stoppers</u>

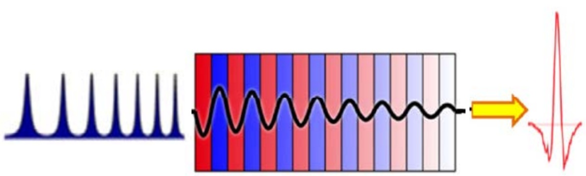
Necessary linac activities during CDS:

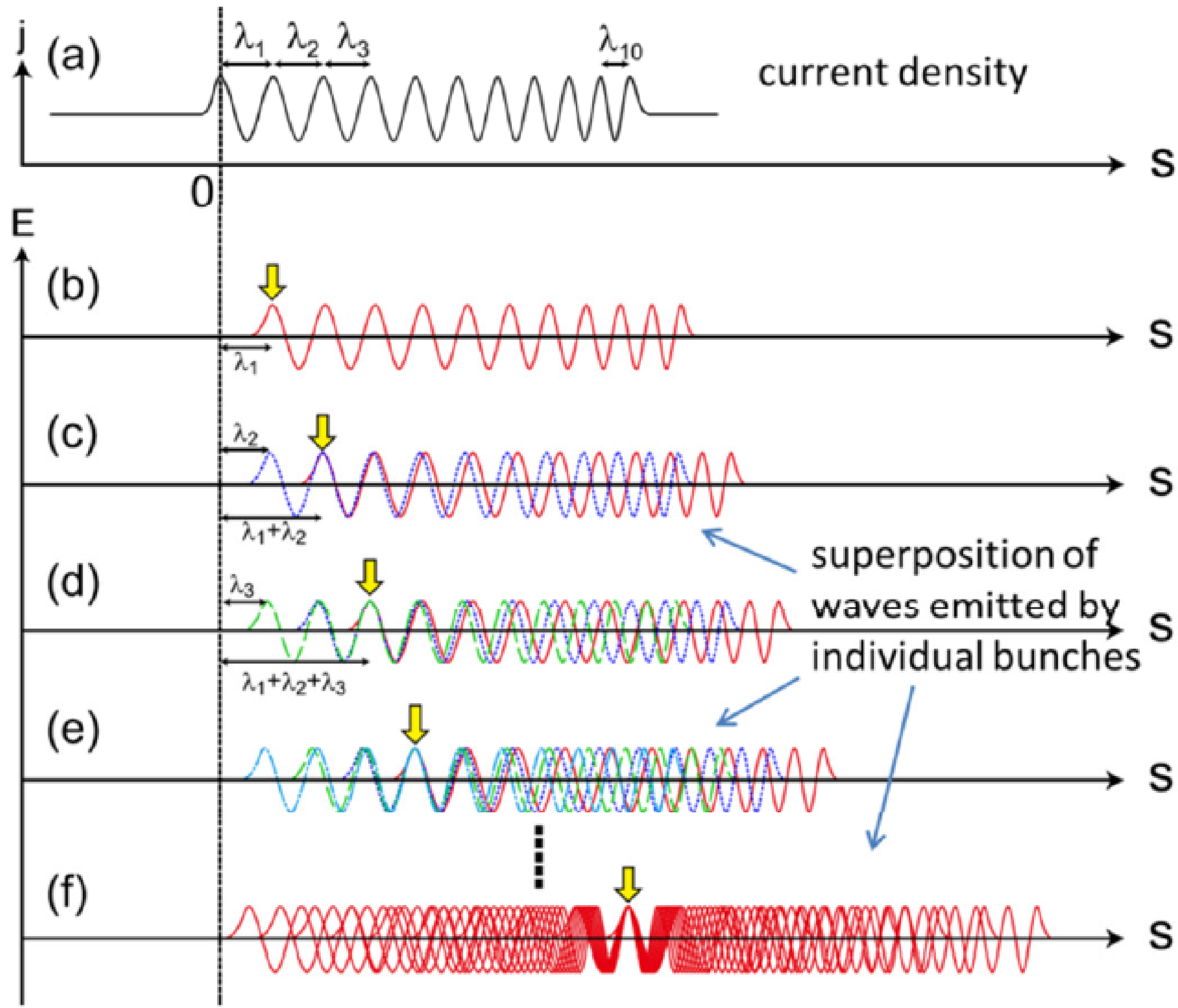
- New gun -> reduce emittance (0.4 um)
- Install TDC -> measure emittance, energy spread, bunch profile
- Investigate if bunch compressors must be changed in order to reduce chirp
- More theoretical studies of linac as FEL driver

Possible SXL upgrades based on SUFEL projects

- THz FEL (single-cycle THz pulses)
- Attosecond pulses (single-cycle soft X-ray pulses)

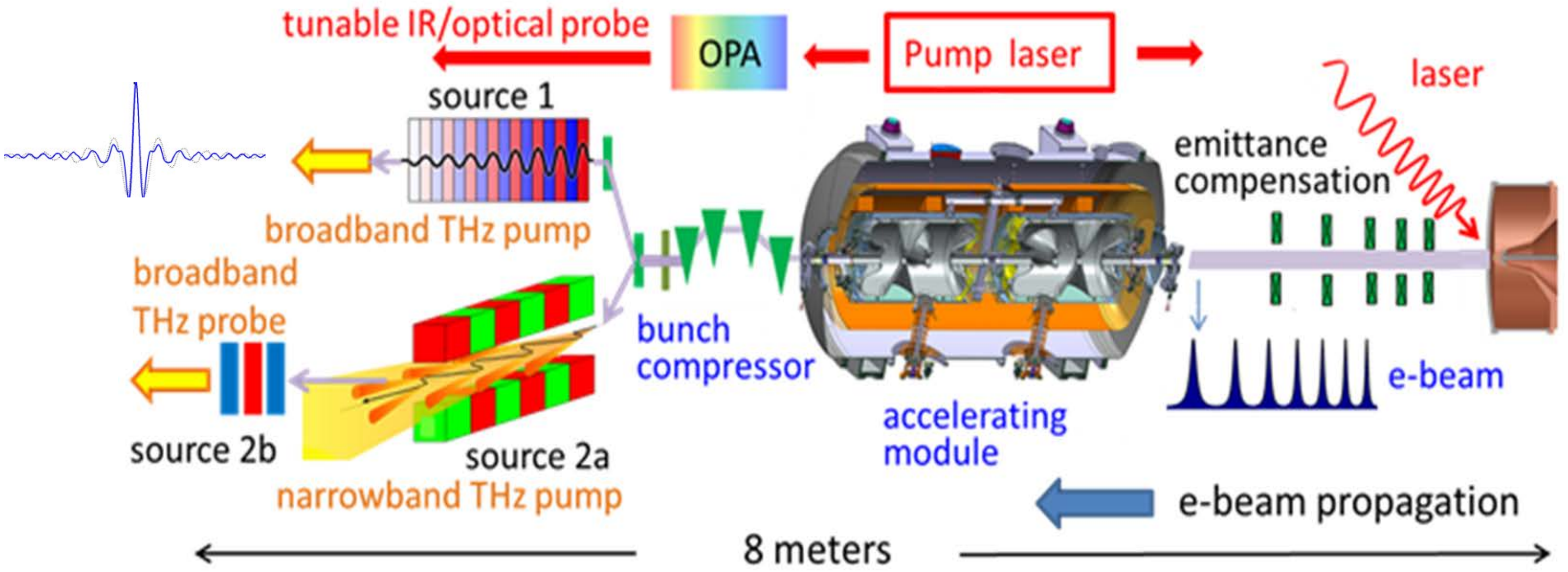
Single-cycle generation





T. Tanaka et al. PRL **114**, 044801 (2015)

THz FEL



Vitaliy Goryashko, UU

Uniqueness:

- The first THz-source designed specifically for pump-probe experiments
- Covers the range of 1.5 - 15 THz, exceeding laser-based THz sources
- Quasi-half-cycle pulses with field strength (GV/m) and repetition rate (1-100 kHz)

White Paper on THz Coherent Light Source in Uppsala

Stockholm-Uppsala Centre for

Free Electron Laser Research

Version 1, February 2016

Contents

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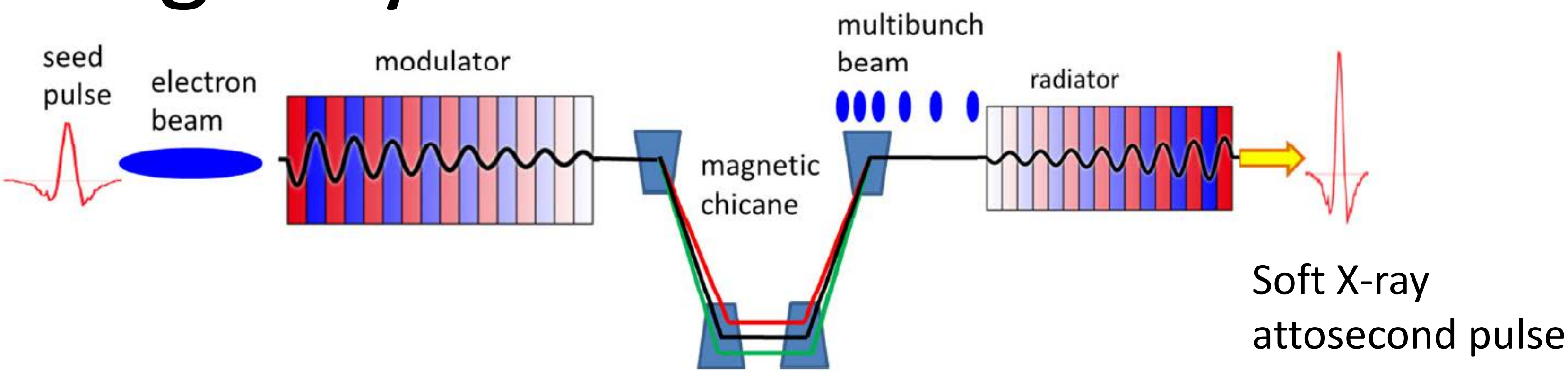
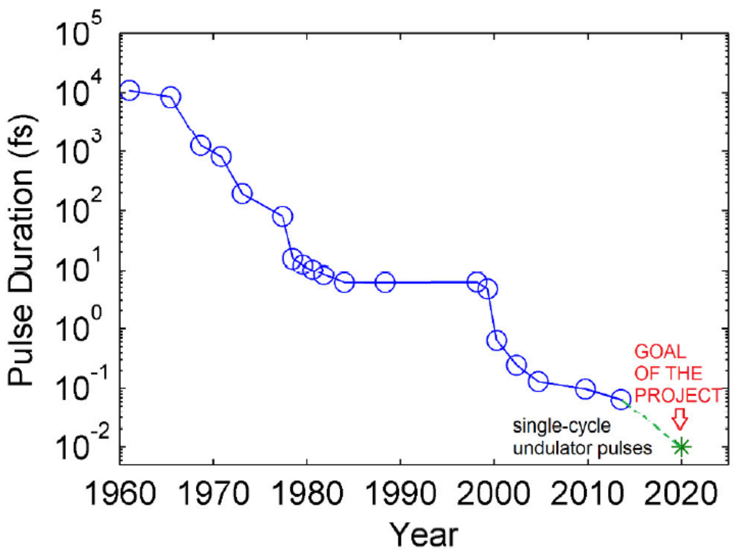
Single-cycle attosecond source



- Lead by Vitaliy Goryashko
- Collaboration with: PITZ (GER), Daresbury (UK), Kharkov (Ukraine), ELI, T. Tanaka (Japan)
- Meeting yesterday at PITZ
- Horizon 2020 application for design study
    - Proof-of-principle in THz range – at PITZ
    - Design for attosecond source

Single-cycle attosecond source



Nature phot. **5**, 655 (2011)
Nature phys. **3**, 381 (2007)

	Our technique	Present HHG	Proposed ELI-ALPS GHHG	SHHG
Pulse length (as)	15	70-500	6	5
Photon energy (eV)	>120	15-120	220-330	400-1000
Pulse energy	10 nJ	100 pJ (below 100 as)	1 nJ	10 mJ

Single-cycle attosecond source

Science case

10 as - timescale for **electron correlation**
- enables detailed study of
charge migration, strongly correlated systems, catalysis, magnetism…

10 nJ required for attosecond pump - attosecond probe -> **attochemistry**

Soft X-rays permits study **more molecules and materials** with attosecond resolution

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