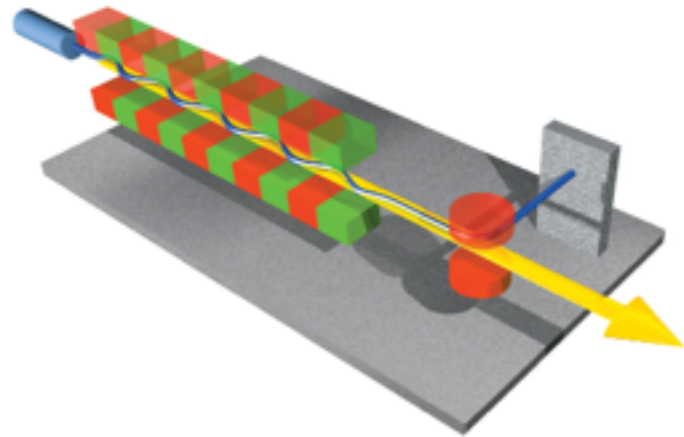


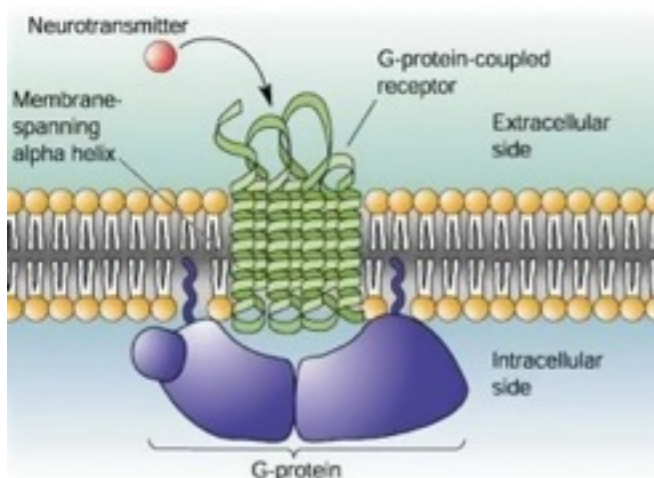
# SwissFEL — Methods and Opportunities



Physical principles of a free electron laser



Technology behind SwissFEL

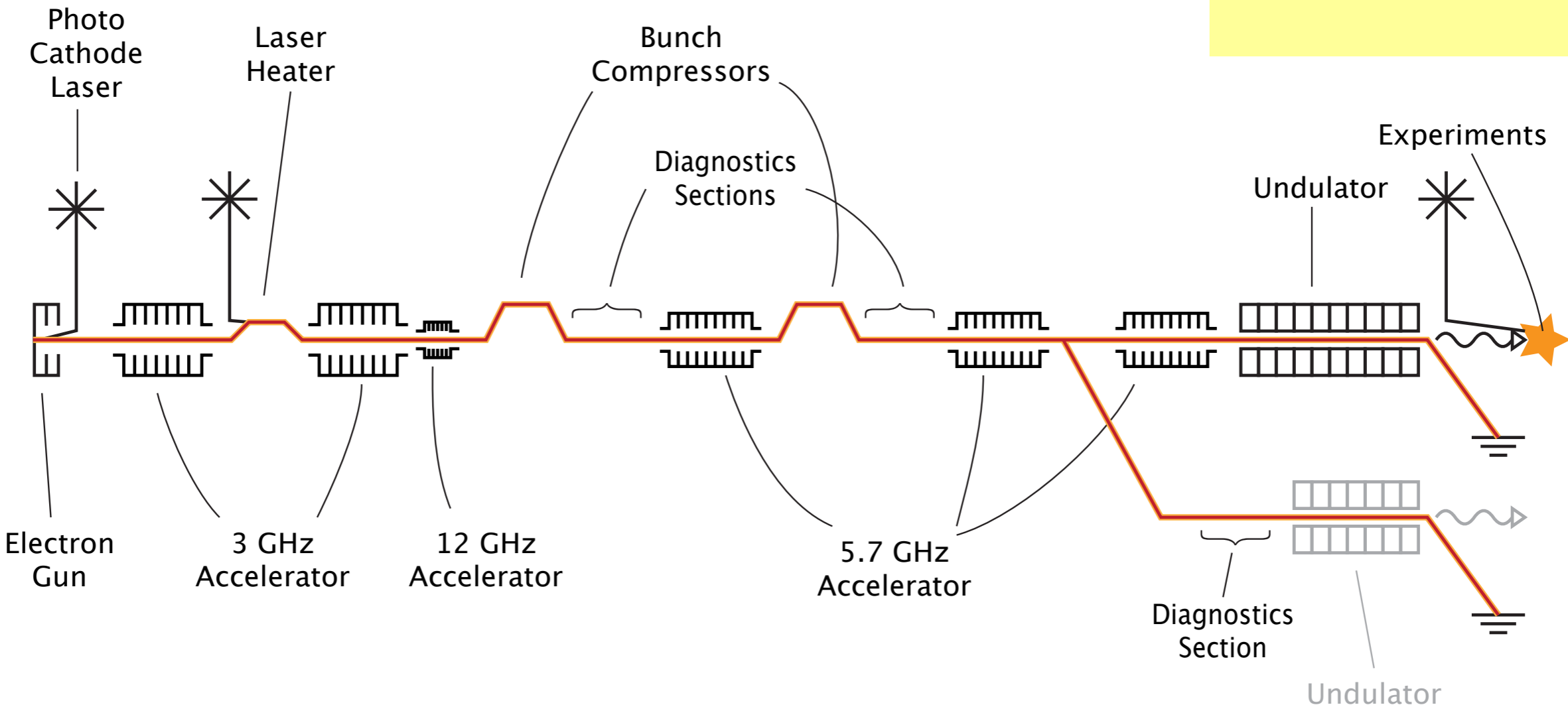


Priority experiments for SwissFEL

# SwissFEL — Methods and Opportunities

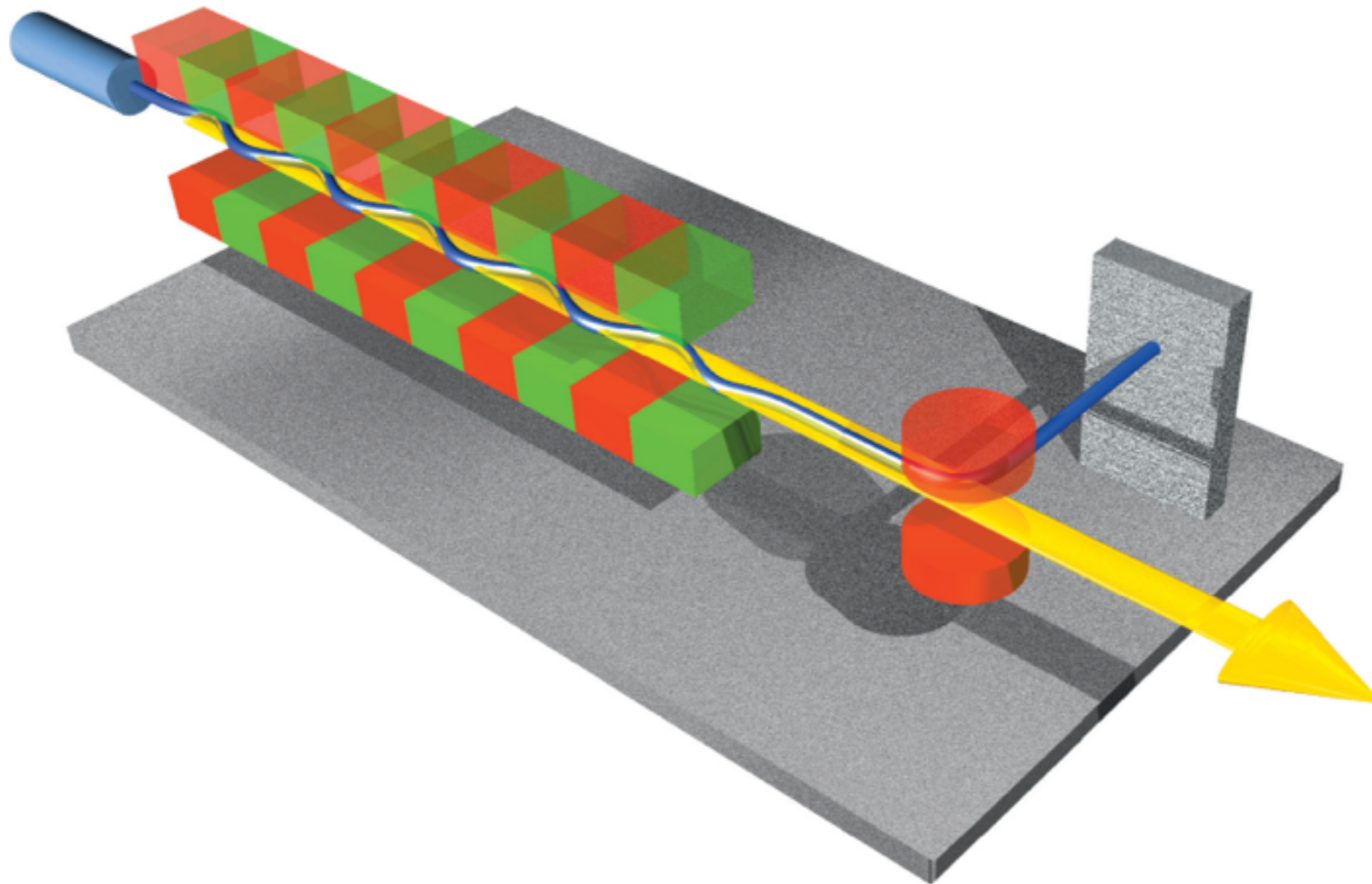
- > X-Ray free electron laser
- > Short pulses, down to few-femtosecond pulse lengths

Main parameters	
Wavelength from	1 Å - 70 Å
Photon energy	0.2-12 keV
Pulse duration	1 fs - 20 fs
e <sup>-</sup> Energy	5.8 GeV
e <sup>-</sup> Bunch charge	10-200 pC
Repetition rate	100 Hz



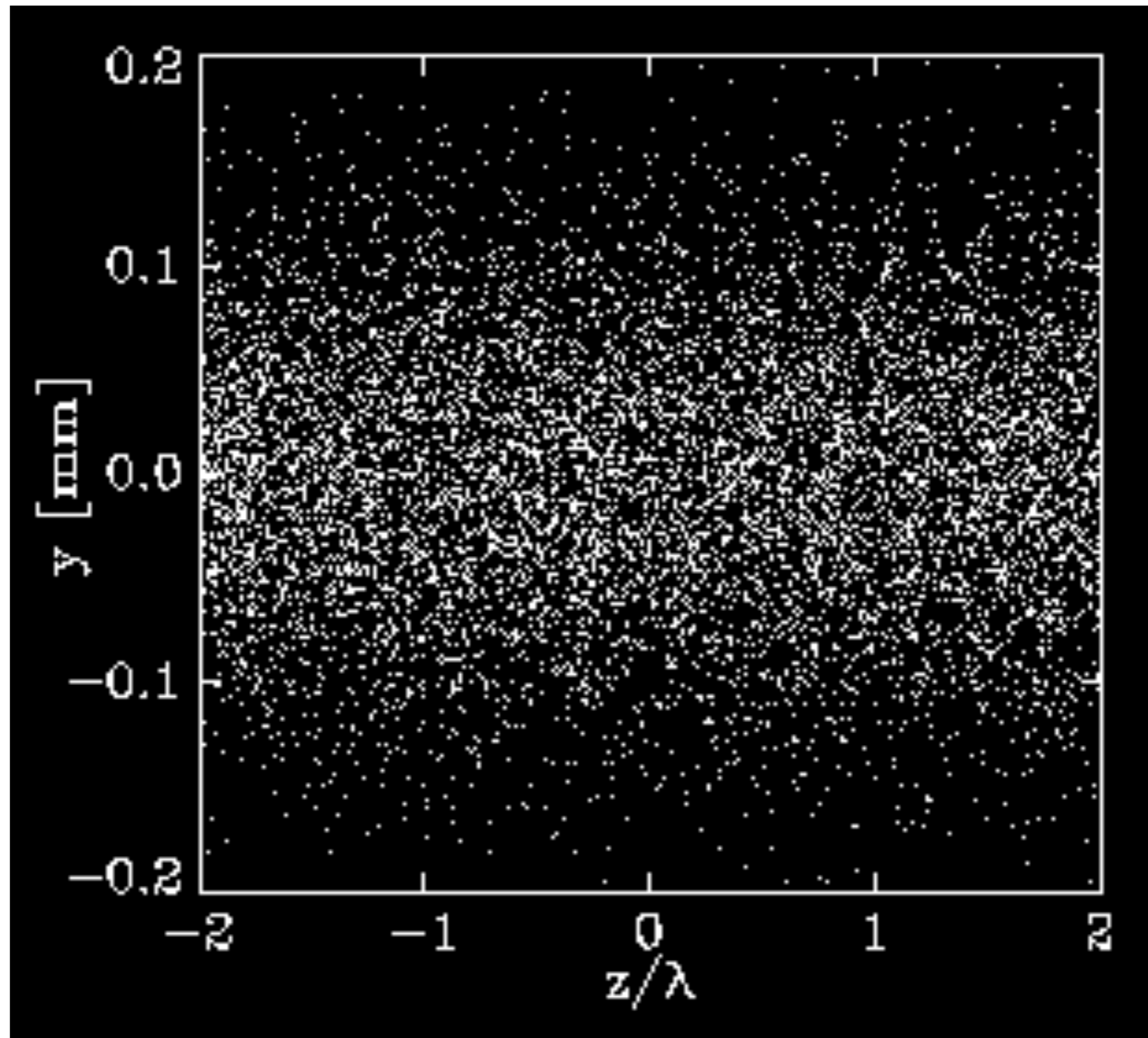
# Physical Principles of a Free Electron Laser

- > Lasing medium: relativistic electron bunch in an undulating magnetic field



# Physical Principles of a Free Electron Laser

> Electric field of the radiation results in microbunching of the electrons:

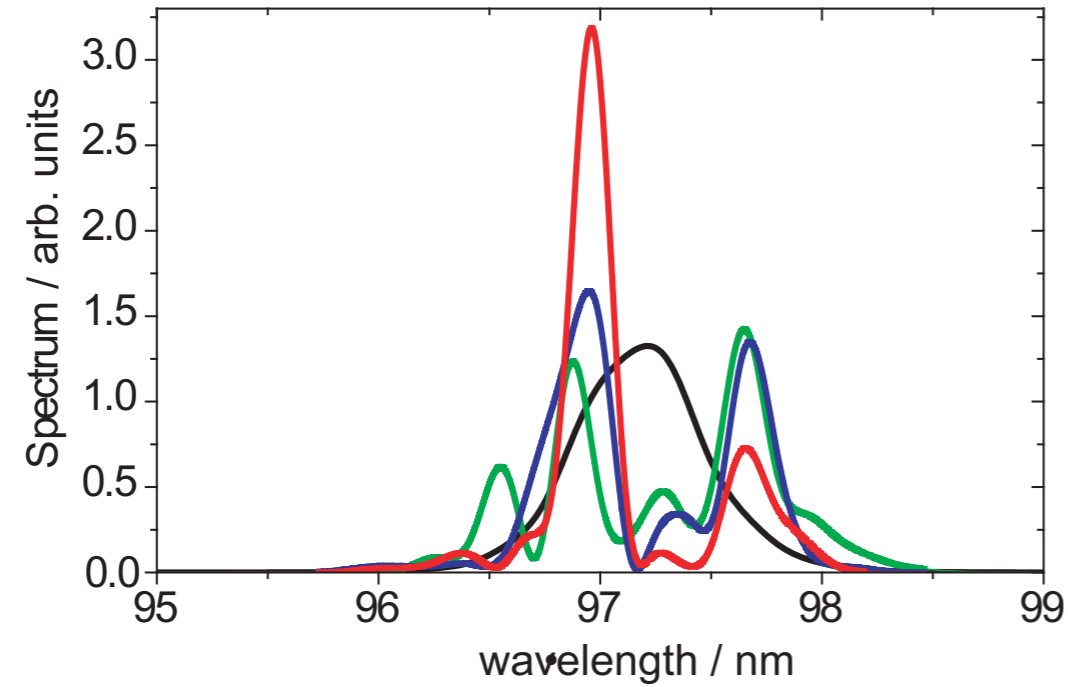


# Properties of FEL radiation

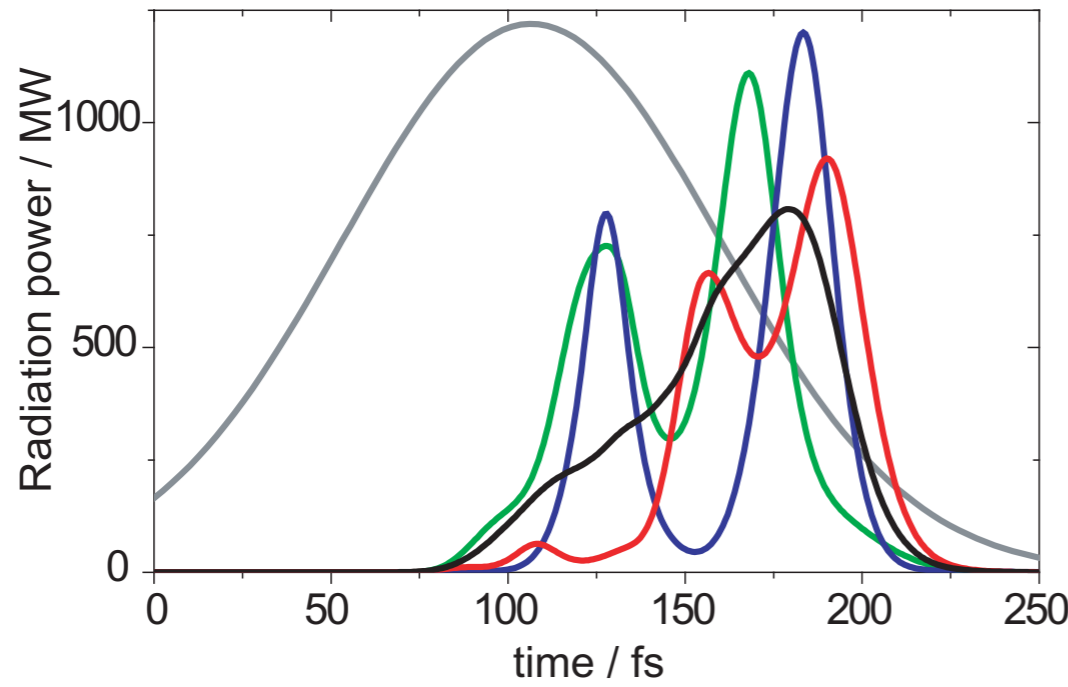
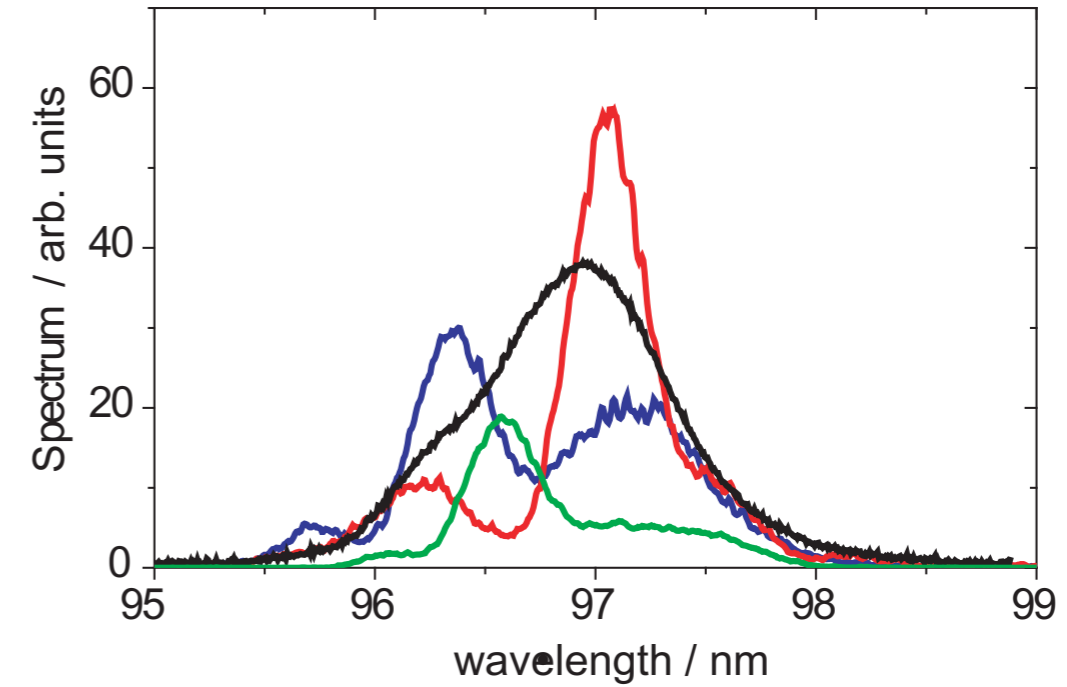
- > Wavelength of the radiation determined by undulator parameters and electron energy
  - > Fully tunable across many octaves
  - > Projects realized from THz to hard X-rays
- > Narrow bandwidth  $\sim 0.1\%$
- > Short pulses of  $\sim$ fs duration have been demonstrated
- > Large degree of coherence
- > Statistical fluctuation of spectral and temporal profile

# Properties of FEL radiation

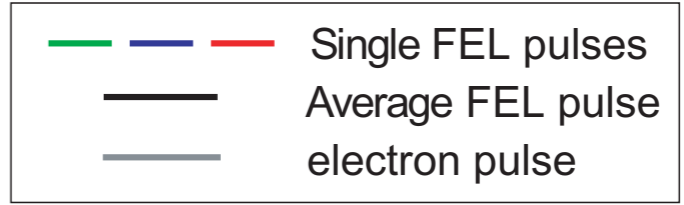
FEL Theory  
(simulated with the code FAST)



Experiment  
(measurements at the TESLA Test Facility)

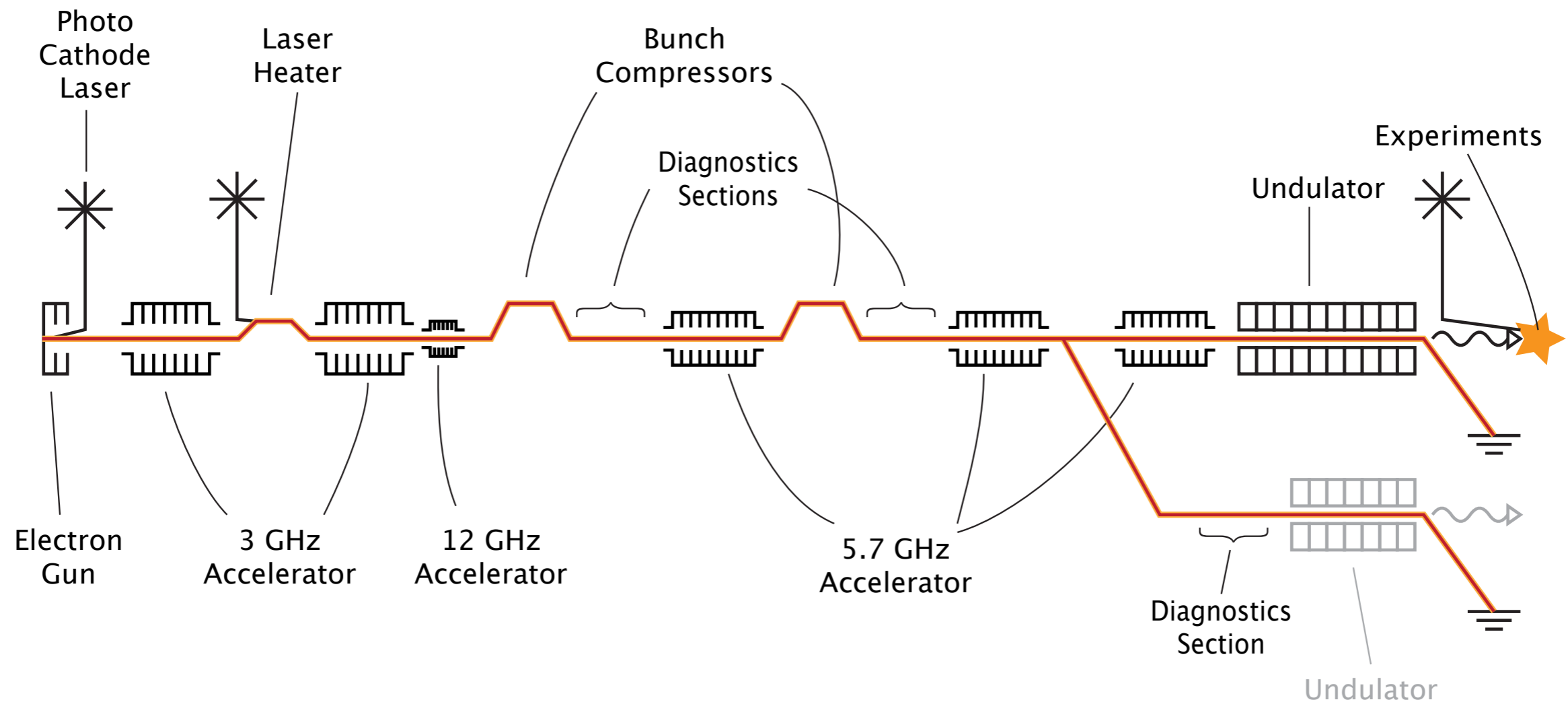


An experiment with sufficient time resolution is still missing

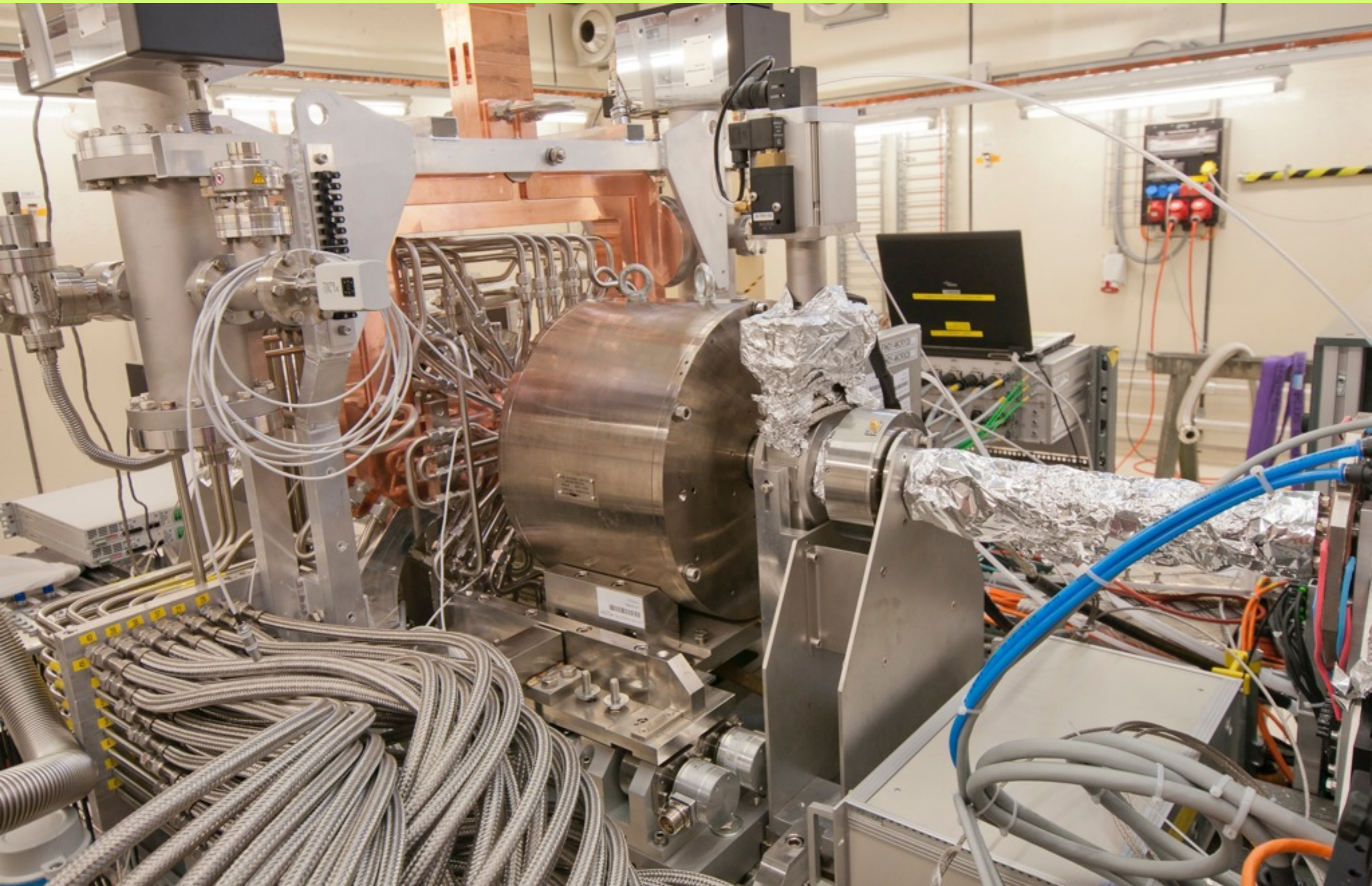


# SwissFEL — Overview

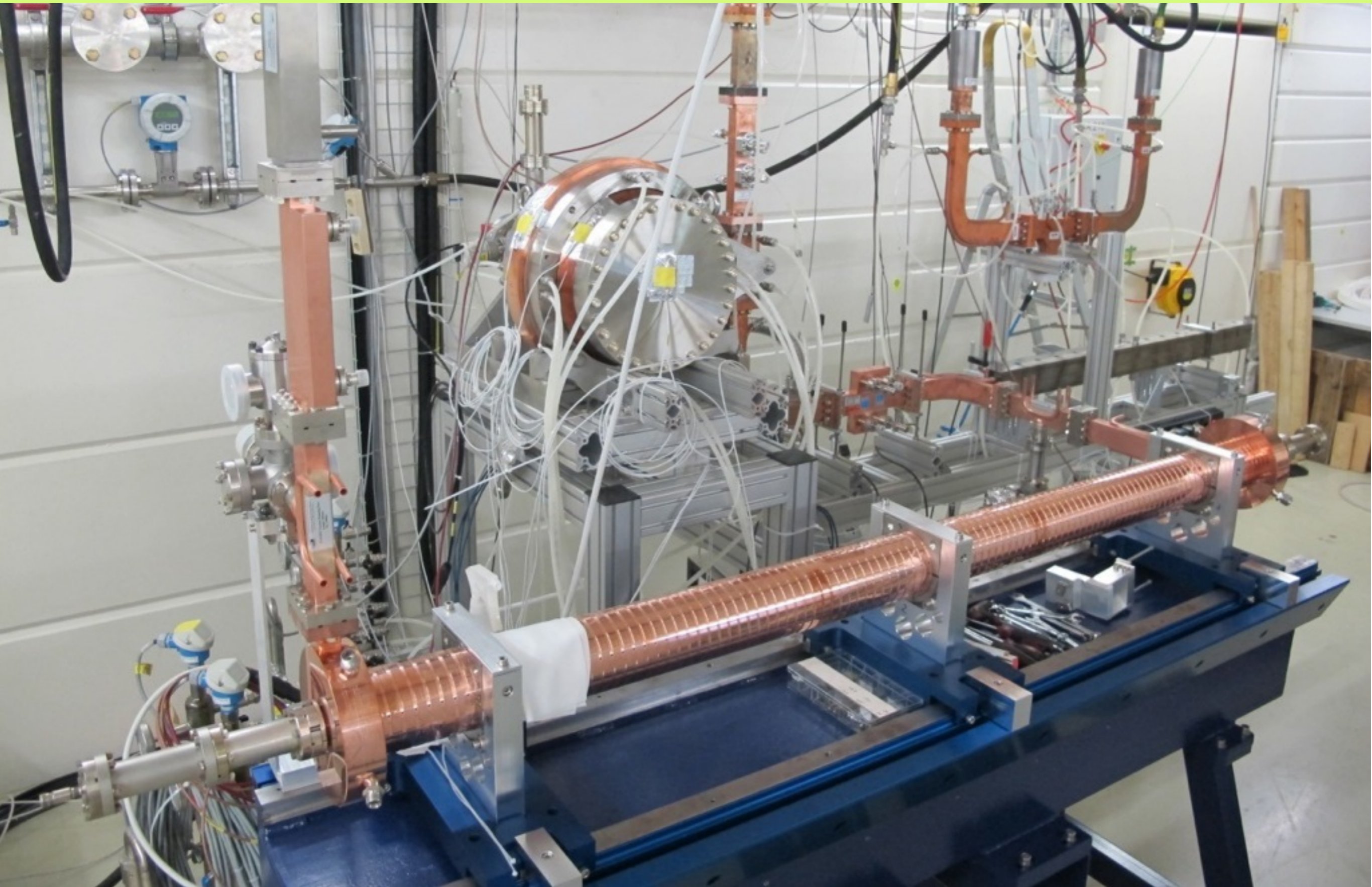
- > X-rays emitted by coherently radiating free electrons
- > Electron pulses, generated by picosecond UV laser
- > Acceleration to relativistic energies
- > Radiation in permanent magnet undulator
- > Pump-probe experiments with Ti:Sa laser



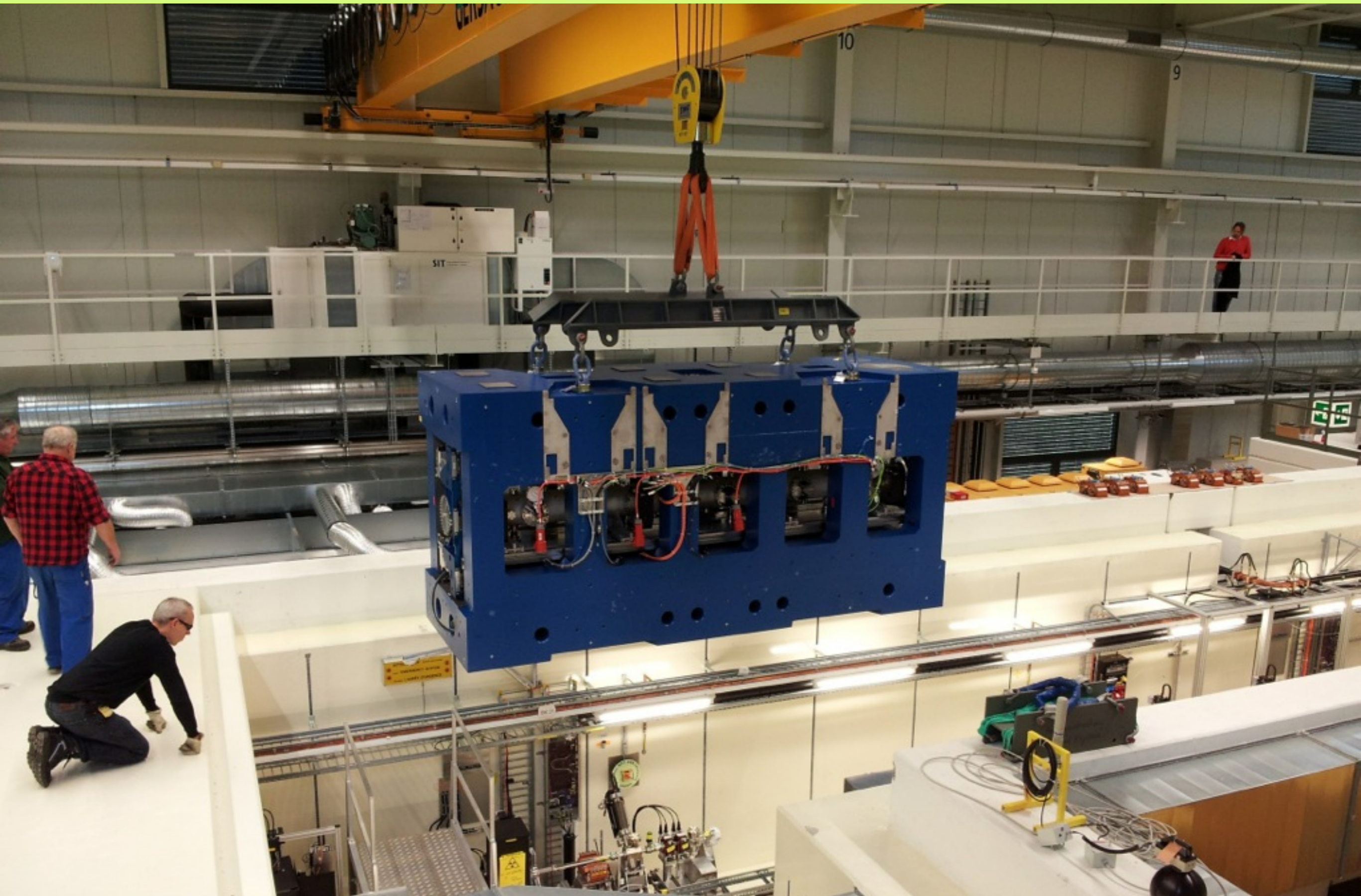
# Electron pulses, generated inside RF accelerating cavity



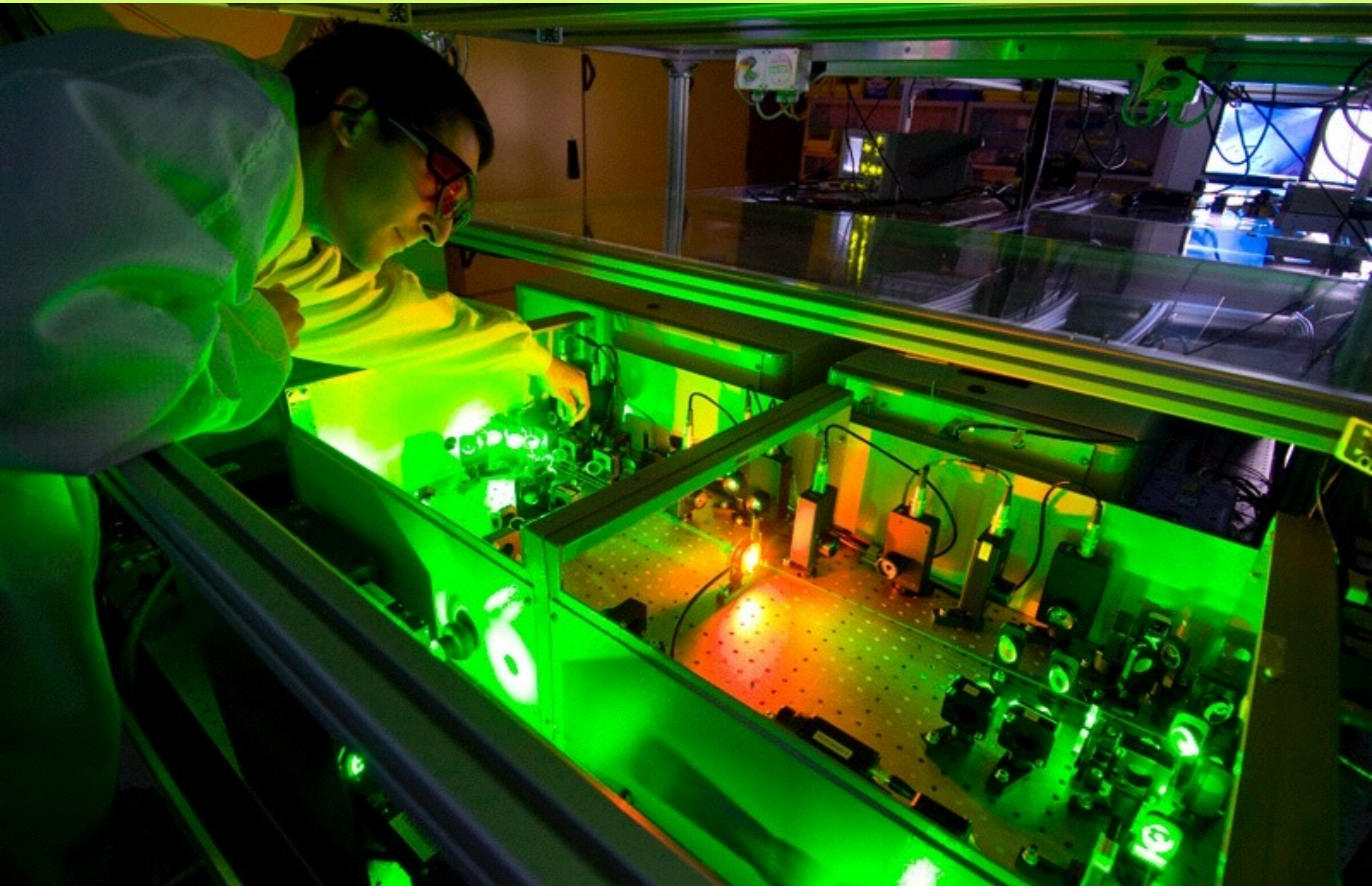
# Acceleration to relativistic energies



# Radiation in permanent magnet undulator

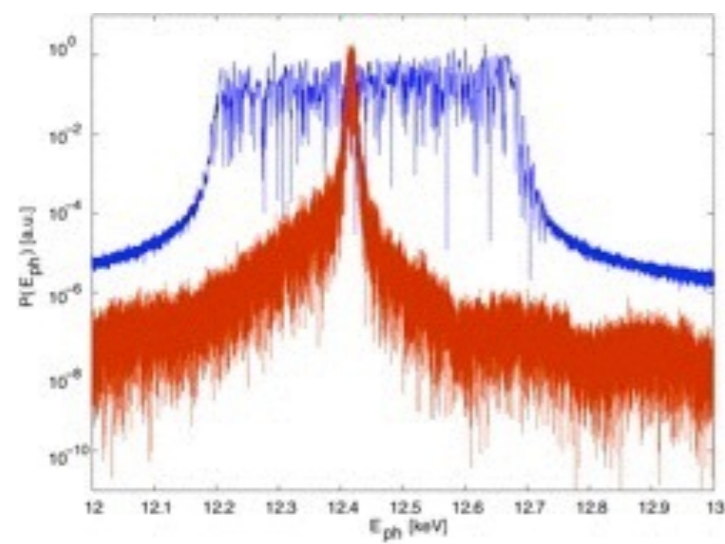


# Pump-probe experiments with Ti:Sa laser

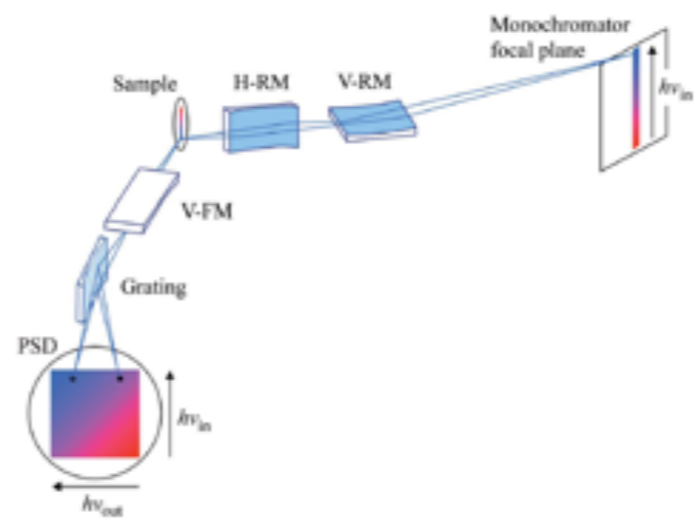


## ◆ Broadband mode

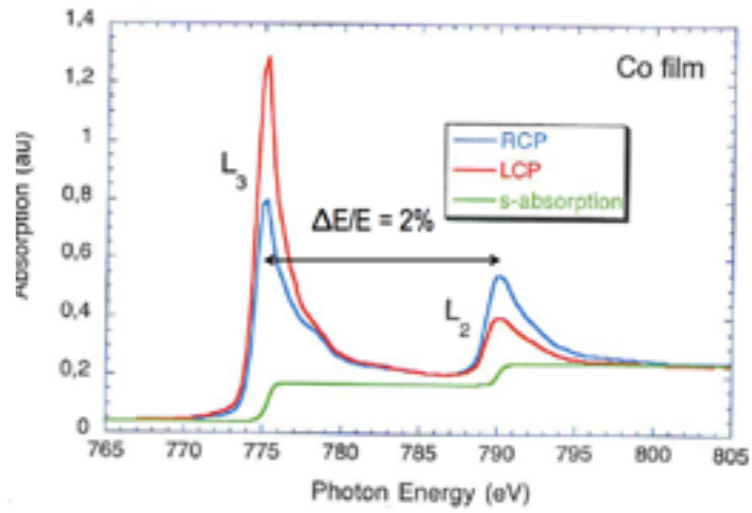
4% FWHM bandwidth, using accumulated wake fields



Reiche (2011)



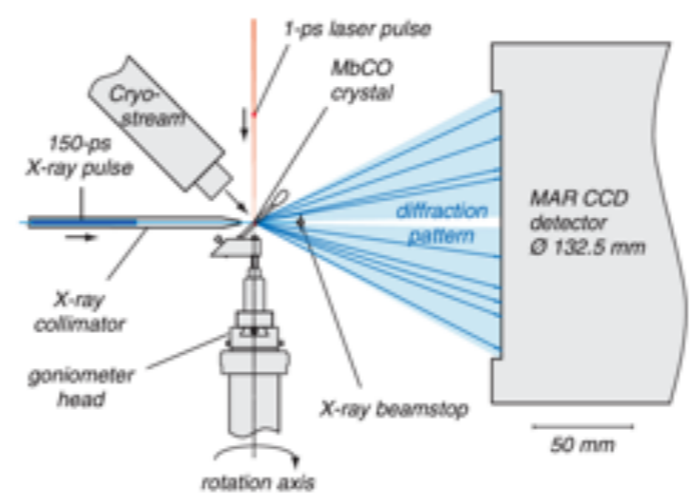
Strokov, J Synch Rad (2009)



single-shot:  
XAS / RIXS / XMCD

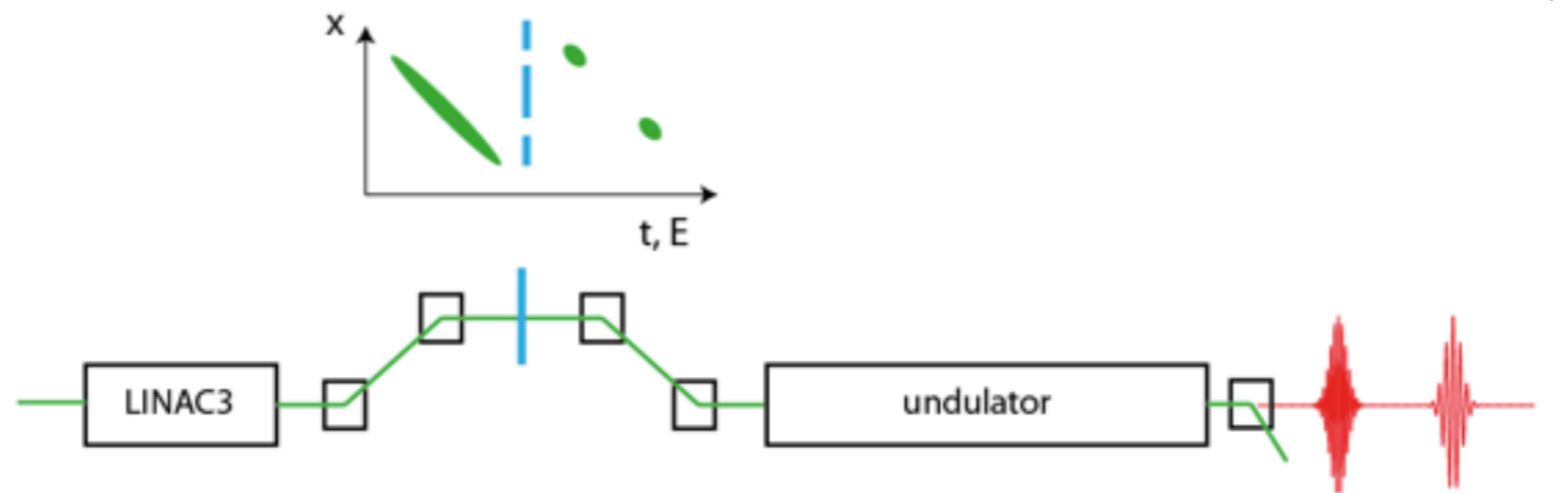
Laue crystallography

Schotte, Science (2003)

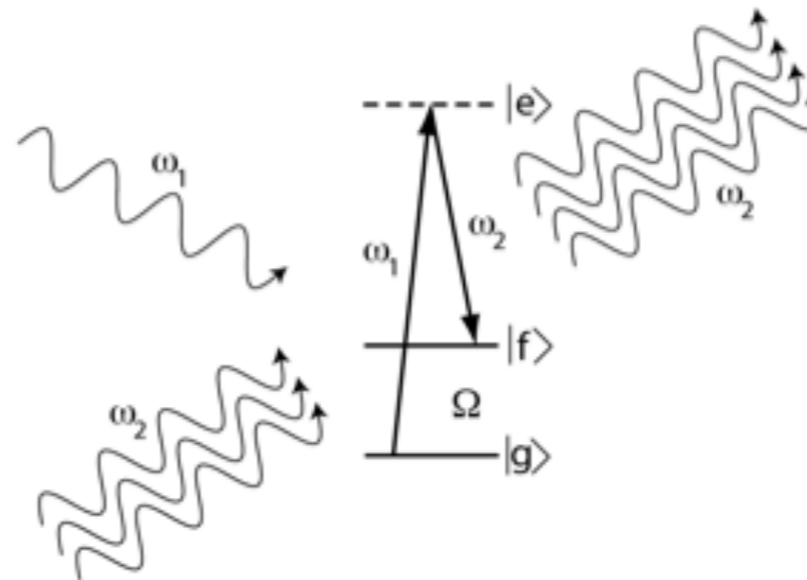


## ◆ Two-color pulses

chirped electron pulse, slotted spoiler in bunch compressor



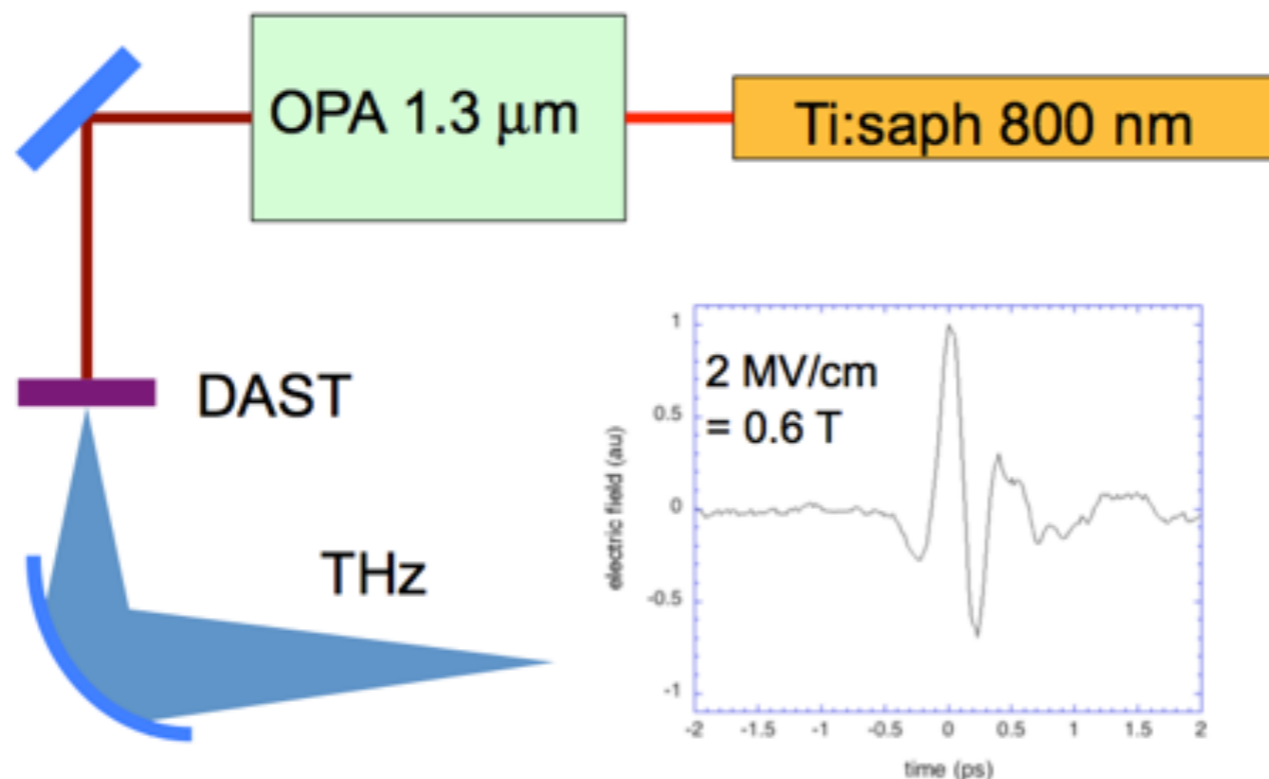
X-ray pump / X-ray probe  
stimulated RIXS



Patterson, SLAC Tech. Rep (2010)

## ◆ High-field THz pump

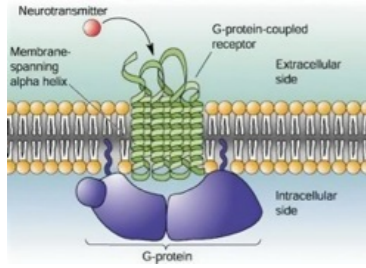
generate single-cycle THz pulse with non-linear crystal



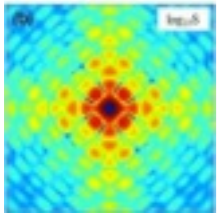
Hauri, Chimia (2011)

synchronized with XFEL gun and pump lasers  
magnetic switching, initiation of chemical reactions  
THz-streaking XFEL pulse arrival time diagnostic

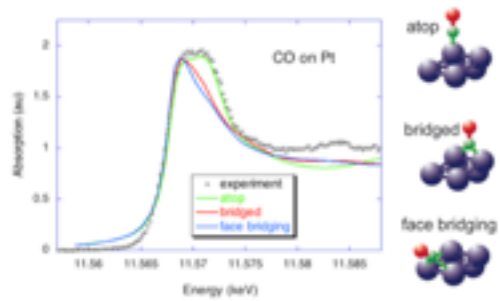
# Priority experiments



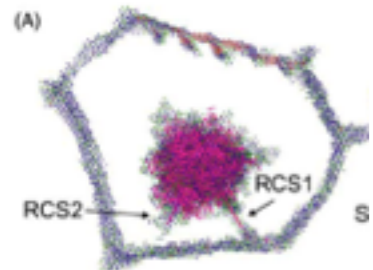
Biochemical structure and dynamics



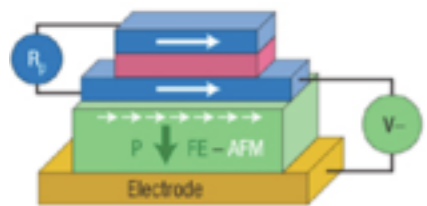
Photochemistry in solution



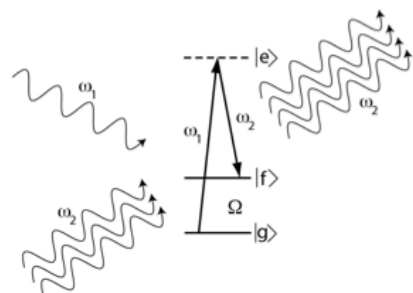
Catalysis and artificial photosynthesis



Dynamics in nuclear materials



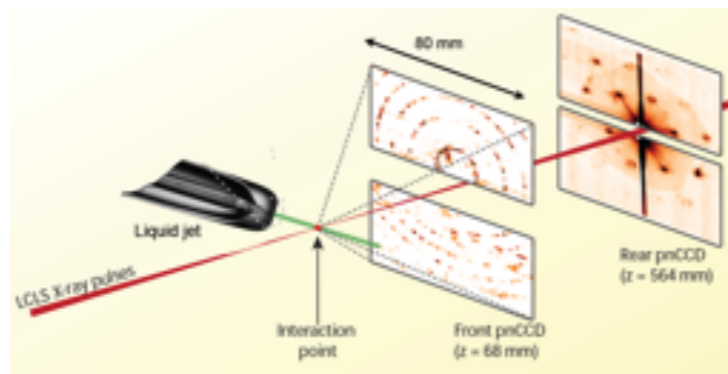
Electronic materials



X-ray non-linear optics

# 1. Biochemical structure and dynamics

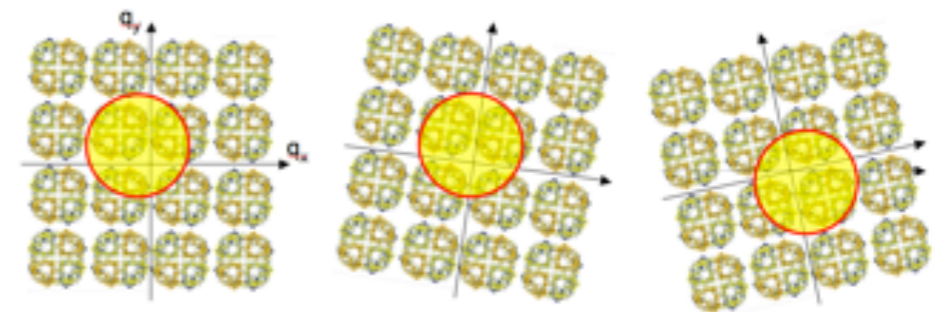
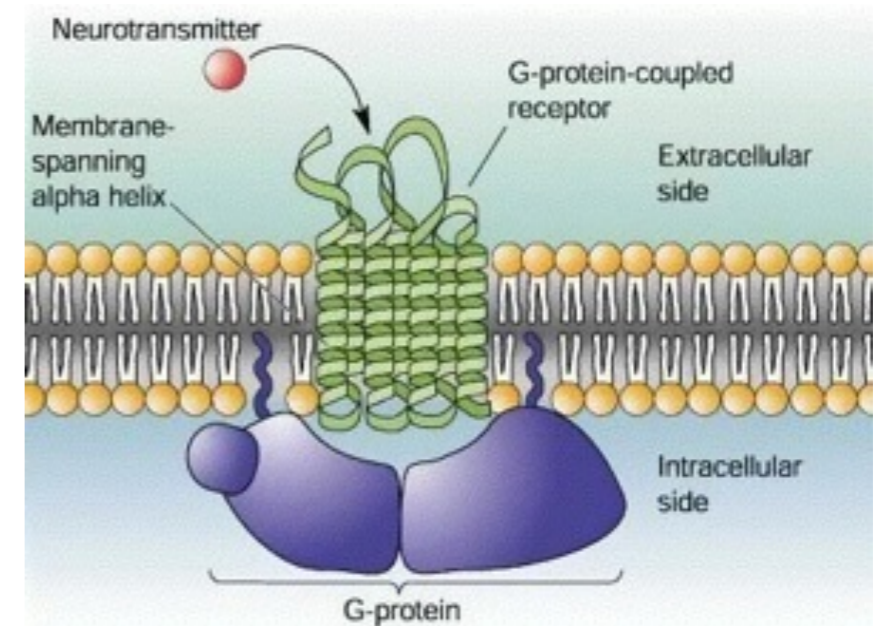
- ◆ *What conformational changes are induced in GPCRs by binding to pharmaceutically important ligands?*



Chapman, Nature (2011)

jet-injection nano-crystallography

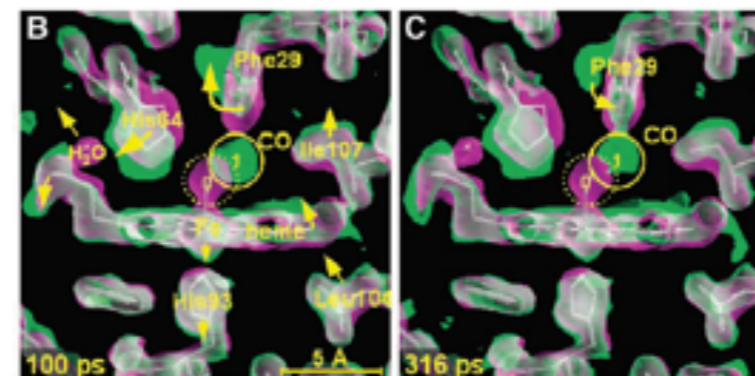
## G-protein-coupled receptors



Kewish, NJP (2010)

ptychographic 2D-crystallography on cryo-stage

pump-probe Laue crystallography



Schotte, Science (2003)

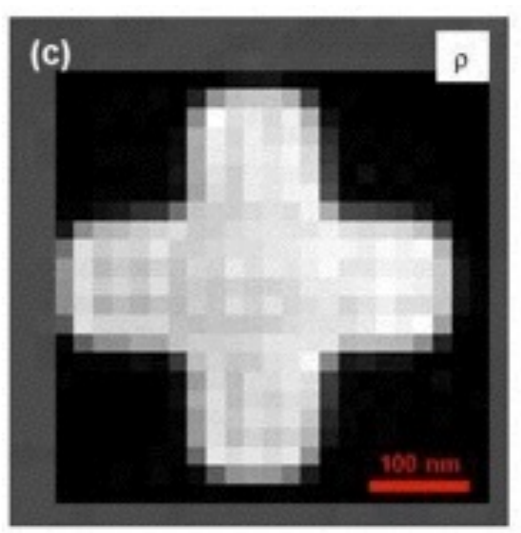
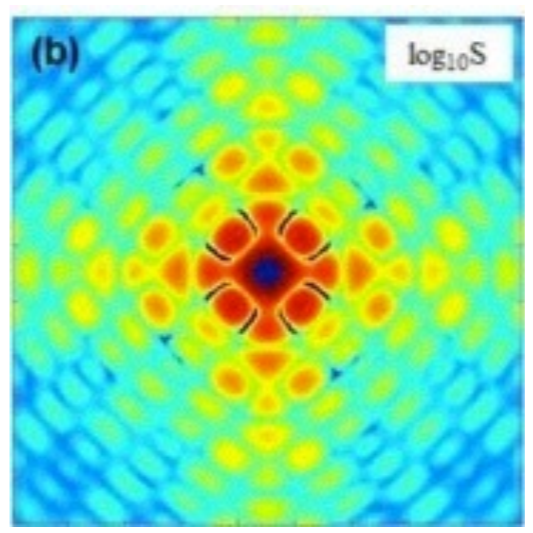
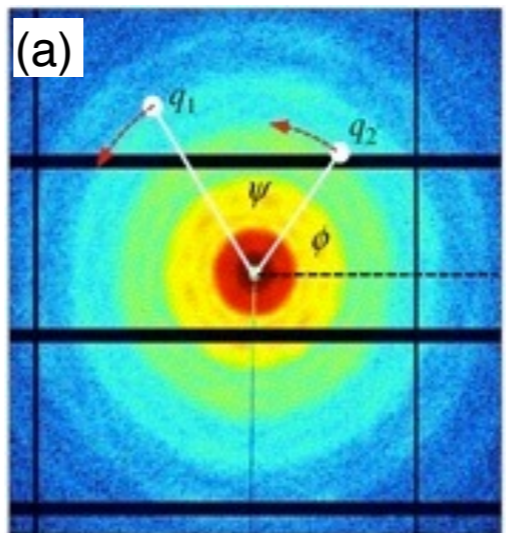
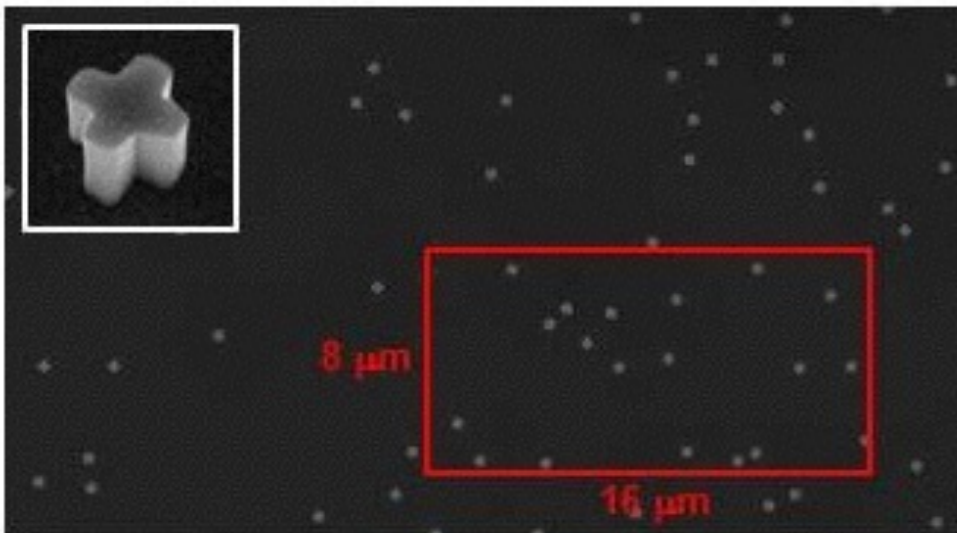
# 2. Photochemistry in solution

- ◆ *To follow in real time the structural changes accompanying a biochemical reaction in solution.*

photo-trigger:  
caged molecules

instantaneous structure:  
cross-correlation scattering

<http://w3.dbb.su.se/~barth>



Pedrini, in press (2012)

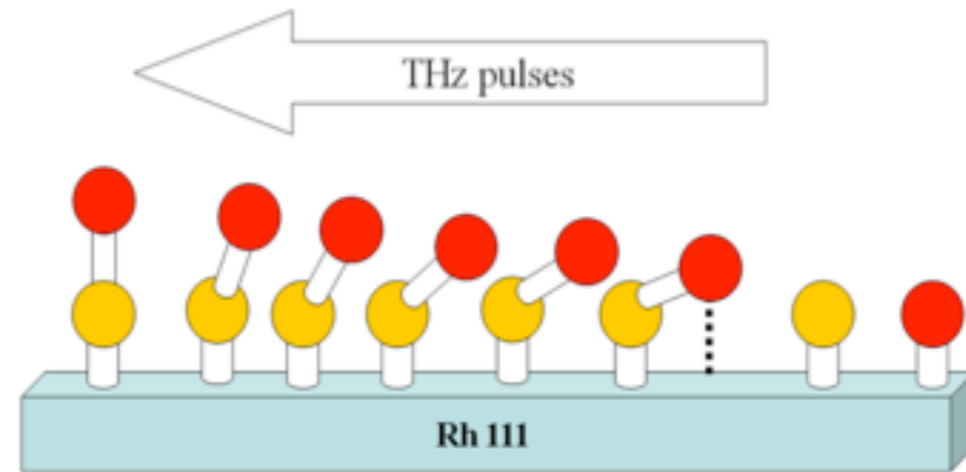
# 3. Catalysis and artificial photosynthesis

- ◆ *How do the timescales for charge separation, trapping and transfer influence catalytic efficiency?*

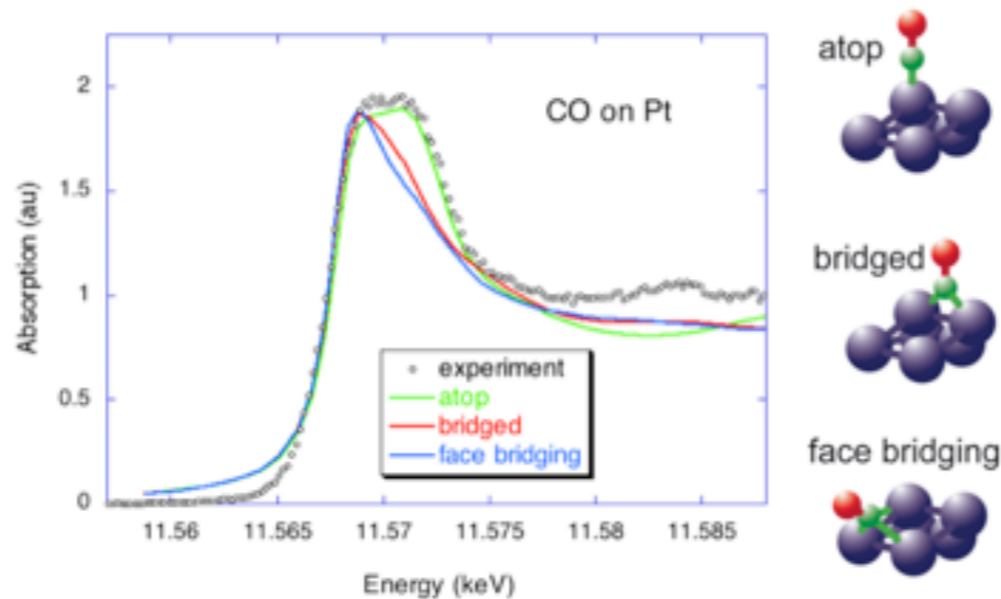
characterize short-lived intermediate states (fs – ns)

THz-induced surface catalysis

Ichsanow, Chimia (2011)



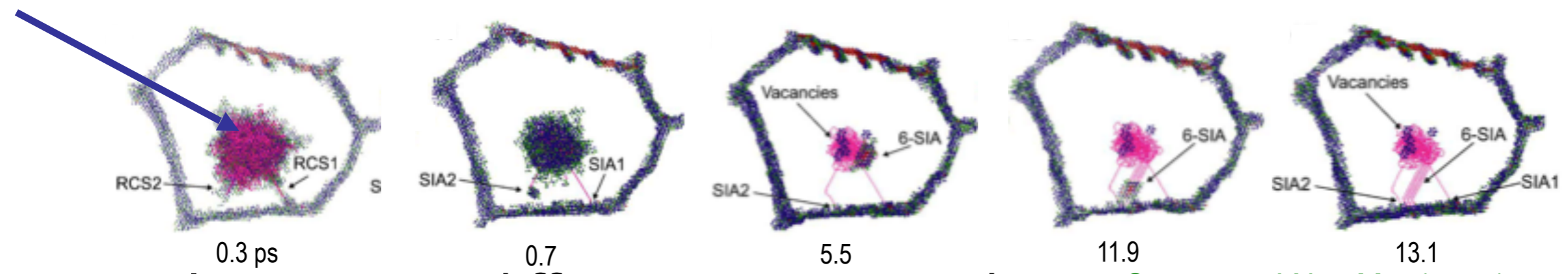
single-shot *p-p* XANES / XES spectroscopy



Safonova, J Phys Chem (2006)

# 4. Dynamics in nuclear materials

- ◆ *Do molecular dynamics calculations correctly describe the development of defect cascades in irradiated steel?*



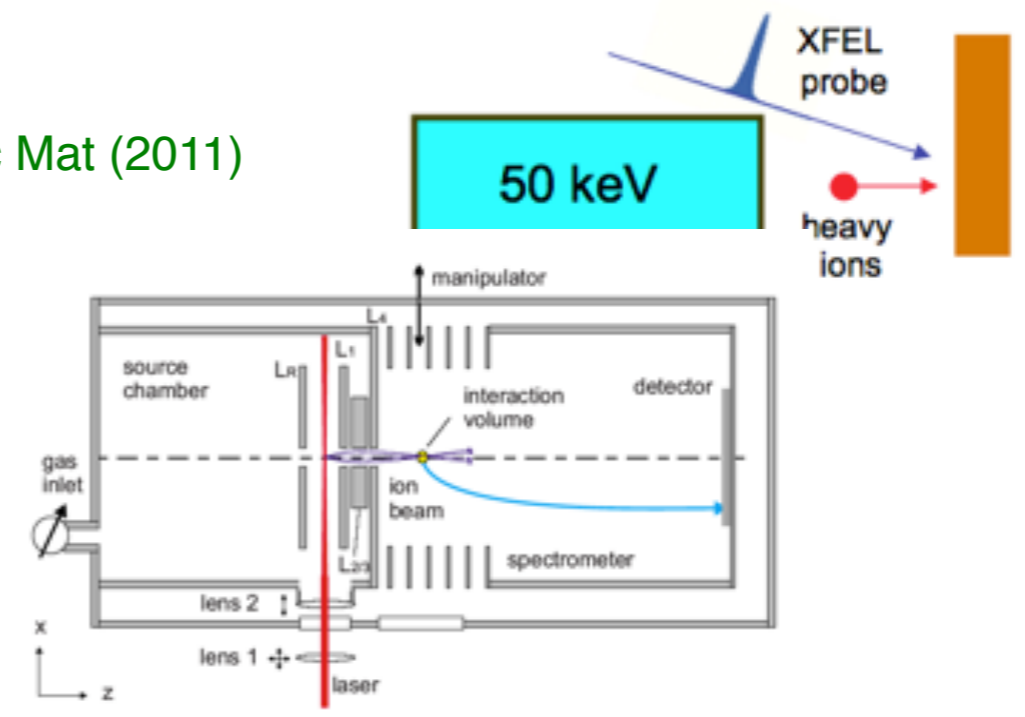
ion implant pump / diffuse scattering probe

Samaras, J Nuc Mat (2003)

Froideval, J Nuc Mat (2011)

photo-ionization single-ion gun

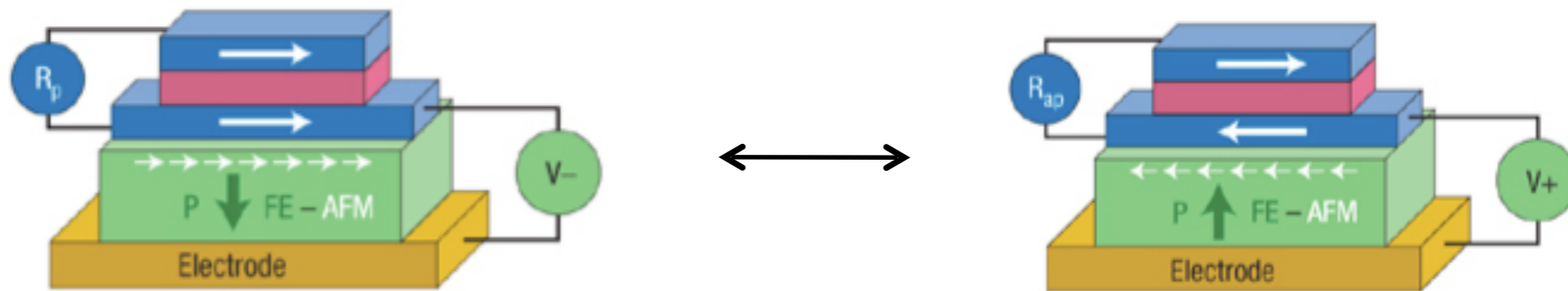
Höhr, Rev Sci Inst (2008)



statistical description of inequivalent events

# 5. Electronic materials

- ◆ *With which phonon velocity does the electric polarization propagate in a switched multiferroic  $\text{BiFeO}_3$ , and with what delay does the magnetization develop?*



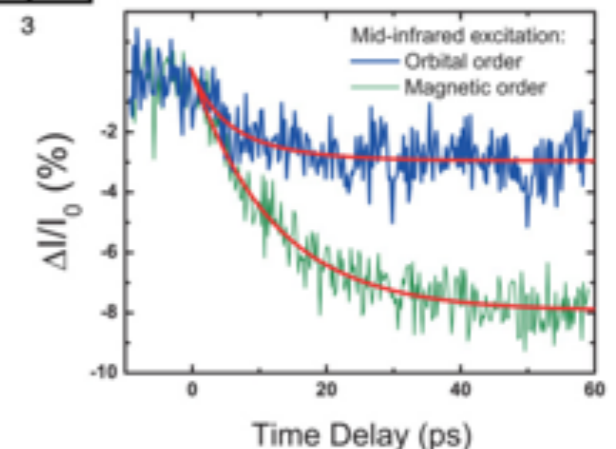
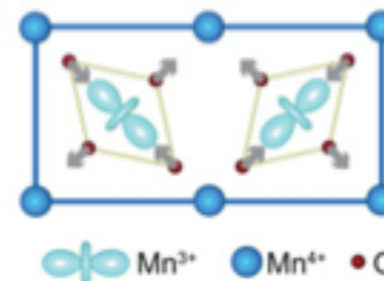
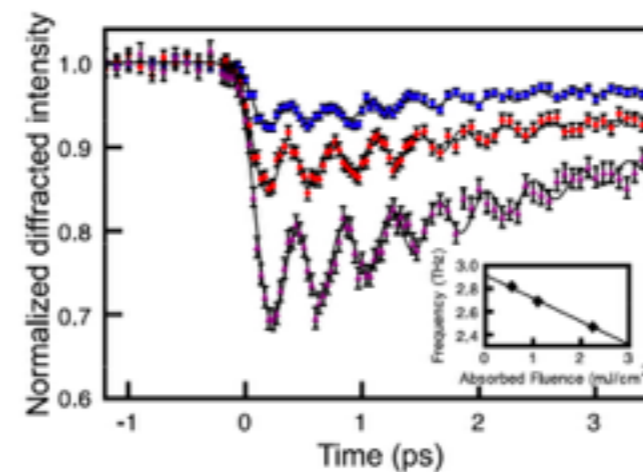
Bibes and Barthelemey, Nat Mat (2008)

pp-XRD atomic structural dynamics

Johnson, PRL (2007)

pp-ResXRD dynamics of electronic and magnetic order

Först, Phys Rev B (2011)



## 6. X-ray non-linear optics

- ◆ *Is stimulated RIXS efficient enough to allow ps time-resolved studies?*

use the high degeneracy of XFEL radiation

impulsive stimulated Raman scattering

X-ray transient grating spectroscopy

t-resolved coherent anti-stokes Raman spectroscopy

Patterson, SLAC Tech. Rep (2010)

# Site for the project



# Status of Construction

2014-03-06



# Status of Construction

2014-03-06

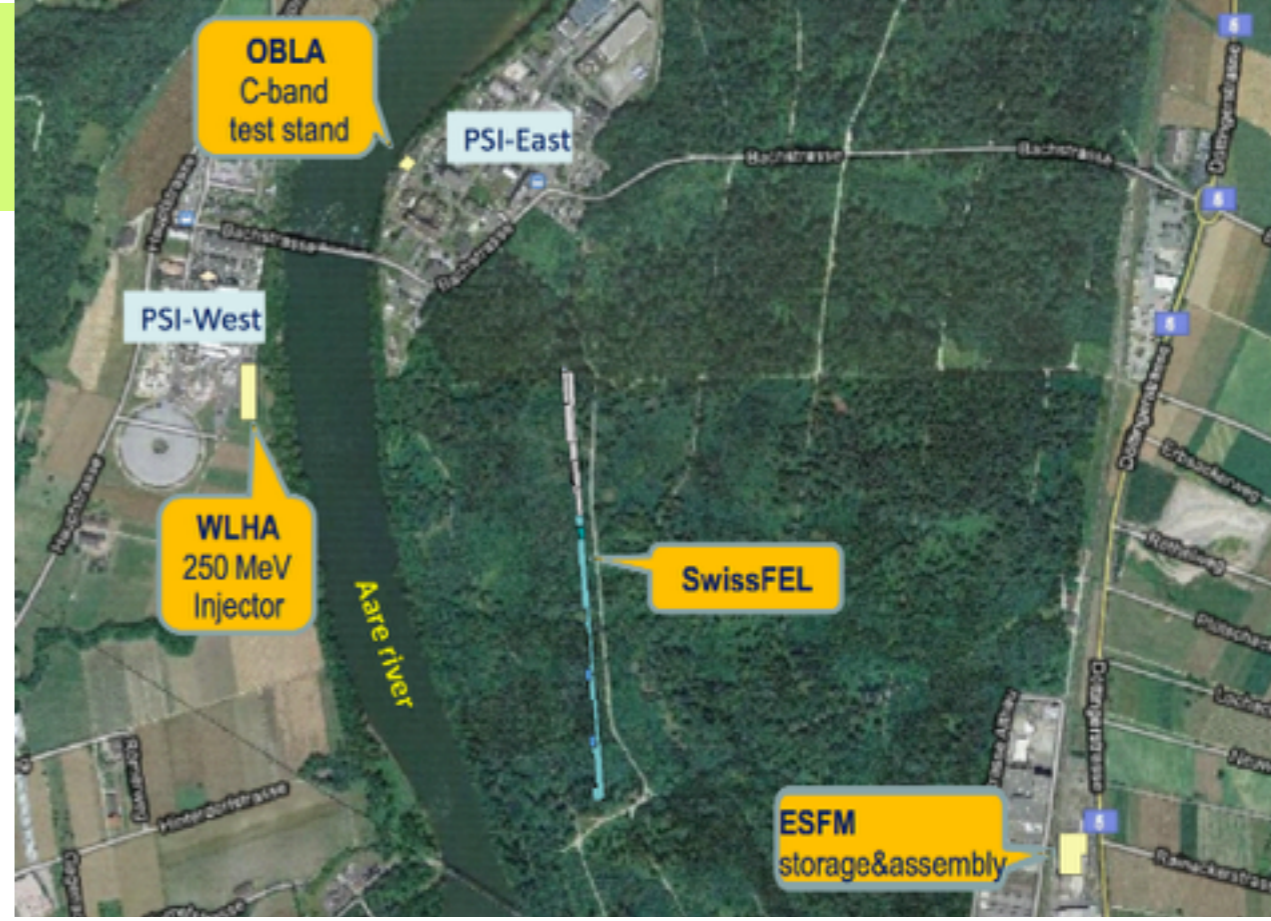


# Status of Construction

2014-05-13 CEST 16:05:01



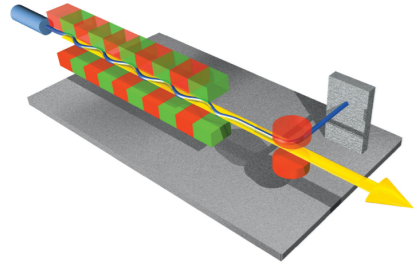
# Installation & Commissioning



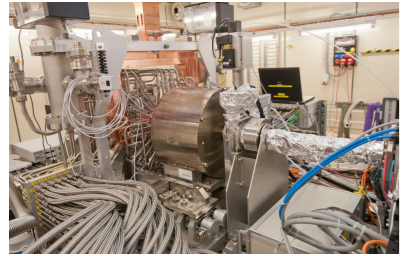
		2014			2015			2016			2017		
OSFA	Injector	civil constr. & infrastruct.			Injector installation			Inj. Com.			Commissioning		
	Undulator-lab	civil constr. & infrastruct.			Undulator assembly & measurement								
	RF gallery	civil construction & infrastructure						klystron modulators 1-13			klystron modulators 14-26		
	Linac & FEL tunnel							accelerator & FEL			Commissioning		
	Photon beamlines							Photon-beamline			Commissioning		
	Experiments										ESA &ESB installation		
	WLHA	Injector beam tests		dismantling	Component pre-assembly and storage								
	ESFM	Component pre-assembly and storage											
	OBLA	C-band component powertests											

Pilot experiments

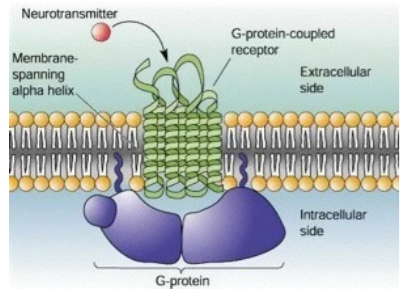
# SwissFEL — Methods and Opportunities



**Physical principles of a free electron laser**



**Technology behind SwissFEL**



**Priority experiments for SwissFEL**

Thank You to:

- > Bruce Patterson
- > Hans Braun
- > Sven Reiche

👉 Slides available at: <http://www.ischebeck.net>



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