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ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

SwissFEL laser infrastructure and R&D activities

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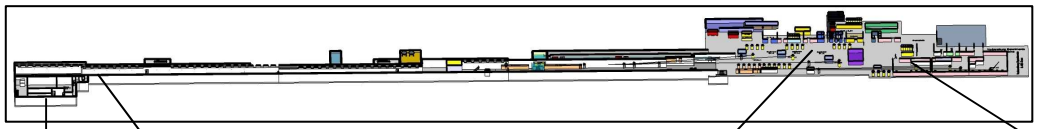
- Overview on SwissFEL laser requirements and infrastructure
- the front end laser system
- Laser-based THz source towards high-power single-cycle pulses
- Undulator test program/seeding at the SwissFEL test injector facility

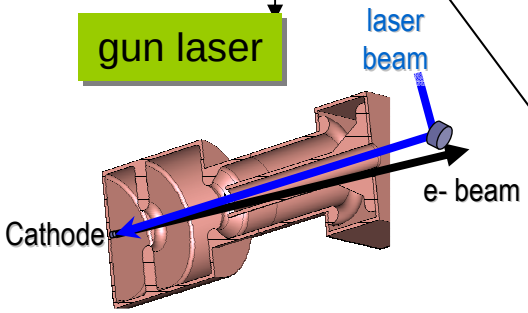
Laser systems at SwissFEL



gun laser

Experimental lasers (SX)

Experimental lasers (HX)



Athos users

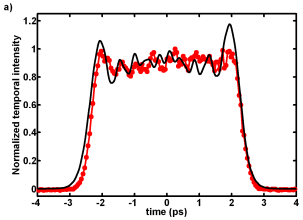
Aramis users

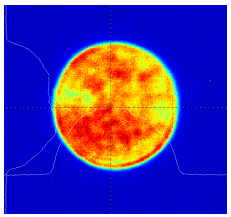
FEL pulse diagnostics

laser-based THz streak camera

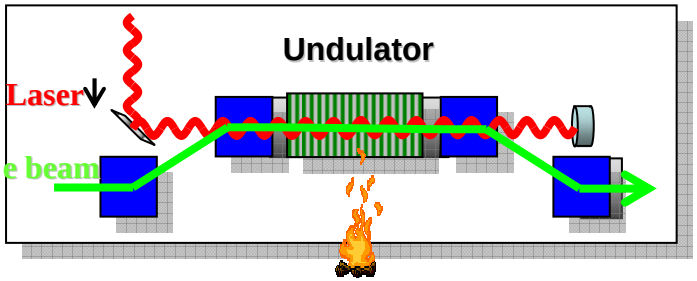
...

Laser requirements
3-10 ps, flattop (σ, τ) DUV (≈260 nm)
<1% energy stability
double pulse operation (Δt=28 ns)



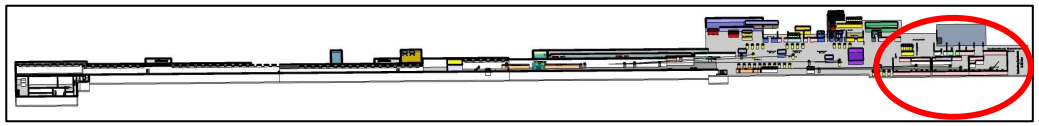


laser heater



Laser requirements
≈50 ps, nIR (≈800 nm), ≈100 μJ/pulse
double pulse operation (Δt=28 ns)

Requirements user systems at SwissFEL

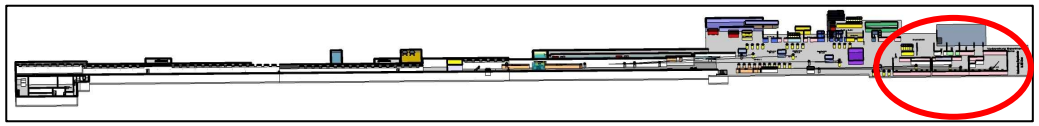


Requirements

- low timing jitter FEL⇔pump/probe laser
- characterize temporal jitter shot-to-shot
- large wavelength range to be covered (THz...VIS....DUV...soft x-rays)
- multi-cycle and single-cycle pulses, pulse trains
- carrier-envelope phase stabilized pulses
- high stability and flexibility at user station
  - long beam path from laserhutch
    - to EHs (up to 40 m)
    - to diagnostics (>60 m)

- laser hutch on first floor (above EH1)
- Ti:sapphire amplifier as front end
- one laser system for all three hutches
- serves all three HX exp. hutches (3 independent beam lines)

Requirements user systems at SwissFEL

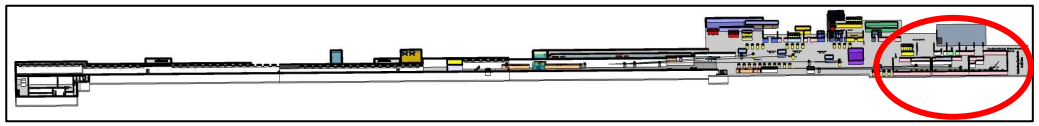


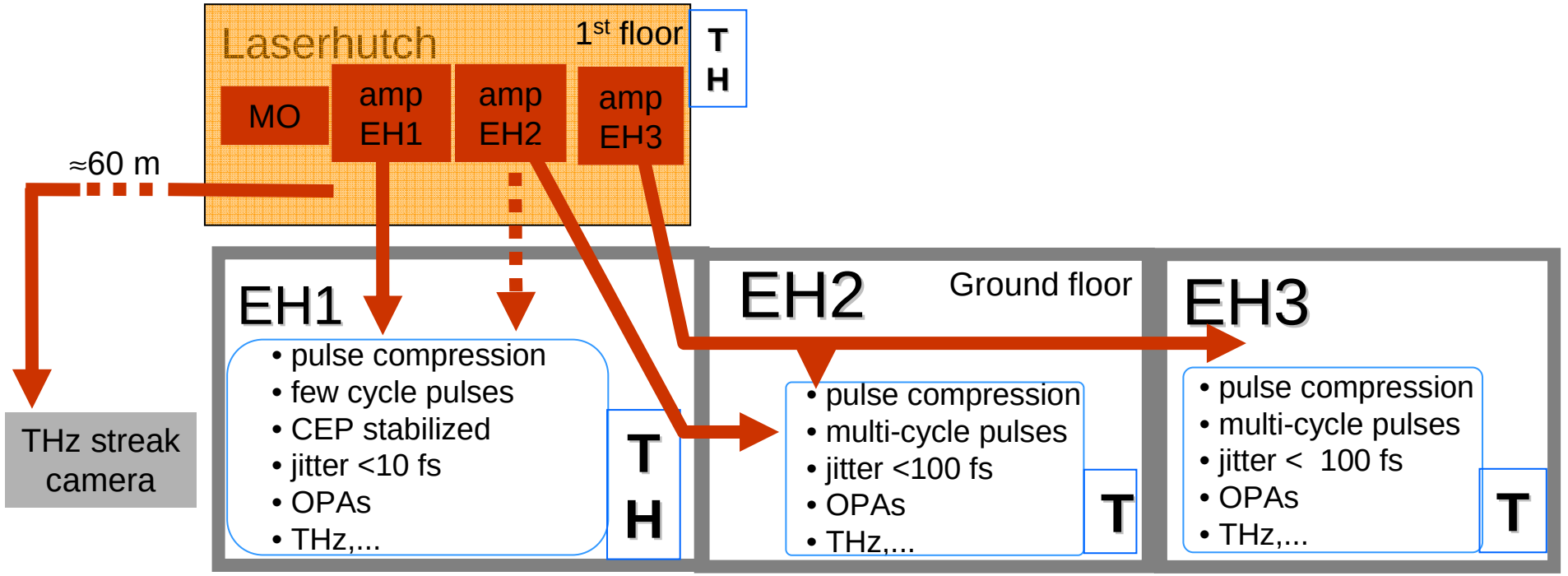
user wish list (tentative)

energy stability	< 1-2%	required for OPAs	
timing jitter	100 fs (<10 fs)	for EH2 and EH3, (EH1)	
wavelength ranges	750-850 nm	20 mJ	
	200-1000 nm	0...1mJ	**SC**, MC
	1-20 um	0...500 μJ	**SC**, MC
	1-15 **THz**	0...20 uJ	**HC, SC**, MC, NB
repetition rate		0...100 Hz	
field-sensitive experiments		yes	**CEP stabilization** in EH1
power level		20 mJ	1 line (freq. conversion)
		20 mJ	1 line (SC pulse generation)
		>>20 mJ	1 line (THz)

HC: half cycle pulses
SC: single cycle pulses
MC: multi cycle pulses
NB: narrow bandwidth

Requirements user systems at SwissFEL

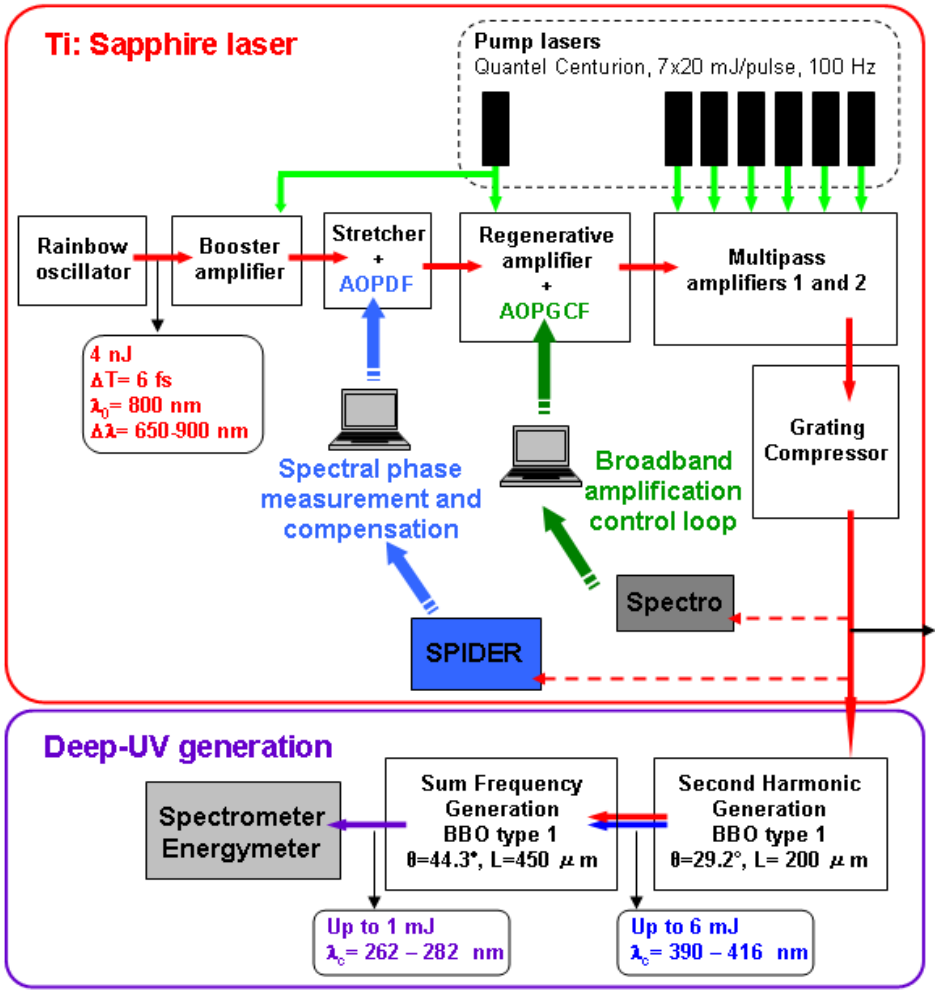


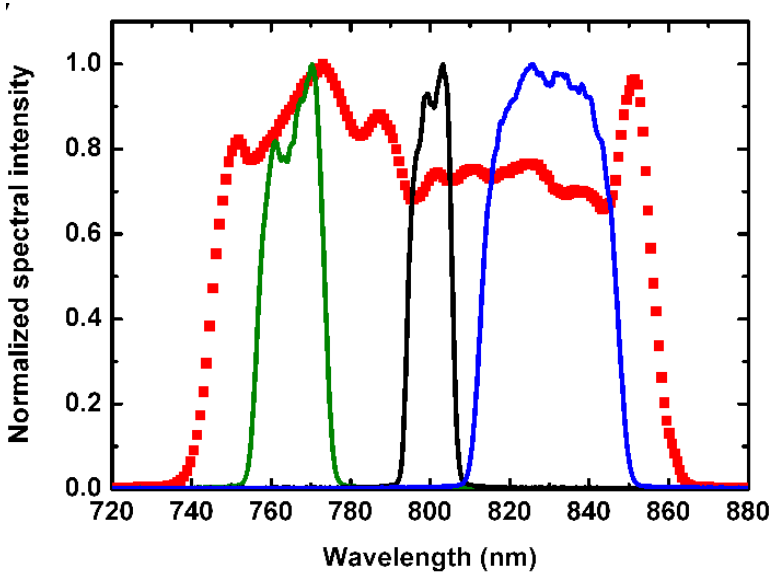


- front end: 1x Ti:Sapphire amplifier with 3 beamlines
- propagation of amplified ps pulses
- compression & frequency conversion in EHs
- one hutch EH1 with highest temporal jitter stability

online information/control at experiment for users
- single shot laser pulse energy
- beam pointing/beam position
- timing jitter
- pump probe delay
- CEP phase
- temporal and spatial profile

Laser systems at SwissFEL





- versatile amplifier system
- wavelength tunable across 120 nm
- multi-color amplification
- pulse durations TL 15 fs…100 fs
- tuning extended into UV and deep UV
- high stability (0.4% rms) => OPA

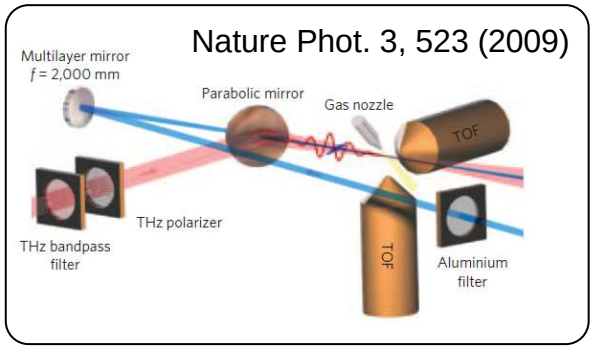
Opt. Express 19, 20128 (2011)
PRL 104, 234802 (2010)
Trisorio et al. APB (2011)
APL 99,161116 (2011)
Opt. Lett, accept. (2012)

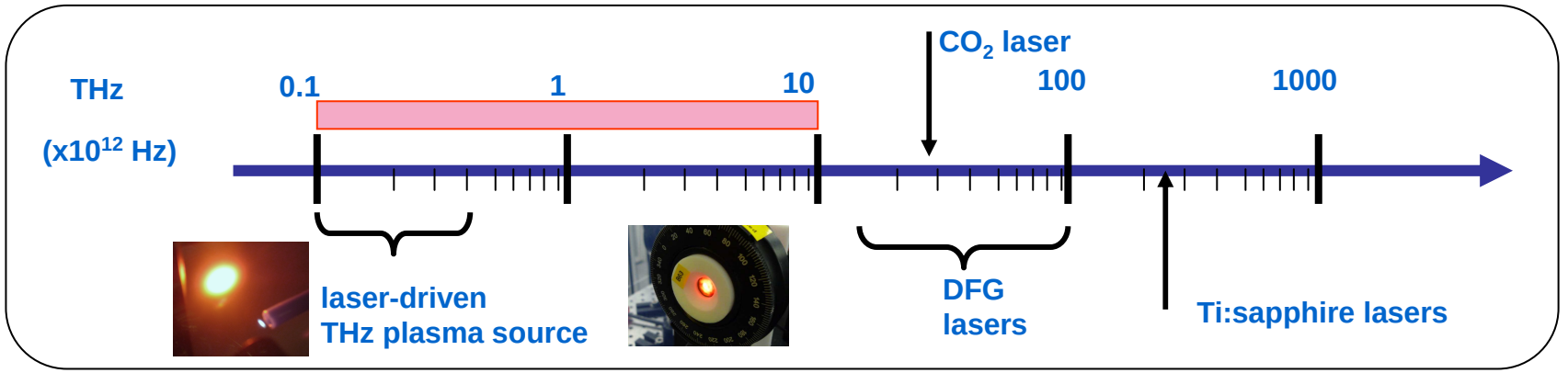
Applications for SwissFEL

- Low-emittance electron gun
- THz generation/THz streak camera
- tunable HHG source/seeding

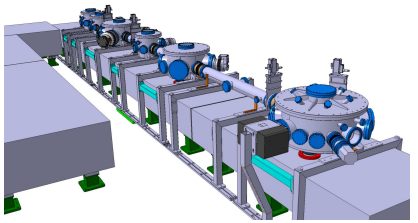
laser development activities

- High power single/few cycle THz source (laser-based)
  - synchronized to Ti:Sapphire laser
  - +/- delay with regards to hard x-ray pulse
  - >1 MV/cm, ≈Tesla
  - THz streak camera, THz applications





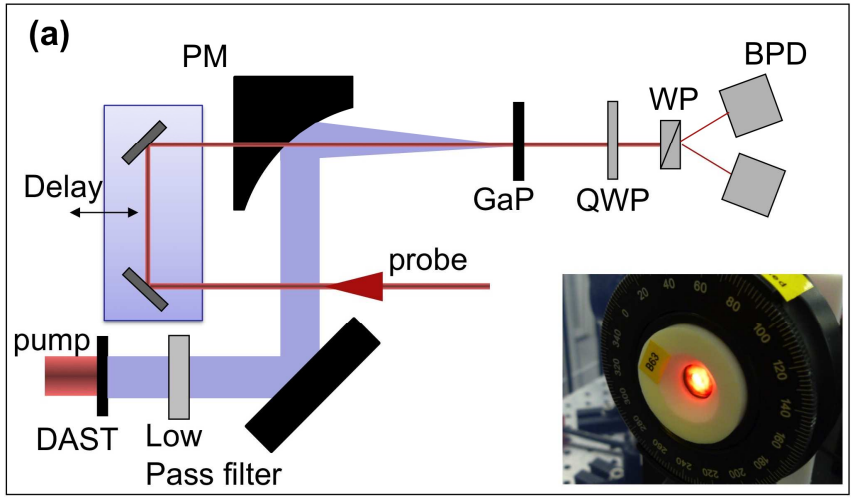
- high-power, table-top soft x-ray source (HHG) coherent imaging, seeding FEL

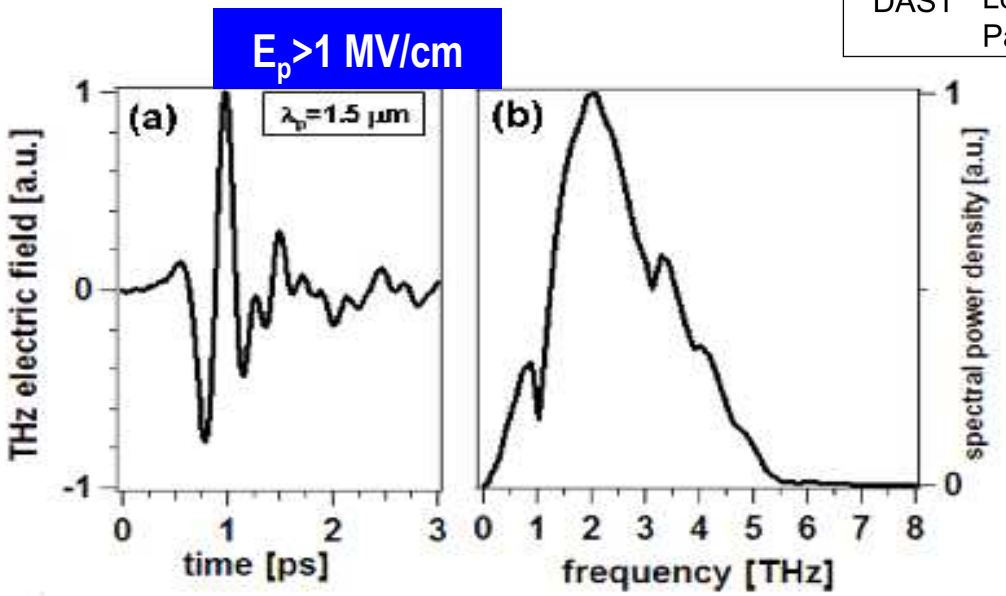


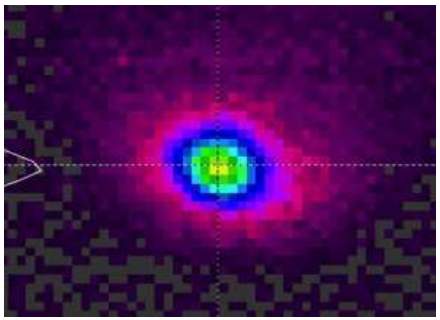
Towards high-power single-cycle THz

Organic crystal

- DAST : 4-N,N-dimethylamino-4'-N'methyl stilbazolium tosylate
- strong optical nonlinearity
- low absorption
- good focusability



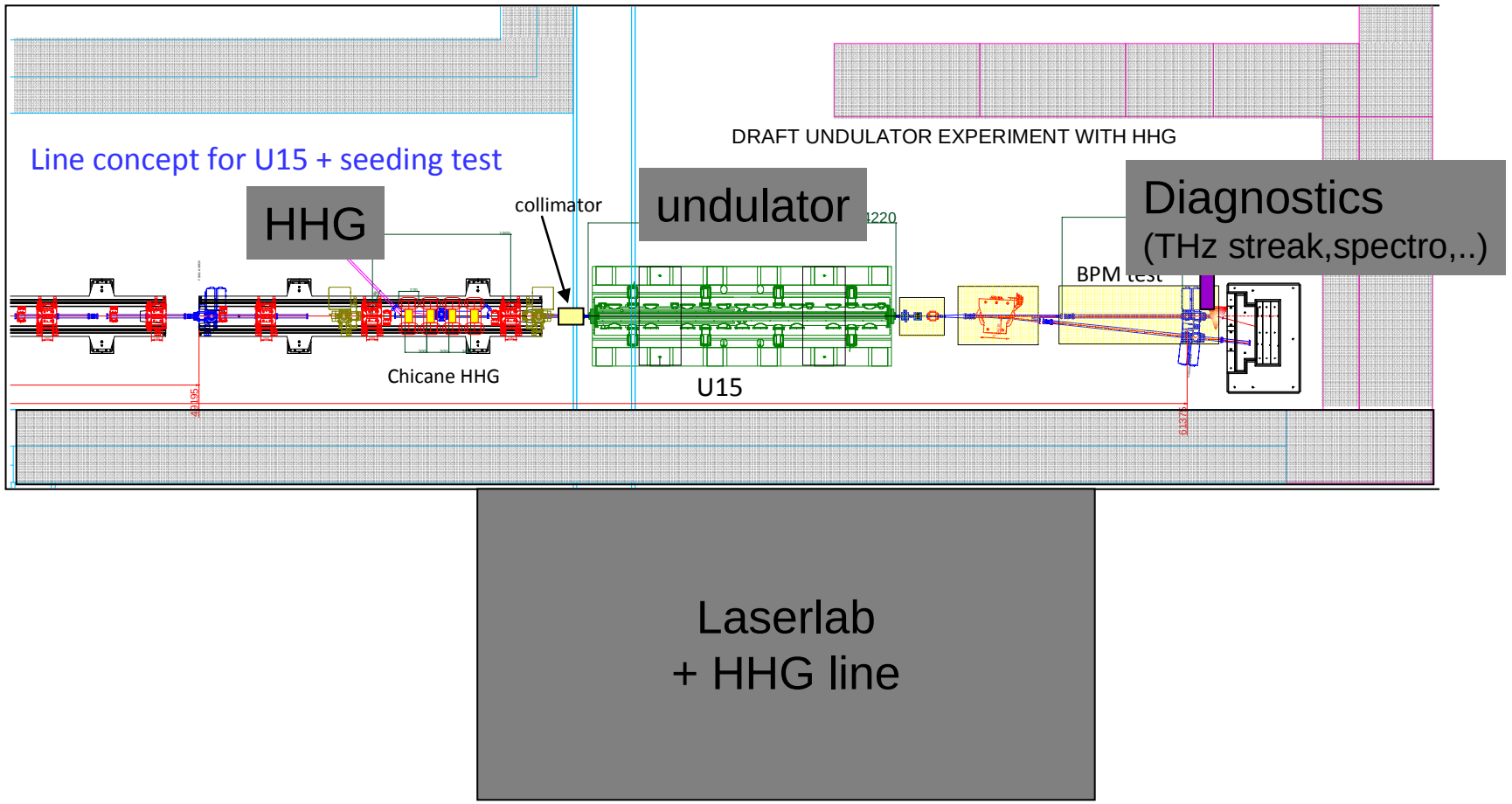




sufficient for a prototype THz streak camera

Hauri et al. Appl. Phys. Lett. 99, 161116 (2011)

undulator test/seeding at SwissFEL test injector facility



Why undulator test/seeding at SwissFEL test injector facility?

- validation of critical components for SwissFEL
- train ourselves in undulator alignment, FEL operation, FEL characterization, arrival time measurements, opt. synchronization
- first time a running FEL at PSI

ID group

- validate prototype undulator U15 with “soft beam”
  - PSI has most aggressive design for undulators (Japan: U15-> U18 after testing)
- validate strategy for beam based alignment of undulator
- test alignment strategy with photons (SE, seeded)
- w/o seeding only weak SE

Diagnostics group and laser group

- validate prototype THz streak camera (tested with seeded FEL)
- validate jitter between FEL and probe pulse
- combine *THz, HHG and FEL pulse* for FEL characterization & experiment
- if time allows, a PE pump-probe experiment,…

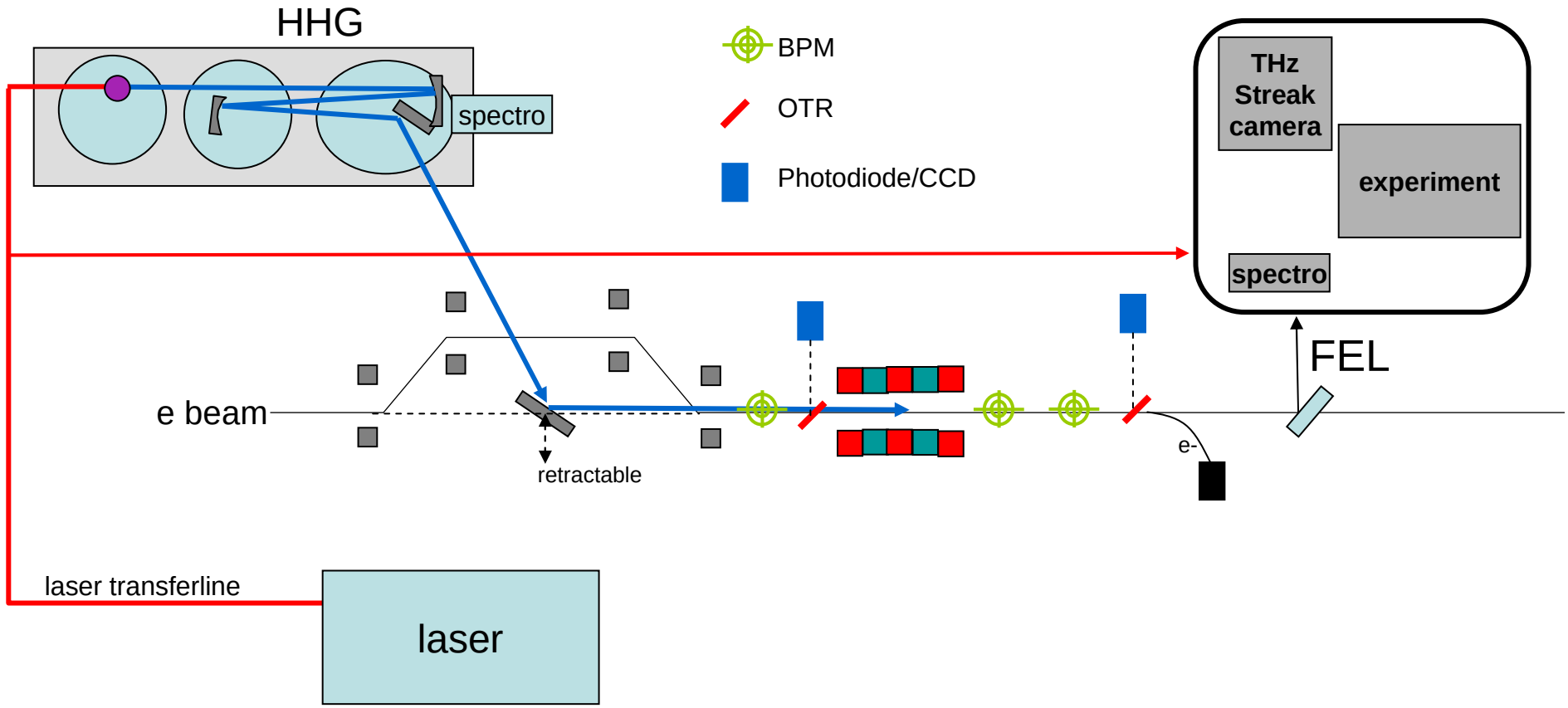
Seeding experiment at SwissFEL test injector facility

Status

- a decision has been taken to install U15 in the injector
  - modification of current beam line
  - e- and γ diagnostics required
- prototype U15 arriving Sept/Oct 2012, tests up to Jan 2013 at SLS
- new laser system (for e.g. HHG) arriving in May 2012
- vacuum system for HHG currently under commissioning
- high harmonic generation starting in June 2012
- optical synchronization scheme foreseen for 2013/14
- laser-based THz source developed
  THz streak camera on track, should be ready end 2012
  (test at HHG beamline, then later on at seeded injector)
- Postdoc and PhD student approved from SNF for seeding experiment
- compact machine

⇒ excellent conditions for HHG seeding

Seeding experiment at SwissFEL test injector facility



many components available, some not yet

- beam optics VUV (multilayer)
- compact VUV spectrometer (bulky one available)
- chicane vacuum chamber (different to laser heater)
- dipoles for chicane
- IR streak camera

Seeding experiment – expected performance

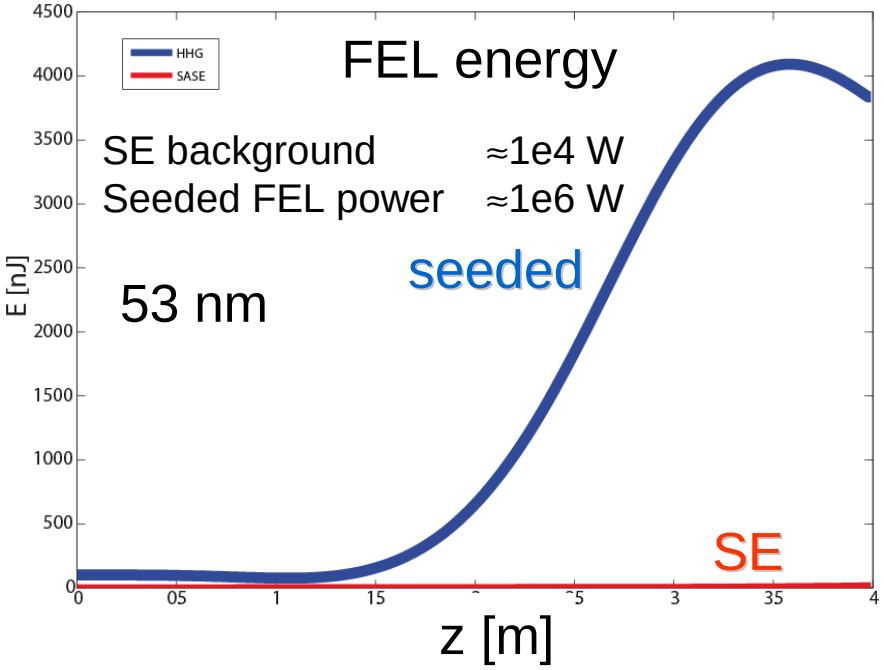
electrons:
250 MeV, 1 ps FWHM
correlated energy chirp 1.6%

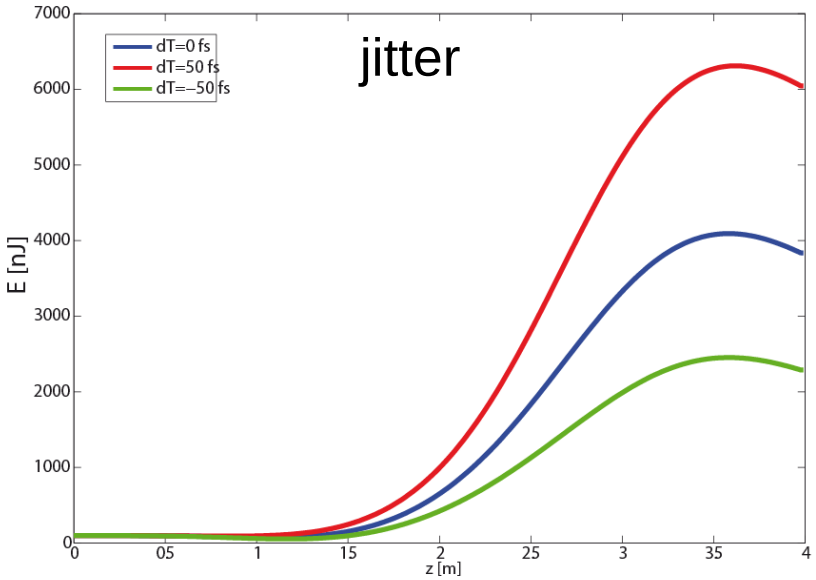
HHG seed:
λ_{HHG}=53 nm/23.4 eV (15th HH of Ti:sapphire)
100 nJ, 60 fs (FWHM,TL), Gaussian, BW 1-2%

FEL:
U15 undulator, K=1.2
bandwidth ≈3e-3
seeded: 4 uJ (≈1e12 photons), 60 fs
saturation reached in 4m U15 module

For 350 MeV => λ_{FEL}=27 nm/45 eV

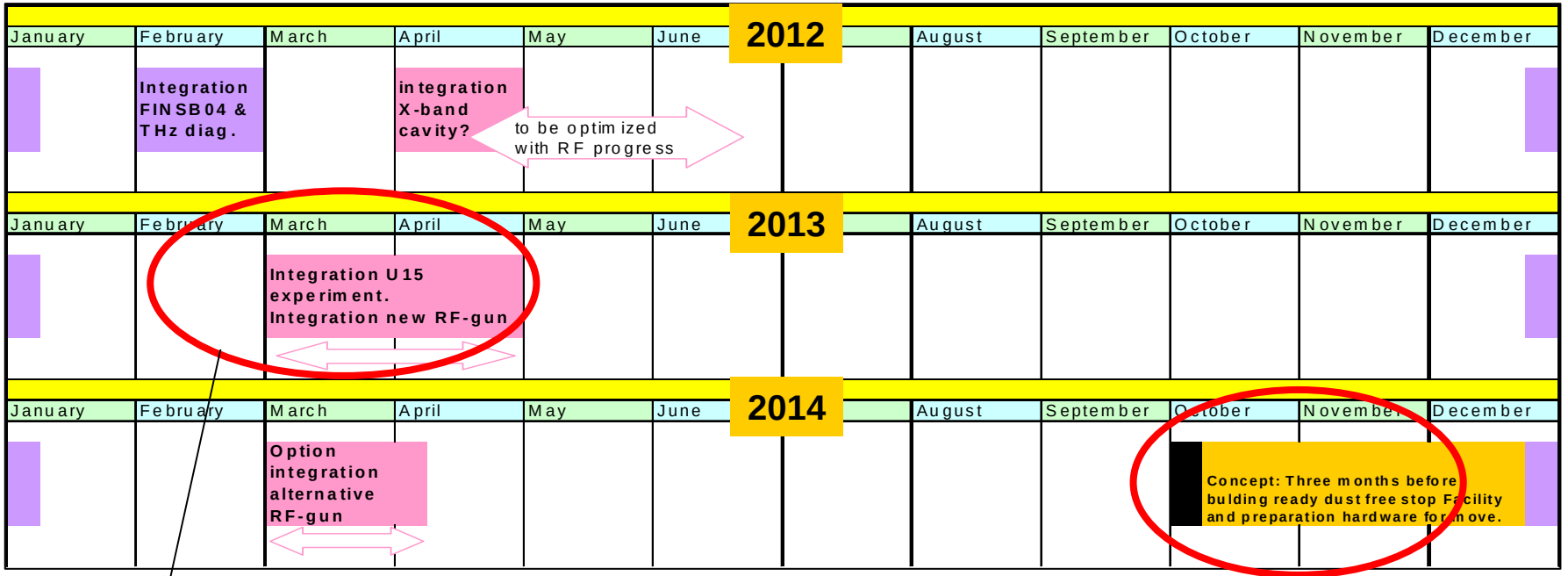
Applications
- PE spectroscopy
- RIXS (Cr, V)
- AMO





for a well matched HH seed!

Time line



Feb 2013: Installation of seeding beam line

2014: undulator test program

Collaborations are welcome!

Oct 2014: Move of injector to SwissFEL facility

- beam optics VUV (multilayer mirrors)
- compact VUV spectrometer (bulky one available)
- chicane vacuum chamber (different to laser heater)
- dipoles for chicane (anticipated for SwissFEL)
- IR streak camera
- manpower (postdocs, students, researchers)