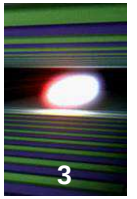
Optical Laser Systems for Experiments – SASE 1 Laser Installation

Max Lederer, WP78, European XFEL

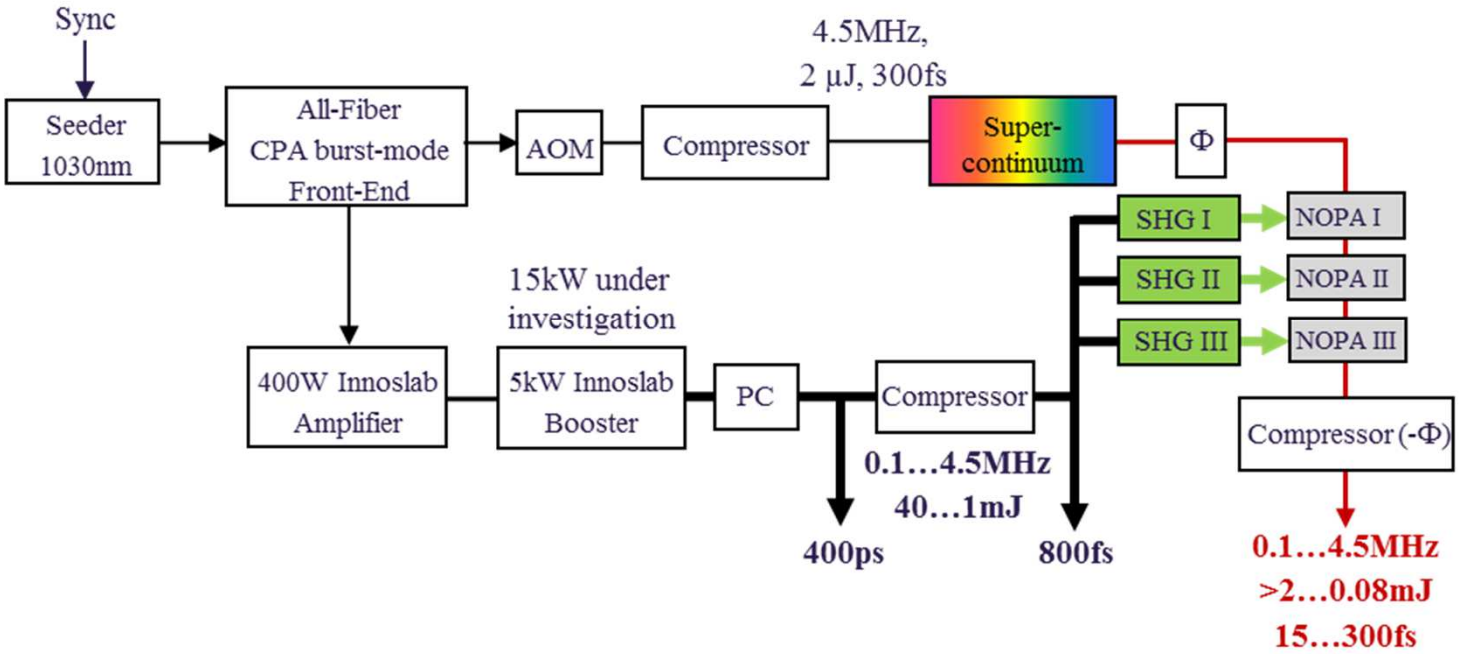
Overview

- Pump-probe laser R&D status
- Laser Group - project interfaces and responsibilities
- Procurement
- Planning
  - Work Breakdown Structure
  - Detailed WP-78 work schedule for SASE 1 PP-laser installation
- SASE 1 pump-probe laser installation
- Summary and outlook



Pump-probe laser R&D status

Pump-Probe laser concept: *fs-pumped NOPA*

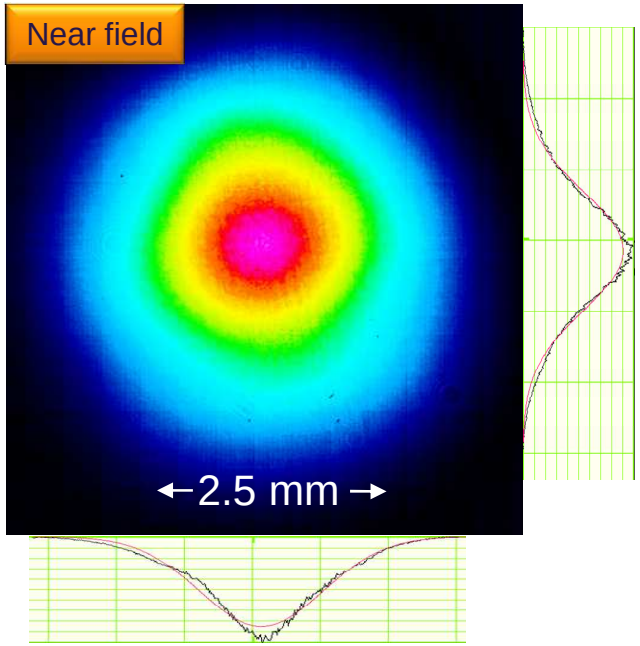


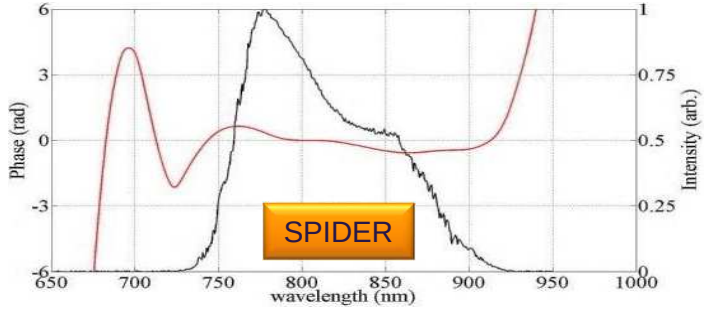
Working points:

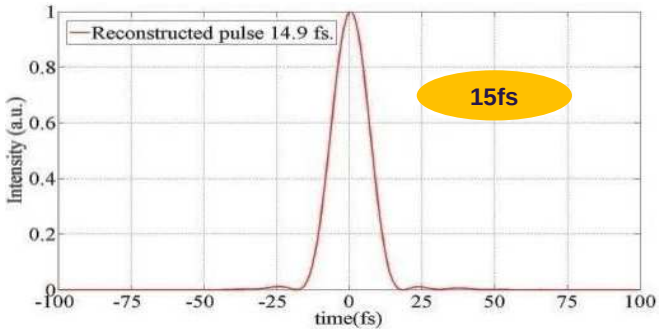
- 4.5MHz and 1MHz: NOPA I + II (BBO)
- 200kHz and 100kHz: NOPA I + II + III (BBO)

1. A. Dubietis, G. Jonusauskas, and A. Piskarskas, "Powerful femtosecond pulse generation by chirped and stretched pulse parametric amplification in BBO crystal," Opt. Commun. **88**, 437–440 (1992)
2. G. Cerullo and S. De Silvestri, "Ultrafast optical parametric amplifiers," Rev. Sci. Instrum. **74**, No. 1 (2003)
3. M.J. Lederer, M. Pergament, M. Kellert, and C. Mendez, "Pump–probe laser development for the European X-Ray Free-Electron Laser Facility," Paper 8934-20, SPIE Conference on Optics and Photonics 2013, 22–16 August 2013, San Diego, Invited talk.
4. M. Pergament, M. Kellert, K. Kruse, J. Wang, G. Palmer, L. Wissmann, U. Wegner, and M. Lederer, "High power burst-mode optical parametric amplifier with arbitrary pulse selection," Optics Express, Vol. 22, Issue 18, pp. 22202-22210 (2014)
5. M. Pergament, M. Kellert, K. Kruse, J. Wang, G. Palmer, L. Wissmann, U. Wegner, M. Emons, M.J. Lederer, "340W Femtosecond Burst-mode Non-collinear Optical Parametric Amplifier for the European XFEL Pump-probe-laser," Advanced Solid State Lasers, 04-09. October 2015, Berlin, Germany, ATu4A.4

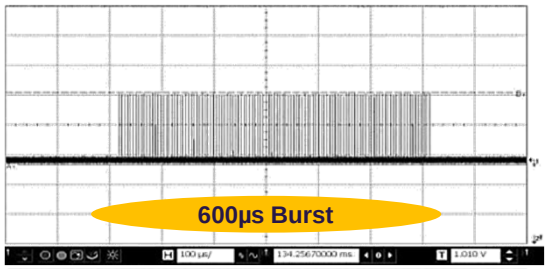
NOPA I + II

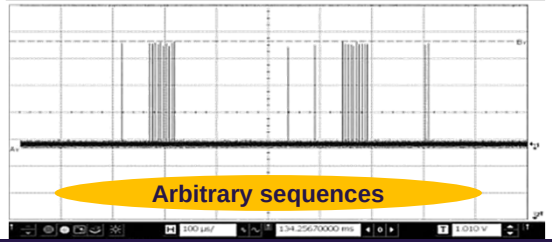






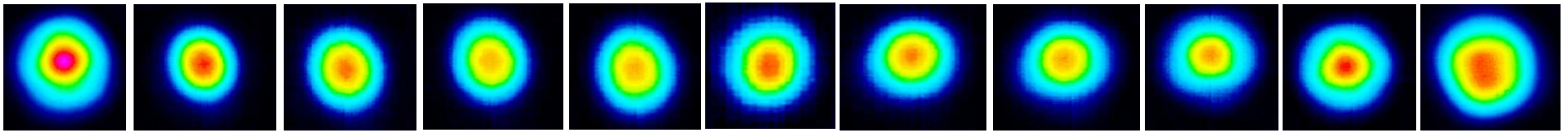
- **Pulse energies:**
  - ⇨ 80 µJ @ 4.5MHz
  - ⇨ 330 µJ @ 1.1MHz
- **Burst power:** 360W (600 µs)
- **Pulsewidth:** 15fs
- **Spectrum:** 13.8 fs Fourier-limited pulse
- **Burst-noise:** 2.5 % rms (scope, high air flow conditions)
- **Burst shape:** clean, arbitrary sequences possible

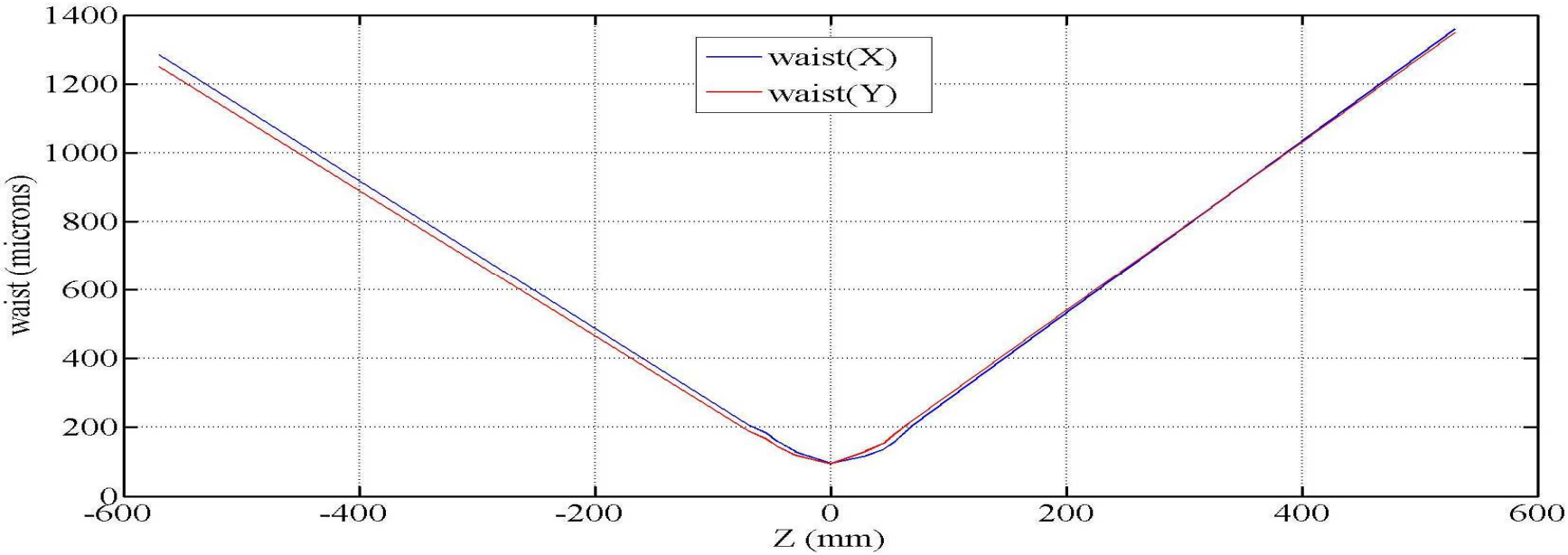




Beam quality NOPA I + II

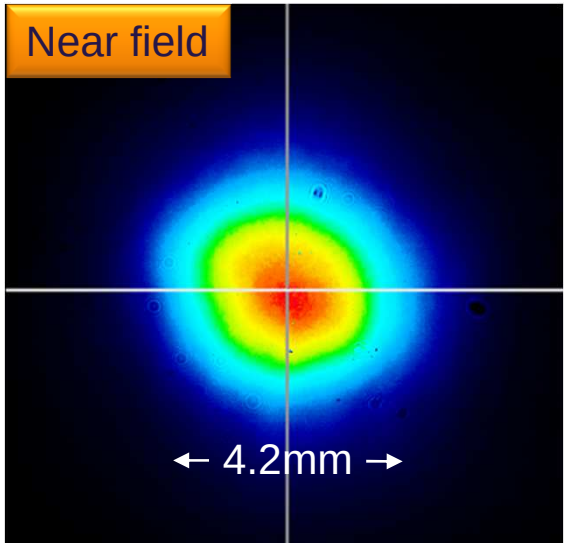
Waist Scan

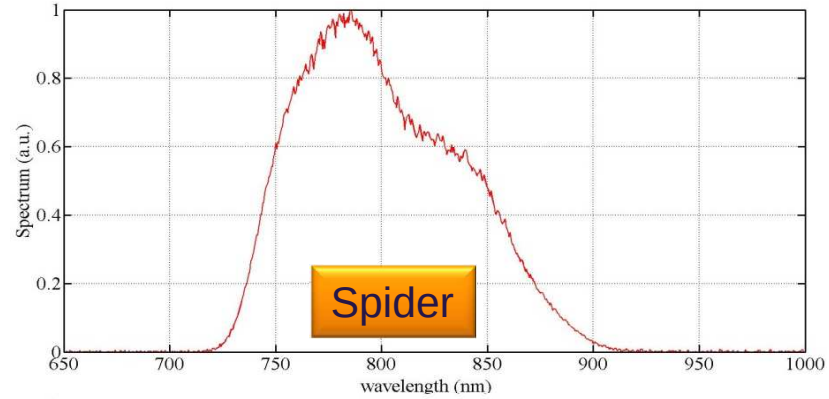


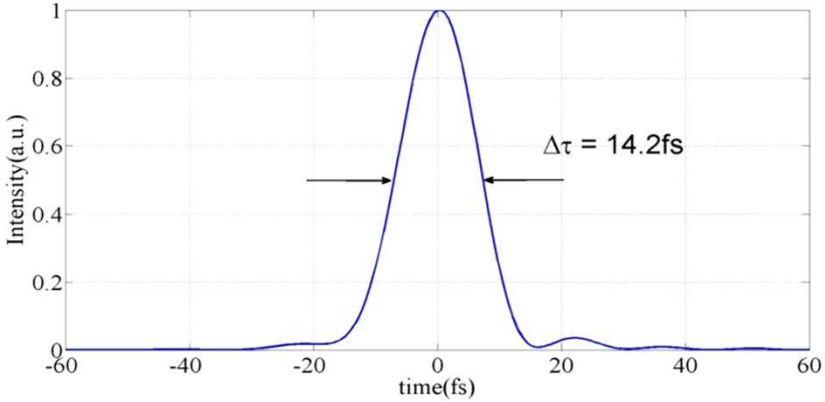


- Gaussian fit >94% for 15 Rayleigh ranges
- Close to diffraction limited Gaussian beam: $M^2<1.1$

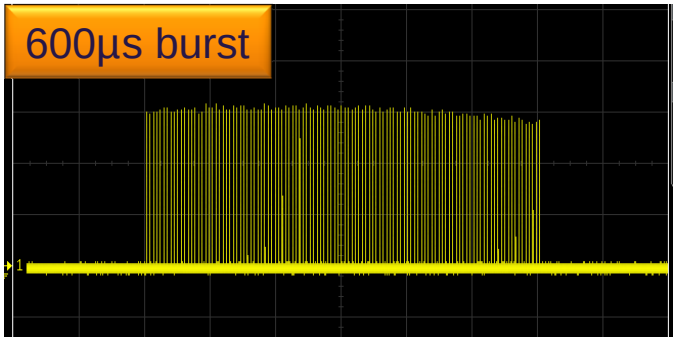
NOPA I + II + III





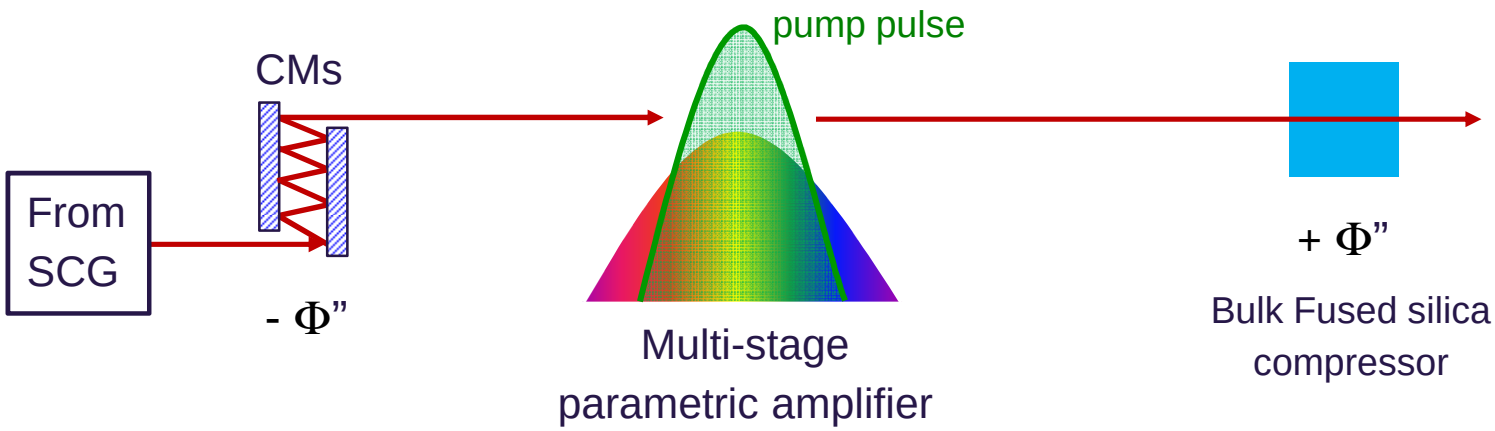


- **Pulse energy:** 1.7mJ @ 188kHz
  2.5mJ @ 100kHz
- **Burst power:** >250W (600 µs)
- **Pulsewidth:** <15fs
- **Beam quality:** similar to NOPA I + II

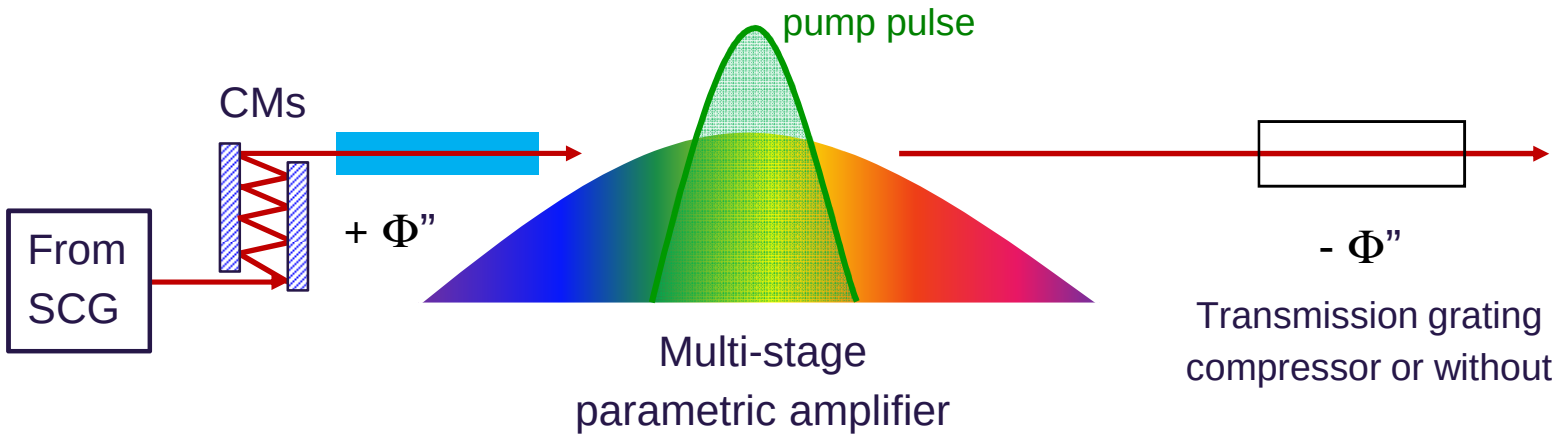


Dispersion management

Short pulse dispersion management: 15fs pulse duration

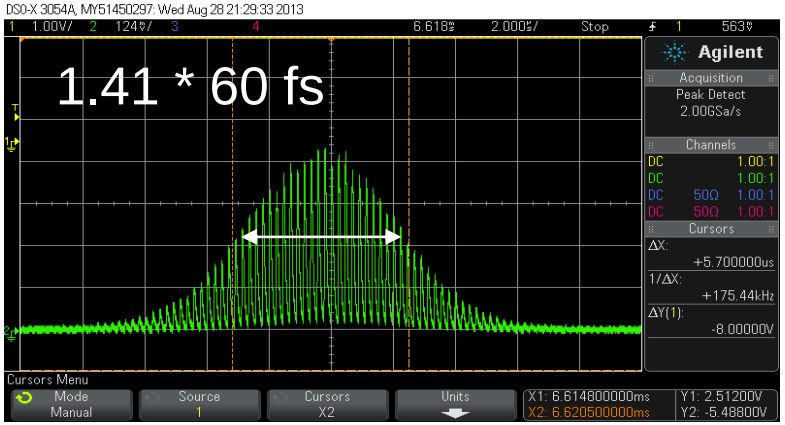


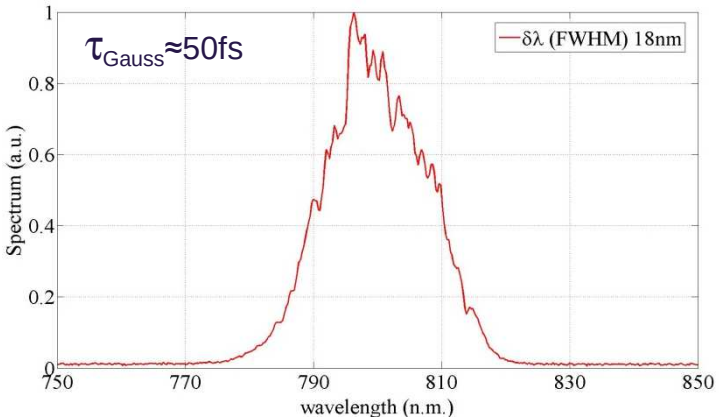
Long pulse dispersion management: 25-300fs pulse duration



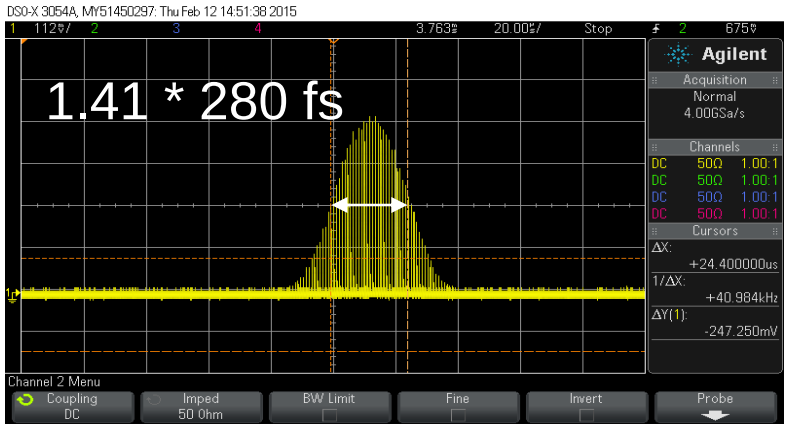
Long pulses from the NOPA

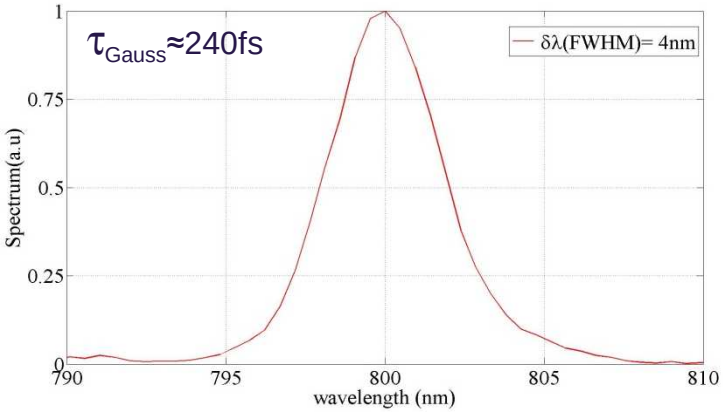
60 fs pulse (Treacy compressor)



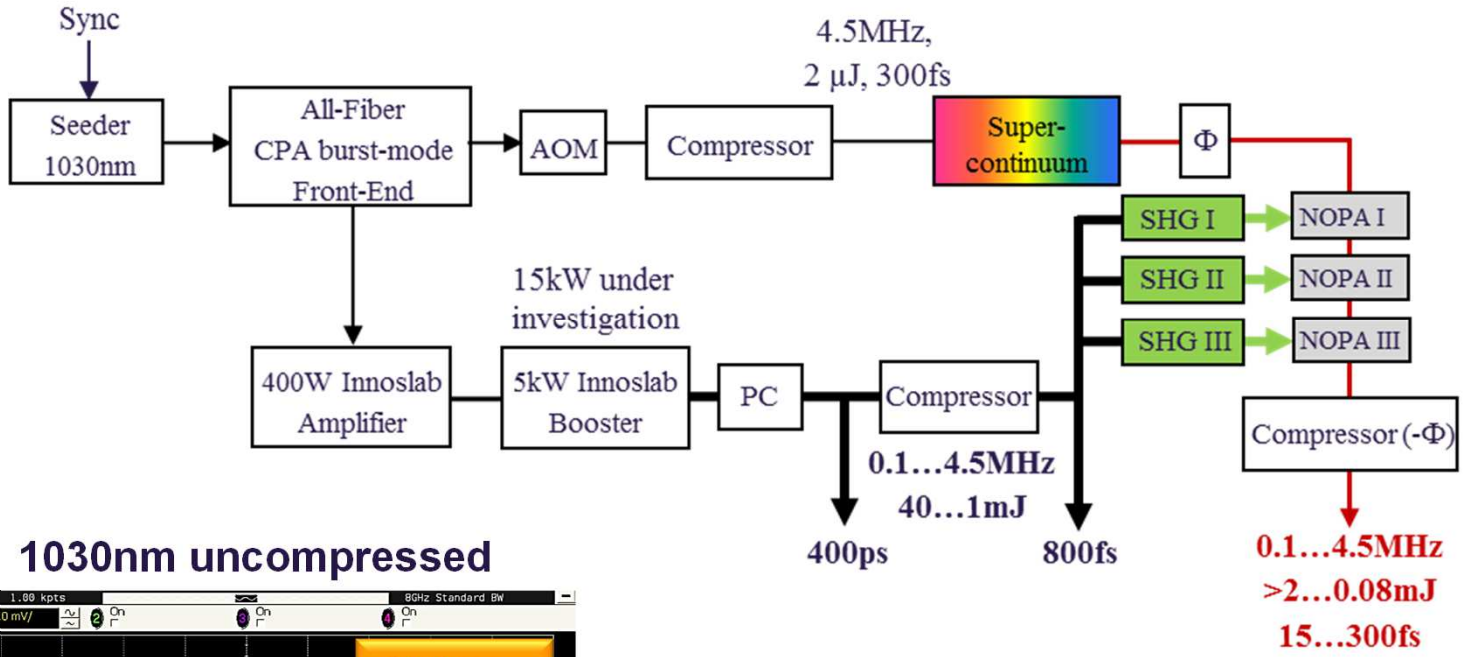


280 fs pulse (No compressor)

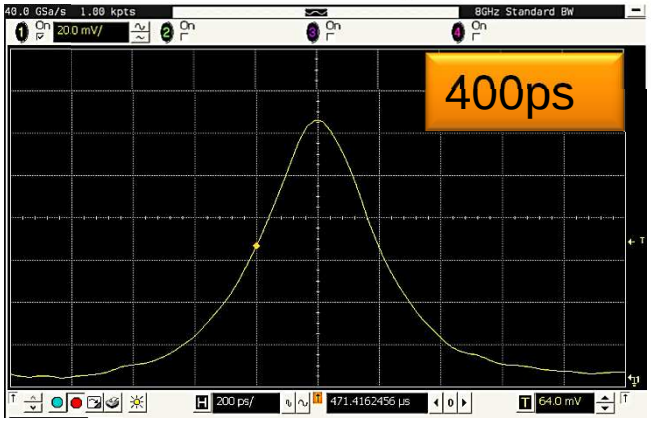




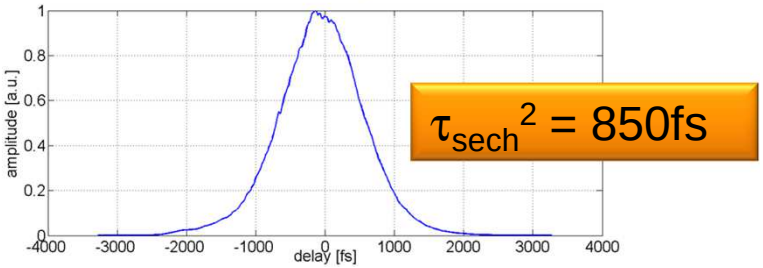
1030nm pump beam and mixed-mode



1030nm uncompressed

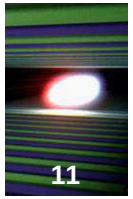


1030nm compressed



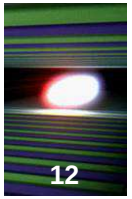
Mixed-mode: e. g. 100kHz, 1mJ / 15fs / 800nm and 10mJ / 400ps / 1030nm

Planned PP-laser deliverables to ILHs



Parameter	@800nm	@1030nm
E_{pulse}	0.05, 0.3, 1, 2 mJ	1, 4, 20, 40 mJ
$f_{intra\text{-}burst}$	4.5, 1, 0.2, 0.1 MHz	4.5, 1, 0.2, 0.1 MHz
$\Delta\tau$	<15 … 250fs (compressed)	≈900fs or ≈0.4ns chirped
$\Delta\lambda$	≈100 … 5nm	≈2nm
f_{burst}	10Hz	10Hz
T_{burst}	≤600µs	≤600µs
Tuning	ca. 100nm dep. on $\Delta\tau$	-
Arbitrary pulse picking	yes	yes
Pulse-to-pulse stability	≤2.5% rms	≤2% rms
Beam quality, M^2	<1.5	<2
Timing jitter / drift	<20fs rms / 10fs(12h)	<20fs rms / 10fs(12h)
Pointing jitter / drift	<Θ/10 rms	<Θ/10 rms

Achievable specifications such as energy stability, pointing and timing drift / jitter are subject to experimental confirmation in hutch.



Laser Group - project interfaces and responsibilities

Laser group at European XFEL GmbH

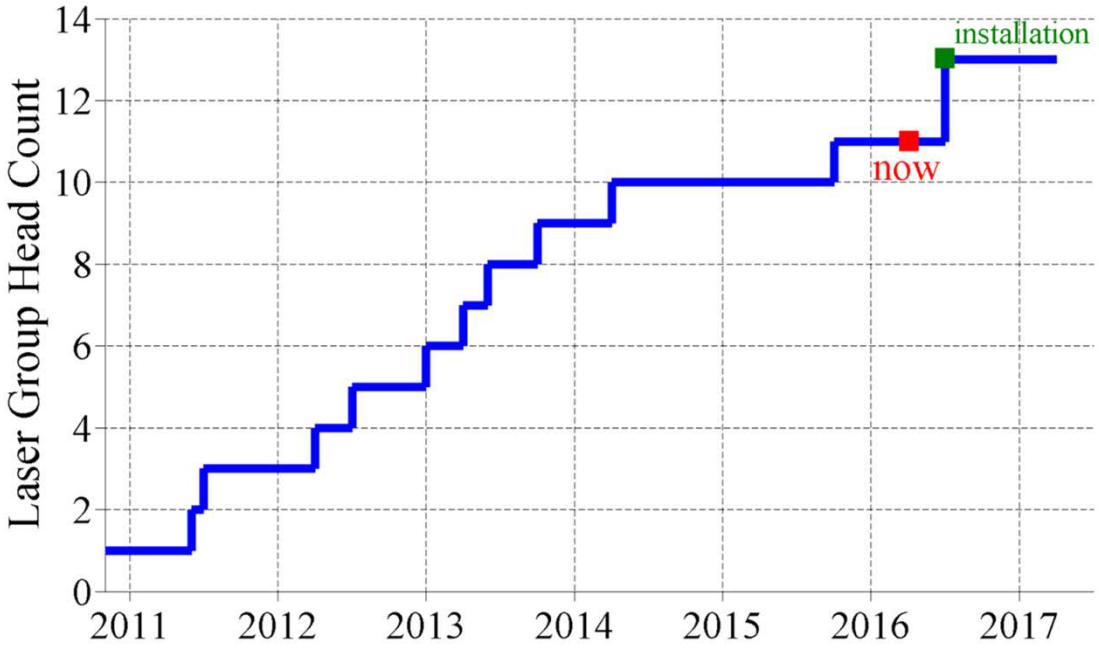
- **Foundation:** project WP-78, November 2010

- **Mission:**

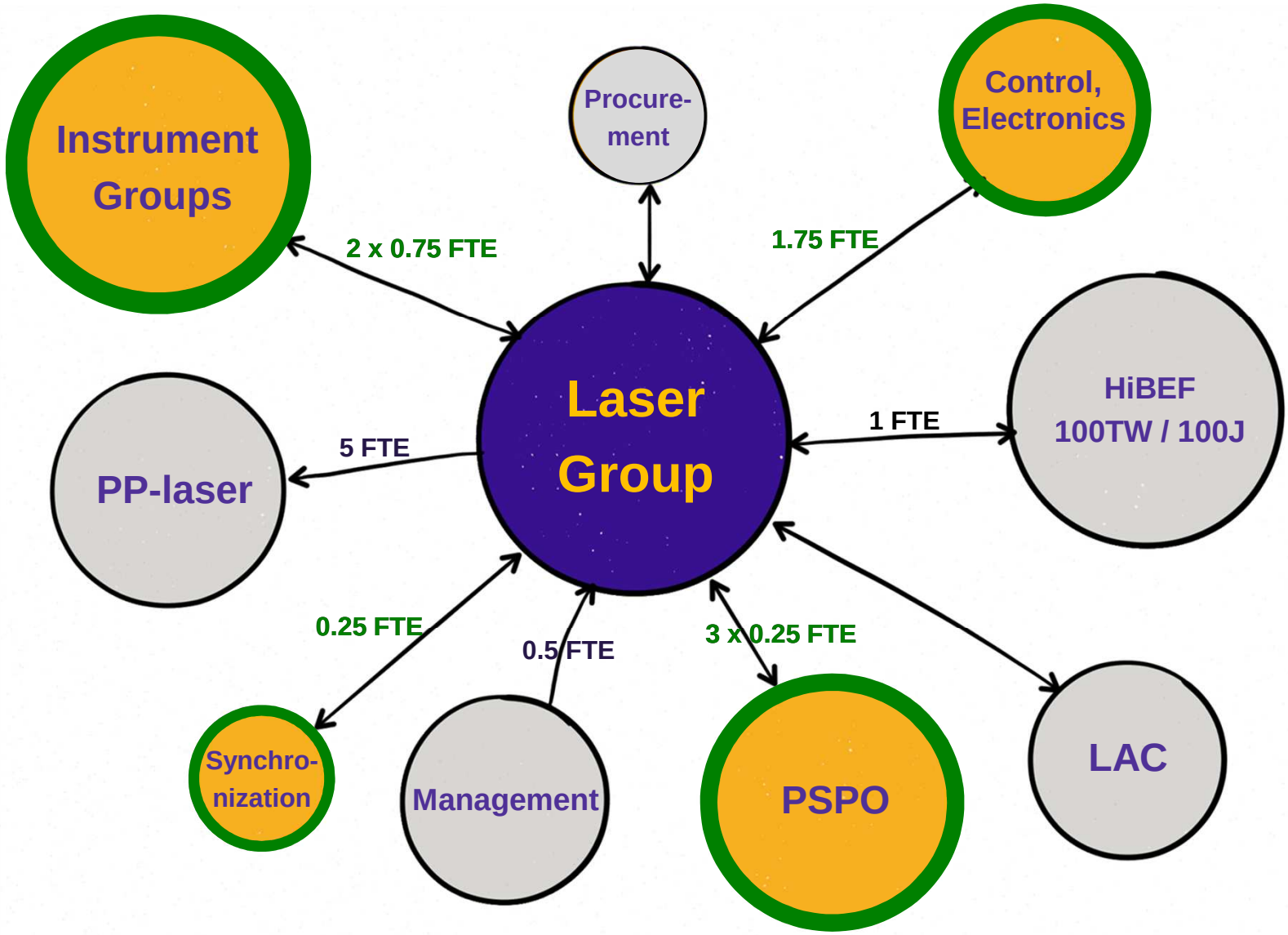
⇨ *Provide and operate laser equipment for the x-ray beam line experiments*
⇨ *In-house developments*
⇨ *Industrial and academic collaborations*

- **Personnel:**

  - Construction phase: **10**
  - Installation, commissioning, operation: **13**



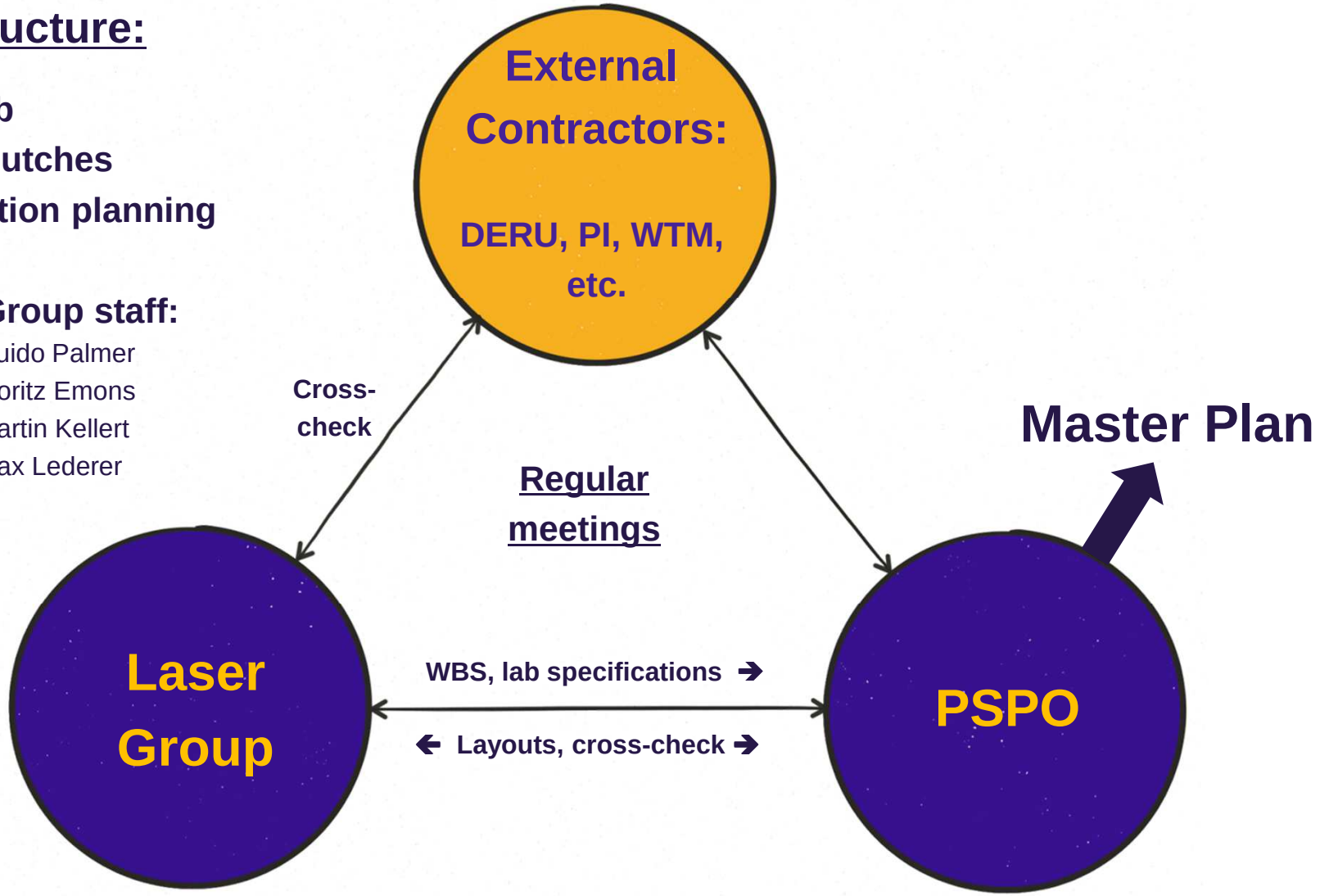
Major interfaces during R&D and construction



Interface: PSPO – Laser Group

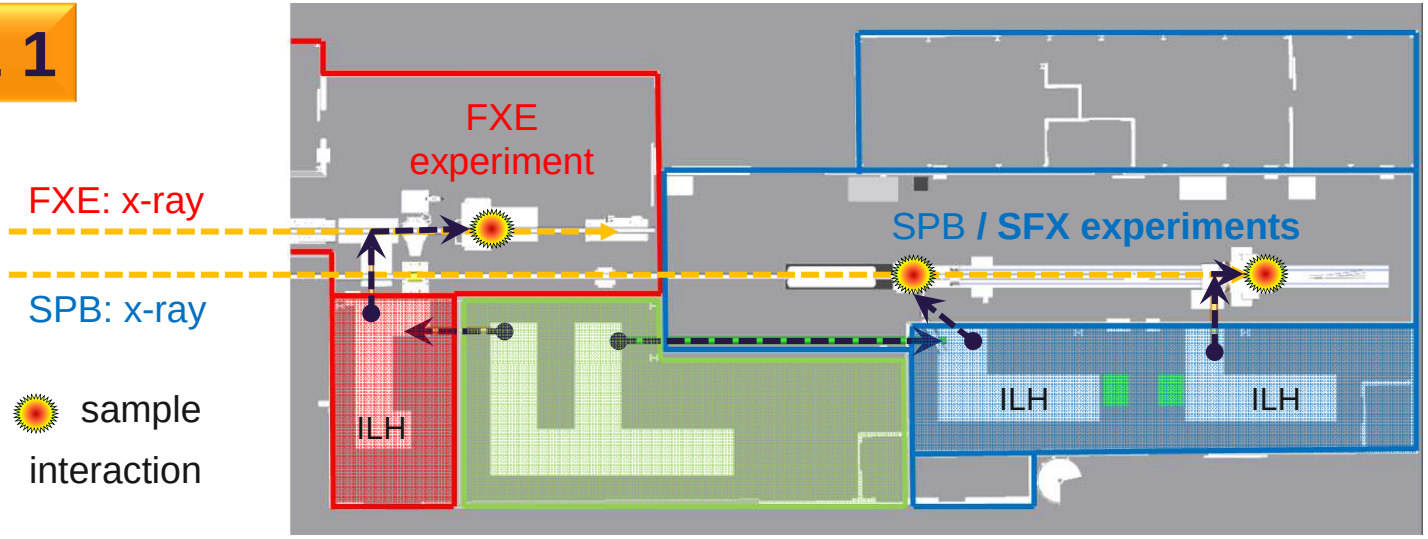
Infrastructure:

- R&D-lab
- Laser hutches
- Installation planning
- ….
- Laser Group staff:
  - Guido Palmer
  - Moritz Emons
  - Martin Kellert
  - Max Lederer



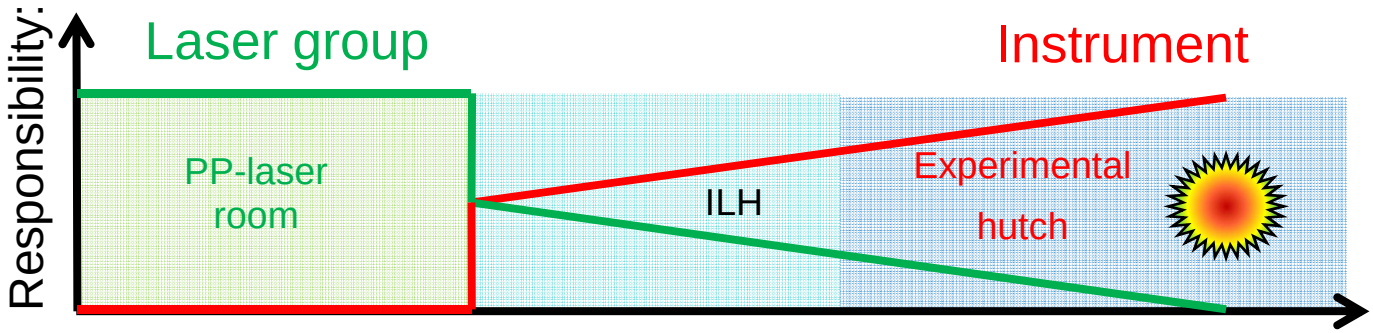
Interface: Instruments – Laser Group

SASE 1

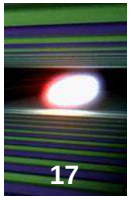


Beam delivery:

- **ILH design**
- **Components selection**
- **Common procurement**
- **….**
- **Laser Group staff:**
  - Guido Palmer
  - Moritz Emons



Interface: Control, Electronics – Laser Group

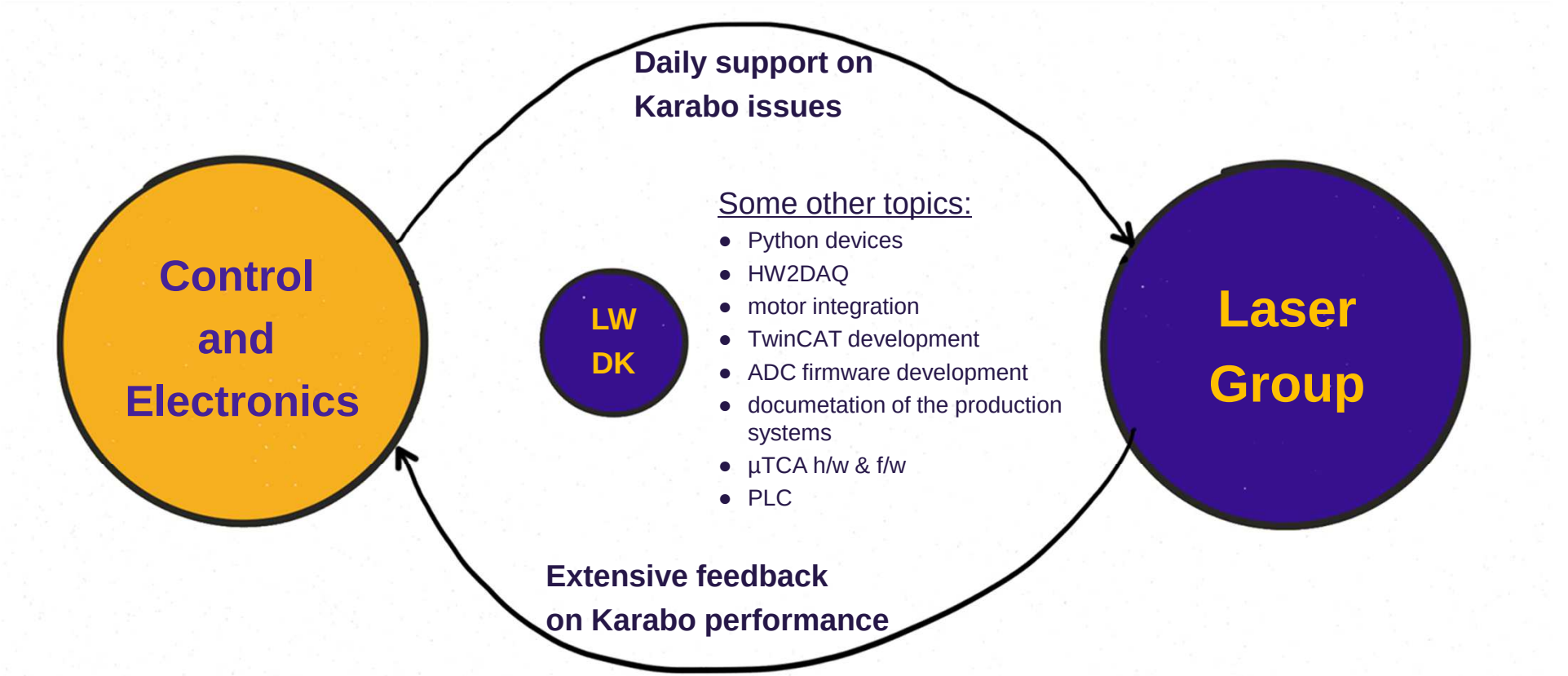


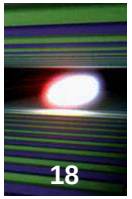
Dedicated „control engineers“ in Laser Group:

- Laurens Wissmann (LW)
- Daniel Kane (DK)

Task:

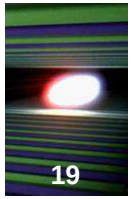
- Laser integration into fledgeling control system „Karabo“.



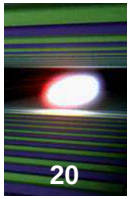


Procurement

Procurement for all PP-lasers



- **Subsystems and long lead items all under way or already in house**
  - ✓ Seed oscillators
  - ✓ Front-Ends (two suppliers)
  - ✓ Power amplifiers
  - ✓ MLD-gratings
  - ✓ ….
- **Calls for tender (*common*)**
  - ✓ Laser tables (PP, ILH, labs)
  - ✓ Special optics, mirrors (PP, ILH)
- **Bread and butter**
  - ✓ Optics, optomechanics
- **Control**
  - Hardware: in progress (80%)
- **Sync**
  - Hardware: contractual arr. with DESY (in legal dept.)
- **Hutches**
  - Tools, furniture, equipment: in progress (80%)



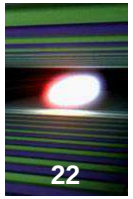
Planning

Work Breakdown Structure (WBS) for PP-laser installation

- Identified stake holders and their function as:
  - ⇨ „coordinator“
  - ⇨ „executor“
  - ⇨ „customer“

- Identified 5 phases with associated tasks:
  - I. Before installation of laser tables (Start hutch construction -> May 2016)
  - II. Installation of laser tables and additional (under-table) infrastructure (June -> Aug. 2016)
  - III. Installation and commissioning of laser components in PP-Hutch (Sept. 2016 -> June 2017)
  - IV. Final Commissioning of AC (Dec. 2016)
  - V. Beam delivery to ILH and experiment (Sept. 2016 -> June 2017)

WBS SASE 1: major tasks and responsibilities

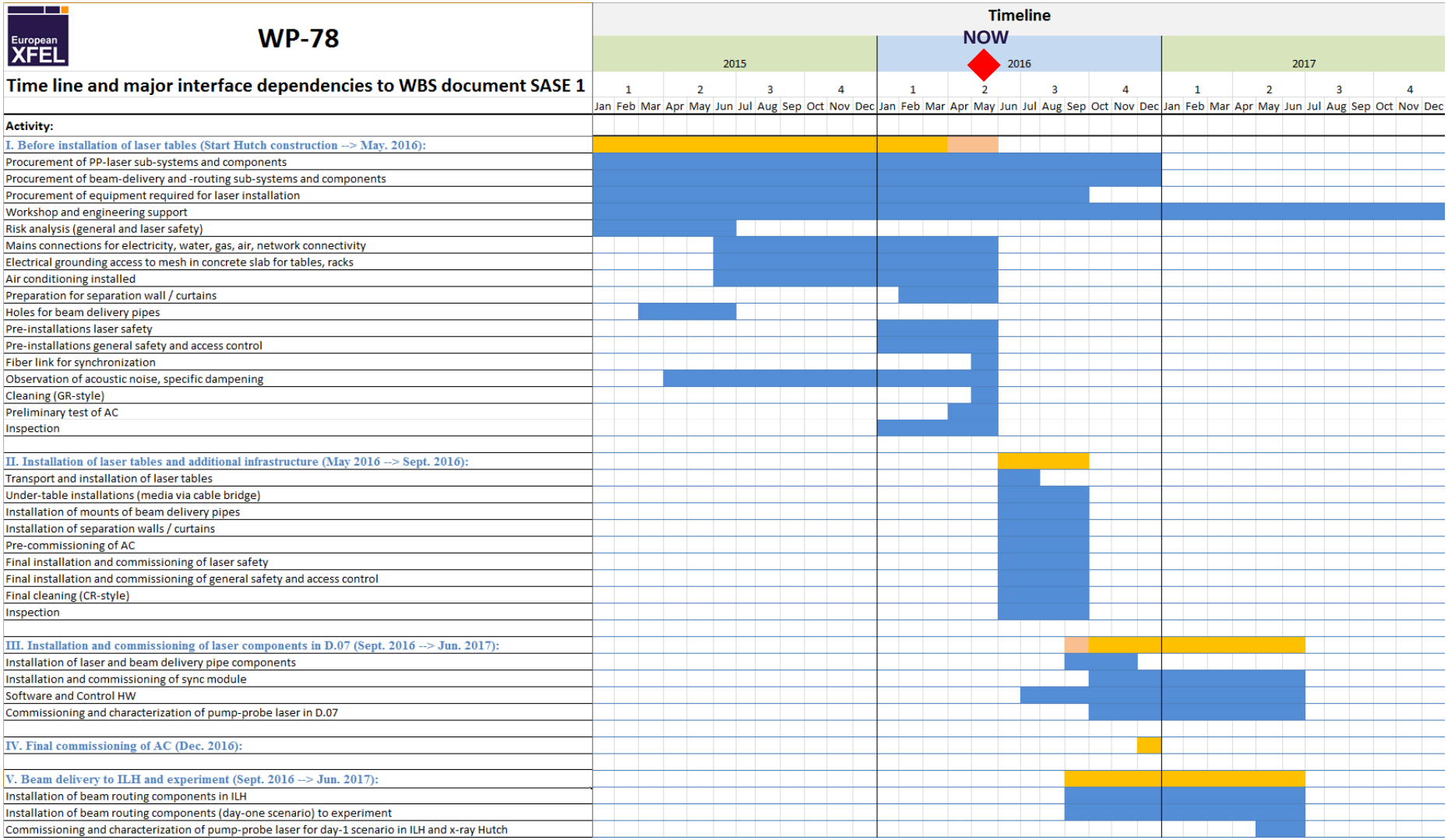


WP-78 Time line and major interface dependencies to WBS document SASE 1	Responsibilities				
Activity:	**Coordinator**	**Executor**	**Customer**	**Location**	**Comments**
I. Before installation of laser tables (Start Hutch construction –> May. 2016):					
Procurement of PP-laser sub-systems and components	WP78	WP78	WP78	AER-19, HERA-S	Ideally finished by the time the laser tables are installed in D.07
Procurement of beam-delivery and -routing sub-systems and components	Instrument groups, WP78	Instrument groups,WP78	Instrument groups, WP78	AER-19, HERA-S, XHEXP1, XHQ	Ideally finished by the time the laser tables are installed in ILH
Procurement of equipment required for laser installation	WP78	WP78	WP78	HERA-S, XHEXP1, XHQ or AER-19	Tools, cabinets instruments, etc. Storage available in XHEXP 1 or XHQ (ca. 50m²)
Workshop and engineering support	TS	"hall engineering crew"?	WP78	D.07	Ad hoc parts and small ancillary installations
Risk analysis (general and laser safety)	WP78, XFEL Safety	WP78	XFEL Safety	D.07	General- and Laser-Safety
Mains connections for electricity, water, gas, air, network connectivity	PSPO + TS	DERU + TGA contractors	WP78	D.07	All wall plugs and outlets, emergency shutdown
Electrical grounding access to mesh in concrete slab for tables, racks	PSPO	WTM + DERU + Electro contractor	WP78	D.07	Additional copper sheet on floor needed?
Air conditioning installed	PSPO + TS	DERU + AC contractor	WP78	D.07	Incl. preliminary test of AC
Preparation for separation wall / curtains	PSPO + TS	DERU + AC contractor	WP78	D.07	Fine / coarse climate zones, installation after table installation
Holes for beam delivery pipes	PSPO, TS, CIE	WTM + Hutch contractor	WP78, instrument groups	D.07 /ILH	Position of holes t. b. d., location of vac. pump and vac. delivery pipes
Pre-installations laser safety	XFEL Safety	IK. Wilt, DESY	WP78	D.07	Double door interlock, shutter control, warning lamps, etc.
Pre-installations general safety and access control	XFEL Safety	Contractor	WP78	D.07	Fire extinguisher, DACHS
Fiber link for synchronization	PSPO, WP18	WP 18	WP78, WP81	SS-Hutch / D.07 / ILH	Fibers to be installed from Sync Sub-Hutch into SASE 1 PP-laser-hutch and WP81 ILH
Observation of acoustic noise, specific dampening	WP78	Contractor	WP78	D.07	Hutch walls receive covering for acoustic dampening.
Cleaning (GR-style)	TS	Contractor	WP78	D.07	First cleaning round: dust free
Preliminary test of AC	DERU	AC contractor	WP78	D.07	AC is tested under preliminary conditions.
Inspection	DERU	Contractors	WP78	D.07	AC, TGA, safety, etc. (supervised by special company)
II. Installation of laser tables and additional infrastructure (May 2016 –> Sept. 2016):					
Transport and installation of laser tables	TS, WP78	TS + specialized company	WP78	D.07 / ILH	Clear way ensured, sufficient lift capacity. Laser tables remain covered for dust protection.
Under-table installations (media via cable bridge)	DERU, WP78	Contractors	WP78	D.07	Media bridge, electrical, water and network outlets, cable/media trays, grounding, AC-inlet piping (if required)
Installation of mounts of beam delivery pipes	WP78, instrument groups + CIE	WP78, instrument groups	WP78, instrument groups	D.07 / ILH	vacuum pump for beam tube, sleeves for hole closure and sealing
Installation of separation walls / curtains	DERU	DERU + contractors	WP78	D.07	Using prepared mounts (see line 16)
Pre-commissioning of AC	DERU	AC contractor	WP78	D.07	AC is tested after table and climate separation installation. Particle and flow measurement above tables.
Final installation and commissioning of laser safety	XFEL Safety	IK. Wilt, DESY	WP78	D.07	Shutters and interlocks tested
Final installation and commissioning of general safety and access control	XFEL Safety	Contractors	WP78	D.07	safety system and access control tested
Final cleaning (CR-style)	TS	Contractors	WP78	D.07	Clean room style cleaning
Inspection	DERU	Contractors	WP78	D.07	AC, TGA, safety, etc. (supervised by special company)
III. Installation and commissioning of laser components in D.07 (Sept. 2016 –> Jan. 2017):					
Installation of laser and beam delivery pipe components	WP78	WP78	WP78	D.07	All sensitive optical and electronic components and sub-systems required for laser operation
Installation and commissioning of sync module	WP18, WP78	WP18	WP78, WP81	D.07	Might require additional under-table installations.
Software and Control HW	WP78, WP76	WP78, WP76	WP78	D.07	
Commissioning and characterization of pump-probe laser in D.07	WP78	WP78	WP78	D.07	
IV. Final commissioning of AC (Dec. 2016):	DERU	AC contractor	WP78	D.07	AC is tested under nominal heat load conditions. Particle and flow measurement above tables.
V. Beam delivery to ILH and experiment (Sept. 2016 –> Jan. 2017):					
Installation of beam routing components in ILH	Instrument groups, WP78	Instrument groups, WP78	Instrument groups	ILH	All sensitive optical and electronic components and sub-systems required for day-1 experiment scenario
Installation of beam routing components (day-one scenario) to experiment	Instrument groups, WP78	Instrument groups, WP78	Instrument groups	ILH and X-ray Hutch	All sensitive optical and electronic components and sub-systems required for day-1 experiment scenario
Commissioning and characterization of pump-probe laser for day-1 scenario in ILH and x-ray Hutch	Instrument groups, WP78	Instrument groups, WP78	Instrument groups	ILH and X-ray Hutch	

WBS SASE 1: major tasks and time line

WP-78

Time line and major interface dependencies to WBS document SASE 1



Detailed (Phase III) WP-78 work schedule for SASE 1 PP-laser installation

SASE 1 Phase III planning including details per task. Status: V6, May 2016

Changes V3 ➪V4:	*new facility dates; few small timing adjustements. Detailled description of each task to be done by individuals in separate files.*
Changes V4 ➪V5:	*more detail*
Changes V5 ➪V6:	*changed timing according to new facility milestones*

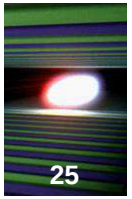
Tasks General — 2016 / 2017

Task	comments, milestones, etc.	No.	Month / KW
Facility, R&D, etc.:	Moving to Schenefeld, Laser tables XHQ-Lab, Equipment XHQ-Lab, Lab 49d	0	All

Tasks SASE 1 — 2016 / 2017

Task	Comments	No.	Month / KW
WBS Phase II:	Laser tables SASE 1 hutches, Equipment	1	All
Laser table installation			ME
Under-table installation DERU	LW monitor cable channel installation		DERU
Equipment			All
Commissioning (AC, safety, CR, Dachs)			GPa, ME
Pre-assembly according to CAD:	complete laser incl. Sync and Control	2	All
Installation of control rack, electronics assembly			LW, DK
Under-table Installation and cabling WP78	cable ducts, rack w. PLCs & oth. Electr. in place		LW, DK
Under-table water installation	Facility water		MK
Network, control rack, basic Beckhoff functionality	Network PP installation in rack only!		LW, DK
Front-End and seeder installation	Sync rack in place.		KK
Laser insterlock installation finished and tested	24V power supply		
Amphos installation	Facility water, 400V power supply		MK
All components on table	Sync components?		All
Beam pipe, alignment laser, vacuum and shutter:		3	GPa, ME
Shutter installation	responsibility not clear!		Witt ?
Installation of beam pipe supports and wall mounts	Need MK2 for drilling holes		GPa, ME, DESY
Installation of vacuum pipes and system for both FXE and SPB			GPa, ME
Alignment lasers 790nm & 1060 nm	Operational PLC and completion of Phase II cabling, check 28		GPa, ME, LW, DK
Comissioning of vacuum system with Karabo control	Operational PLC and completion of Phase II cabling, check 28		GPa, ME, LW, DK
Seeder, long delay, FC:		4	JW, KK
Front-End:		5	KK
XF2 compressor, AOM:		6	KK, MK, MP
	trigger, 24V power supply		
TEM XF2:		7	KK, MK
Amphos commissioning:		8	MK, UW
	10/20Hz Hz trigger		
SCG and Dispersion:		9	MP, UW
Imaging of 1030nm XF2 and delay installation			
Alignment of SCG stage			
Alignment of DCM			
Collimation of the beam and imaging to I stage			
Diagnostics installation and test			
Documentation of the reference points			
Control and monitoring commissioning:		10	LW, DK
Ongoing bugfixing of all integrted components.			
BCC CM:		11	JW
TEM Amphos:		12	KK
PC:		13	MK
	trigger		
Galvo:		14	UW
galvo and housing on table, routing beam to galvo	facility water, trigger and trigger inhibit, Galvo PC and Galvo power supply,		
Fine tuning of galvo parameters installation of diagnostics and long term test	2 working Karabo cameras and spare lenses, this setup is temporary, only 2% before HILTI testing		
HILTI testing	Full Galvo integration		
Amphos compressor including beam shaping:		15	MK, MP
Compressor SPB			
Compressor FXE			
BCC DM:		16	JW, UW
Pump - seed timing:		17	KK, MP
Sync commissioning:		18	LW
Electronics&Software tests	Optical link in place, all DOOCS servers available, Karabo/DOOCS bridge exists.		
Long-term stability test.	NO out-of-loop measurement foreseen!		
NOPA commissioning:		19	MP, UW, MK, KK, JW,...
Pump beam 1030nm Imaging I, II, III stages (all rep. rates)			
Compensation telescope installation			
SHG for all stages and 2w beam alignment			
I stage time overlap and alignment			
Imaging 800nm I to II stage			
II stage time overlap and alignment			
Diagnostics I and II stage instalation and test			
1.1 MHz and 4.5 MHz switch and charactirization			
Documentation of the reference points I and II stage			
Imaging 800nm II to III stage			
III stage time overlap and alignment			
Diagnostics III stage instalation and test			
200kHz and 100kHz switch and charactirization			
Documentation of the reference points III stage			
Compression test all rep.rates			
Laser housing:		20	ME
Operations support:		21	All

Detailed (Phase III) WP-78 work schedule for SASE 1 PP-laser installation



SASE 1 Phase III planning including details per task. Status: V6, May 2016

Changes V3 ⇨V4:			*new facility dates; few small timing adjustements. Detailled description of each task to be done by individuals in separate files.*
Changes V4 ⇨V5:			*more detail*
Changes V5 ⇨V6:			*changed timing according to new facility milestones*

Tasks General			2016
		Month	Apr May June July Aug Sept Oct Nov Dec
	comments, milestones, etc.	KW	14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52
Facility, R&D, etc.:	Moving to Schenefeld, Laser tables XHQ-Lab, Equipment XHQ-Lab, Lab 49d	0	All

Tasks SASE 1				2016
			Month	Apr May June July Aug Sept Oct Nov Dec
			KW	14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52
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	trigger, 24V power supply			
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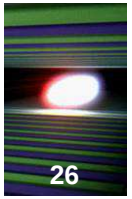
Alignment of DCM				
Collimation of the beam and imaging to I stage				
Diagnostics installation and test				
Documentation of the reference points				
Control and monitoring commissioning:		10	LW, DK	
Ongoing bugfixing of all integrted components.				

Interface: Sync (WP18) – Laser Group



WP 18:

- Ch. Gerth, C. Sydlo

Task:

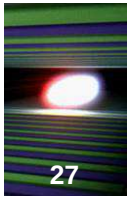
- L2RF- and/or L2L synchronization of PP- and other lasers

Meeting on 15. 09. 2015:

- 3 x PP laser (L2L): Origami-10, 1030 nm, 170 fs, 54.16 MHz
- 1 x TW-laser (L2L): type t. b. d., 800nm, 15fs , 81.25 MHz
- 1 x FXE (L2RF): Tangerine, 1030nm, 400 fs, 54.16 MHz
- Clarified WP18 requirements and technical interfaces (power, beam height, space, etc.)
- Subsequent clarification of cabling responsibilities (fiber from sync sub-hutch to laser hutches): lies with WP18
- Cable routing inside laser hutch is clarified.
- Procurement of laser table for sync sub-hutch as part of WP78 order
- Step wise synchronization: first L2RF then L2L (latest May 2017)

Next steps:

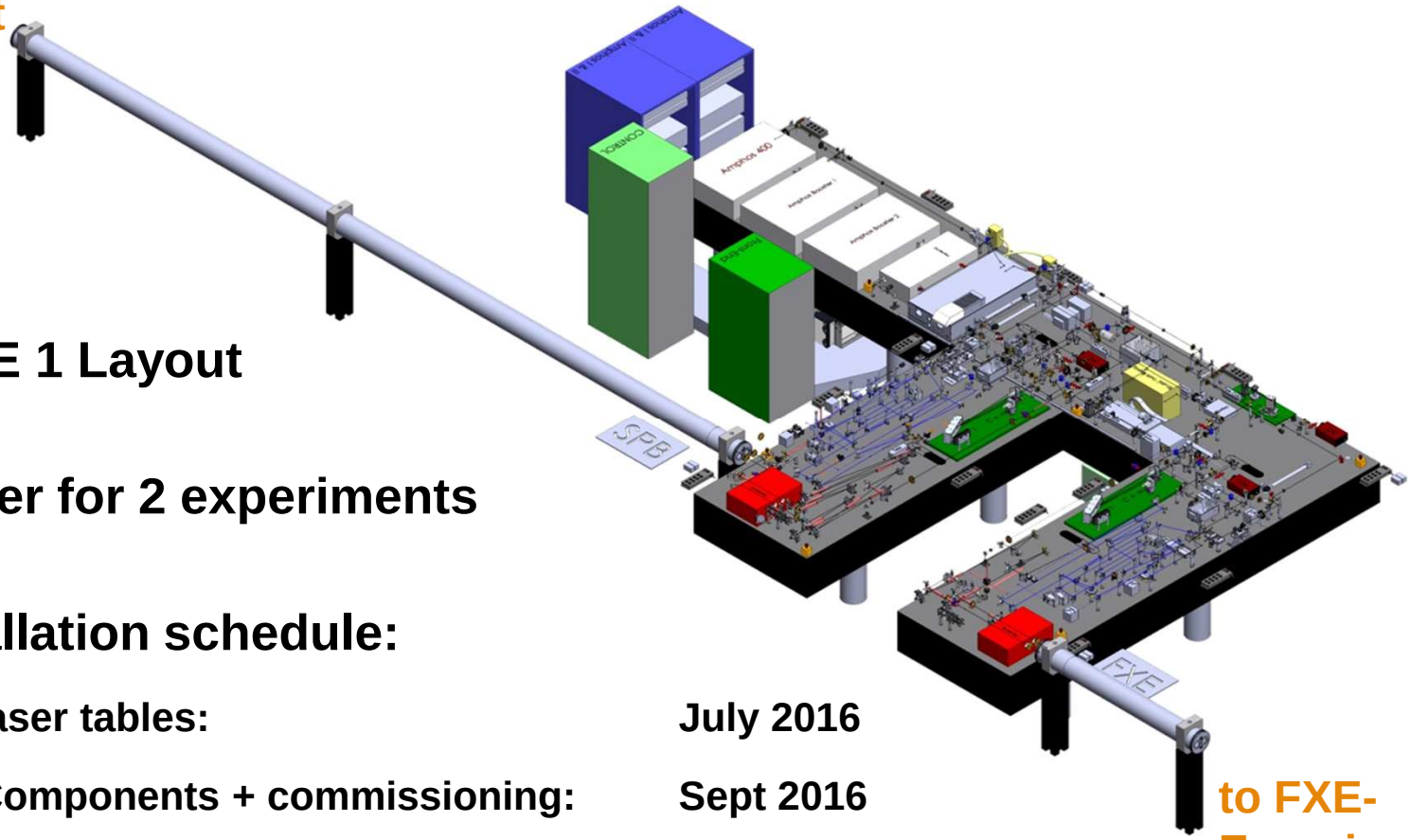
- Ratification of reembursement agreement (currently with DESY legal department).
- Origami-10 synchronization test by WP18: details follow in meeting on 23rd May
- Reassess time schedule for sync commissioning in SASE 1.



SASE 1 Pump-probe laser installation

Production system SASE 1

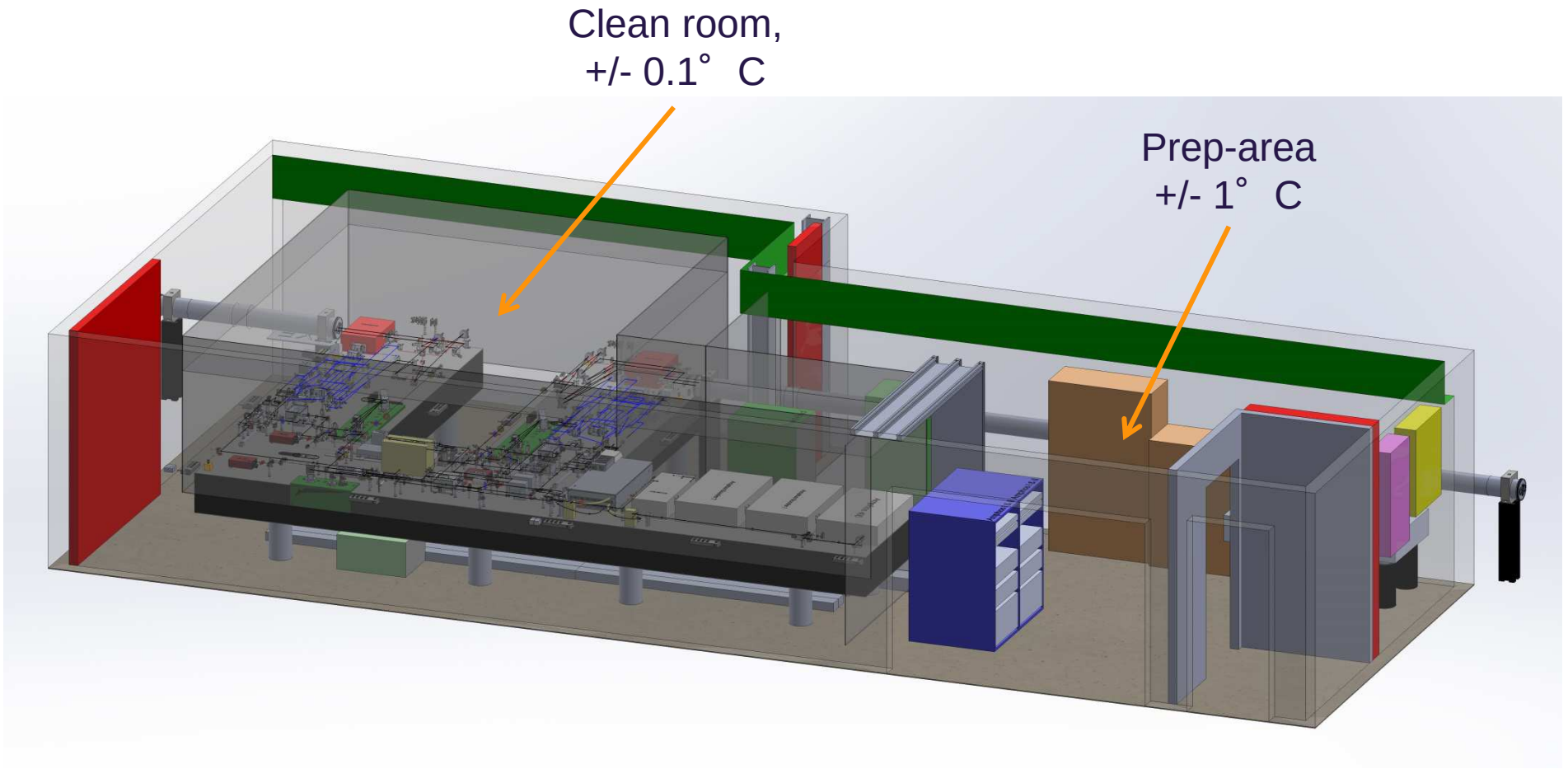
to SPB-Experiment



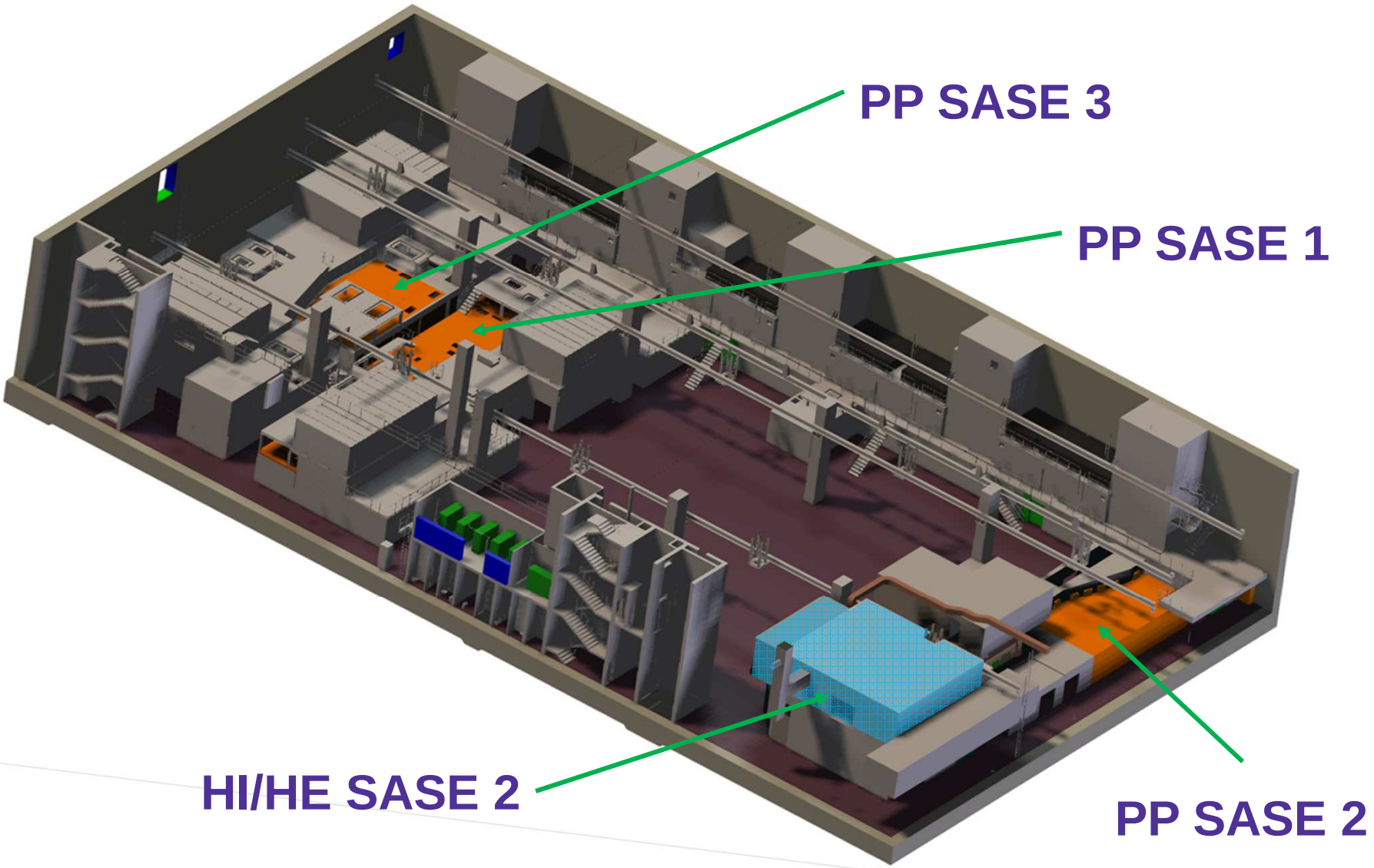
- SASE 1 Layout
- 1 laser for 2 experiments
- Installation schedule:
  - laser tables: July 2016
  - Components + commissioning: Sept 2016
  - Beam at experiment: June 2017

to FXE-Experiment

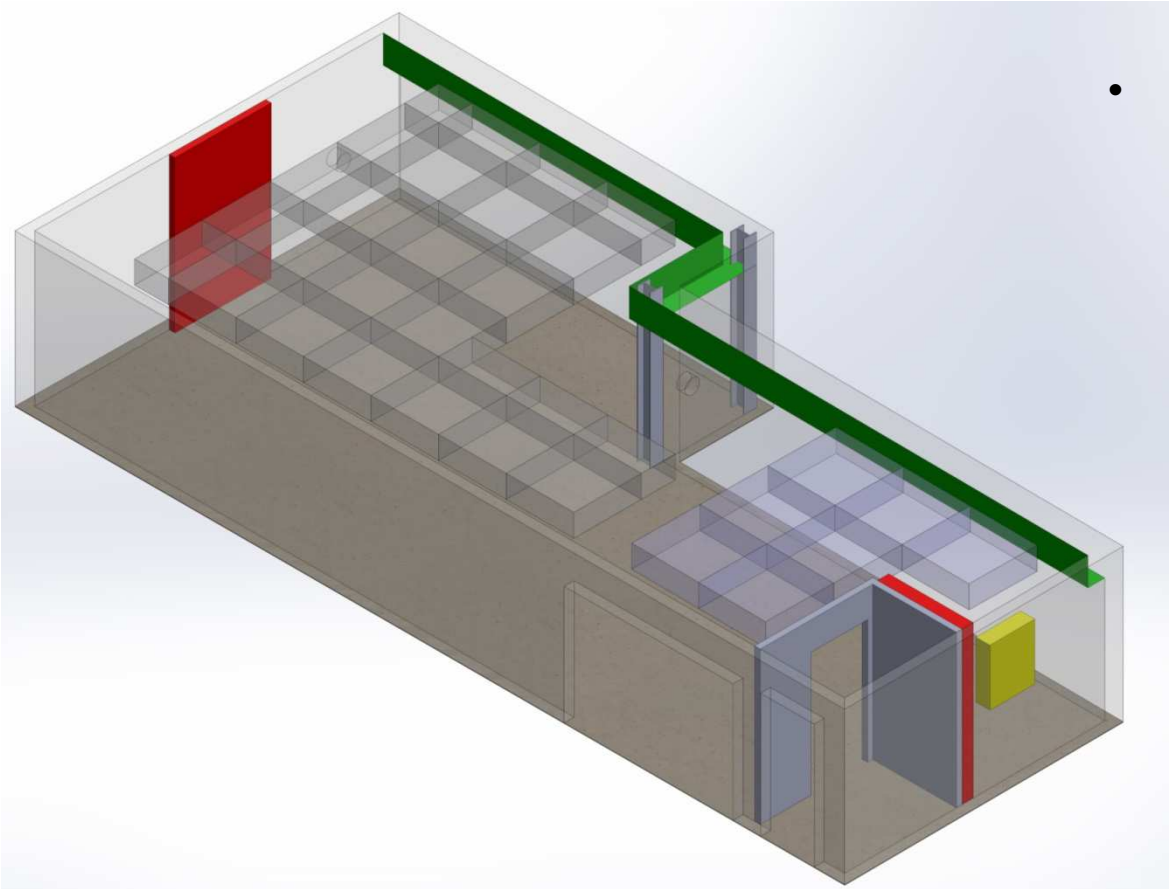
Pump-probe laser hutch SASE 1



XHEXP 1 with laser installations



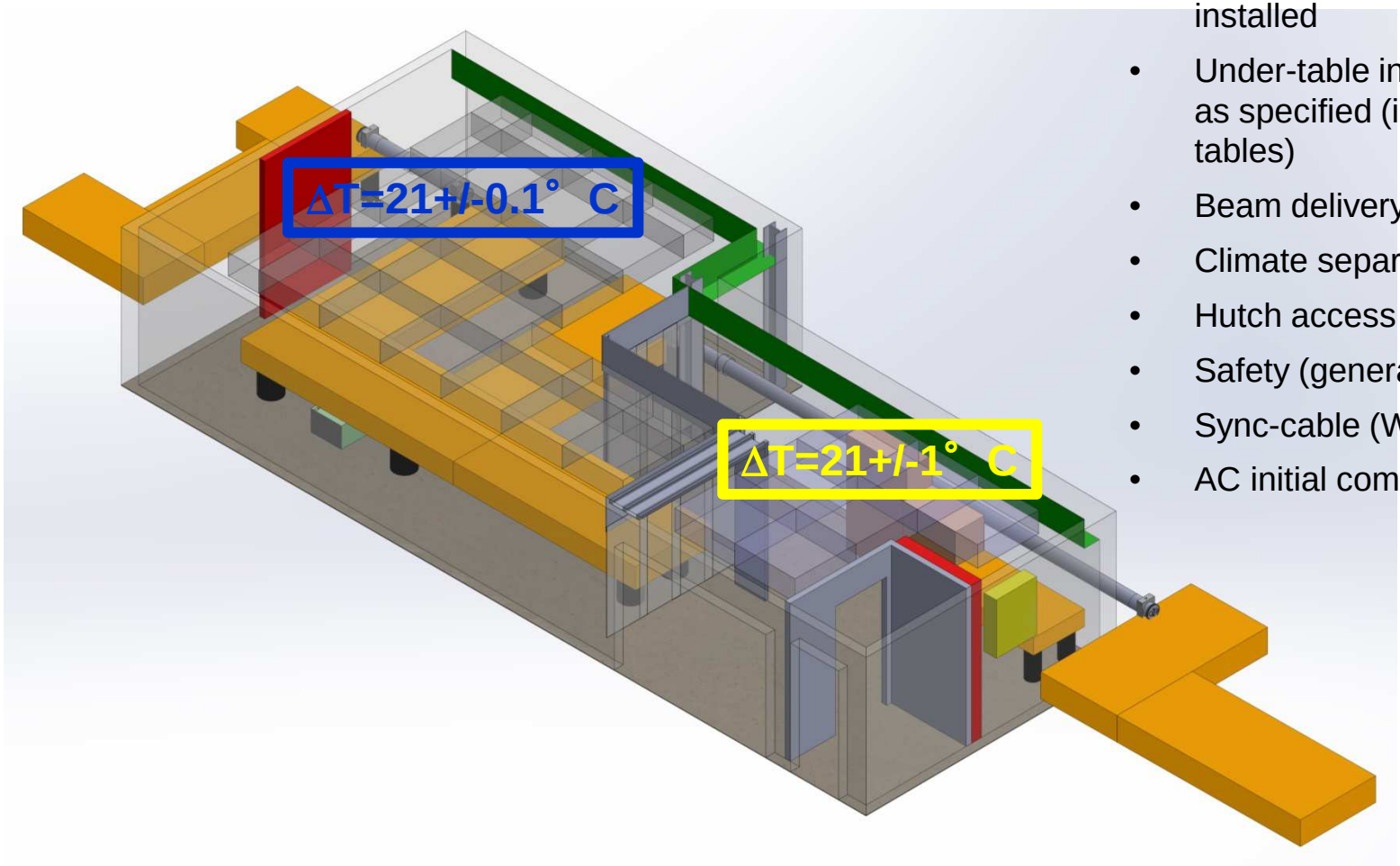
I: Before installation of laser tables (-> May 2016)



At the end of phase I we have:

- Electricity, network, water, gas at access points
- AC installed and GR condition

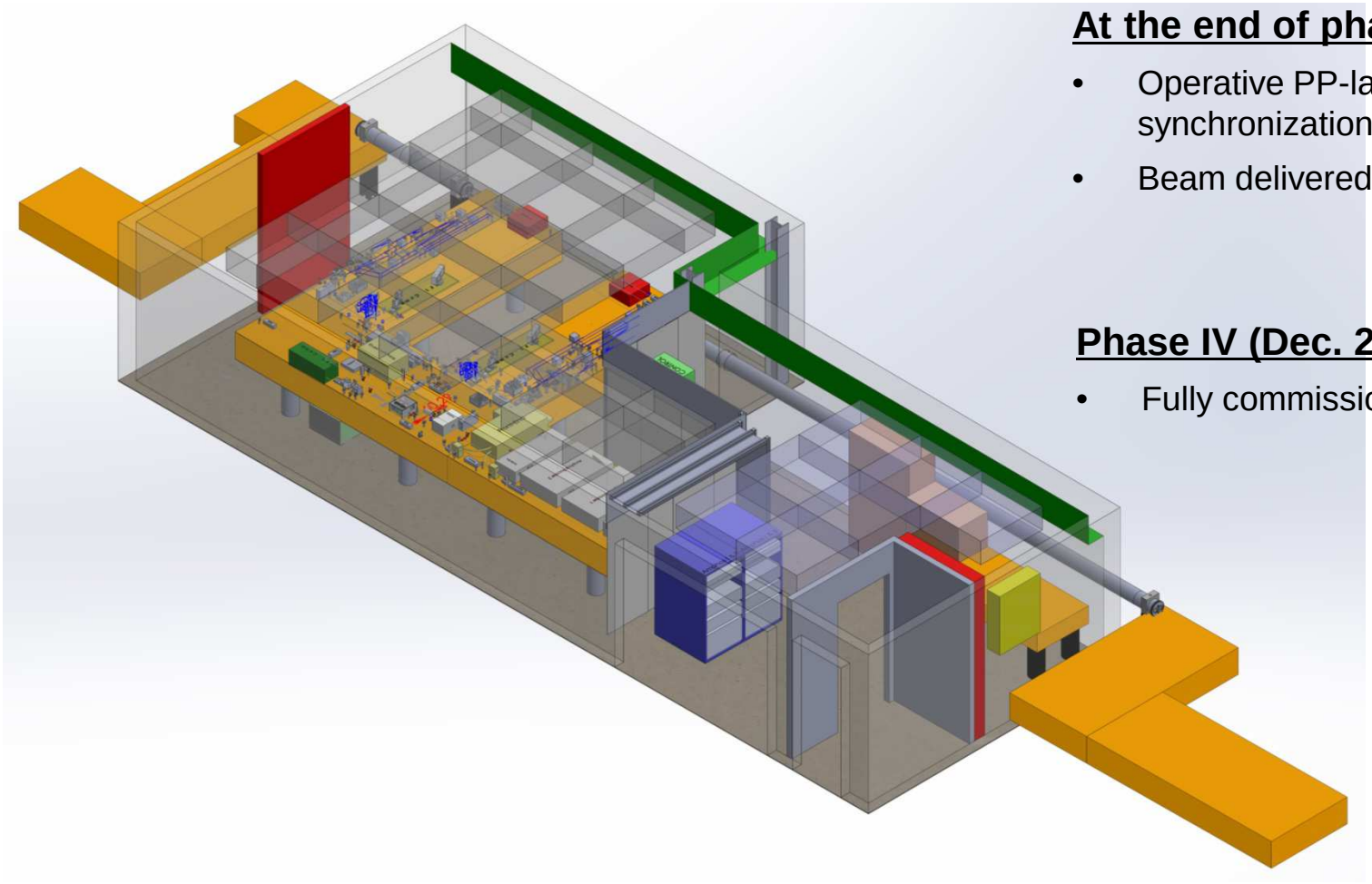
II: Installation of laser tables and additional (under-table) infrastructure (Jun. -> Sept. 2016)



At the end of phase II we have:

- Laser tables and furniture installed
- Under-table installation complete as specified (incl. Grounding of tables)
- Beam delivery pipes installed
- Climate separation
- Hutch access control
- Safety (general and laser)
- Sync-cable (WP-18)
- AC initial comm. and CR conds.

III and IV: Installation and commissioning of laser components in PP-Hutch (Sept. 2016 -> June 2017)



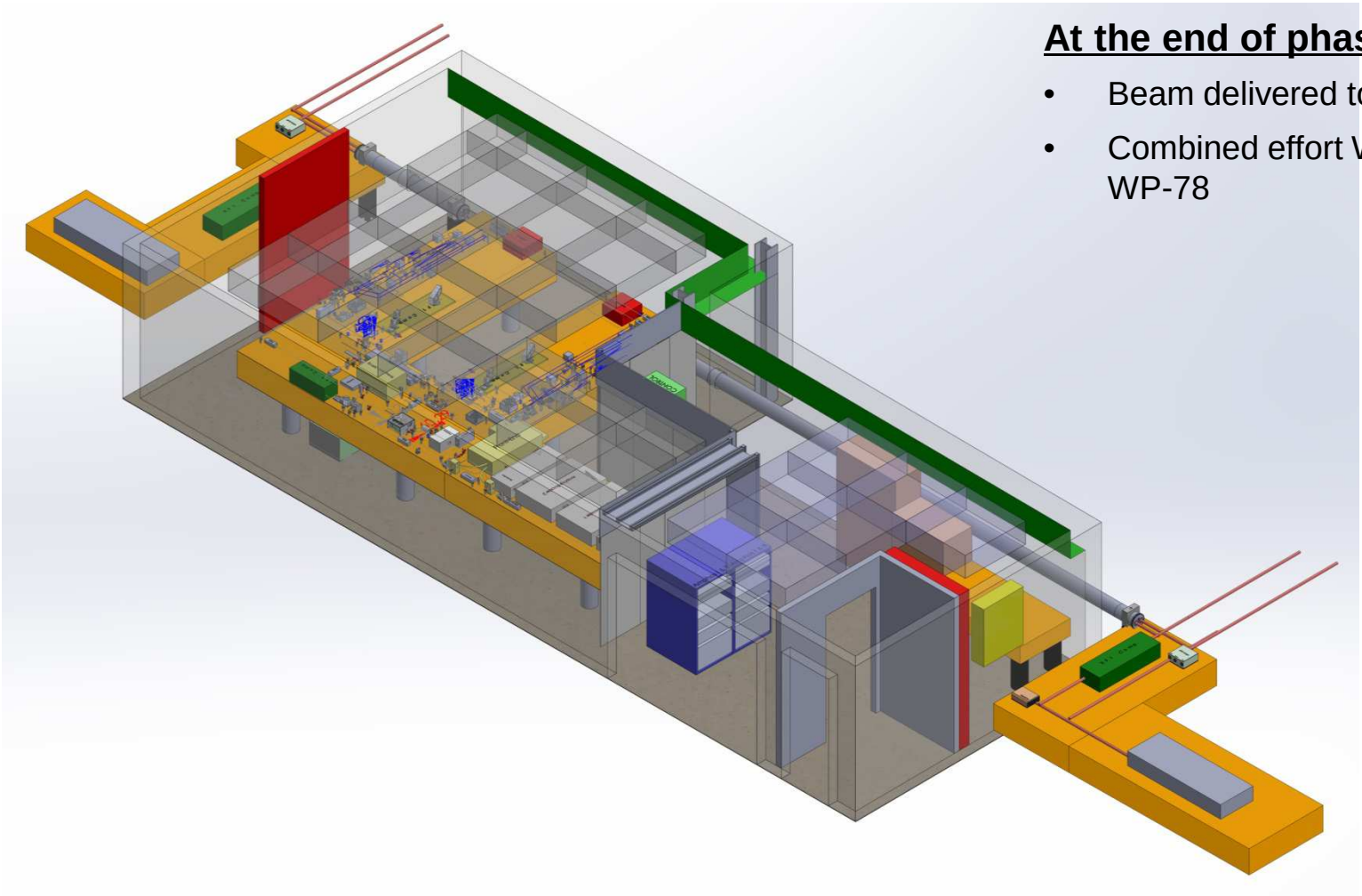
At the end of phase III we have:

- Operative PP-laser with synchronization and Karabo-control
- Beam delivered to ILH

Phase IV (Dec. 2016):

- Fully commissioned AC

V: Beam delivery to ILH and experiment (Sept. 2016 -> Jun. 2017)



At the end of phase V we have:

- Beam delivered to first experiment
- Combined effort WP-81/84 and WP-78

Schedules

General PP-laser installation schedule:

Task 1:	Laser tables and infrastructure in PP and ILH-hutches	**month 1-3**
Task 2:	Components + commissioning in PP and ILH-hutches	**month 4-11**
Task 3:	Beam at experiment for day-1	**month 12**

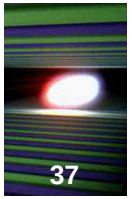
SASE-specific infrastructure milestones (status April 2016):

SASE 1	Milestone	Date
	„sensitive equipment (start **Task 1**)	19.05.2016
	„infrastructure complete“ (start **Task 2**)	26.09.2016
SASE 3		
	„sensitive equipment (start **Task 1**)	29.10.2016
	„infrastructure complete“ (start **Task 2**)	23.12.2016
SASE 2		
	„sensitive equipment (start **Task 1**)	14.01.2017
	„infrastructure complete“ (start **Task 2**)	10.03.2017

Summary and outlook

PP-laser installation at SASE 1

- ⇨ **PP-laser R&D status:** **advanced, on schedule**
- ⇨ **PP-laser procurement (all):** **advanced, on schedule**
- ⇨ **Installation planning:** **WBS and detailed planning**
- ⇨ **Hutch construction:** **currently phase II (WBS)**
- ⇨ **Start of phase III (WBS):** **September 2016**



Thank you!

WP78:

Mikhail Pergament
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Jin Wang
Guido Palmer
Gerd Priebe
Laurens Wissmann
Ulrike Wegner
Moritz Emons
Daniel Kane
Max Lederer