



SCS Optical Laser Delivery

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Schenefeld, 23 January 2017

Overview

Pump-probe laser at European XFEL

- Laser system
- Burst mode operation
- Sample heating

SCS optical delivery

- Instrument laser hutch
- Frequency conversion (nHG, OPA, THz)
- Laser in-coupling (LIN)
- THz in-coupling

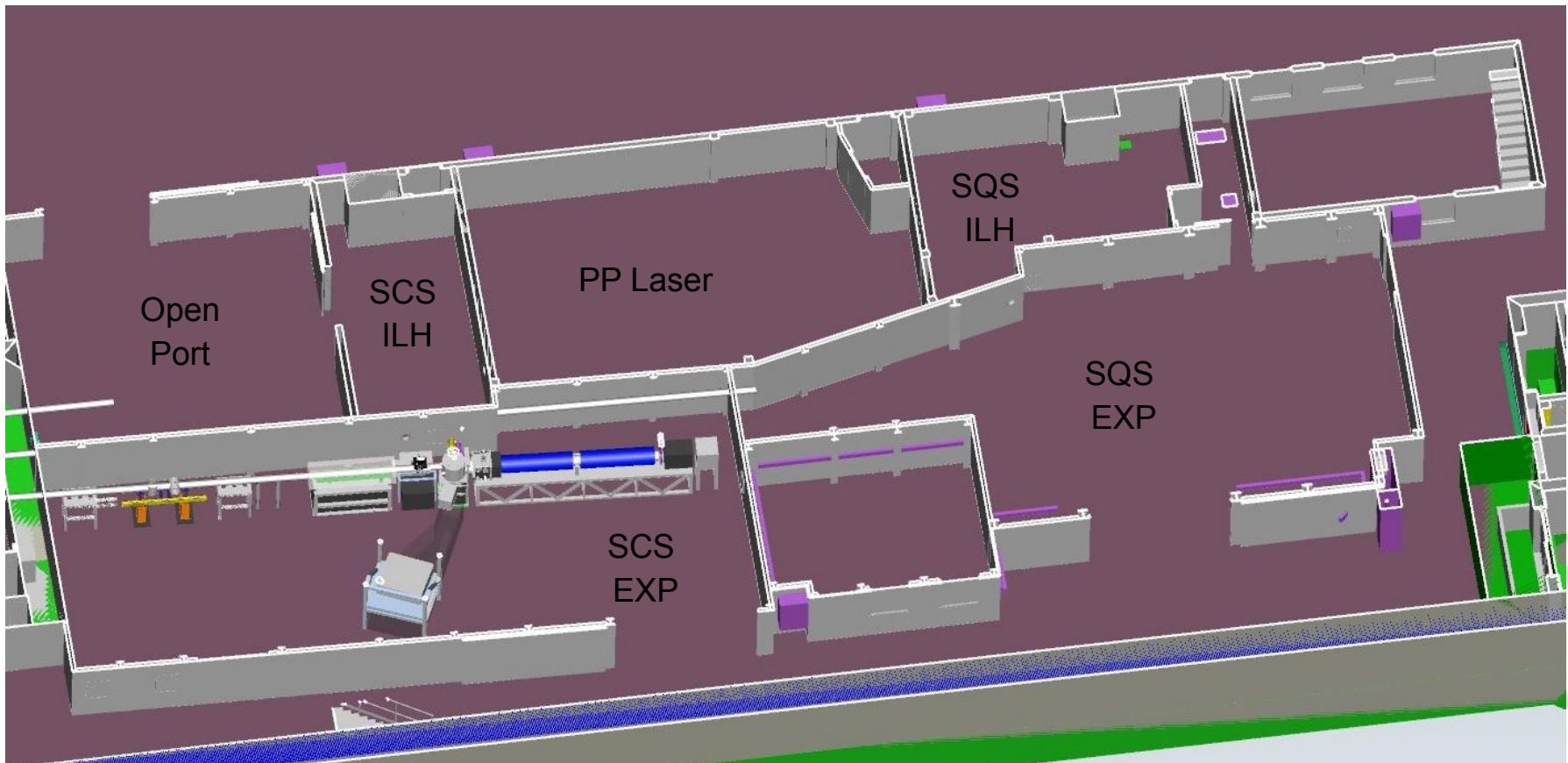
Temporal diagnostics

- Pulse arrival monitor
- X-ray – optical cross-correlator

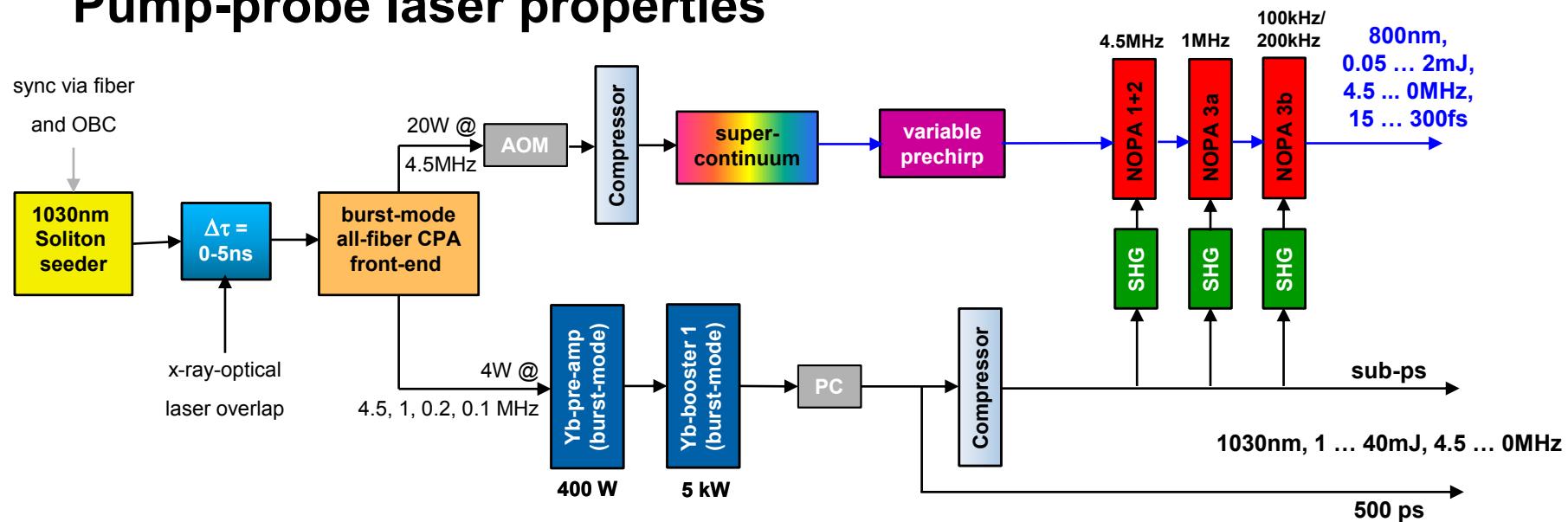


European XFEL

SASE 3 Experimental Area



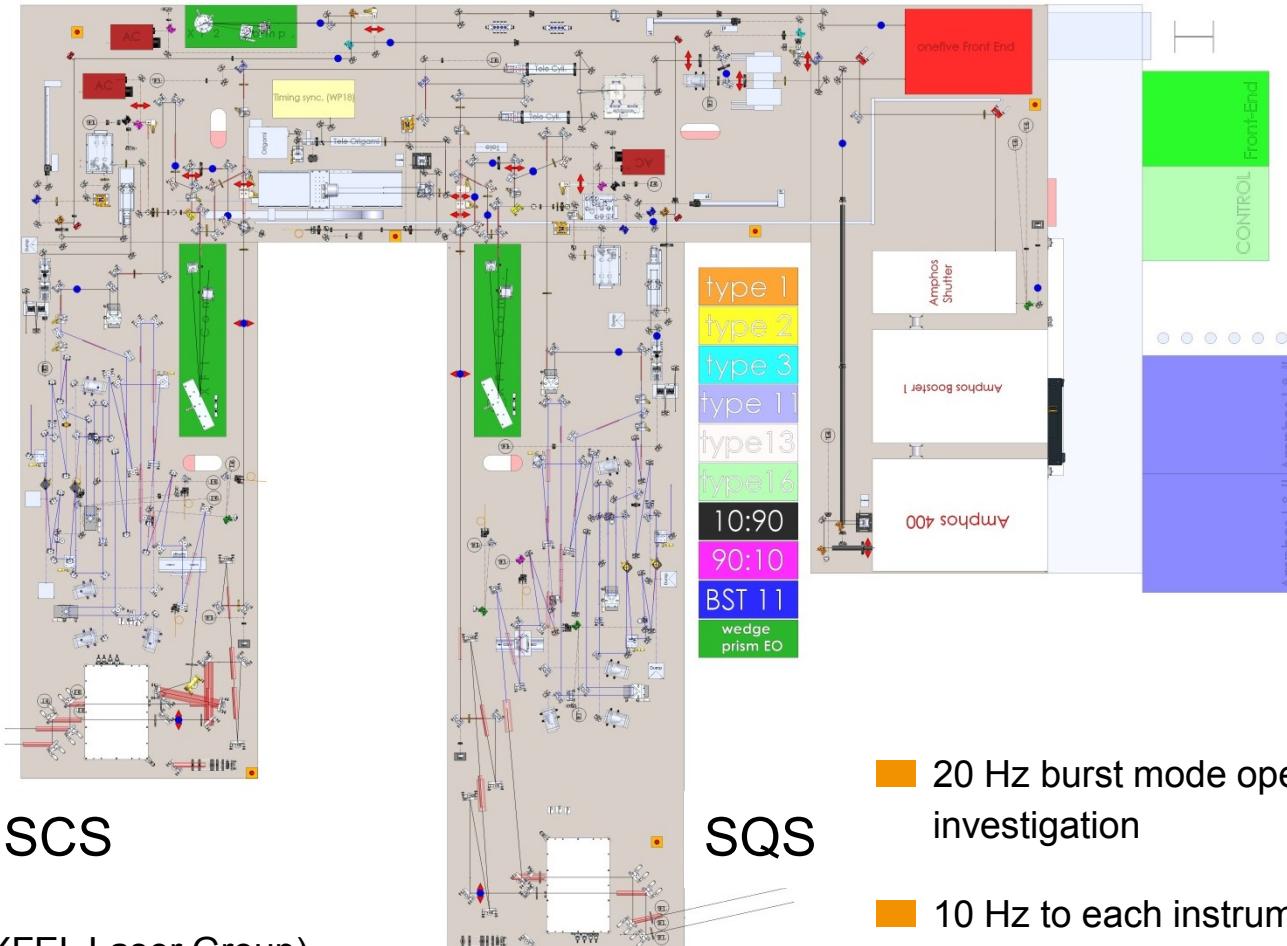
Pump-probe laser properties



- Synchronized seed laser-oscillator and delay stage for X-Ray – OL overlap
- Burst-mode Yb-all-fiber CPA front-end: 2 synchronous outputs, 100kHz, 200kHz, 1MHz and 4.5MHz
- White light seed generation in YAG ($\Delta\lambda \geq 700 - 900$ nm) & var. pre-chirp
- Burst-mode 3-stage Yb:amplifier chain (Innoslab-technology): up to 40 mJ, 100kHz – 4.5MHz
- Arbitrary pulse and burst selection for „pulse-on-demand“ (PoD)
- NOPA with 3 working points

Guido Palmer (XFEL Optical Laser Group)

The pump-probe laser



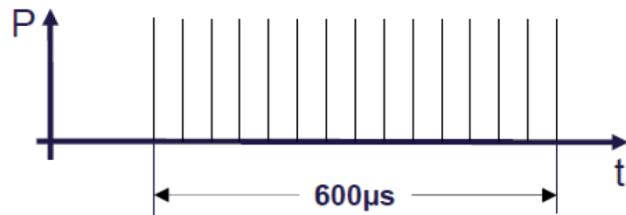
Moritz Emons (XFEL Laser Group)

- 20 Hz burst mode operation under investigation
- 10 Hz to each instrument
- No changeover time

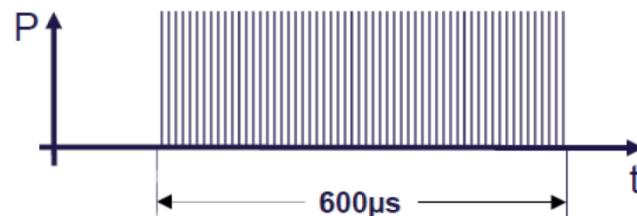
Pump-probe laser operating modes

EXFEL X-ray burst

- 0.6% duty cycle at 10 Hz
- 1 to 2700 pulses

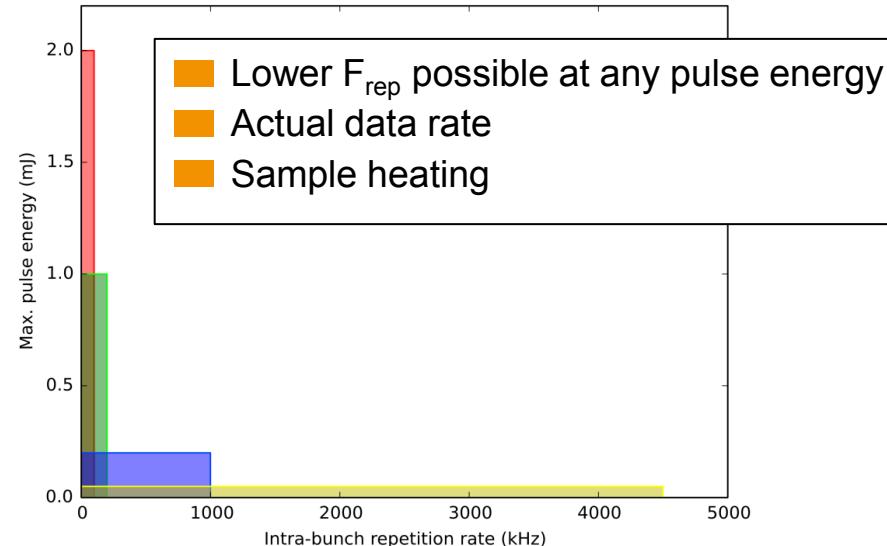


$P_{burst}=1\text{ kW}$, $P_{ave}=6\text{ W}$ @ 800nm

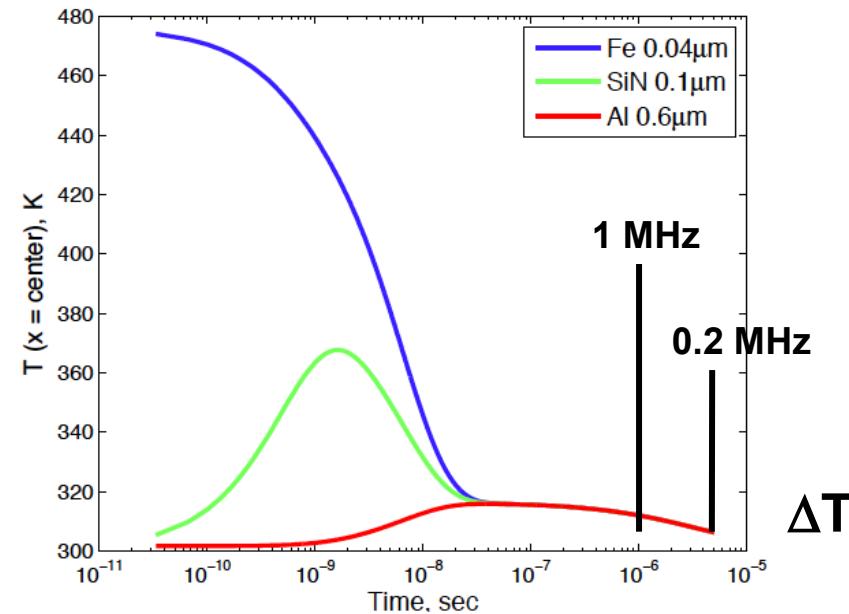
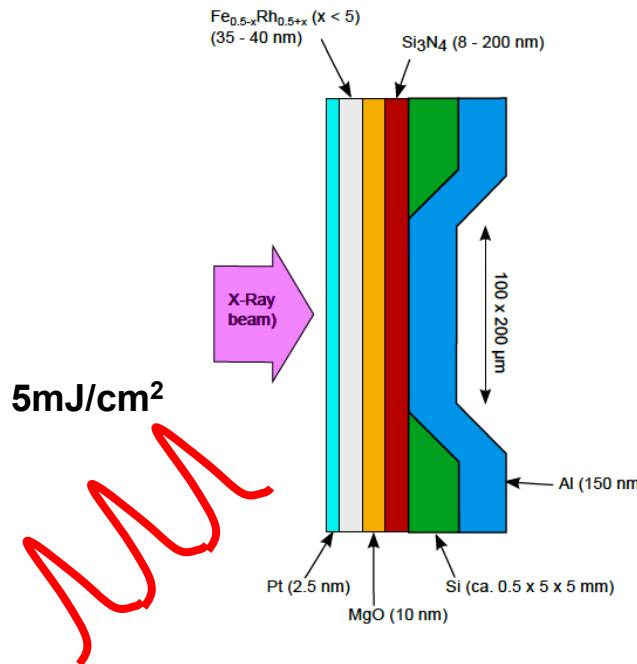


PP laser burst

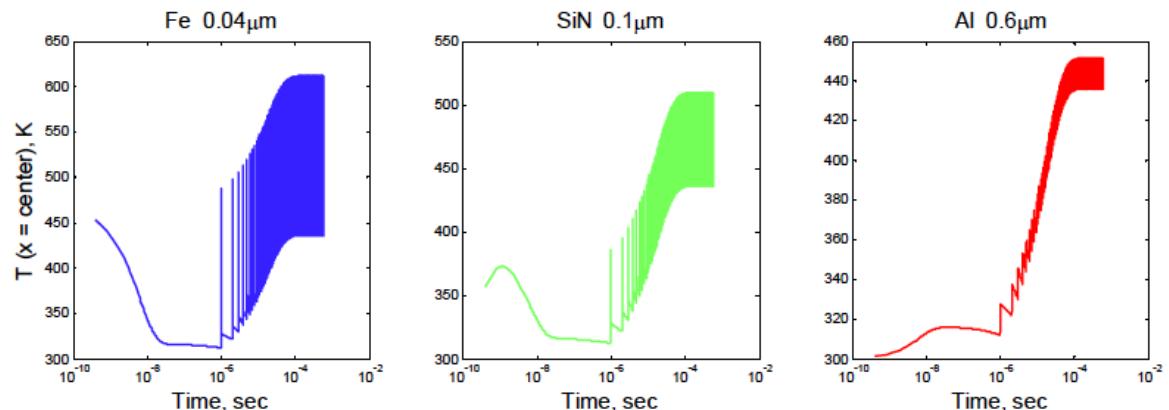
Mode	F_{rep} / MHz	$\Delta t / \text{ns}$	F_{eff} / kHz	800 nm		1030 nm	
				E_{pulse} / mJ	E_{pulse} / mJ	E_{pulse} / mJ	E_{pulse} / mJ
1	4.5	222	27	0.05		1	
2	1	1000	6	0.2		4	
3	0.2	5000	1.2	1		20	
4	0.1	10000	0.6	2		40	
				Pulse duration		15-300 fs	<1ps or 400 fs



Sample Heating Example: FeRh



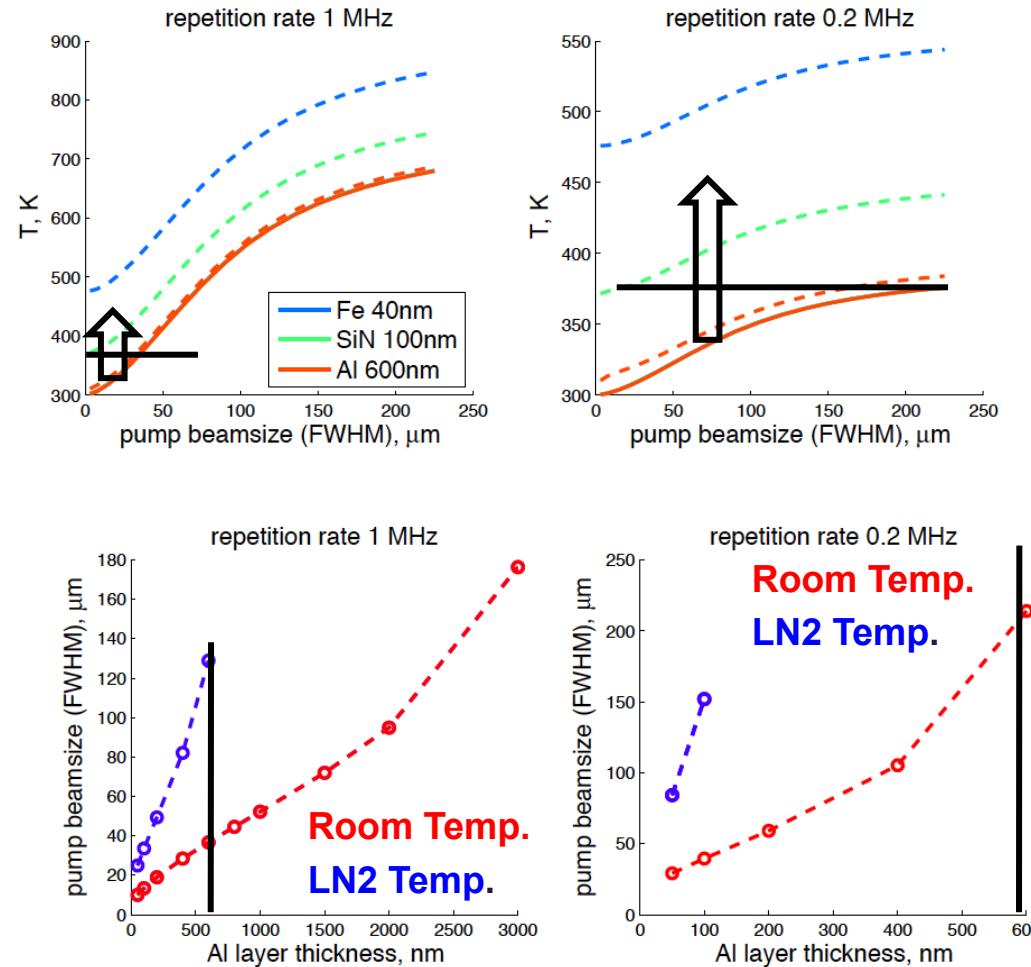
Alexander Yaroslatshev



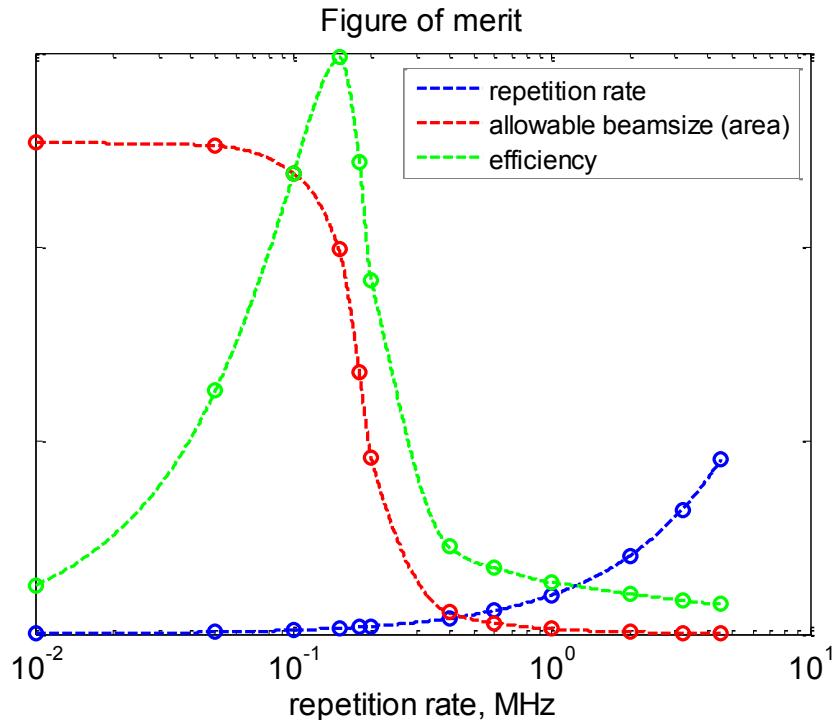
Sample Heating Example: FeRh

Driving an AFM-FM phase transition in FeRh

- Pump beam size at 1 MHz and 0.2 kH
- Heat sink and initial temperature selection important to stay below a target temperature



Sample Heating Example: FeRh

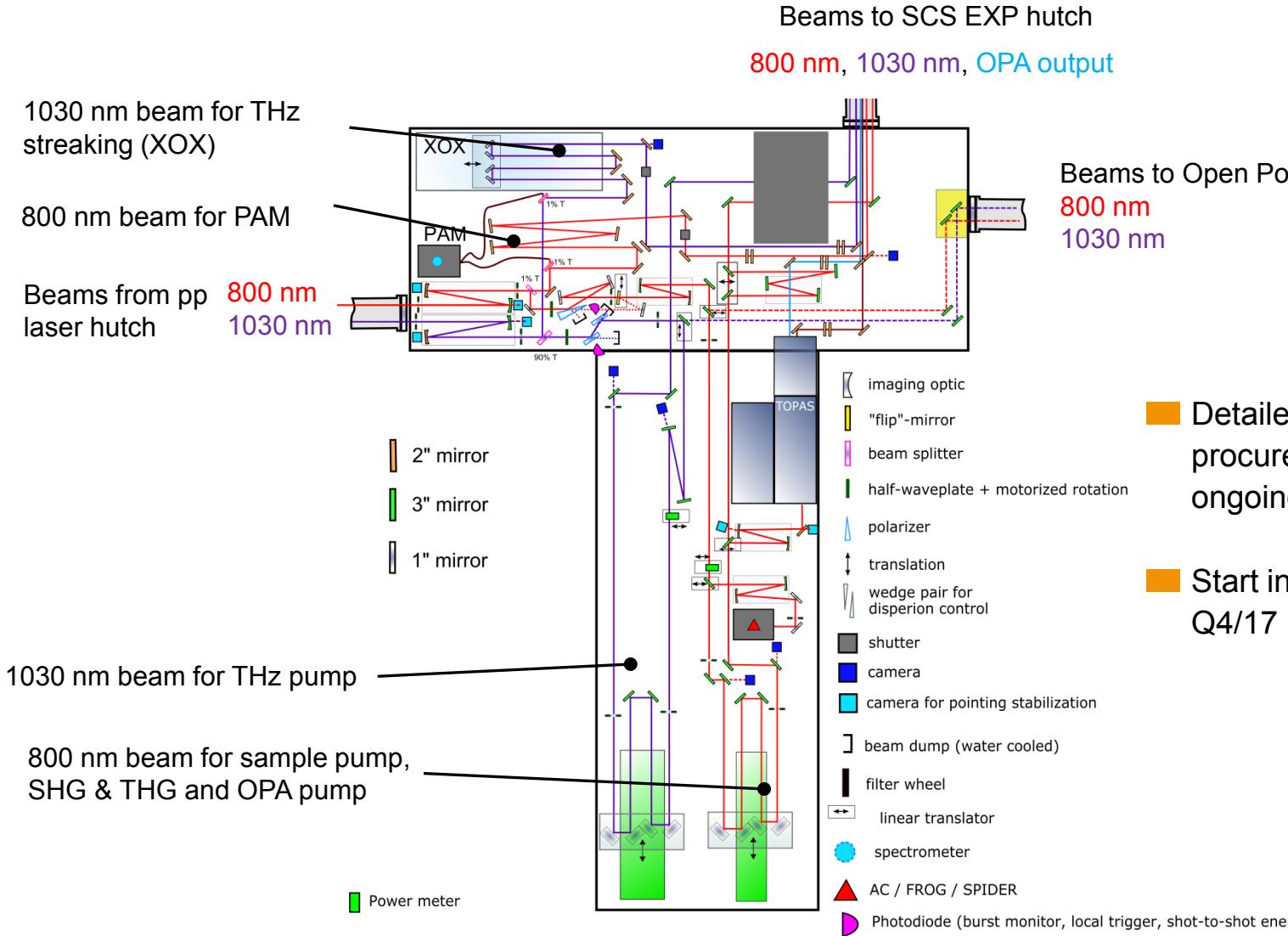


Sample dimension 200 μm diameter
Layers: Fe 40 nm, SiN 100 nm, Al 600 nm

repetition rate	0.15 MHz
pump beam size (FWHM)	200-350 μm
probe beam size (FWHM)	70-120 μm
sample size	200 μm
pump fluence (800 nm)	5 mJ/cm ²
probe fluence (707 eV)	0.5 mJ/cm ²

- The pump beam size is restricted by:
 - At high repetition rates – beam size becomes too small ($< 10 \mu\text{m}$)
 - At low repetition rates – by heating the sample holder and prevention of heat removal

SCS Instrument Laser Hutch

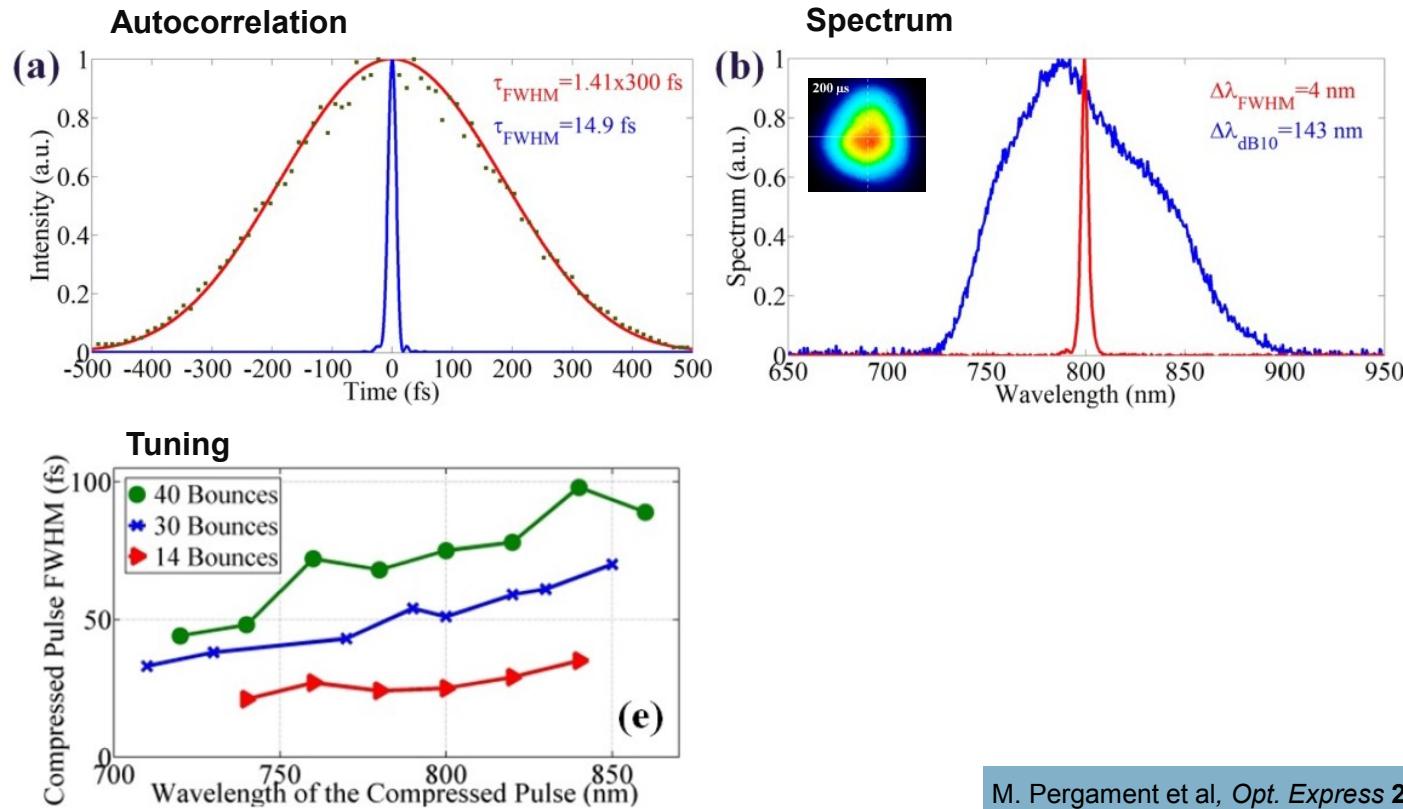


■ Detailed design and procurement are ongoing

■ Start installation
Q4/17

Pump-probe laser tuning properties

- 800 nm NOPA pulses and immanent tuning capabilities

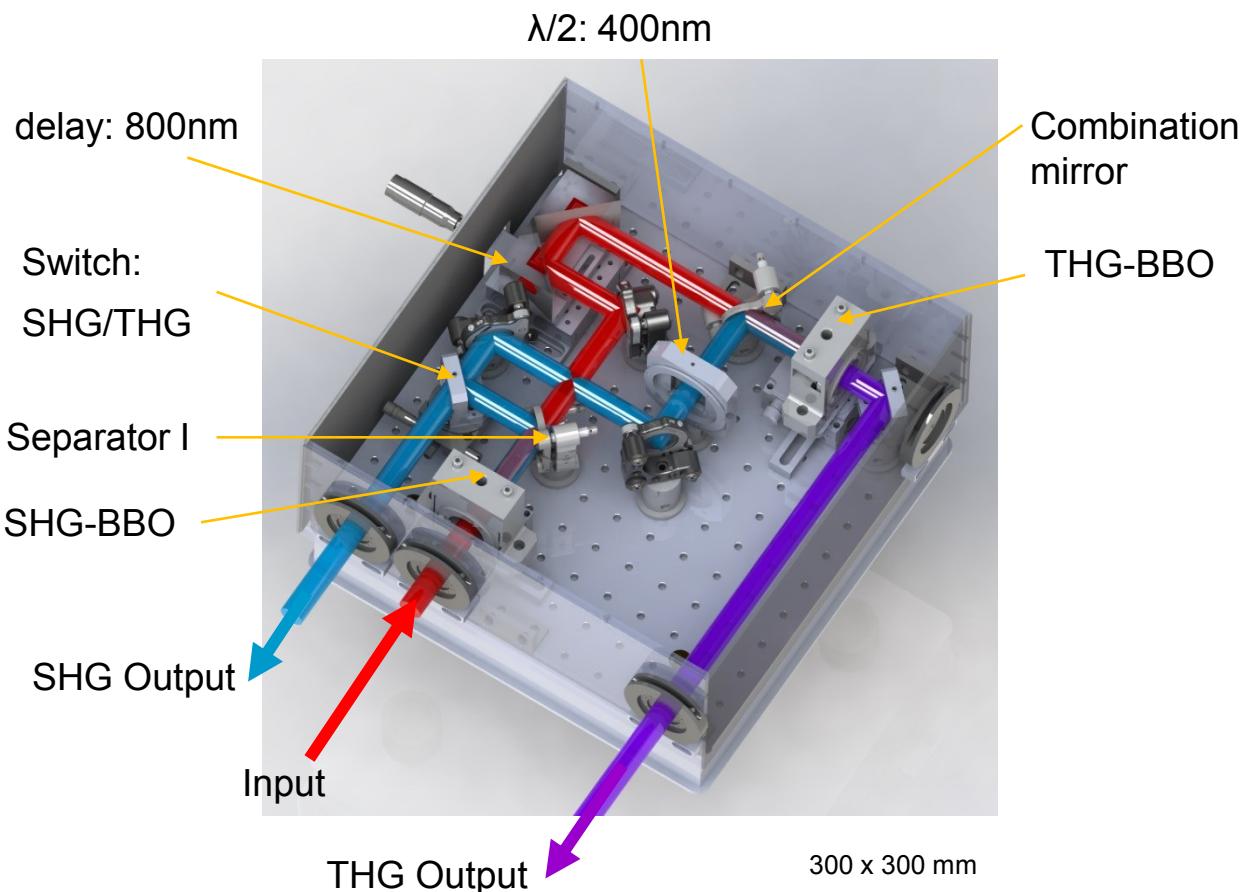


M. Pergament et al, *Opt. Express* **22**, 22202-22210 (2014)

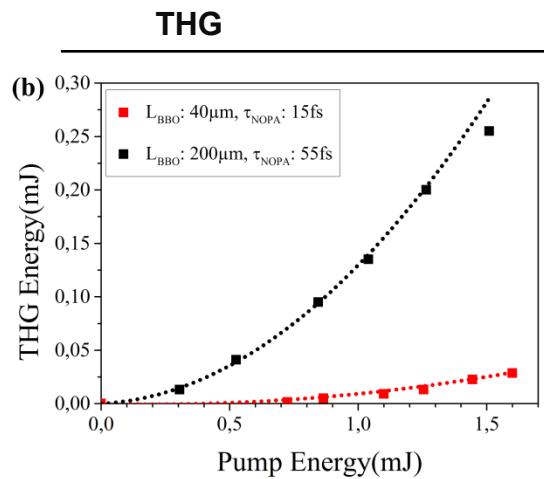
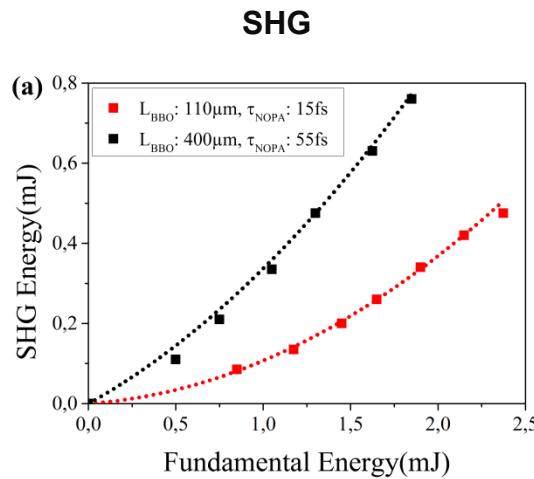
M. Pergament et al, *Opt. Express* **24**, 29349-29359 (2016)

Conversion results with 800 nm at 100 kHz

■ **$SHG = 400\text{ nm}$, $THG = 266\text{ nm}$**



Conversion results with 800 nm at 100 kHz

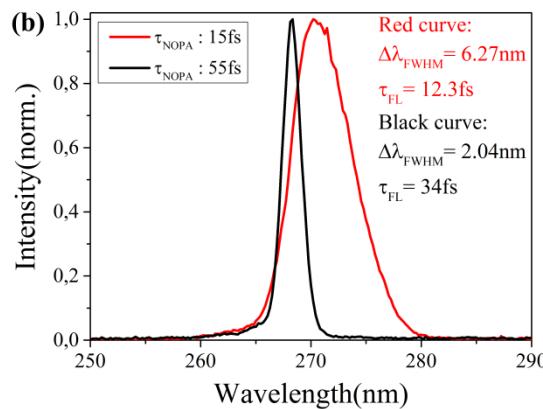
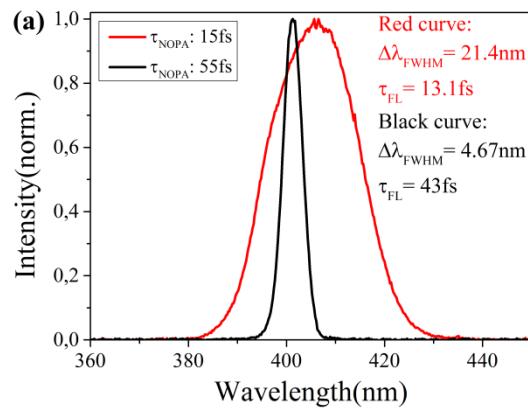


■ 15 fs – pump pulses with 2.37 mJ:

■ 400 nm: $E_{SHG} = 475 \mu\text{J}$, $\eta_{SHG} = 20\%$
■ 266 nm: $E_{THG} = 28 \mu\text{J}$, $\eta_{SHG} = 1.7\%$

■ 55 fs – pump pulses with 1.76 mJ:

■ 400 nm: $E_{SHG} = 760 \mu\text{J}$, $\eta_{SHG} = 43\%$
■ 266 nm: $E_{THG} = 255 \mu\text{J}$, $\eta_{SHG} = 17\%$



Conversion results with 800 nm at 100 kHz

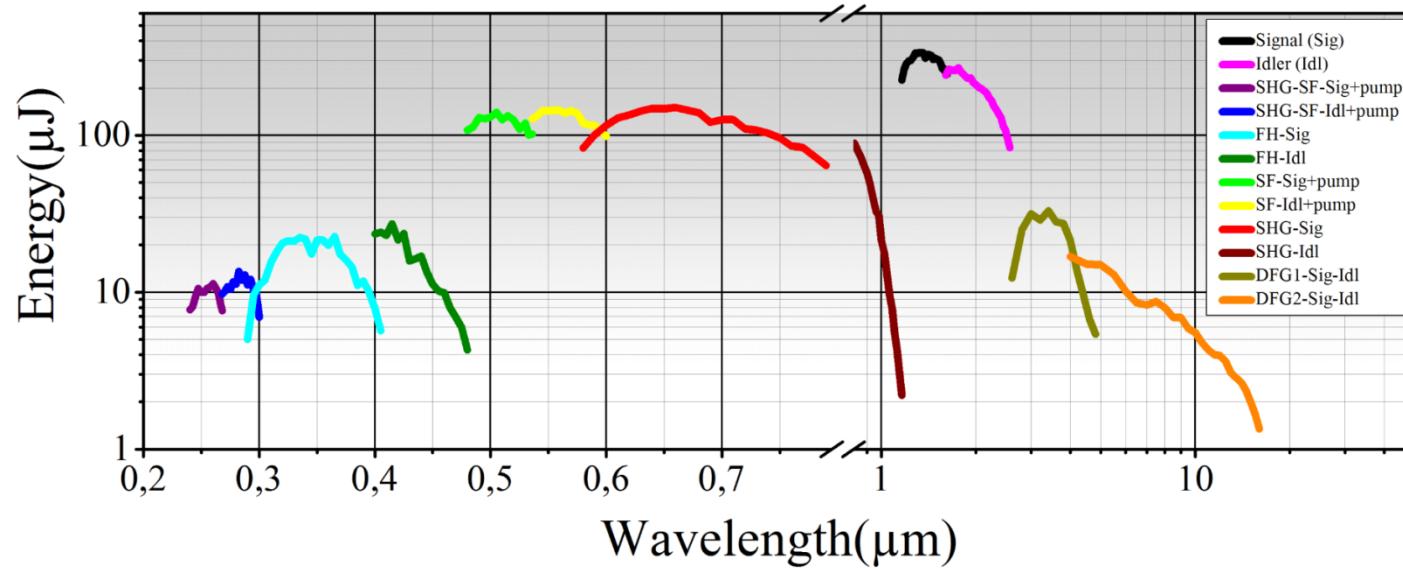
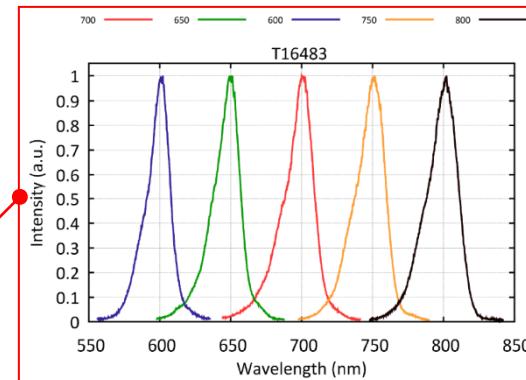


■ Development in collaboration with Light Conversion Ltd.

■ TOPAS-prime with extensions: NirUVIS and NDFG

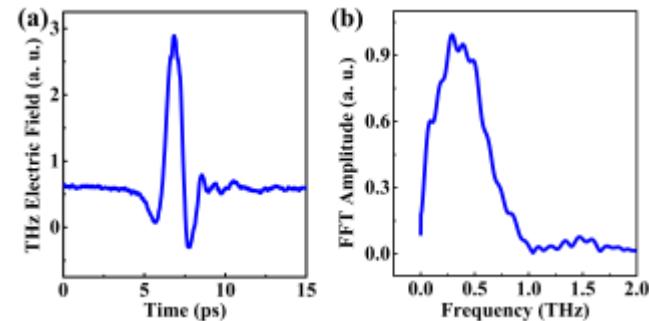
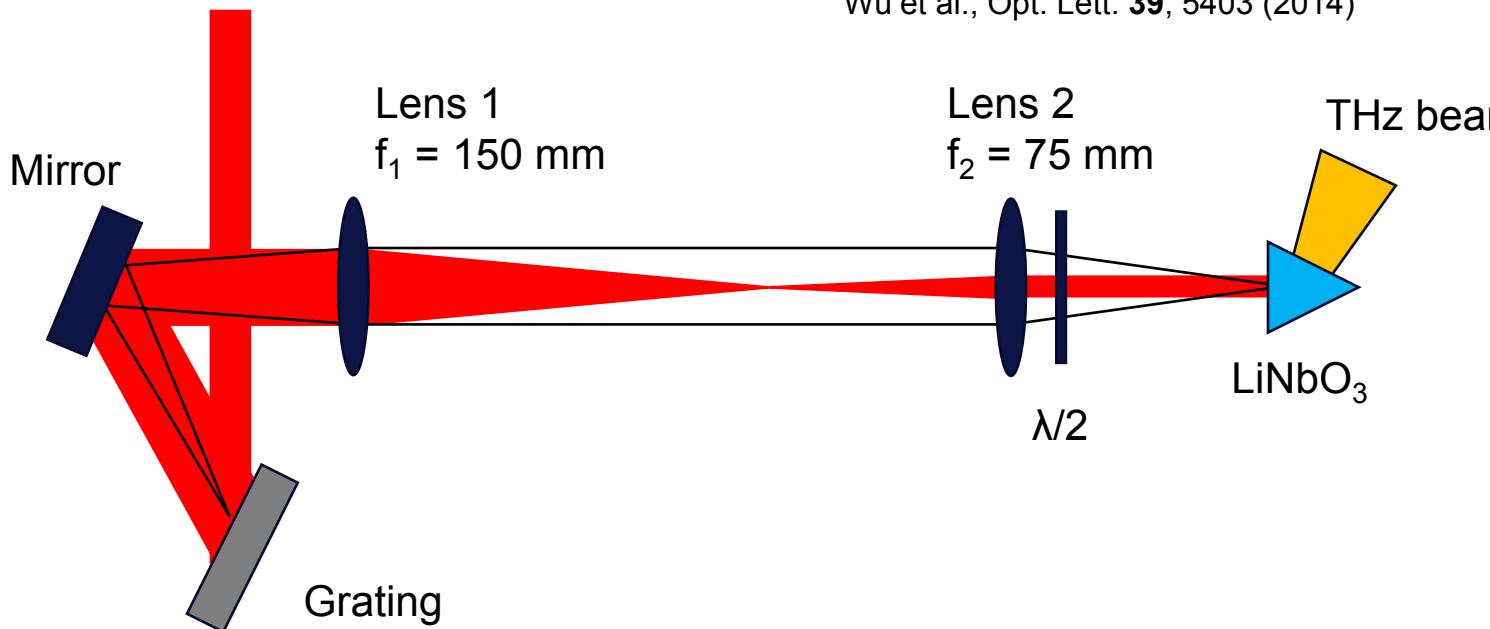
■ TOPAS results with pump:

■ $E = 1.8 \text{ mJ}, \varnothing = 8 \text{ mm } (1/e^2), 55 \text{ fs}$



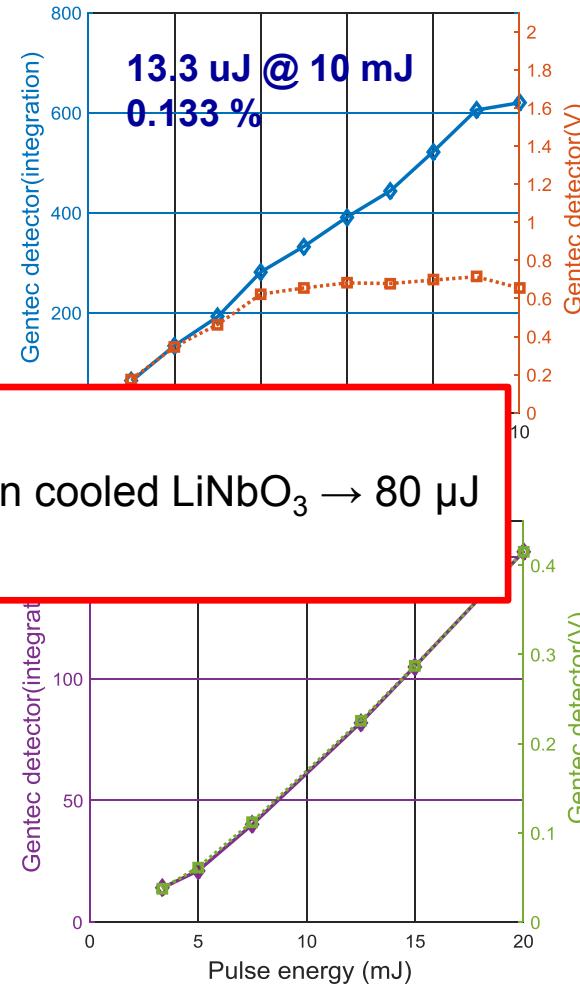
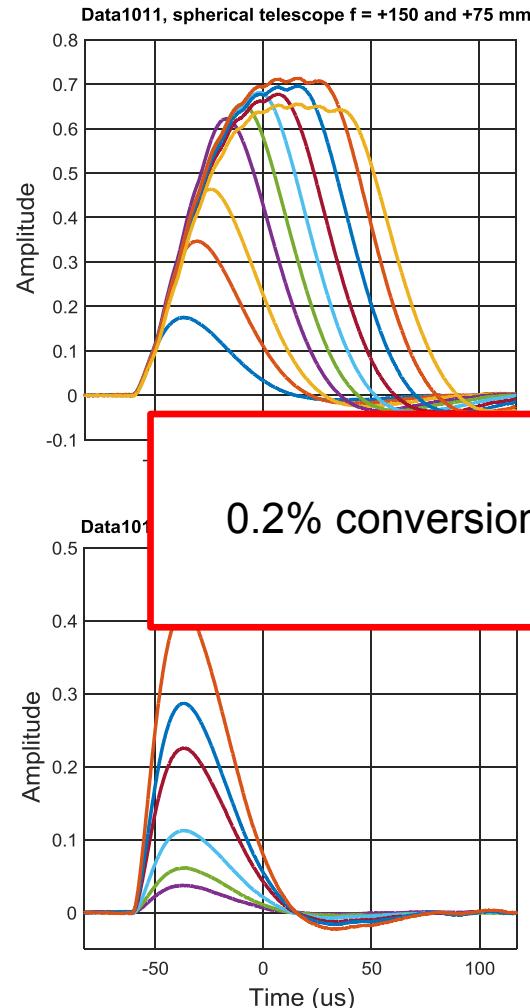
Frequency Conversion: Terahertz

- 1030 nm, 850 fs
- 0.1 – 30 mJ
- 100 kHz x 600 μ s x 10 Hz

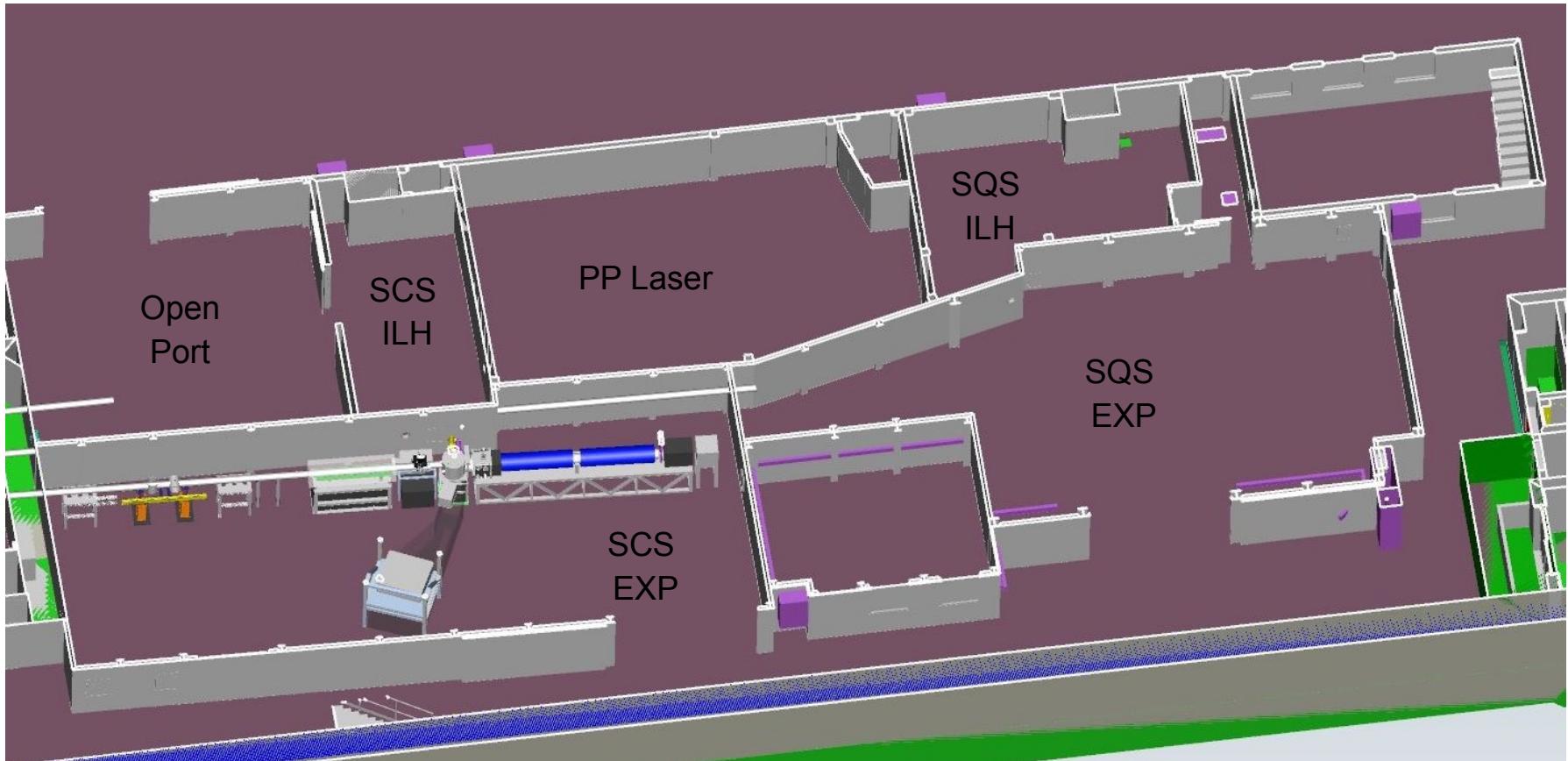


Wu et al., Opt. Lett. **39**, 5403 (2014)

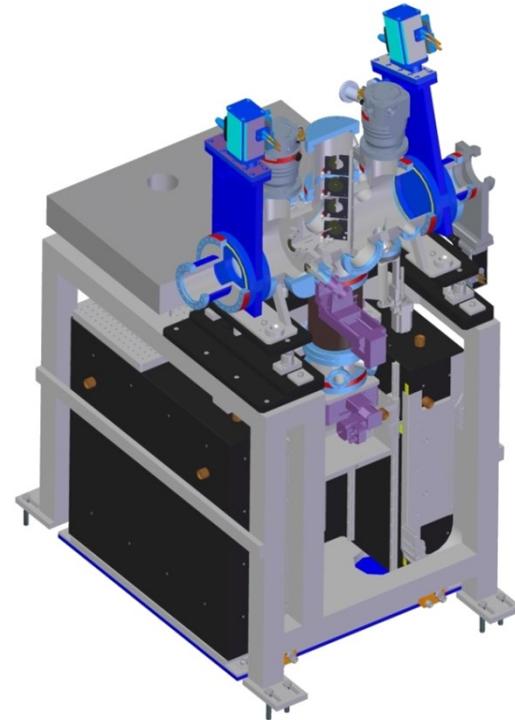
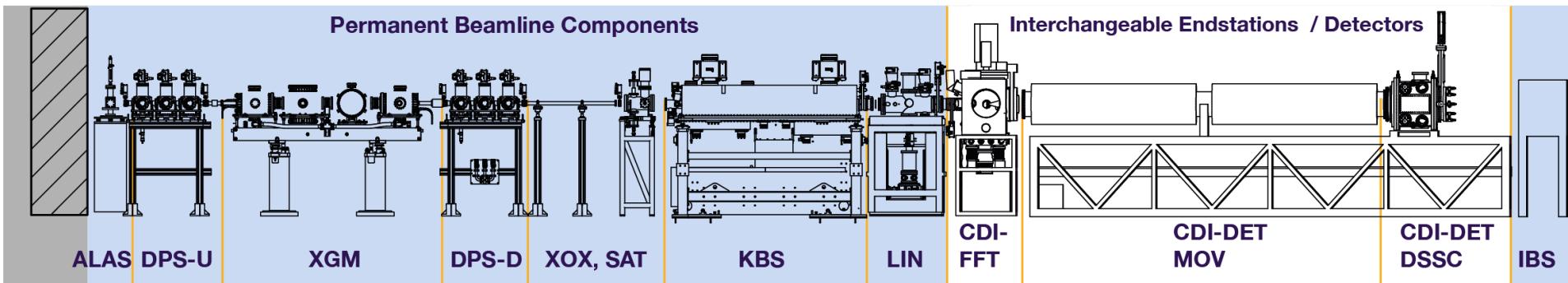
Frequency Conversion: Terahertz



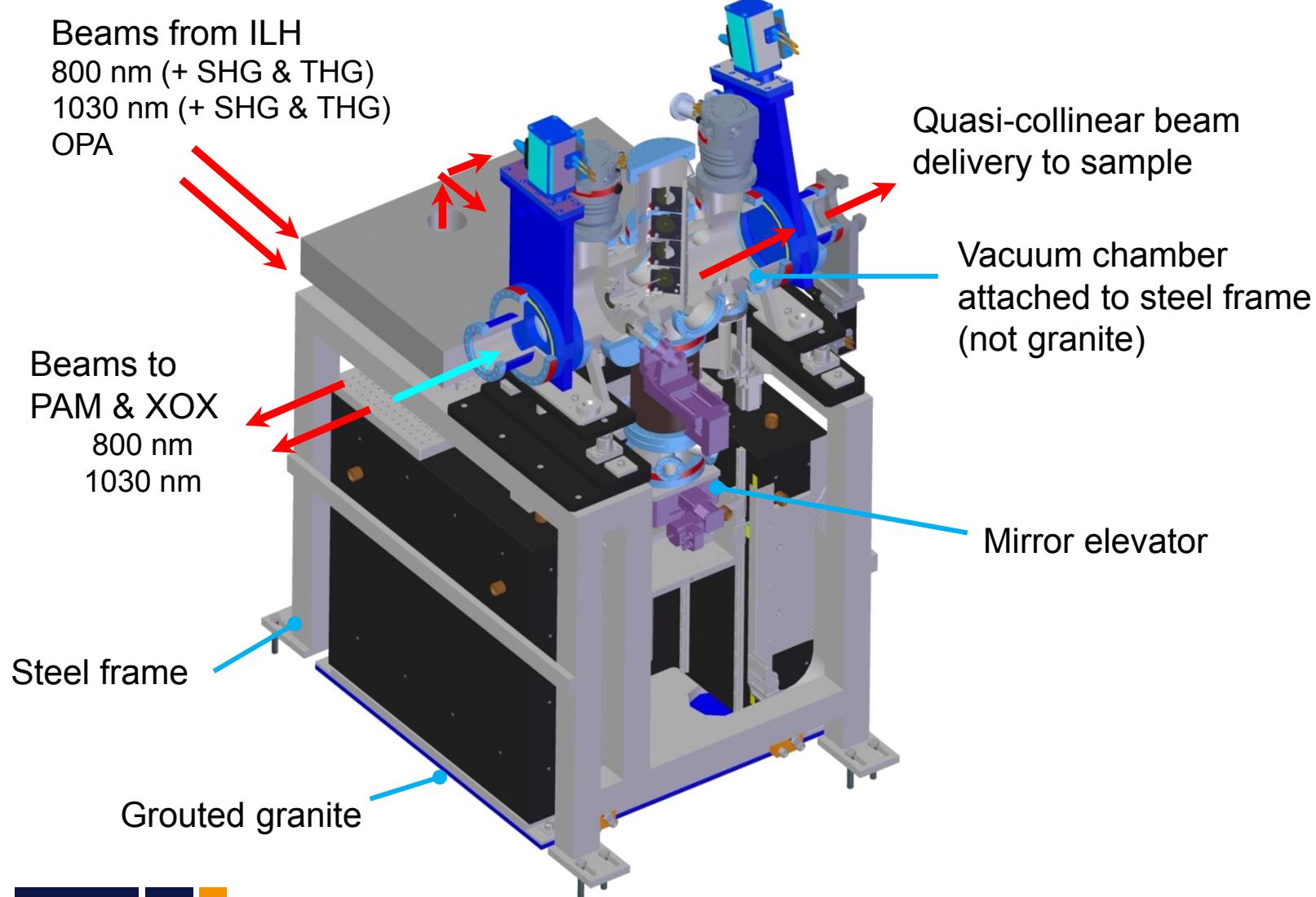
SCS Laser In-coupling



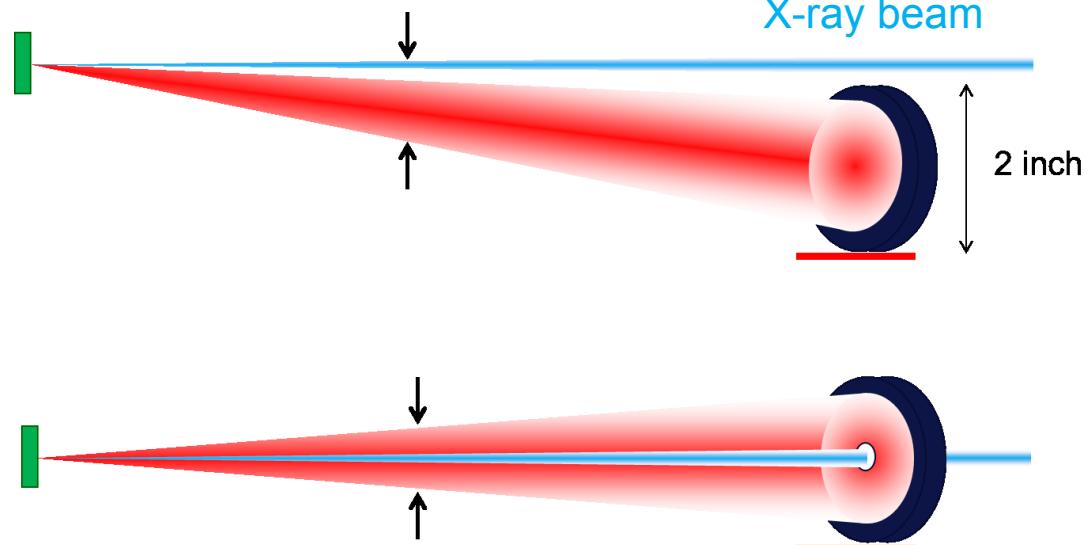
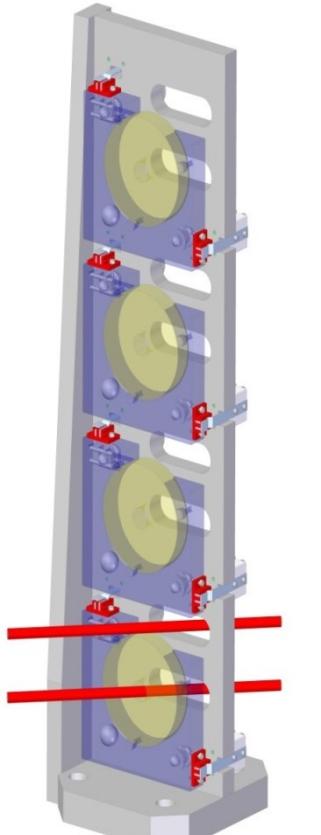
SCS Laser In-coupling (LIN)



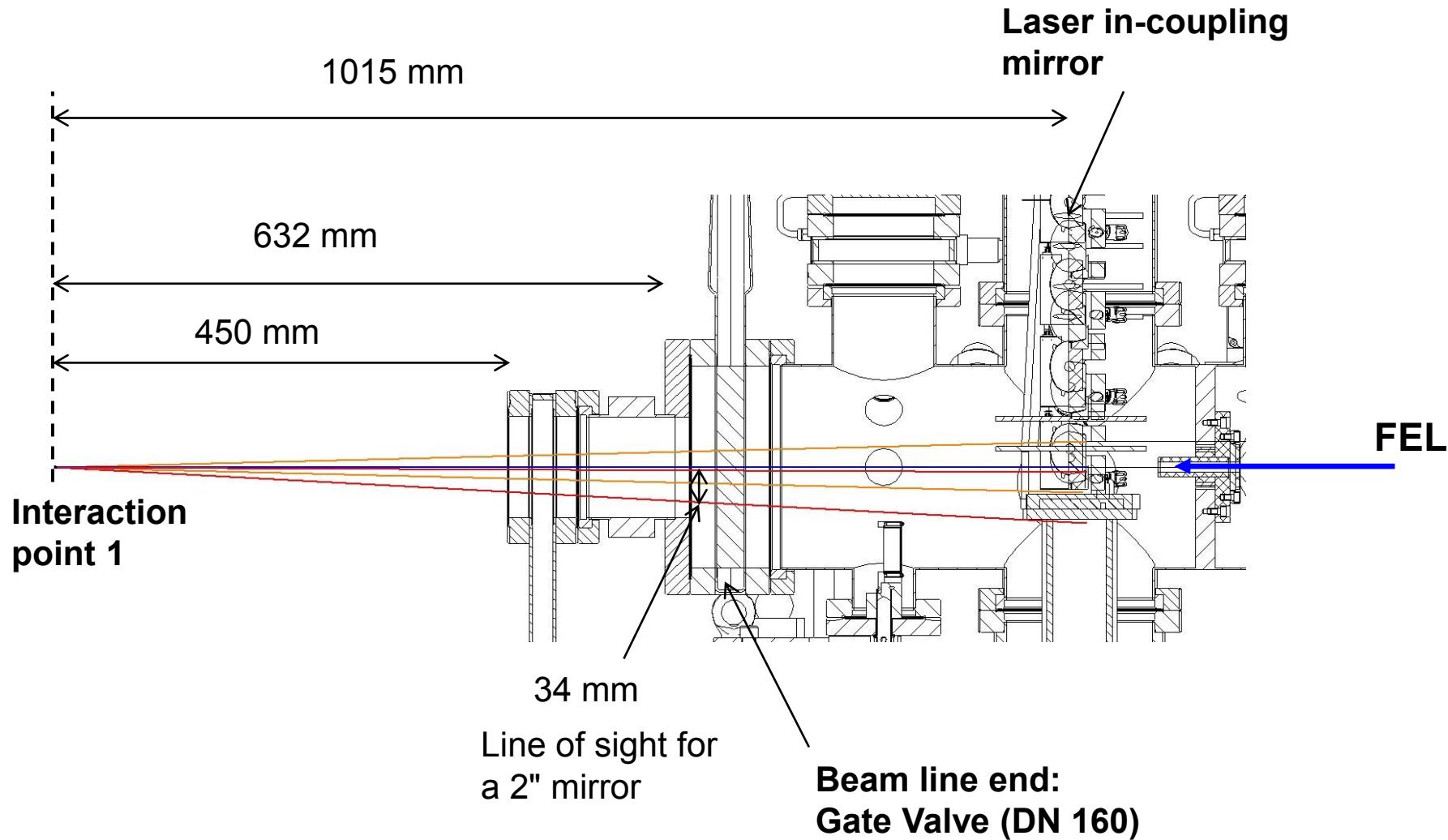
SCS Laser In-coupling



SCS Laser In-coupling

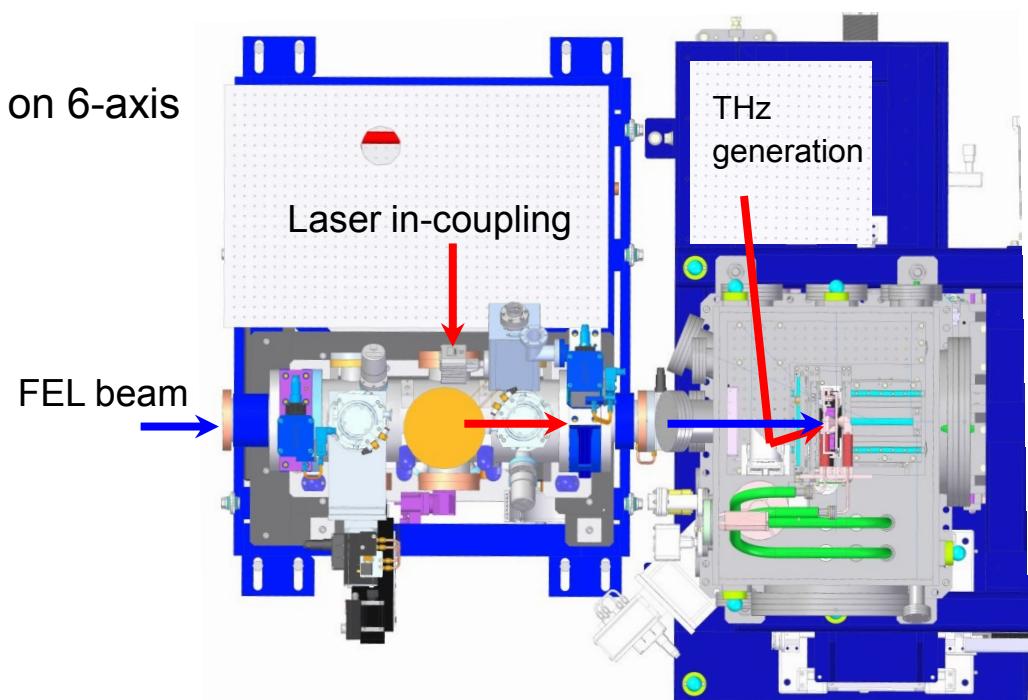
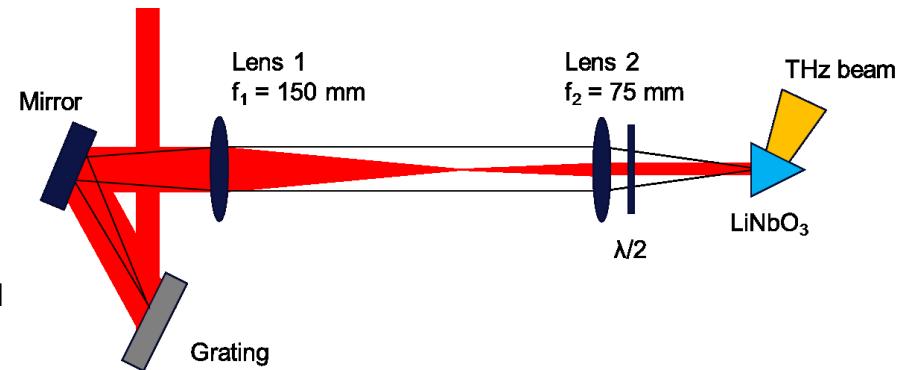


SCS Laser In-coupling



THz In-coupling

- THz generation in lithium niobate
 - 1030 nm, 40 mJ, 800 fs drive
 - 0.2% conversion in cooled $\text{LiNbO}_3 \rightarrow 80 \mu\text{J}$
- Separate in-coupling near the experiment
 - Also for other wavelengths
- Off-axis parabolic mirror in vacuum on 6-axis manipulator



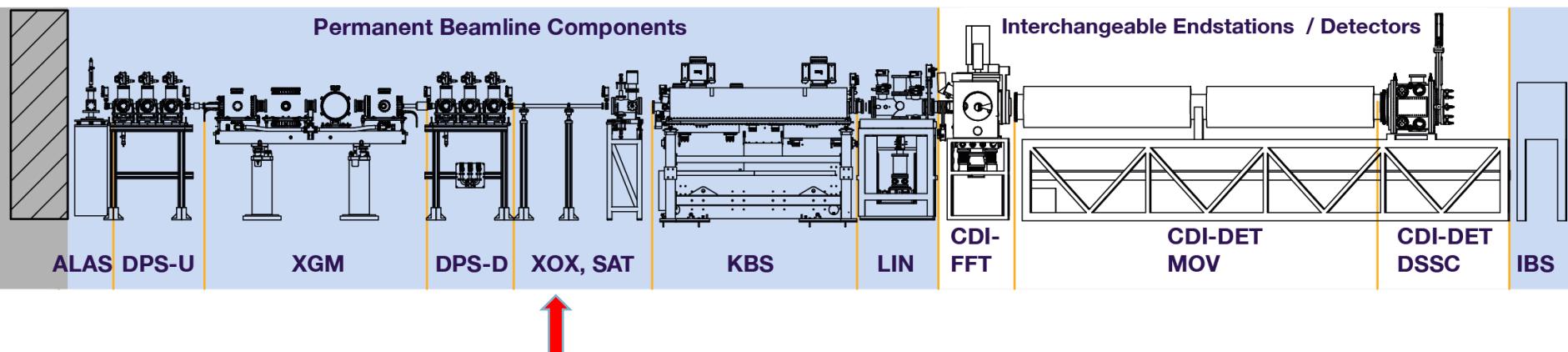
Temporal Diagnostics

■ Transient reflectivity: Photon arrival time monitor

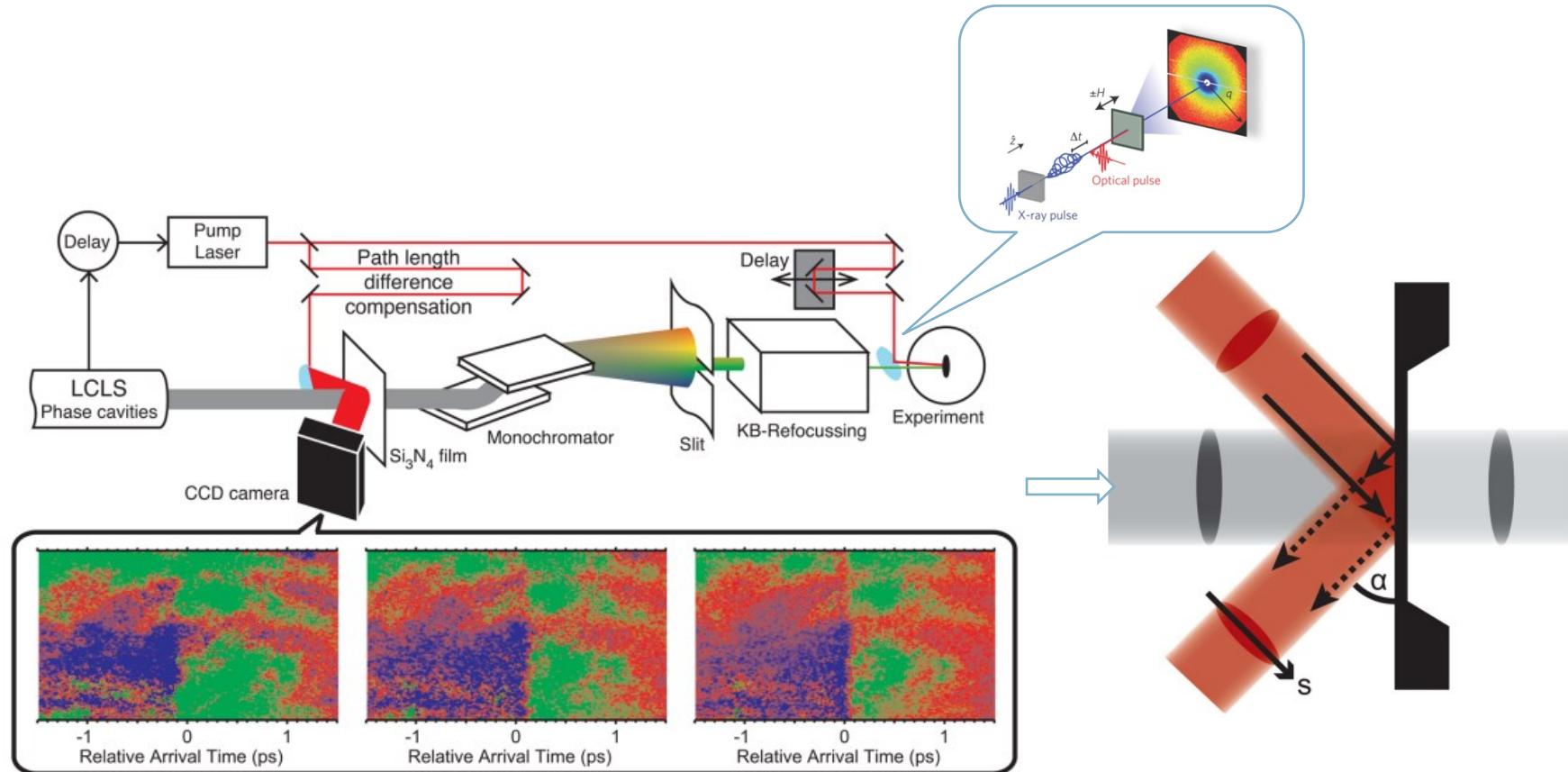
■ Spatial encoding

■ Spectral encoding

■ THz streaking: x-ray – optical cross correlator

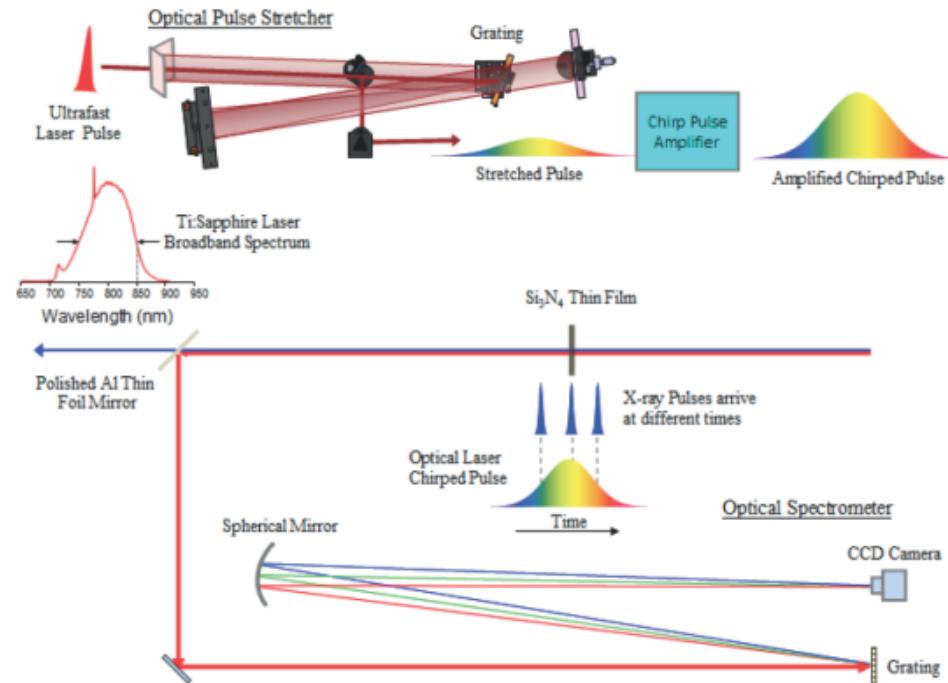


Spatial encoding



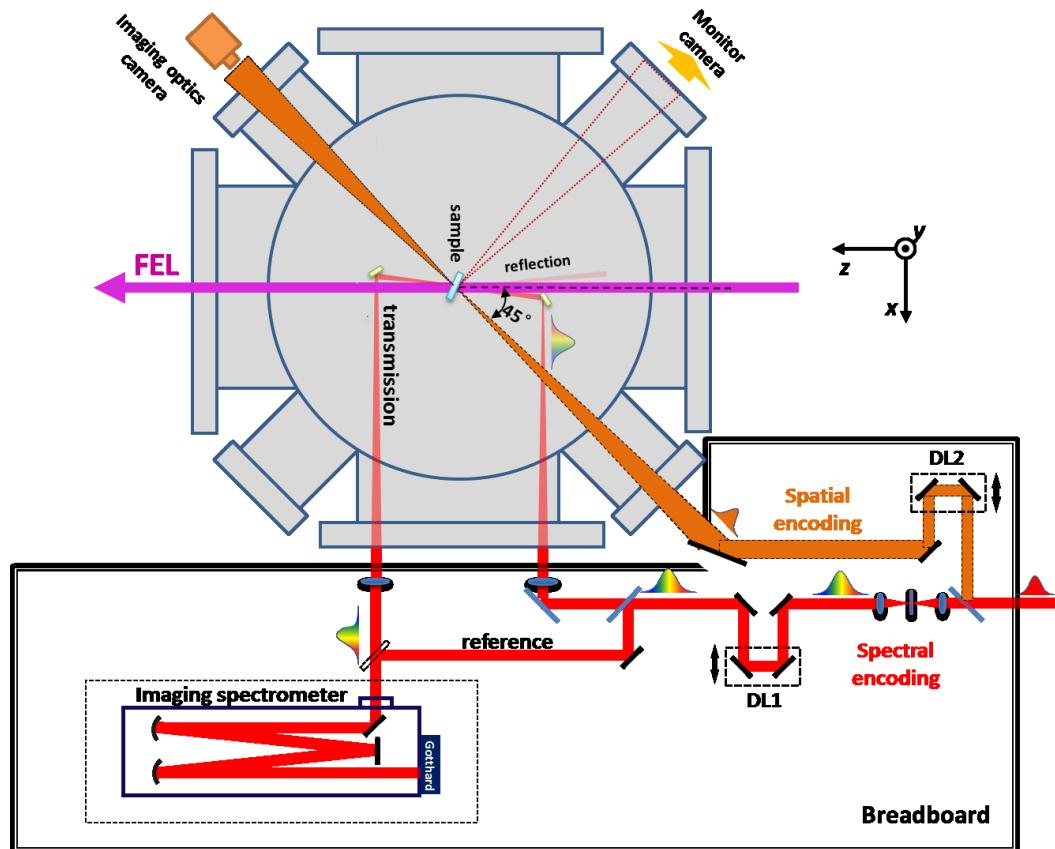
Beye et al., App. Phys. Lett. **100**, 121108 (2012)

Spectral encoding



B. Li, X-Ray Photon Temporal Diagnostics for the European XFEL, Technical Report TN-2012-002-01 (2012.)

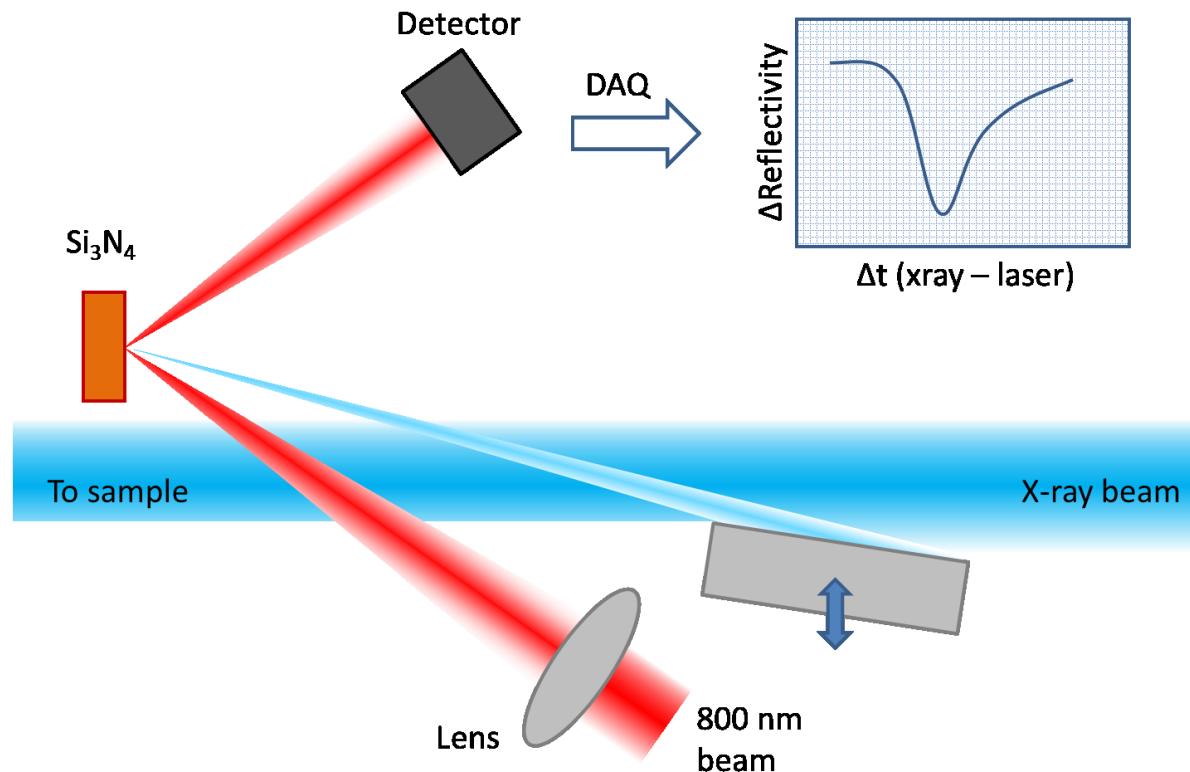
Temporal Diagnostics: Photon Arrival Monitor



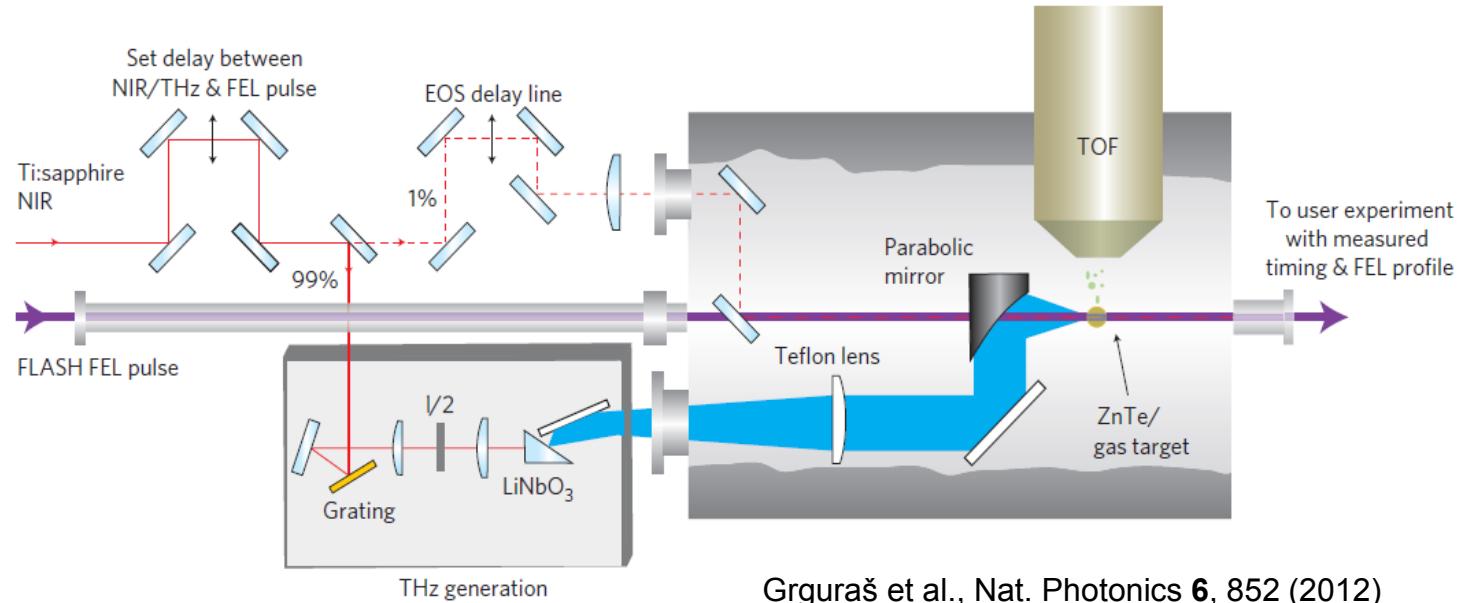
J. Liu, F. Dietrich, J. Grünert: "Technical Design Report: Photon Arrival Time Monitor (PAM) at the European XFEL", XFEL.EU TR-2017-002 (2017)

X-ray pick off mirror

- Pick off edge of x-ray beam
- Focus to increase intensity at low X-ray pulse energies



THz streaking of photoelectrons



- Pick off x-ray beam
- Solid target
- No residual gas
- High target density
- R&D project with WP74 (X-ray photon diagnostics, Jan Grünert, Jia Liu)

Workshop Announcement

- Science case for THz – X-ray experiments
- Sources to enable them
 - Laser based
 - Accelerator / undulator based

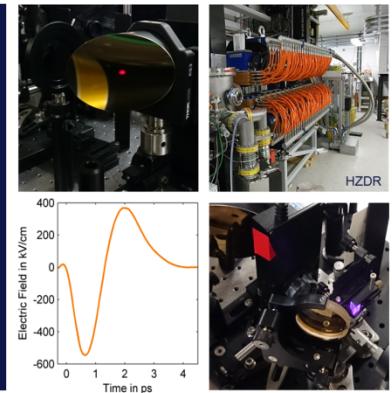


Terahertz science at European XFEL

01–02 June 2017 / European XFEL, Schenefeld, Germany

The **interaction of terahertz radiation with matter** excites novel states with unique properties. These non-equilibrium states will benefit from ultrafast characterization using the ultrashort and highly brilliant X-ray pulses available at FELs. With this in mind, we are pleased to announce a terahertz workshop, with the aim to find the most scientifically promising strategies to combine terahertz radiation with the unique X-ray pulses generated at European XFEL.

The 2 day workshop will be led by 18 presentations from invited international scientists. The first day will explore the **scientific motivation for THz - X-ray experiments**. The second day will focus on the **two main routes to THz generation in the frequency range from 0.1 to 20 THz (3 mm to 15 μm)**: On the one hand, state of the art laser-based sources; and on the other, undulator sources based on a second, smaller accelerator. Specific aspects will be compatibility with the MHz repetition rate of the European XFEL and novel opportunities for coherent control in the multi-THz regime. We intend to discuss how individual research projects can benefit from a combination of these sources.



Registration deadline

- <https://indico.desy.de/conferenceDisplay.py?confId=16848>
- Registration opens 01 March–01 May 2017
- Places are limited to approximately 90 and will be filled on a first-come, first-served basis

Organizers

Robert Carley
Andreas Scherz
Peter Zalden
European XFEL, Schenefeld, Germany

Programme Committee

Mikhail Krasilnikov (PITZ@DESY)
Max Lederer (European XFEL)
Andreas Scherz (European XFEL)
Mikhail Yurkov (DESY)
Peter Zalden (European XFEL)

Confirmed speakers

Andrea Cavalleri (MPSD)
Stefano Bonetti (Stockholm)
Dmitry Turchinovich (U Mainz)
Aaron Lindenberg (SLAC)
Max Lederer (European XFEL)
Matthias Hoffmann (LCLS)
Franz Kärtner (DESY CFEL)
Michael Gensch (HZDR)
Mikhail Krasilnikov (PITZ@DESY)
Christoph Hauri (PSI)
Andrey Savilov (IAP, RAS, N. Novgorod)
Karsten Holdack (HZB)

- We encourage all participants to submit a poster to ensure that a broad range of THz - X-ray science can be discussed.
- A workshop dinner will take place on the evening of 1 June.

Acknowledgements

■ WP 74 X-ray Photon Diagnostics

■ Jia Liu

■ WP 78 Optical Lasers

■ Guido Palmer, Moritz Emons

■ SCS

■ Andreas Scherz

■ Jan Torben Delitz

■ Manuel Izquierdo

■ Alexander Yaroslavtsev

■ Justine Schlappe

■ Laurent Mercadier

■ PR

■ Frank Poppe

■ Thank you!