Industrial Femtosecond Lasers & Scientific Laser Systems

Linas Giniūnas

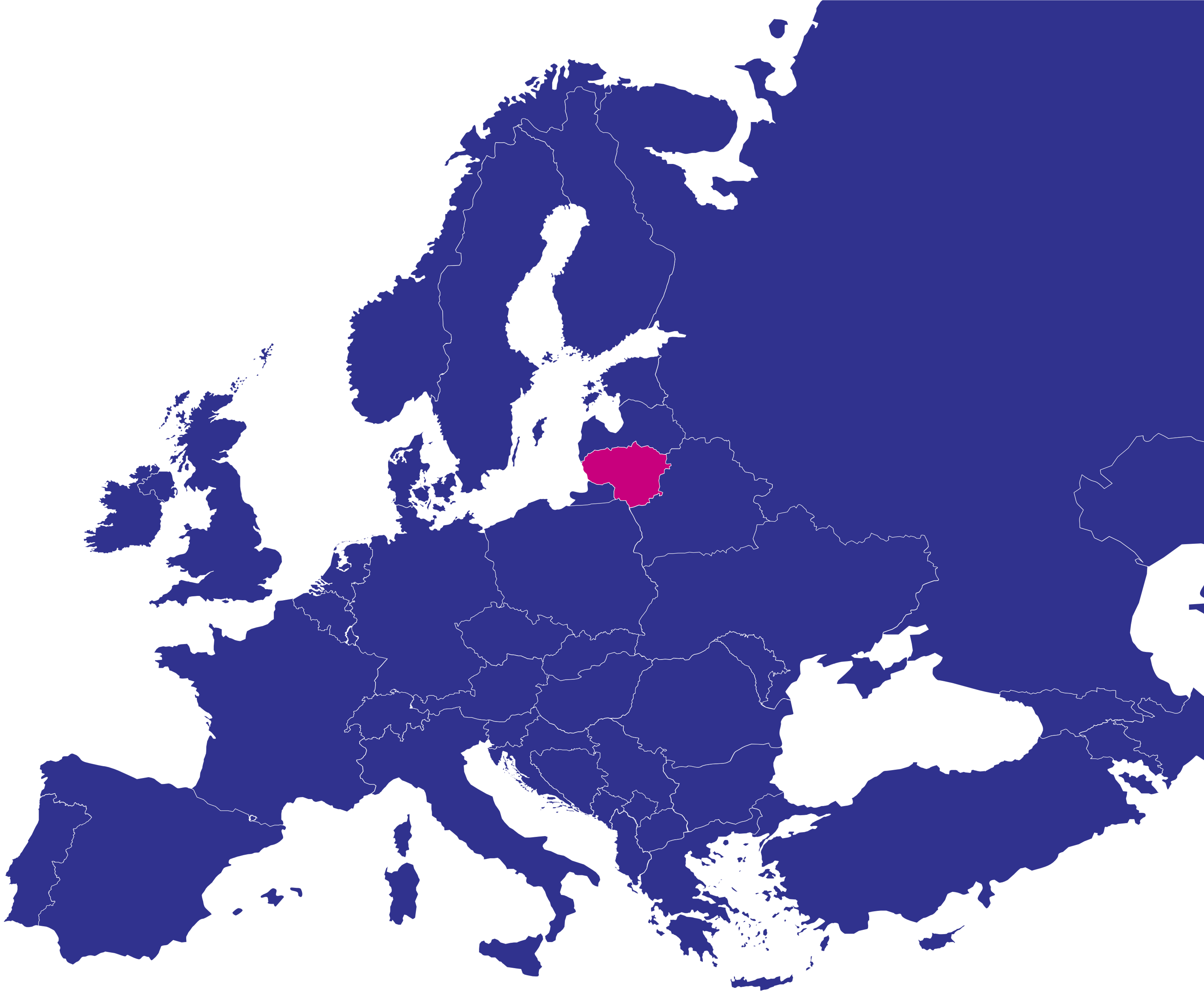
Laser Division Manager

- Who we are
- Femtosecond Lasers
- Laser systems for science (OPA)
- fs lasers for accelerators and sinchrotrons
- Fiber delivery
- High harmonics and x-ray

WHO WE ARE

LIGHT CONVERSION, founded in 1994 with roots at the Vilnius University, is a pioneer in femtosecond OPAs and Yb-based lasers

- **> 28 years** experience
- **> 65 M€** turnover
- **400** employees
- Worldwide network
- Total area **15 000 m^2**
- Clean-room 2500 **m^2**



LIGHT CONVERSION

New facility opened in 2022

FOCUS ON FEMTOSECONDS

Lasers: **CARBIDE**, **PHAROS**

Optical Parametric Amplifiers: **TOPAS**, **ORPHEUS**

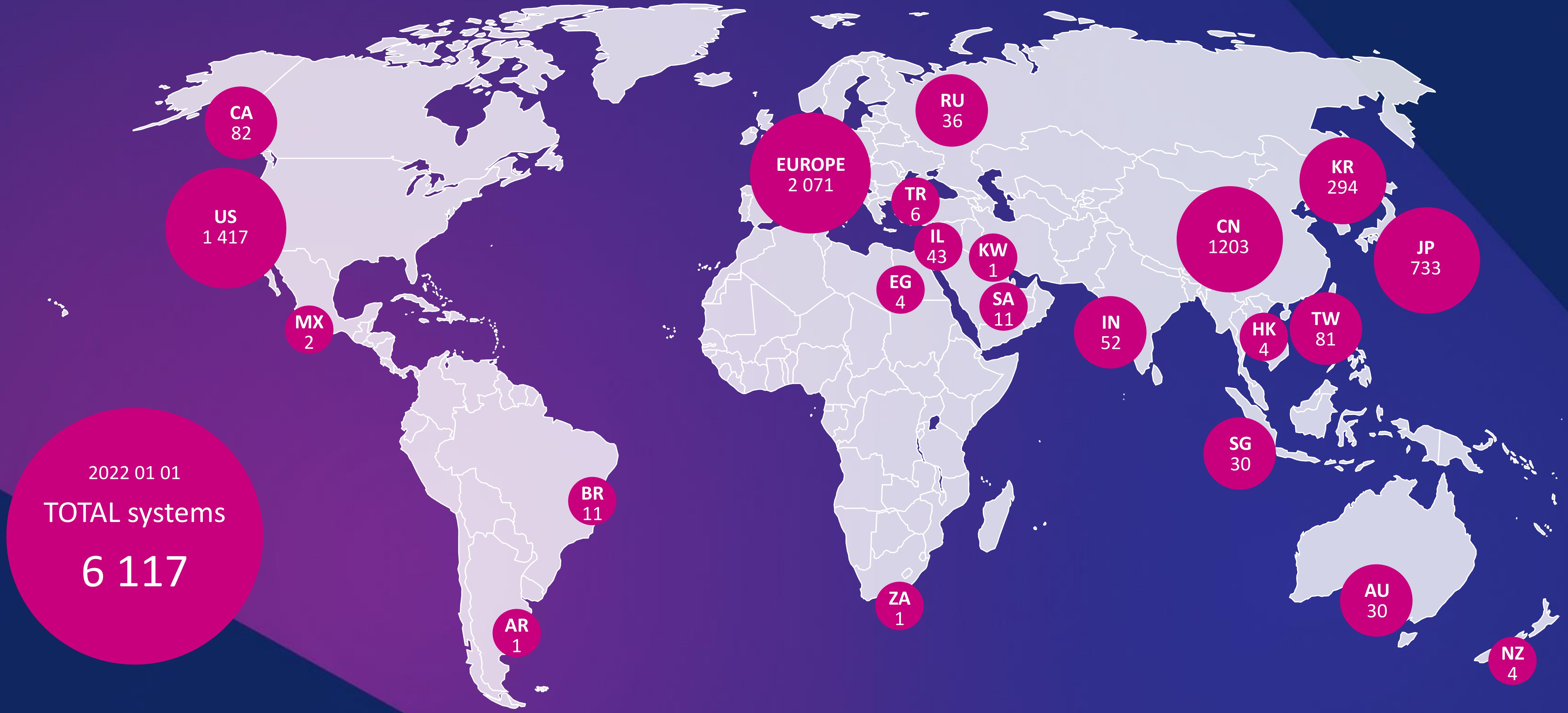
Complete TR spectroscopy solutions: **HARPIA**

High peak power systems: **OPCPA**

Locking to synchrotrons, CEP stability and other custom solutions.

LIGHT CONVERSION

WORLDWIDE SALES



LIGHT CONVERSION

Light Conversion in World's Top 100 Universities

Our systems are installed in **95 of top 100** universities!

1	MIT	26	U Toronto	=51	Shanghai Jiao Tong U	=75	U Wisconsin - Madison
2	U Oxford	=27	McGill U	=51	TU Munich	77	Southampton U
3	Stanford U	=27	Australian NU	53	Duke U	78	Lomonosov Moscow SU
3	U Cambridge	=27	U Manchester	=54	Carnegie Mellon U	=79	U Copenhagen
5	Harvard U	30	Northwestern U	=54	City Hong Kong U	=79	Yonsei University
6	CalTech	31	Fudan U	56	VU Amsterdam	81	POSTECH
7	Imperial College London	32	U CA, Berkeley	57	Tokyo Tech	=82	Durham U
8	ETH Zurich	33	Kyoto U	58	TU Delft	=82	Tokohu U
8	U College London	34	HKUST	59	Monash U	=82	Illinois at Urbana-Champaign U
10	U Chicago	35	King's College London	60	Brown U	=85	Auckland U
11	National Singapore U	36	Seoul National U	61	U Warwick	=85	U Washington
12	Nanyang Technology U	37	U Melbourne	62	U Bristol	87	Université Paris-Saclay
13	Pennsylvania U	38	Sydney U	63	Ruprecht-Karls U, Heidelberg	88	Lund U
14	EPFL	39	Chinese University of Hong Kong	64	Ludwig-Maximilian U, Munchen	89	Georgia IT
14	Yale	40	UCLA	65	Malaya U	90	KTH Royal Institute of Technology
16	U Edinburgh	41	KAIST	66	Hong Kong Polytechnic University	91	Birmingham U
17	Tsinghua U	42	New York U	67	Texas A&M U	92	St Andrews U
18	U Peking	43	UNSW Sydney	68	National Taiwan U	93	Leeds U
19	Columbia U	44	Université PSL, Paris	69	Buenos Aires U	94	U Western Australia
20	Princeton U	45	Zhejiang U	=70	KU Leuven	95	Rice University
21	Cornell U	46	British Columbia U	=70	Zurich U	96	Sheffield U
22	Hong Kong U	47	U Queensland	72	Sorbonne U	97	U Pennsylvania
=23	U Tokyo	48	California U, San Diego	73	Glasgow U	98	Sungkyunkwan U
=23	Michigan U	49	Ecole Polytechnique	74	Korea U	99	UST China
25	U Johns Hopkins	50	London School of Economics	=75	Osaka U	100	TU Denmark

Source: QS World University Rankings 2022

Pre-assembly laboratories
Class 10.000 (ISO-7)

- Assembly of electronics with housing
- Assembly of subcomponents

PHAROS/CARBIDE assembly
Class 100 (ISO-5)

- Production of microoptics
- Assembly of laser cavity
- Final laser assembly and testing

MILESTONES

1994

TOPAS – optical parametric amplifiers

TWINKLE laser

1995

QUANTRONIX – exclusive worldwide distributor

2005

Multiple partnerships as OEM supplier for TOPAS products

2006

Femtosecond laser PHAROS

Sales and service centers in USA and Japan

ALTOS PHOTONICS

PHOTO TECHNICA

2008

Industrial 24/7 PHAROS

2009

ORPHEUS – optical parametric amplifier

2012

HARPIA spectrometer

2013

Femtosecond laser CARBIDE 5 W

2014

New R&D, production facilities

2015

Industrial 24/7 CARBIDE 5 W

2016

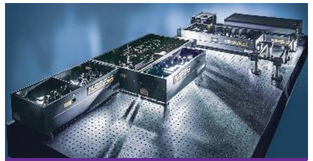
LIGHT CONVERSION CHINA Office

2017

CARBIDE 40 W laser

OPCPA for ELI-ALPS, 1st stage

2018



New HARPIA generation - complete automated solutions for spectroscopy

Headquaters expansion to >6500m^2

LIGHT CONVERSION SOUTH KOREA Office

2020

CARBIDE 80 W laser

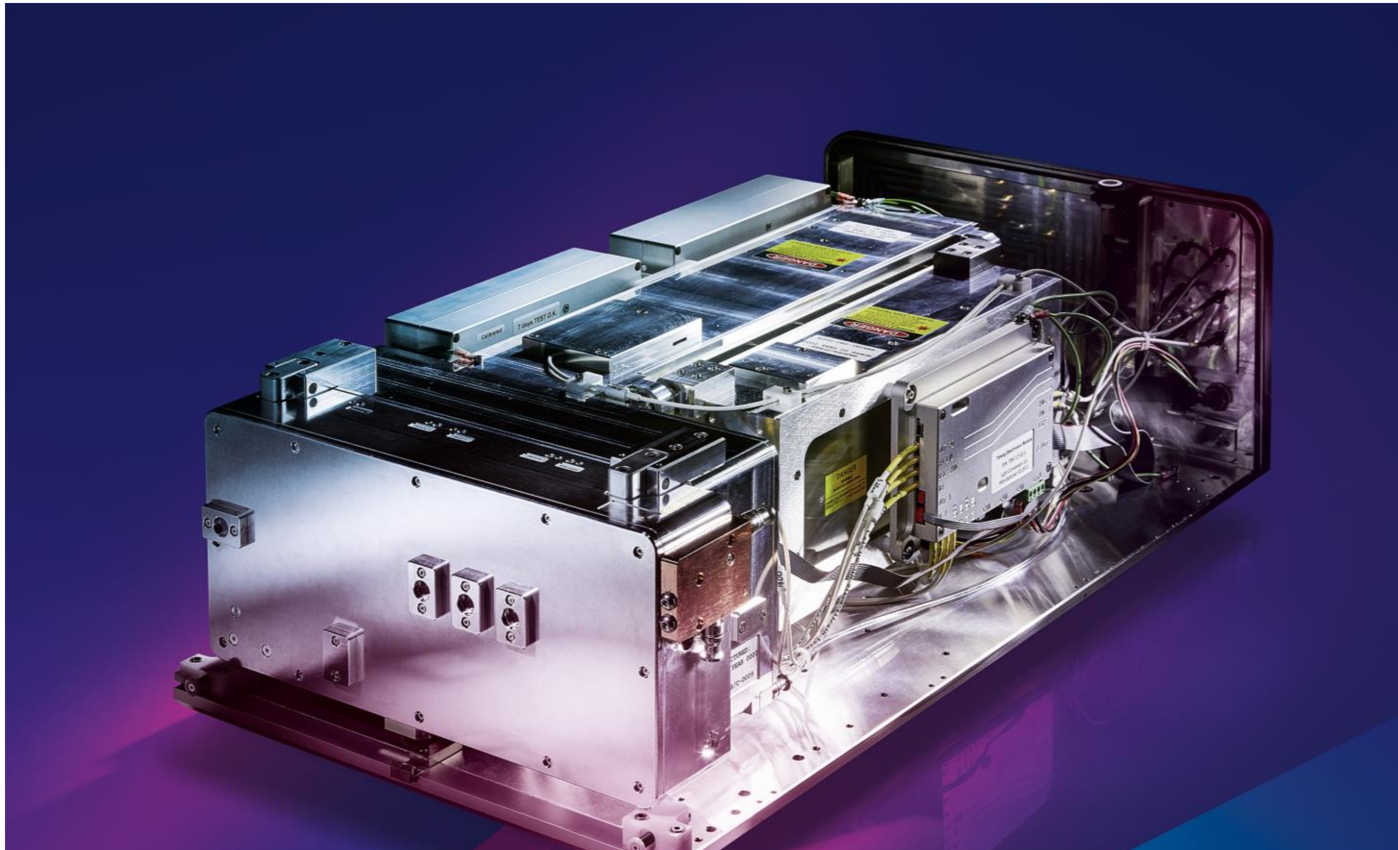
PHAROS PH2 20W-2mJ

Femtosecond Lasers

PHAROS & CARBIDE

PHAROS

- Industrial design
- Robust
- Compact
- Flexible output :
  - pulse duration (190 fs – 20 ps)
  - repetition rate (single pulse – 1 MHz)
  - output power up to 20 W
  - pulse energy up to 2 mJ
  - wavelength converters (UV - midIR)



> 13 years history

30 % - scientific, 70 % - industrial

> 1500 systems installed

AUTOMATED HARMONICS GENERATORS

In one module:

- 1030 and 515 nm
- 1030, 515 and 343 nm
- 1030, 515 and 257 nm
- 1030, 257 and 206 nm

Conversion efficiency

515 nm	343 nm	257 nm	206 nm
> 50 %	> 25 %	> 10 %	> 5 %
	Limitations:	<1 W	< 0.15 W

CARBIDE

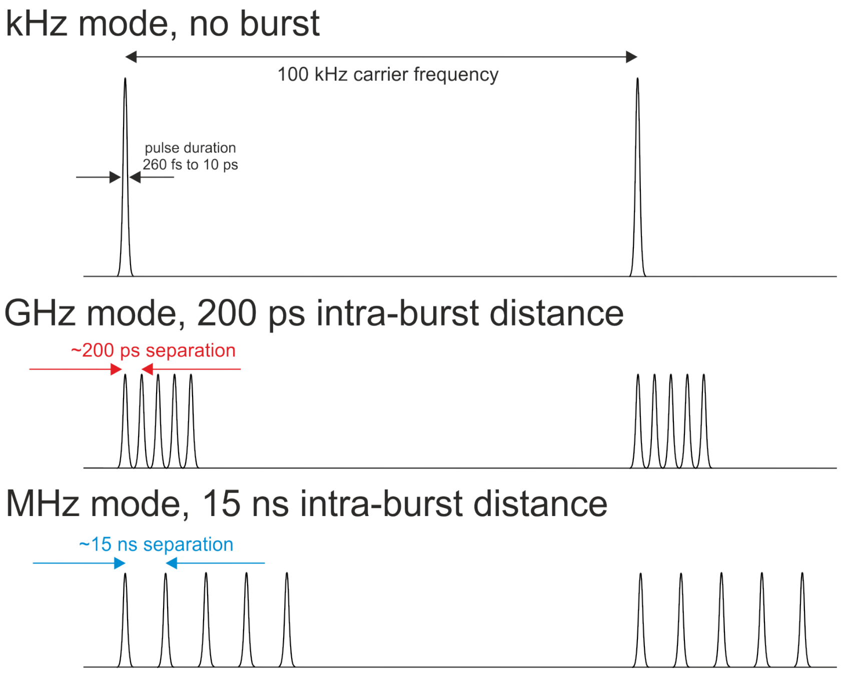
- Maintenance free operation
- Based on PHAROS technology
- >600 units worldwide
- 24/7 operation
- MTBF >2 years

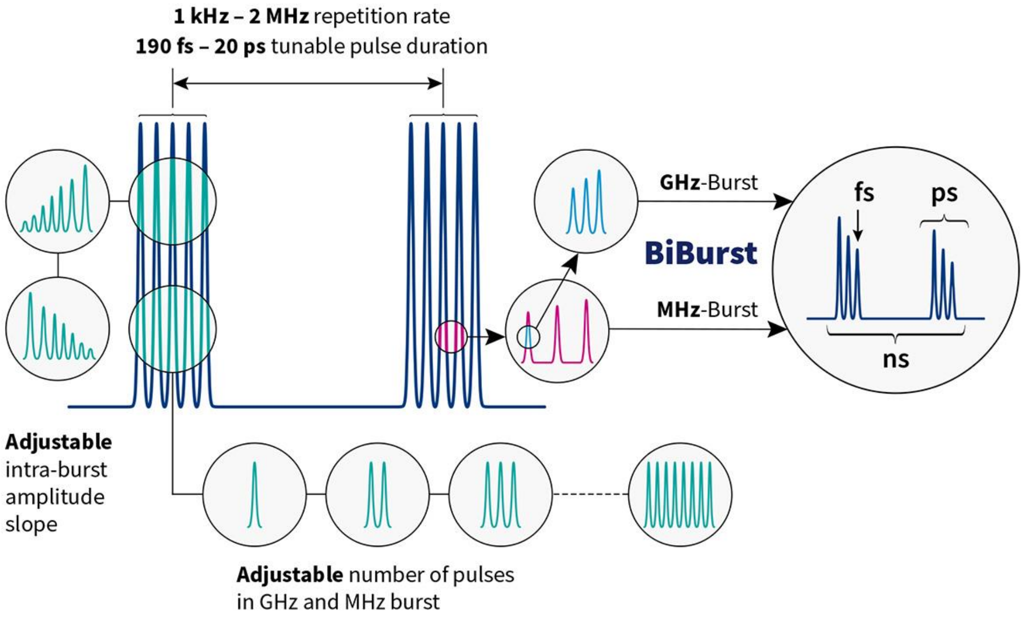
PRODUCT NAME	CB3-40W	CB3-80W	CB5	
Cooling method	Water-cooled		Air-cooled 1)	
Max. average power	> 40 W	**> 80 W**	> 6 W	> 5 W
Pulse duration (assuming Gaussian pulse shape)	< 290 fs			
Pulse duration adjustment range	290 fs – 10 ps			
Max. pulse energy	> 0.4 mJ	**> 0.8 mJ**	> 100 μJ	> 83 μJ
Base repetition rate 2)	100 – 2000 kHz		60 – 1000 kHz	
Pulse selection	Single-shot, Pulse-on-Demand, any base repetition rate division			
Center wavelength	1030 ± 10 nm 3)			
Polarization	Linear, vertical			
Beam quality	TEM_{00}; $M^2 < 1.2$			
Output pulse-to-pulse stability 4)	< 0.5 % rms over 24 hours			
Output power stability	< 0.5 % rms over 100 hours			
Beam pointing stability	< 20 μrad/°C			
Pulse picker	FEC 5)		included	included, enhanced contrast AOM 6)
Pulse picker leakage	< 0.5 %		< 2 %	< 0.1 %

LIGHT CONVERSION

Tunable GHz and MHz burst with burst-in-burst capability

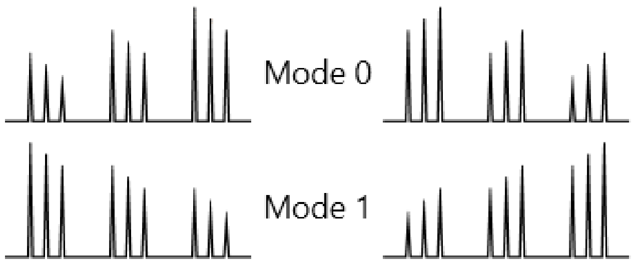
- “kHz mode”. Single pulses as with standard PHAROS
- “GHz” mode. Unique feature. Intra-burst pulse distance within 100s of ps. Predefined during manufacturing
- “MHz mode”. “classical” burst with fixed Intra-burst pulse distance of ~15 ns
- Possibility to vary intra-burst amplitude slope
- Laser with motorized compressor, thus individual pulse durations can be tuned between ~260fs – 10ps (20ps)

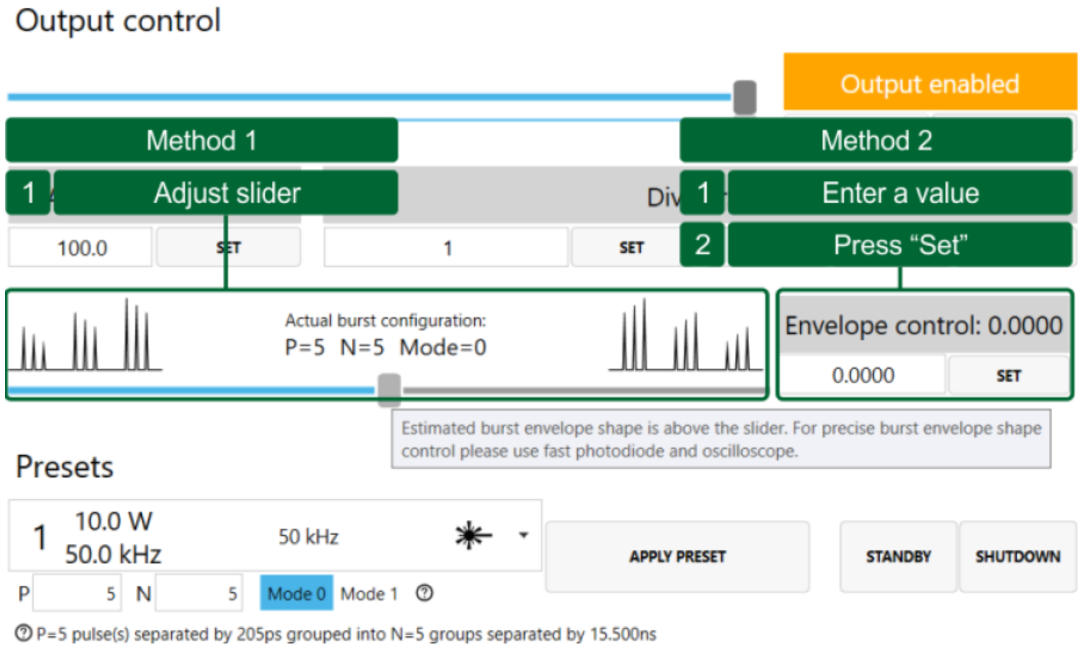


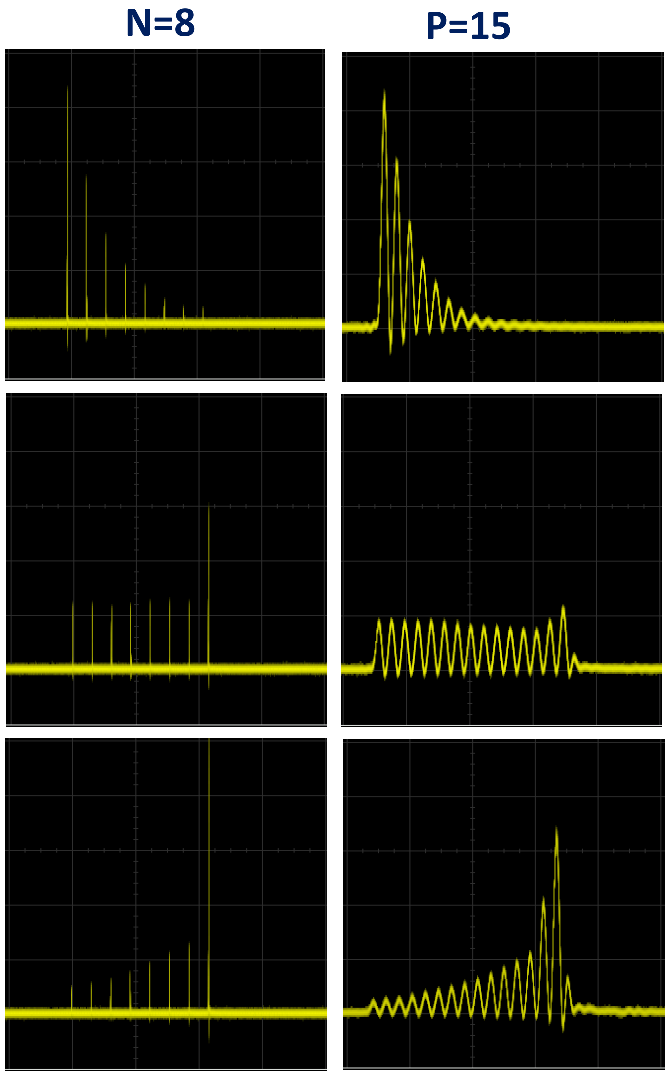


Tunable GHz and MHz burst with burst-in-burst capability

Controllable BiBurst shape

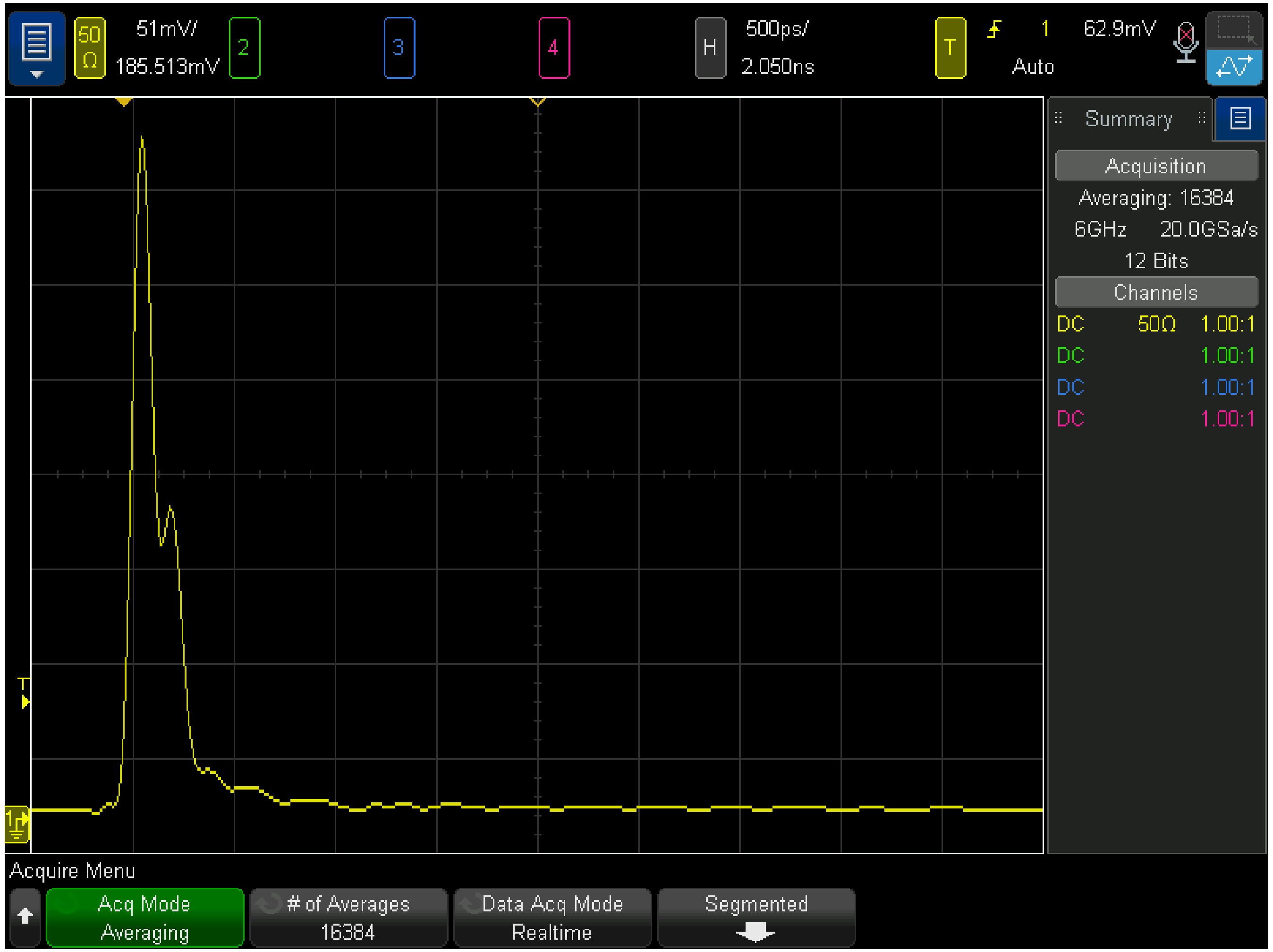






Applications for Bi-Burst in material processing

- Micro-drilling
- High contrast marking
- Milling of complex 3D surfaces
- Surface polishing
- Fabricating Intra-Ocular-Lenses
- Creating hydrophilic/hydrophobic surfaces

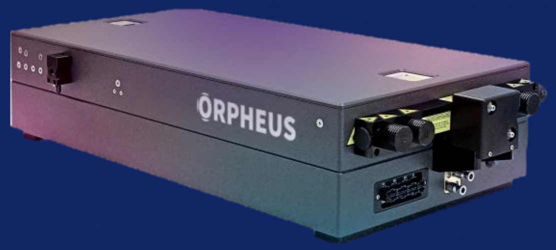


LIGHT CONVERSION

Scientific systems

Orpheus, Topas, HARPIA, OPCPA

OPTICAL PARAMETRIC AMPLIFIERS ORPHEUS



Collinear

210 nm – 16000 nm

120 fs – 300 fs

Non-collinear

260 nm – 900 nm

20 – 80 fs

Hybrid

315 nm – 2500 nm

25 fs – 100 fs

FLINT

Femtosecond Yb Oscillator	
1030 nm output power	up 20 W
1030 nm pulse energy	>250 nJ
Pulse duration	<160 fs
Repetition rate	76 MHz
Centre wavelength	1035 nm
CEP stabilization (Optional)	Yes
Lock to external clock, e.g. Synchrotron (Optional)	Yes
Automated 2H generator (Optional)	515 nm
515 nm output power	8 W
Number of output ports	2+residual fundamental
Shutters	Automated
Automated compensation of slow output power deviations	Yes
Continuously adjustable power distribution ratio between fundamental and 2H channels	Yes
Acousto-Optical Modulator	Optional

- Femtosecond transient absorption and reflection
- Femtosecond transient absorption and reflection microscopy
- Femtosecond multi-pulse transient absorption and reflection
- Femtosecond fluorescence upconversion
- Picosecond-to-microsecond fluorescence using TCSPC
- Intensity-dependent transient absorption and reflection, time-resolved fluorescence
- Time-resolved femtosecond stimulated Raman scattering (FSRS)
- Flash photolysis

ORPHEUS-OPCPA

- <6 fs transform-limited pulse duration
- Up to 100 kHz repetition rate
- Up to 22 W output power
- Up to 1.1 mJ output energy

Wavelength	800 nm	1.6 µm	2 µm	3 µm
Pulse duration (compressed)	< 10 fs	< 40 fs	< 25 fs	< 45 fs
Transform-limited pulse duration (uncompressed, for seeding larger amplifiers)	< 6 fs	< 30 fs	< 15 fs	< 35 fs

	Repetition rate	**Pulse energy / Output power**			
ORPHEUS-OPCPA	10 kHz	120 µJ / 1.2 W	240 µJ / 2.4 W	180 µJ / 1.8 W	120 µJ / 1.2 W
ORPHEUS-OPCPA-HE		0.55 mJ / 5.5 W	1.1 mJ / 11 W	0.8 mJ / 8 W	0.5 mJ / 5 W
ORPHEUS-OPCPA-HR	100 kHz	25 µJ / 2.5 W	55 µJ / 5.5 W	40 µJ / 4 W	30 µJ / 3 W
ORPHEUS-OPCPA-HP		100 µJ / 10 W	220 µJ / 22 W	150 µJ / 15 W	120 µJ / 12 W

ELI-ALPS SYLOS OPCPA SYSTEM

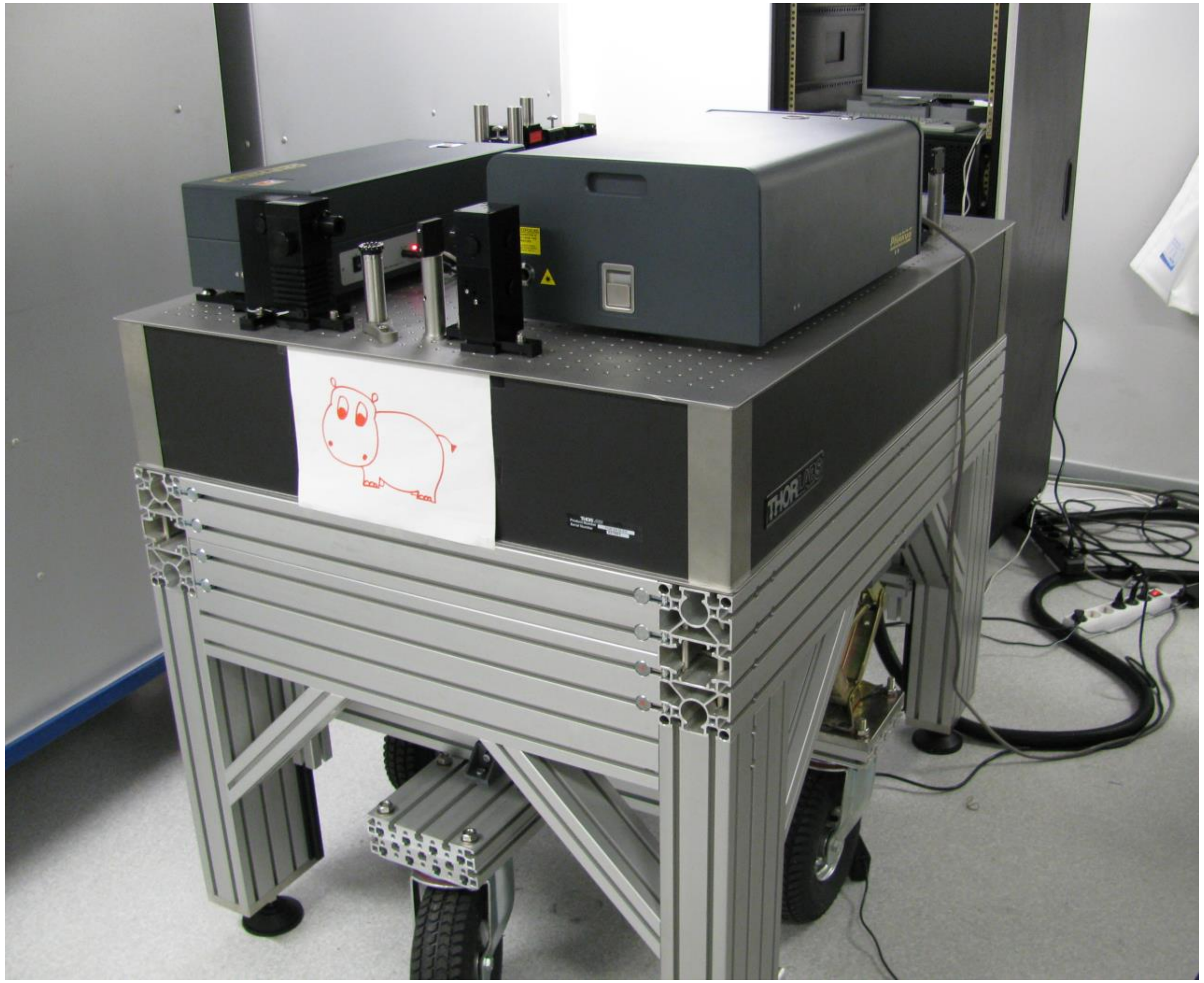
- SYLOS has been launched in ELI-ALPS facility in Hungary on 15th of May 2019

- Energy: > 50 mJ
- Pulse duration: < 10 fs
- Rep. rate: 1 kHz
- Peak power: > 5 TW

fs laser locked to a clock

Deutsches Elektronen-Synchrotron, DESY 1, Petra III, Hamburg

Installation 20.11.2009



Dr. Markus Drescher and Prof. Schlie, Centre for Ultrafast Imaging (CUI), University of Hamburg, Institut für Laserphysik

PHAROS 6W
ORPHEUS (210nm-2600nm) (130 kHz)
HIRO 2H-3H-4H

GERMANY

DESY (6 *Pharos* lasers):

- Group of Dr. Bridge Murphy, University Kiel (with Menlo electronics for Synchronization, 83,33 MHz, OPA Orpheus)

- Prof. Kaertner, Uni Hamburg, Dr. Alke Meents (Menlo, 83,333 MHz)

- Dr. Ingmar Hartl: **3 *Pharos* systems** with UV-harmonics and oscillator with piezos (Sync.-ready); they develop a new accelerator technology where the fs-UV serves as gun for electron injection, sync. will be realized by new opto-electronic methods.

- DESY-Zeuthen, Dr Gross Pharos with Sync. ready

Synchrotron BESSY II Berlin (2 *Pharos* lasers):

Bessy II is an electron storage ring for soft X-ray radiation in contrast to Petra-3 at Desy which emits X-rays with higher Energy spectrum

- Prof. Bargheer, Uni Potsdam - BESSY II, 62.5MHz

- Prof. Woltersdorf, University Halle (Installation soon)

Helmholtz-Zentrum Dresden-Rossendorf, HZDR (2 *Flint* oscillators)

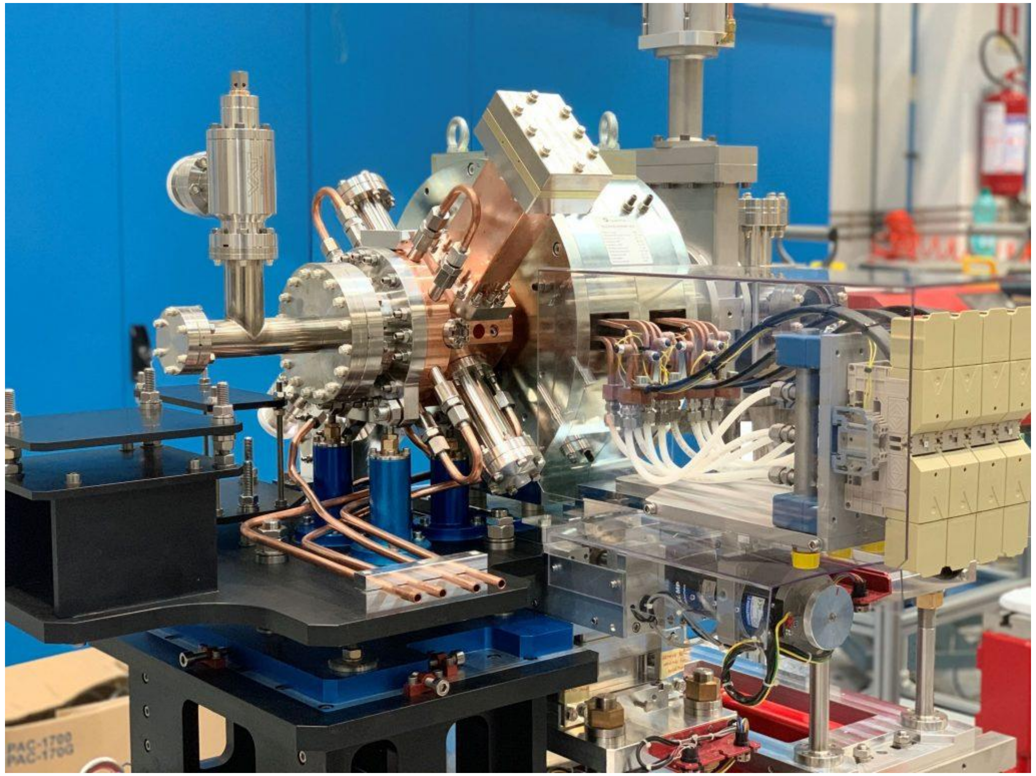
- Dr. Markus Loeser; 2 *Flint* oscillators as synchronized seeders for their amplifier chain.

Helmholtz-Zentrum Berlin. *Pharos* laser, 2020

SWITZERLAND

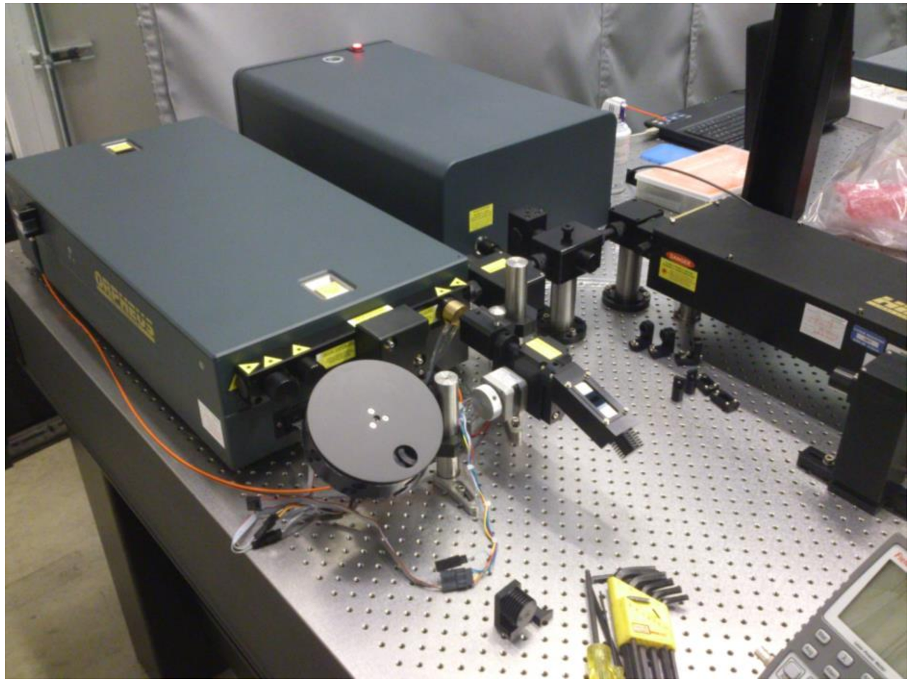
CERN, 2020

- Dr. Eduardo Granados, photoelectron injection



USA

- Dr. Dr Gilles Doumy, Argonne National Laboratory, 2013
- MIT/Arizona State University, 2016
- Prof. Siddharth Karkare, Arizona State University, 2019
- Prof. Anshul Kogar, UCLA, 2020
- Prof. Tony Heinz, Ralph H Page, SLAC National Accelerator Laboratory, 2021



UNITED KINGDOM, ITALY

Dr. Robin L. Owen, **Diamond Light Source,** the UK's national synchrotron science facility, 2018;
https://www.jove.com/t/62200/fixed-target-serial-data-collection-at-diamond-light-source

TU Graz, Elettra Sinchrotron Trieste, 2018

Elettra Sincrotrone Trieste

CHINA, TAIWAN

University of Science and Technology of China (Prof.Liu Yi) 2019

Shanghai Institute of Optics and Fine Mechanics 2019, 2020

Aerospace Information Research Institute (Xuan Hongwen) 2021

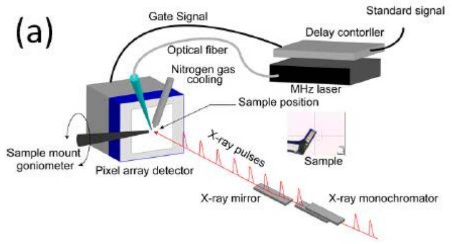
National Synchrotron Radiation Research Center, NSRRC, Taiwan 2021

JAPAN

High Energy Accelerator Research Organization (KEK), 2018

きる．ポンプ光であるパルスレーザーは200 fsのパルス幅をもつYb：KGW結晶をレーザー媒質とした高出力レーザー Pharos（Light Conversion Co. Ltd.）の第3高調波

(a)



(b)

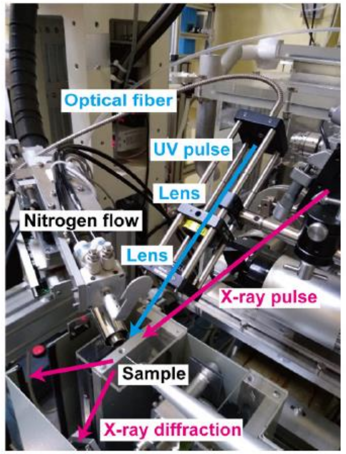


図5　(a)周波数可変の時間分解結晶構造解析法の概略図，(b) X線パルスとレーザーパルスの照射位置関係．((a) Time-resolved X-ray crystallography with variable frequency.(b) Photograph around the sample.)

とのヘテロエキシマーによるものであることが報告されており，ns程度の緩和時間をもつことが時間分解分光実験により報告されている.[9] しかしながら，6-CNの基底状態は通常の結晶構造解析により報告されているものの，6-CNの励起状態の構造詳細は実験的には明らかになっていない．

われわれは，高繰り返し化した時間分解結晶構造解析法により6-CNの光励起構造の観測を行った．6-CN結晶は，黄色の発光色をもつY体を用いた．測定周波数は，レーザー照射による温度上昇を抑えるためにX線の繰り返し周波数794 kHzの1/4分周である199 kHz（測定間隔：5.04 μs）に設定した（図6参照）．検出器の計測周波数も199 kHzに設定し，ポンプ－プローブ時間分解結晶構造解析法によるY体の6-CN結晶の励起構造の解析を行った．図7に結晶内の6-CNの励起後150 psのF_O（観測された構造因子）と励起前のF_Oの差フーリエマップを示す．電子密度の減った部分を赤色，増えた部分を緑色で示してある．これは，赤色から緑色の方向へ原子位置の変位が観測されたと解釈することができ，6-CN分子が光励起によりわずかに湾曲している様子がうかがえる．

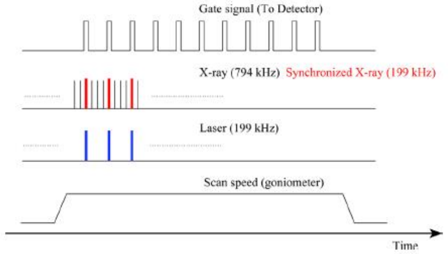
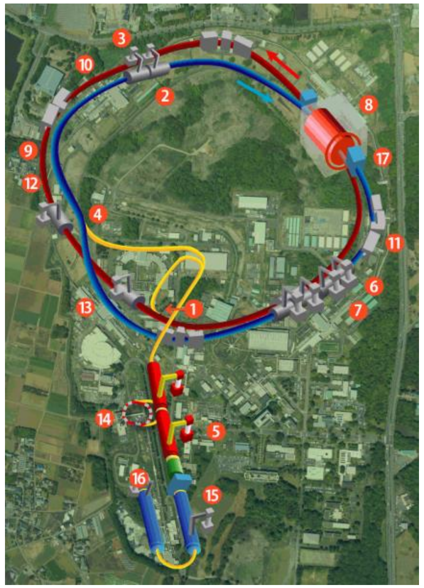
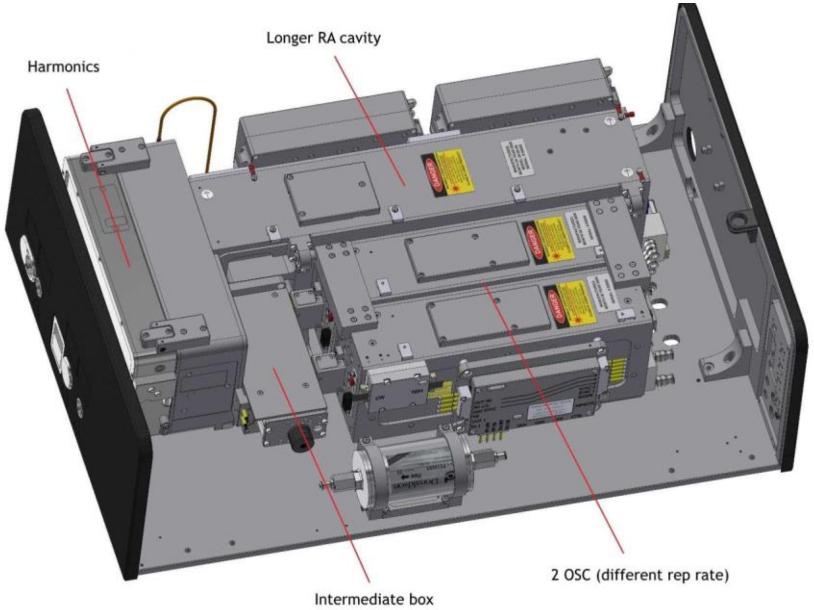
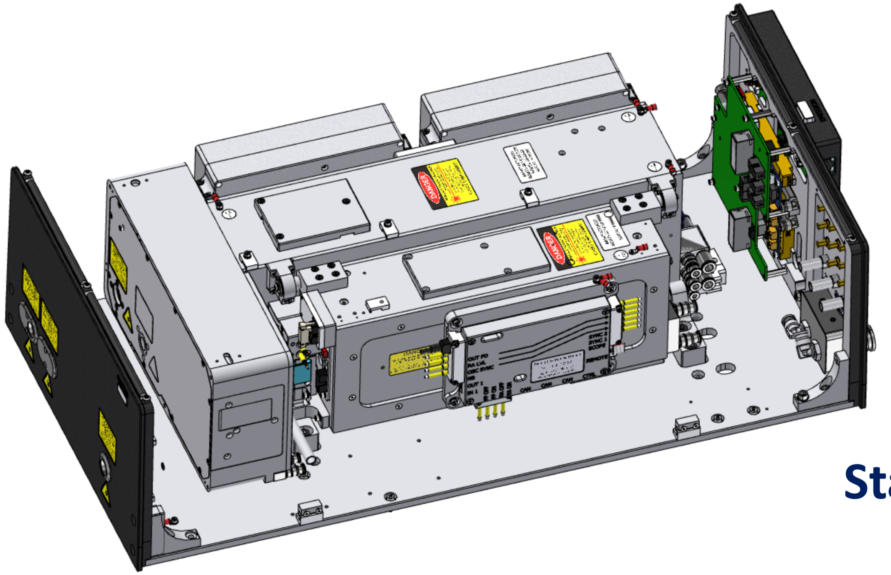


図6　199 kHzに分周した時間分解結晶構造解析法のタイミングチャート．(Timing chart of the time-resolved X-ray crystallography with 199 kHz)





KEK customized *Pharos*



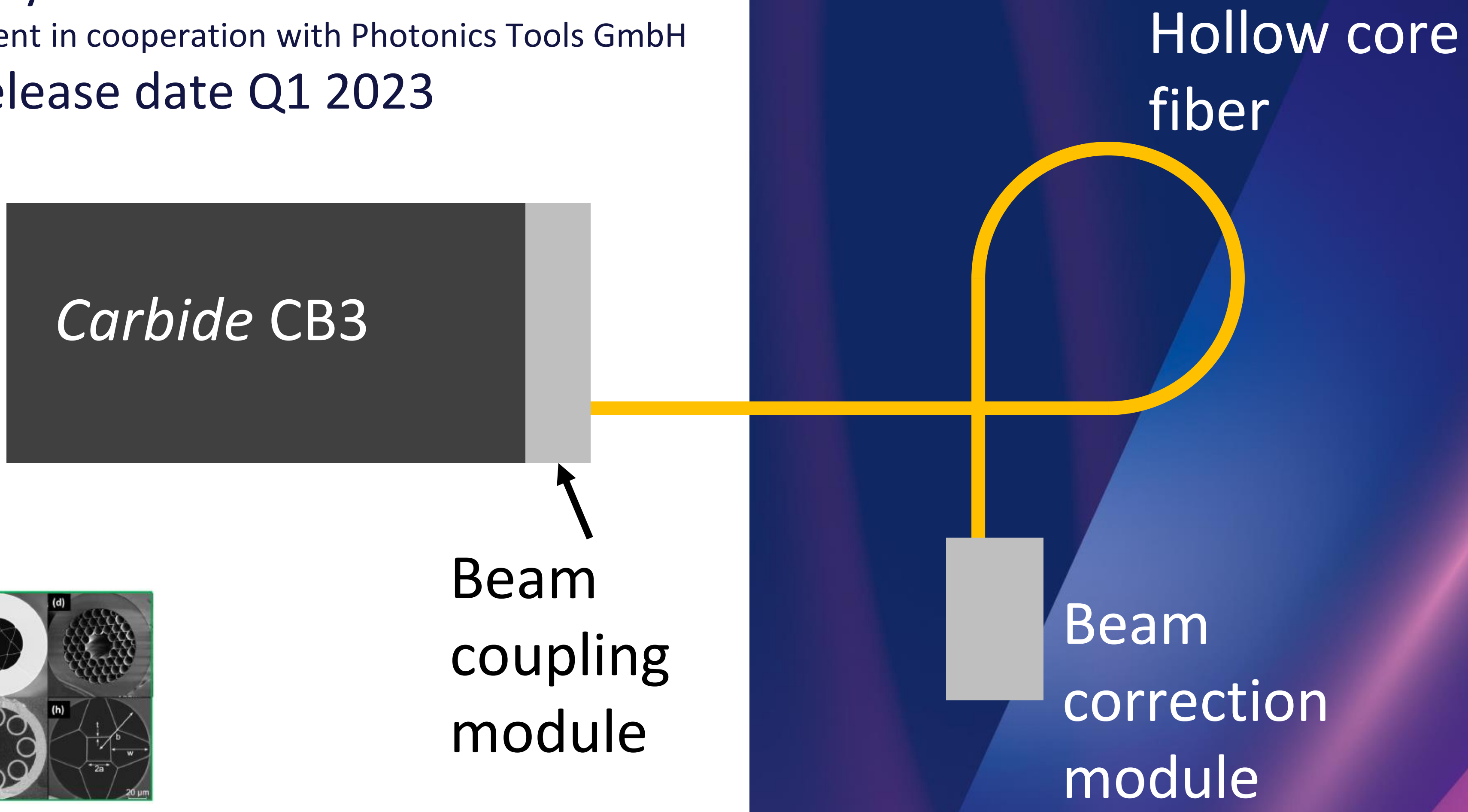
Standard *Pharos*

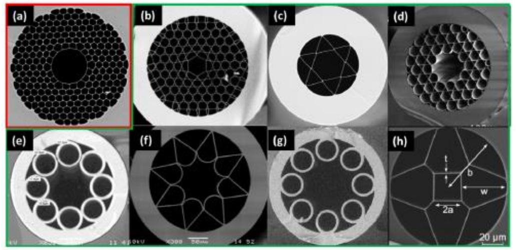
fs laser – fiber delivery

Fiber delivery for fs laser *Carbide*

Under development in cooperation with Photonics Tools GmbH

Expected release date Q1 2023

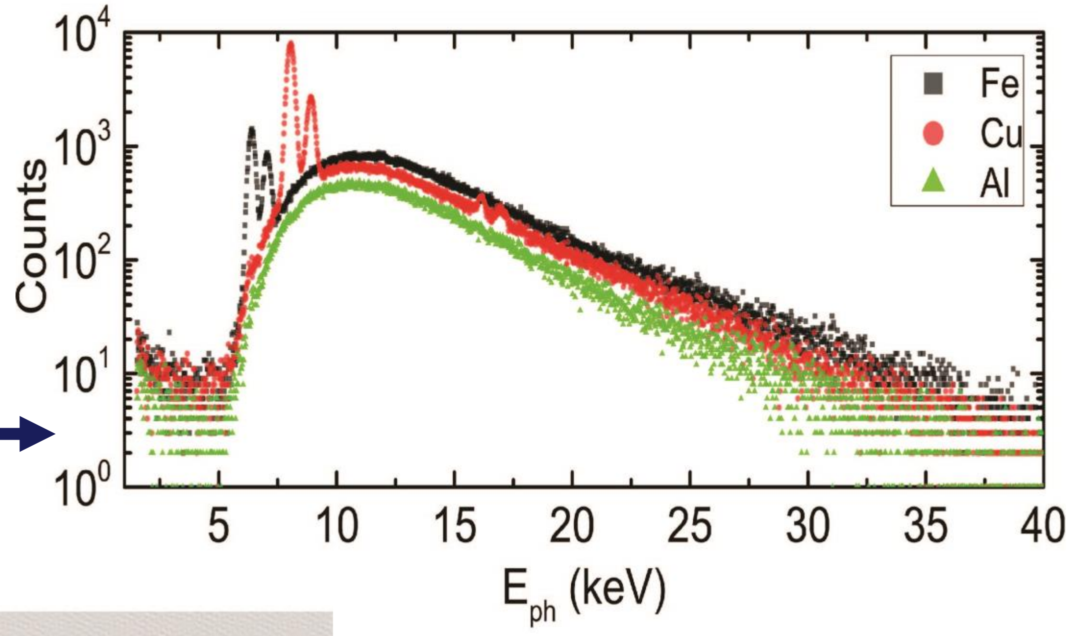




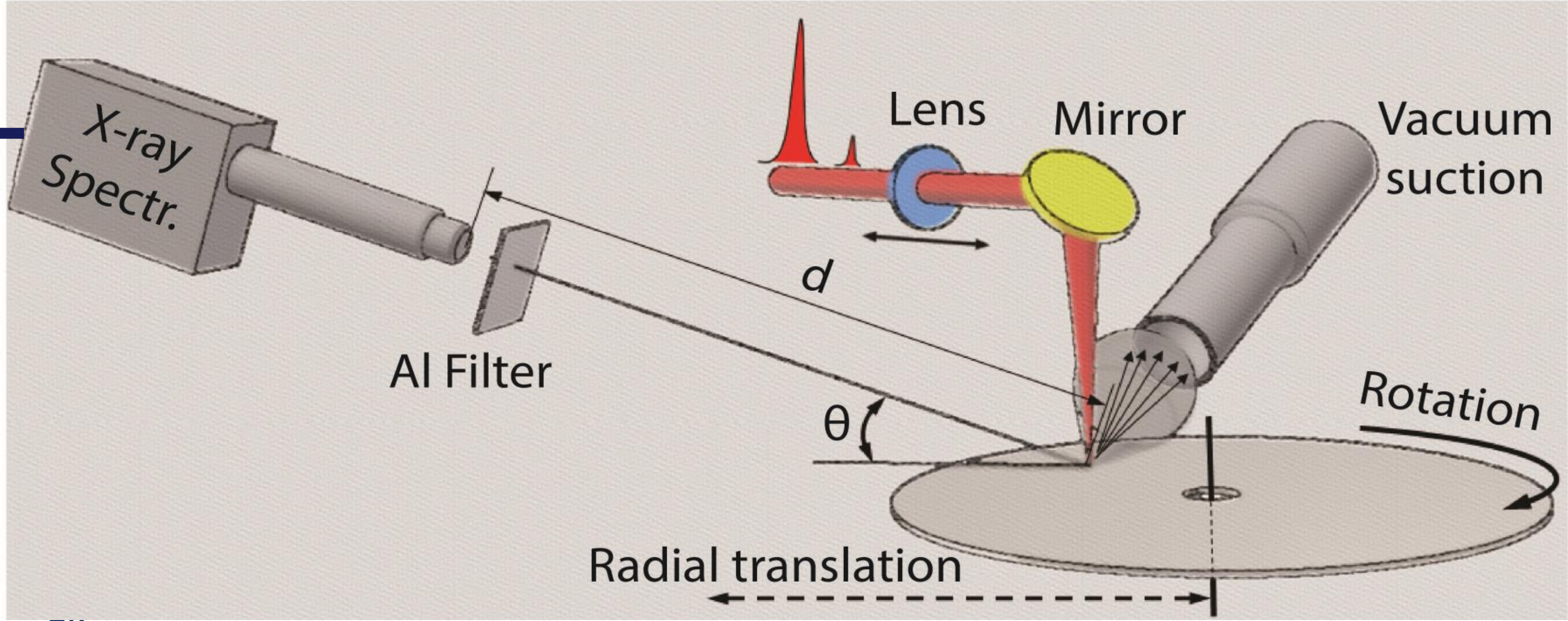
https://doi.org/10.1364/OE.22.023807

fs pulses in UV, DUV and x-ray

High-brightness X-ray source



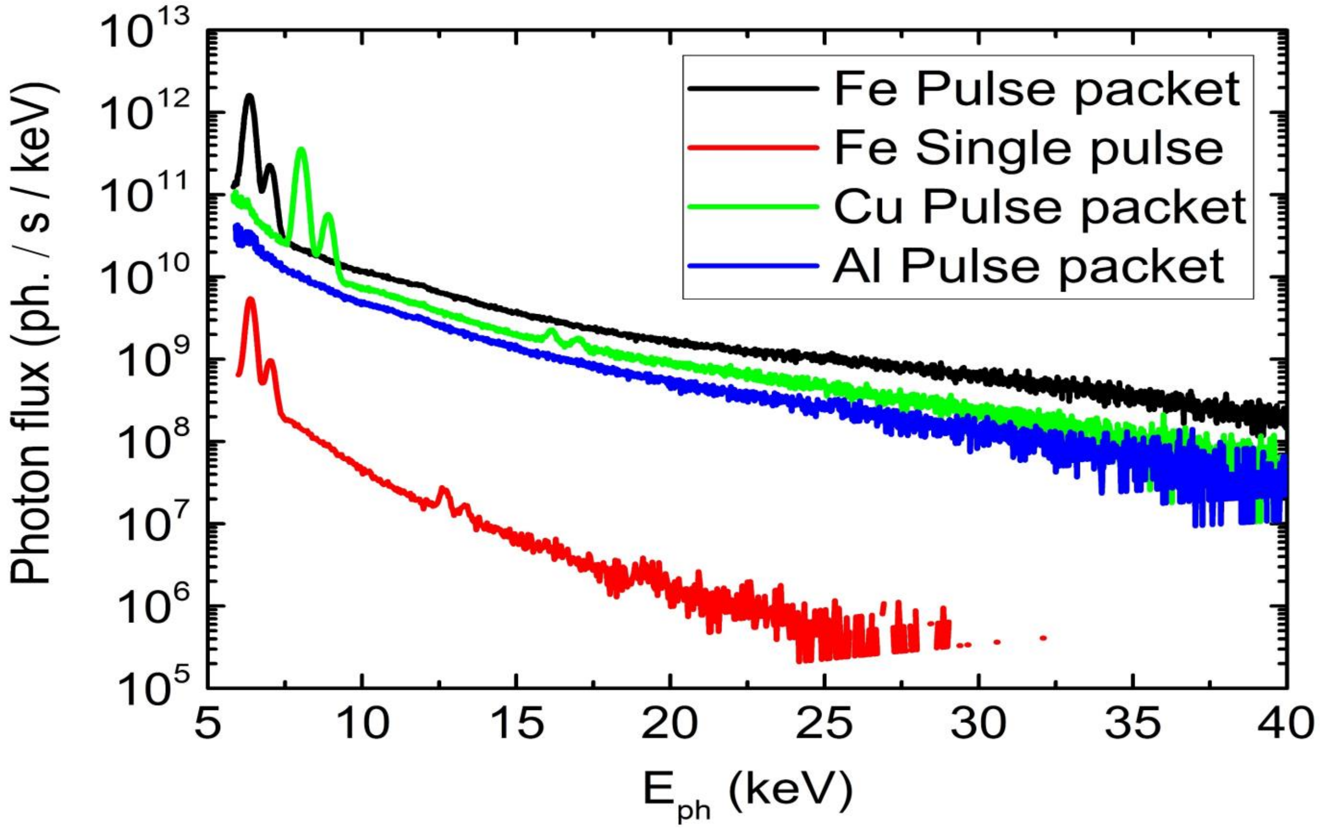
F = 150 mm;
Beam diameter = 45 µm (at e^{-2}); 26 µm (FWHM).



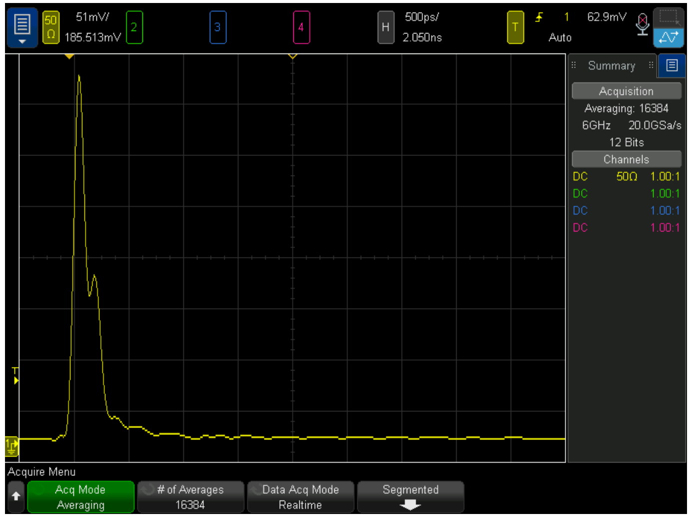
Target: **Fe,** Cu, Al.
10 m/s – 40 m/s

- https://www.optica.org/en-us/events/congress/high-brightness_sources_and_light-driven_interacti/schedule/?day=Thursday

Increase in x-ray generation efficiency by two orders of magnitude using packet of fs pulses



X-ray emission dependence on the number of pulse pairs in a microsecond burst while retaining the same average beam power.



LIGHT CONVERSION

Thank you!

LINAS@LIGHTCON.COM

Do you have a femtosecond?