THALES
Building a future we can all trust

High peak power laser for I-LUCE and latest laser technology developments

Christophe SIMON-BOISSON,

HPLA Workshop , INFN-LNS Catania
17/11/2025

www.thalesgroup.com

Summary of Thales laser activity

A world leader in high-power solid-state laser systems

- Over **30 years of laser expertise**
- **World record 1 petawatt (PW) laser** with the BELLA system (USA) in 2012
  World record 10 PW with ELI-NP system (Romania) with one beam in 2019
- Laser solutions for **industrial processes** and new **medical applications**
- **World's only company** to send operational laser to Mars (with CNES and NASA) in 2011 and 2020
- Long-standing laser research partnership between Thales and Gérard Mourou, winner of 2018 **Nobel Prize in Physics**

Gérard Mourou
2018 Nobel Prize in Physics

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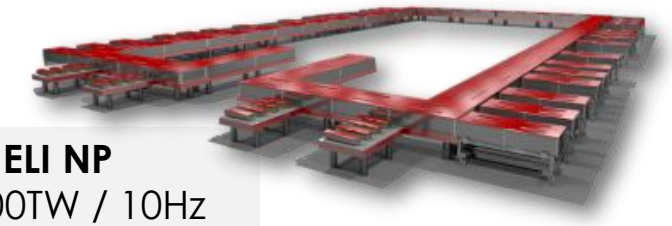
QUARK COMMUNITY

CALA (3PW)
90J / 1Hz

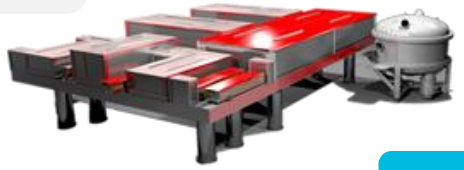


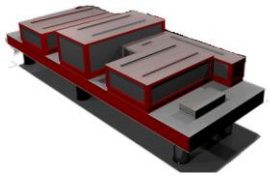
ELI NP
2x 100TW / 10Hz
2x 1PW / 1Hz
2x 10PW / 1sh/min

A.Gonsalves, PRL 122, 084801 (2019): **8 Gev**
A.Picksley, PRL 133, 255001 (2024): **10 GeV**

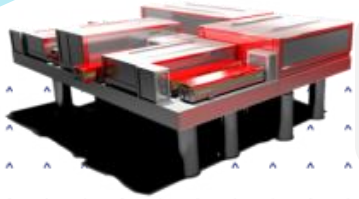
LBNL BELLA
1,3PW / 1Hz

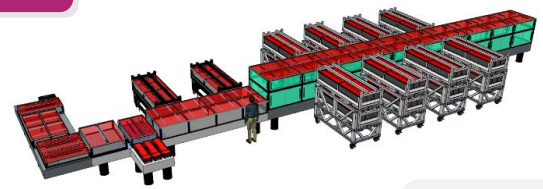
SCAPA
350TW / 5Hz





USC
45TW / 10Hz





Riken Harima
2x 500TW / 1Hz

Peking Uni.
2PW / 1Hz

DESY 200TW / 5Hz
Peking Uni. 200TW / 5Hz
Weizmann 2x100TW / 1Hz

3 PW
10 PW
1 PW
2 PW
350 TW
500 TW
45 TW
200 TW

I-LUCE LASER SYSTEM FOR INFN-LNS : Laser Specifications

Specifiche tecniche	unità	Uscita principale	Uscita secondaria	Commenti
Energia in uscita	J	≥ 8	≥ 1.5	
Durata dell'impulso	fs	≤ 23	≤ 23	
Potenza di picco	TW	≥ 320	≥ 40	
Frequenza di ripetizione	Hz	2.5	10	
Spettro (FWHM)	nm	≥ 40	≥ 40	
Lunghezza d'onda centrale	nm	800 nm +/- 10 nm	800 nm +/- 10 nm	
Profilo del fascio		Cilindro supergaussiano		
Diametro del fascio	mm	≥ 100	≥ 100	
Strehl ratio (senza specchio deformabile)	%	≥ 60	≥ 60	
Contrasto:				
- ns		<1:10^8	<1:10^8	
- @5 ps		<1:10^5	<1:10^5	
- @10 ps		<1:10^7	<1:10^7	
- @100 ps		<1:10^10	<1:10^10	
Stabilità energetica (rms)	% RMS	< 1.5	< 1.5	oltre 5000 colpi
Stabilità della potenza (più di 8 ore)	% RMS	≤ 2.5	≤ 2.5	escluso il tempo di accelerazione
Stabilità del puntamento	µrad RMS	< 5	< 5	oltre 5000 colpi
Polarizzazione		Linearità migliore di 1:100	Linearità migliore di 1:100	

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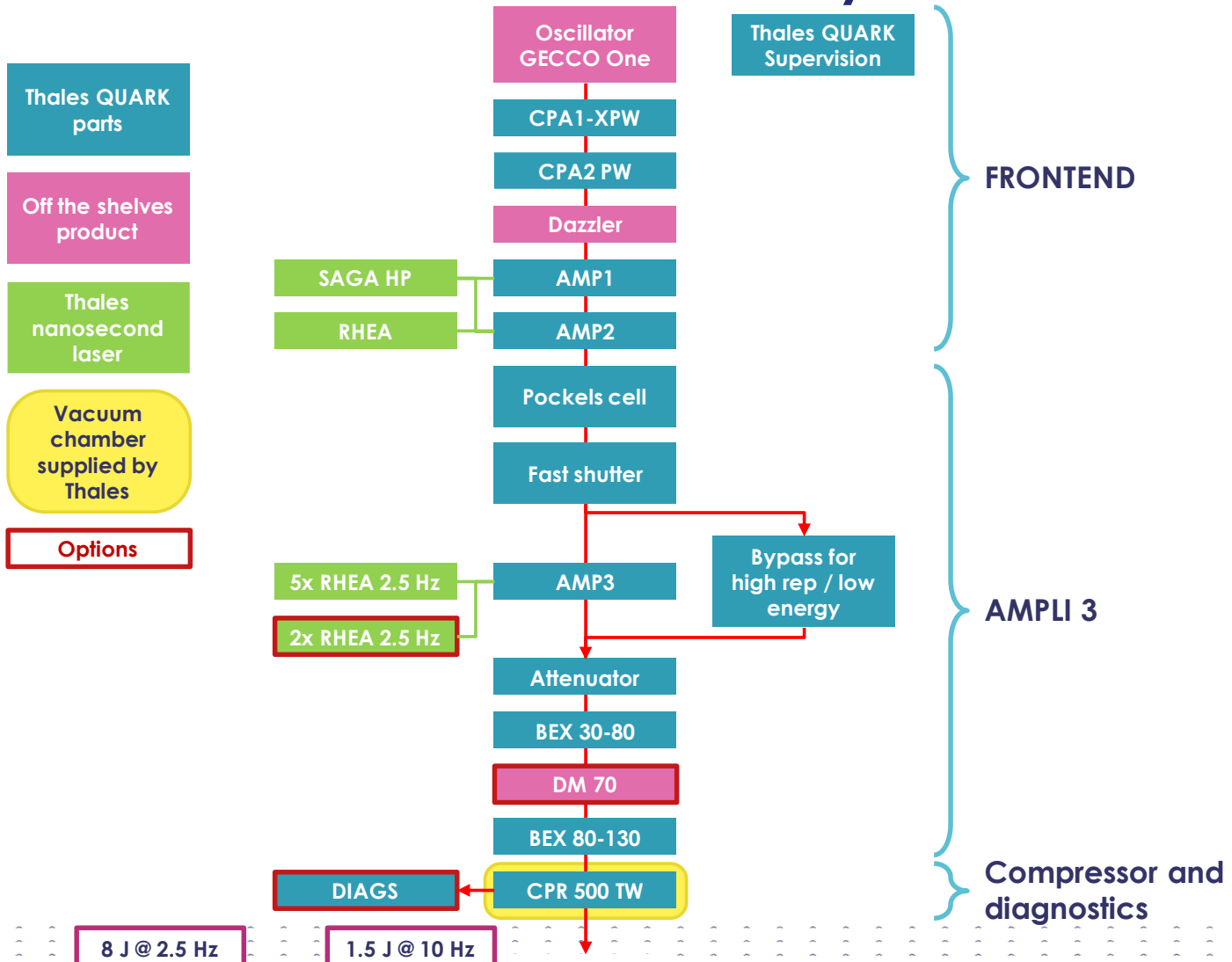
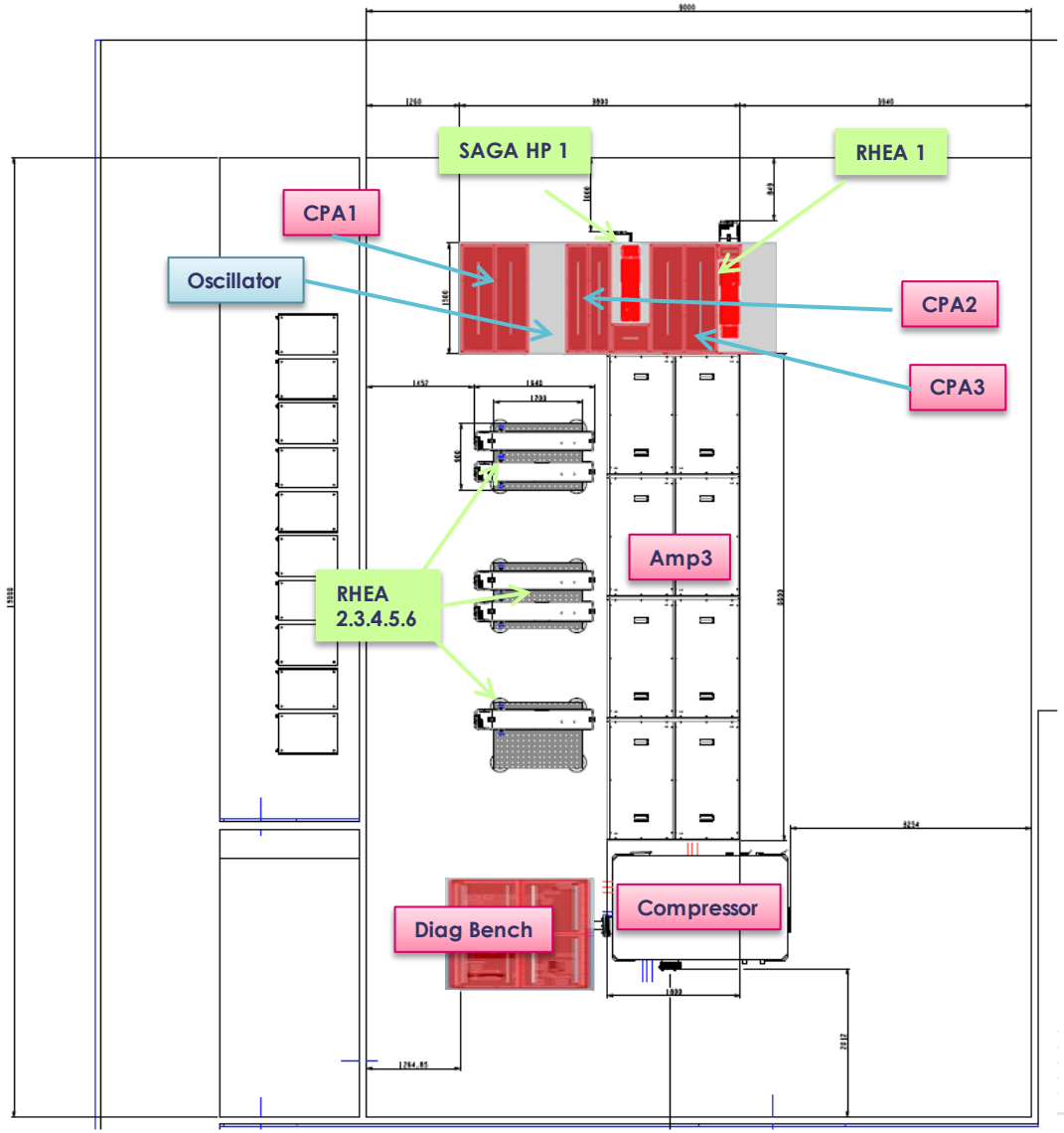
I-LUCE LASER SYSTEM FOR INFN-LNS : Laser system architecture



I-LUCE LASER SYSTEM FOR INFN-LNS : Laser system physical implementation

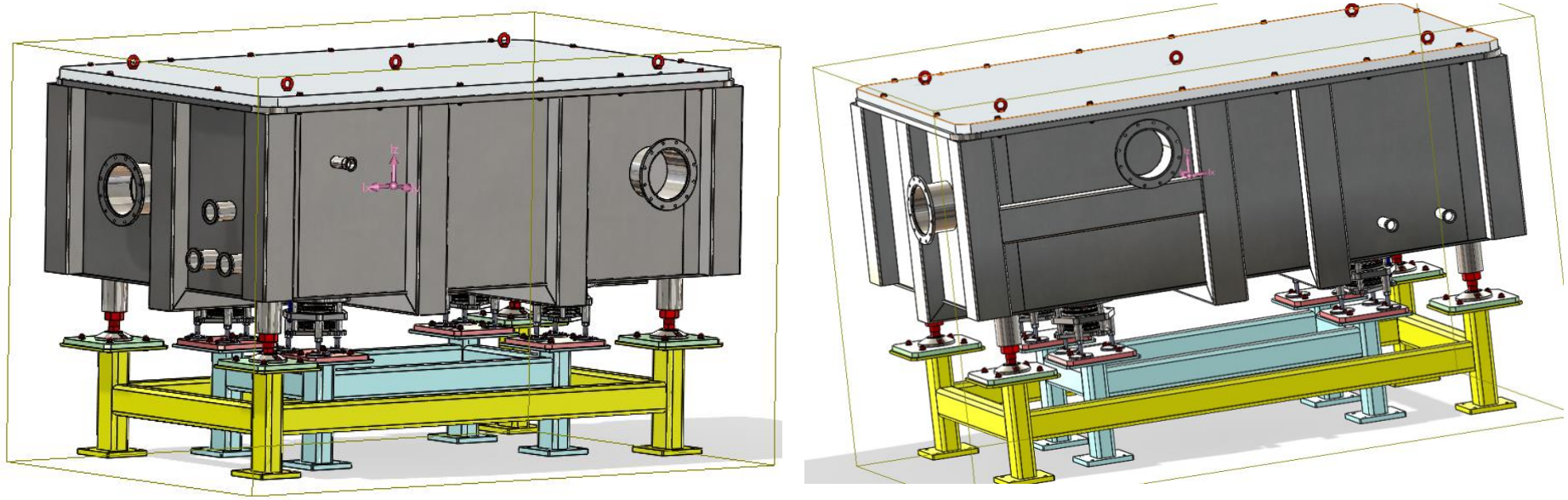


Top view of the system with the lab room. Location of subsystems is highlighted.

I-LUCE LASER SYSTEM FOR INFN-LNS : Compressor vessel

> Compressor under vacuum (2210x1260)

- Input 1135mm – Output 1300mm (vs ground)

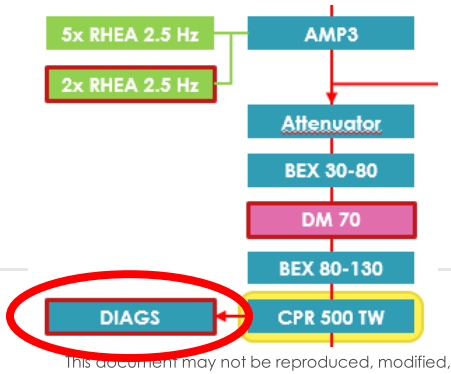


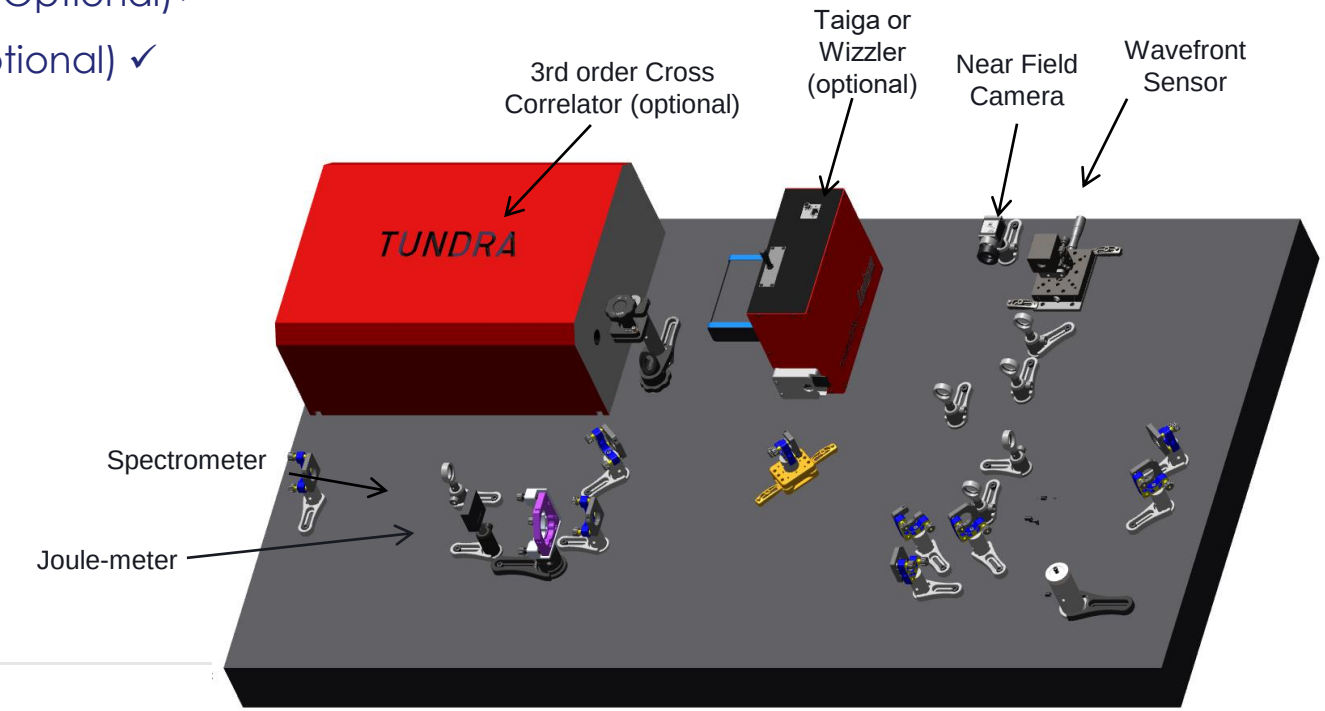
3D views of compressor vacuum chamber

I-LUCE LASER SYSTEM FOR INFN-LNS : Diagnostics bench

> DIAGNOSTIC BENCH “Standard” with beam-size adaptation

- TELESCOPE for Beam Reduction: Concave/Convex type (to adapt)
- SPLITTING/IMAGING
- One near field diagnostic (Basler type camera)
- One wave front diagnostic (wave front sensor)
- One temporal diagnostic (pulse width) (Optional)✓
- One temporal diagnostic (contrast) (Optional) ✓





3D views of diagnostic bench

HPLS 10 PW laser at ELI-NP - *« The most powerful laser in the world »*

System aiming to deliver two laser beams with three possibe peak power

2x10 PW, 1 tir/min
2x1 PW, 1 Hz
2x100 TW, 10 HZ

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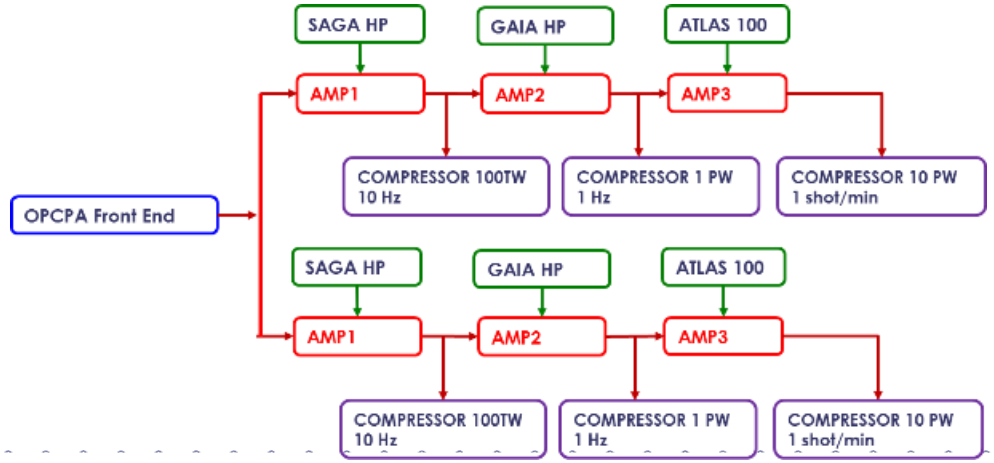
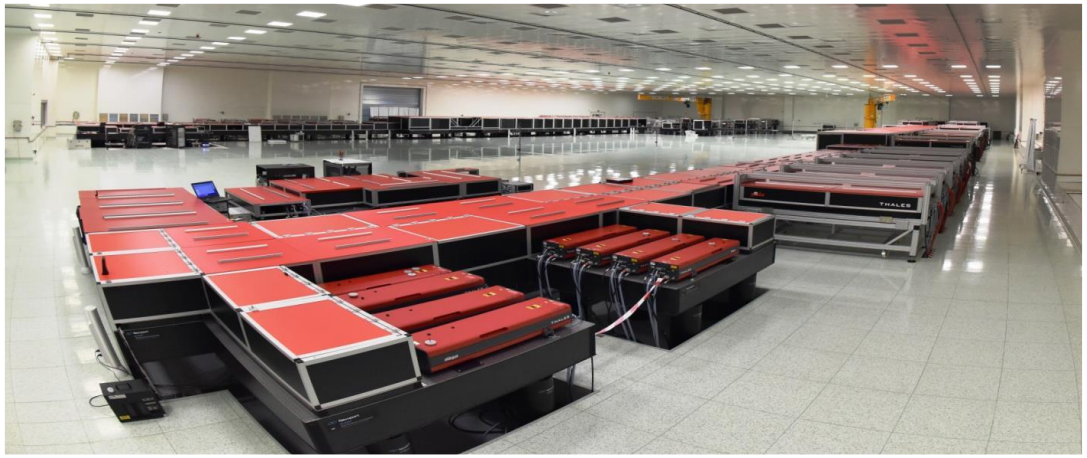
48 pump lasers

A dedicated clean room (ISO7)
2 400 m²





THALES - ELI ; the most powerful laser in the world (ecliptique.com)

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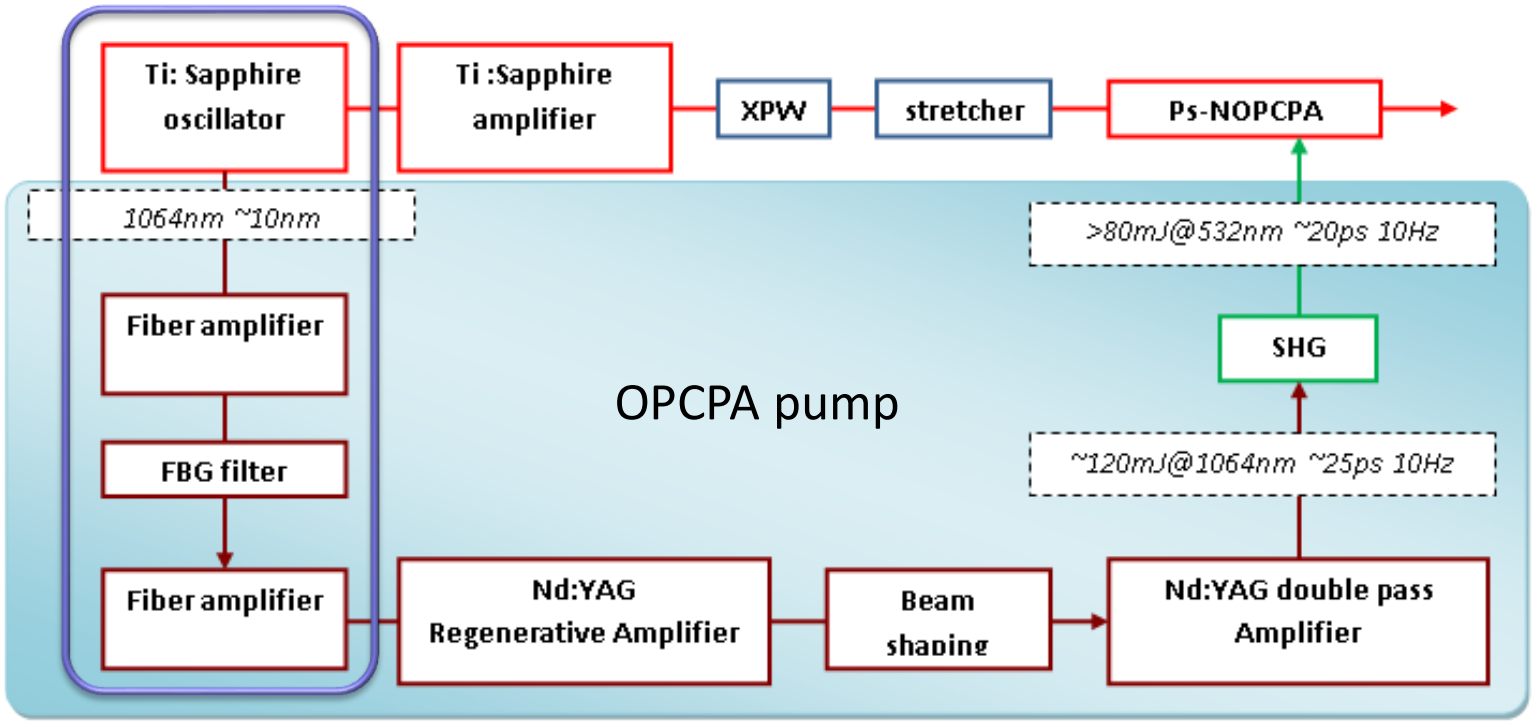
High Contrast Front End for multi-PetaWatt laser systems

From oscillator supplier

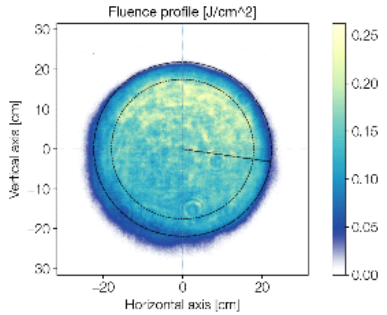


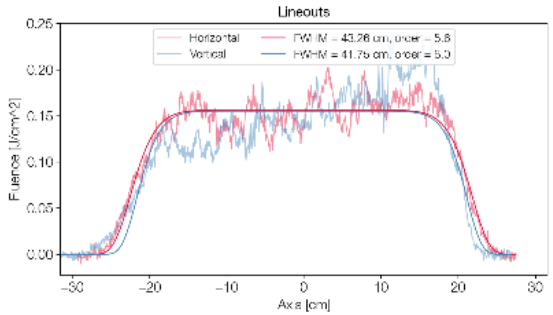
4 such front ends installed:

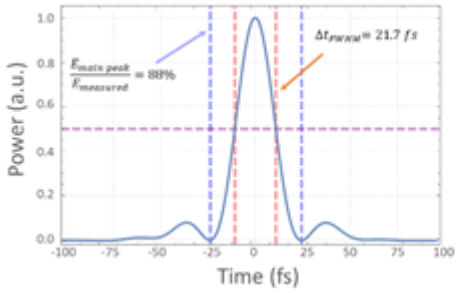
- ELI-NP (Romania): q=2
- Apollon (France) : q=1
- Peking University (China): q=1

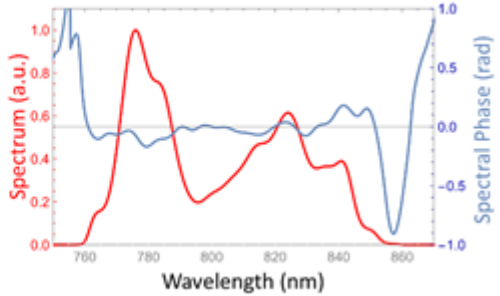
HPLS 10 PW laser at ELI-NP - *« The most powerful laser in the world »*

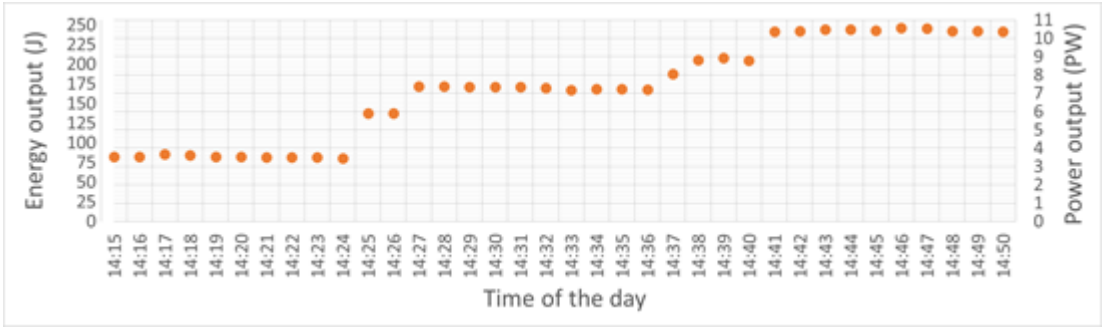
Retrieved peak power (from energy and duration measurements) = 10,2PW (in the main pulse)



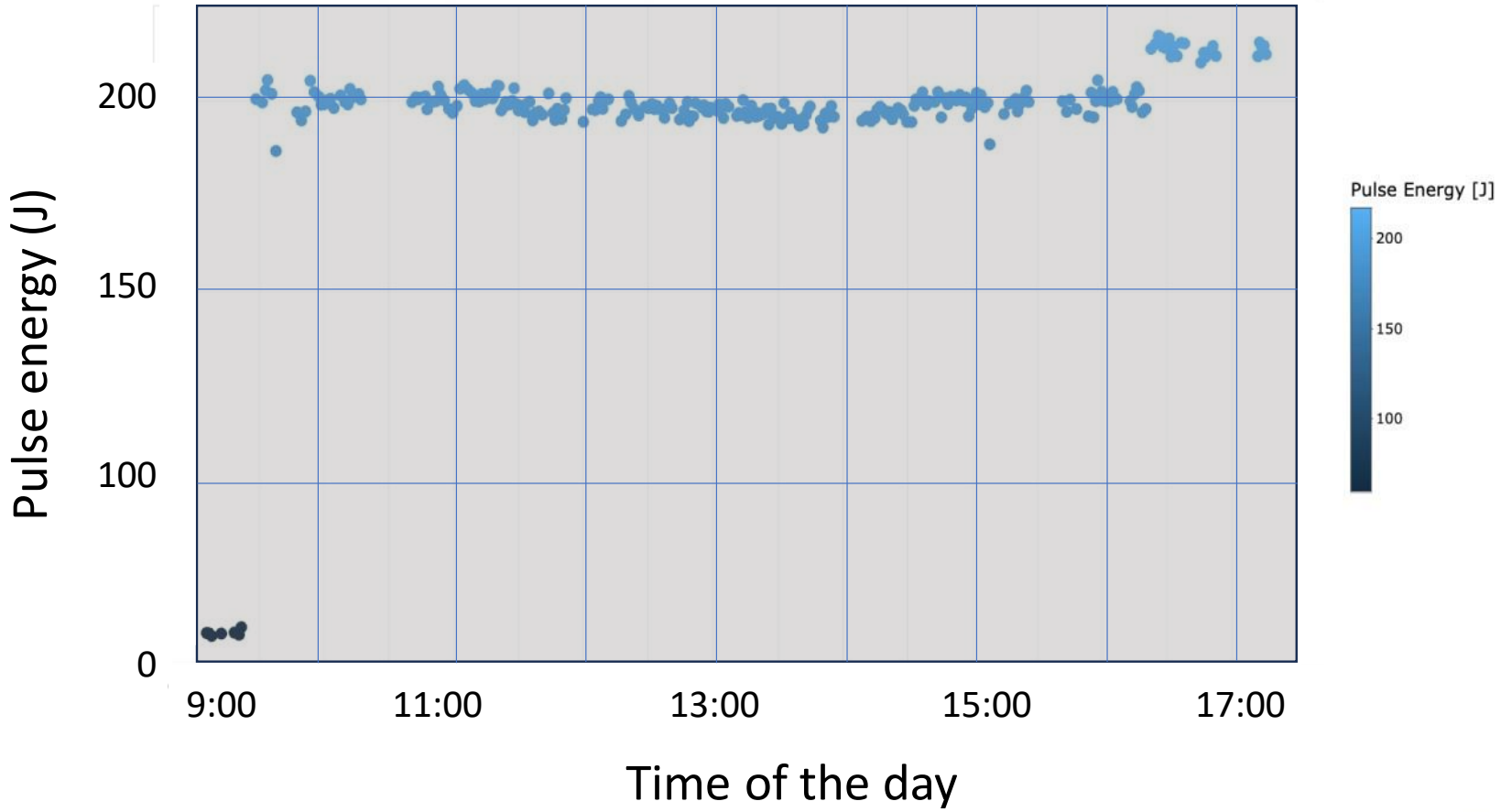








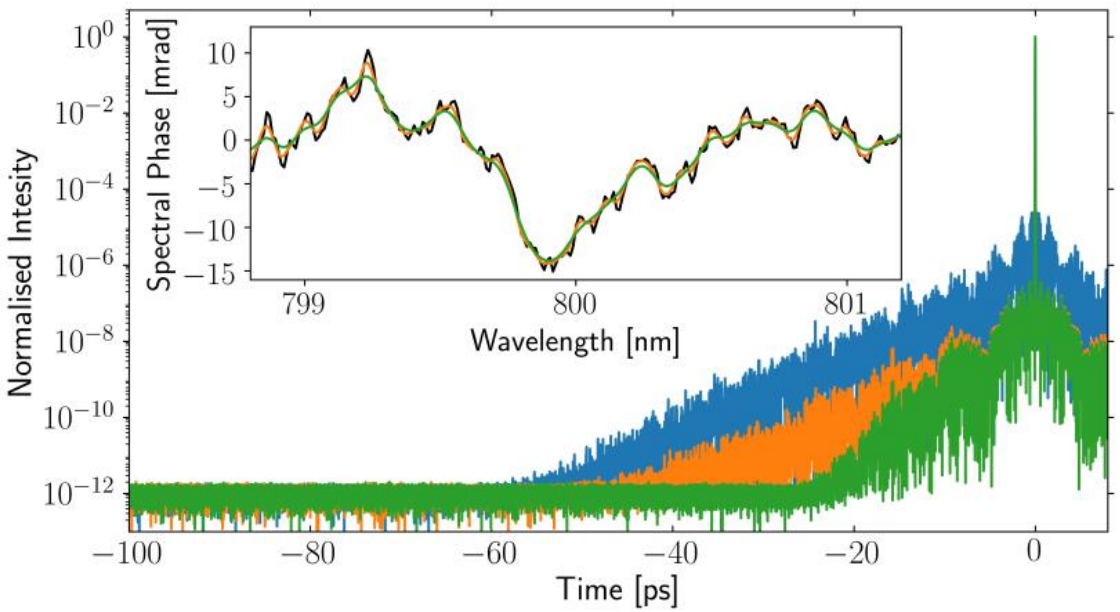
HPLS 10 PW laser at ELI-NP - *« The most powerful laser in the world »*

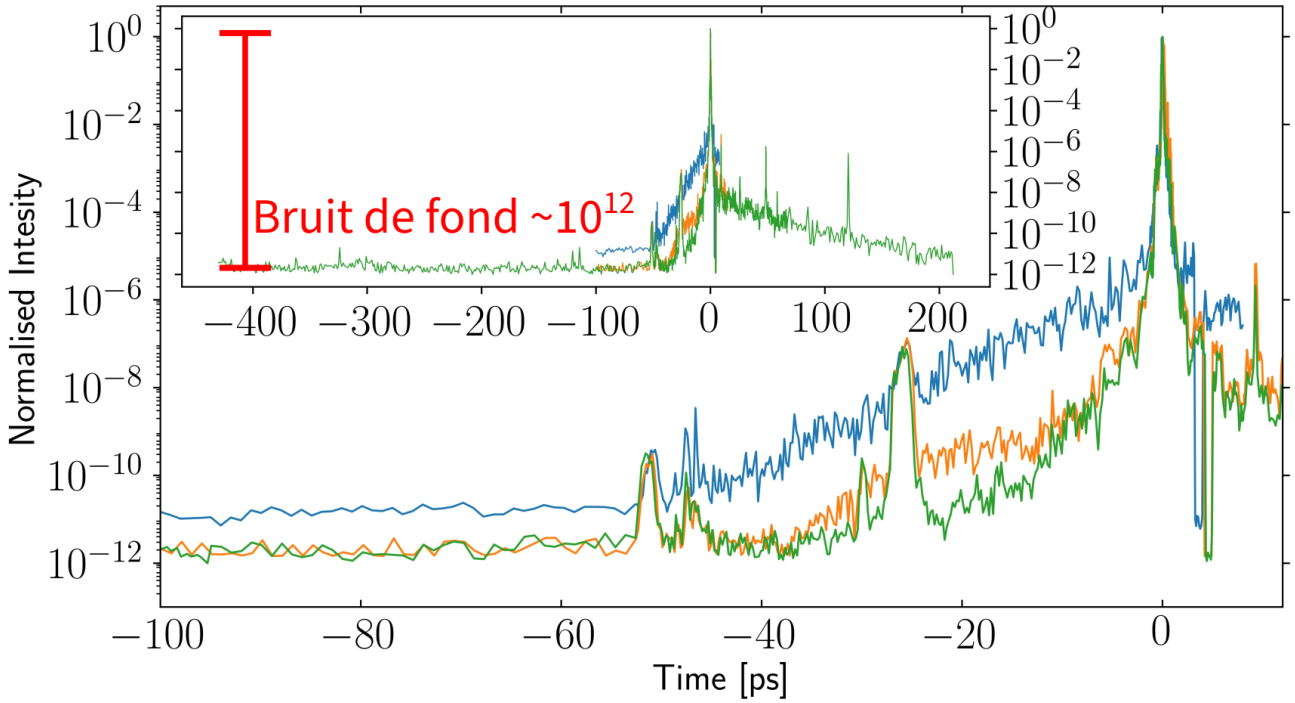


Courtesy of ELI-NP

World Record, ELI-NP delivers 274 shots in one day at 10 PW output of its High Power Laser System

Improvement of temporal contrast with low rugosity convex mirror in stretcher





Ranc & al, Optics Letters, 45, 16, 4599 (2020)

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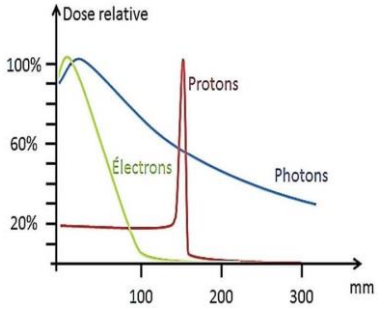
Increase the repetition rate of lasers: a need for industrial & medical applications

Rationale

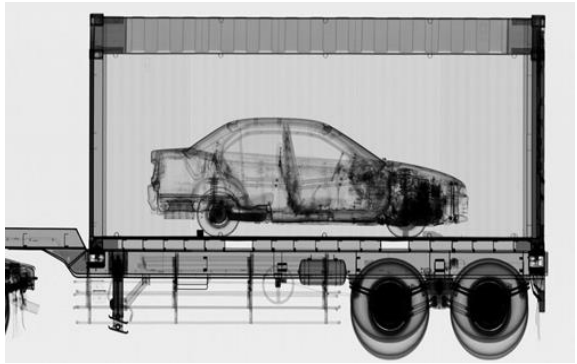
- **Titanium Sapphire is confirmed as the ideal technology for producing high-energy ultrashort pulses (< 30 fs)**
- **Development of 1J / 100 Hz laser system for scientific, industrial and medical applications**



Revolutionising the way we treat cancer - Ebeam4Therapy

MULTI SCAN 3D

Home - Multiscan3D (multiscan3d-h2020.eu)



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LAPLACE HC platform at LOA for electron acceleration (within Heracles joint research lab)

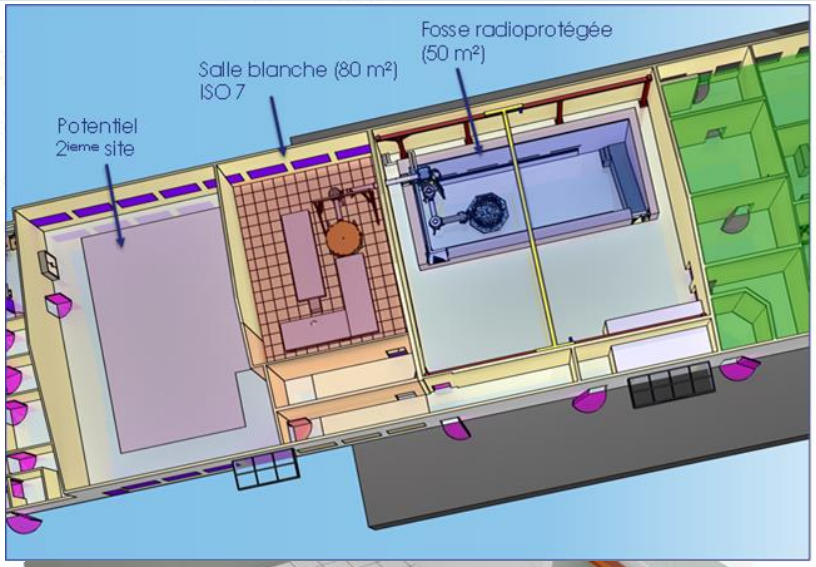
The LAPLACE Project

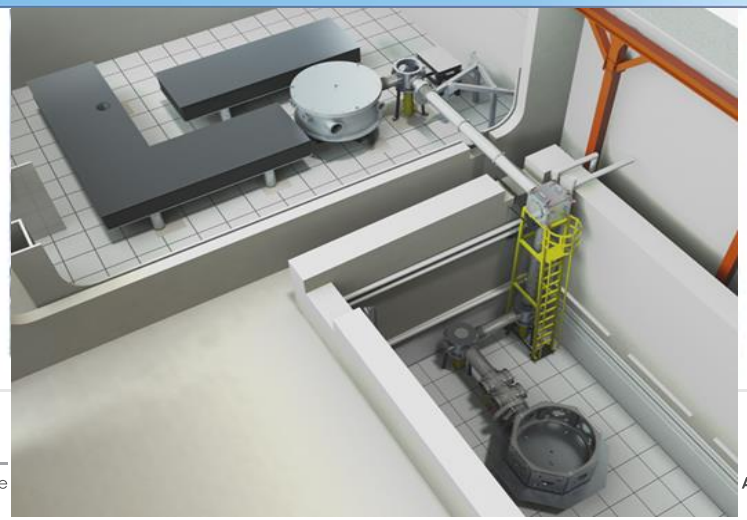
LAPLACE HC

- 80 m² clean room
- Laser 1 J @ 100 Hz
- 50 m² radioprotected area
- 2nd radioprotected area in option

Average power of ~ 100 W (vs 1 W now)

O. Chalus , WG2 Th. (THALES LAS)





[LAPLACE – Laser Plasma Acceleration Center at LOA (laplace-loa.fr)]

High rep-rate Ti:Sa

200 mJ 100 Hz

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New High rep-rate Ti:Sa laser system: **200 mJ @ 100 Hz**

> Front-end adapted to contrast need

- single CPA – double CPA w/ XPW – **OPCPA based** – …

> Diode-pumped pump laser for amplifiers: THEIA

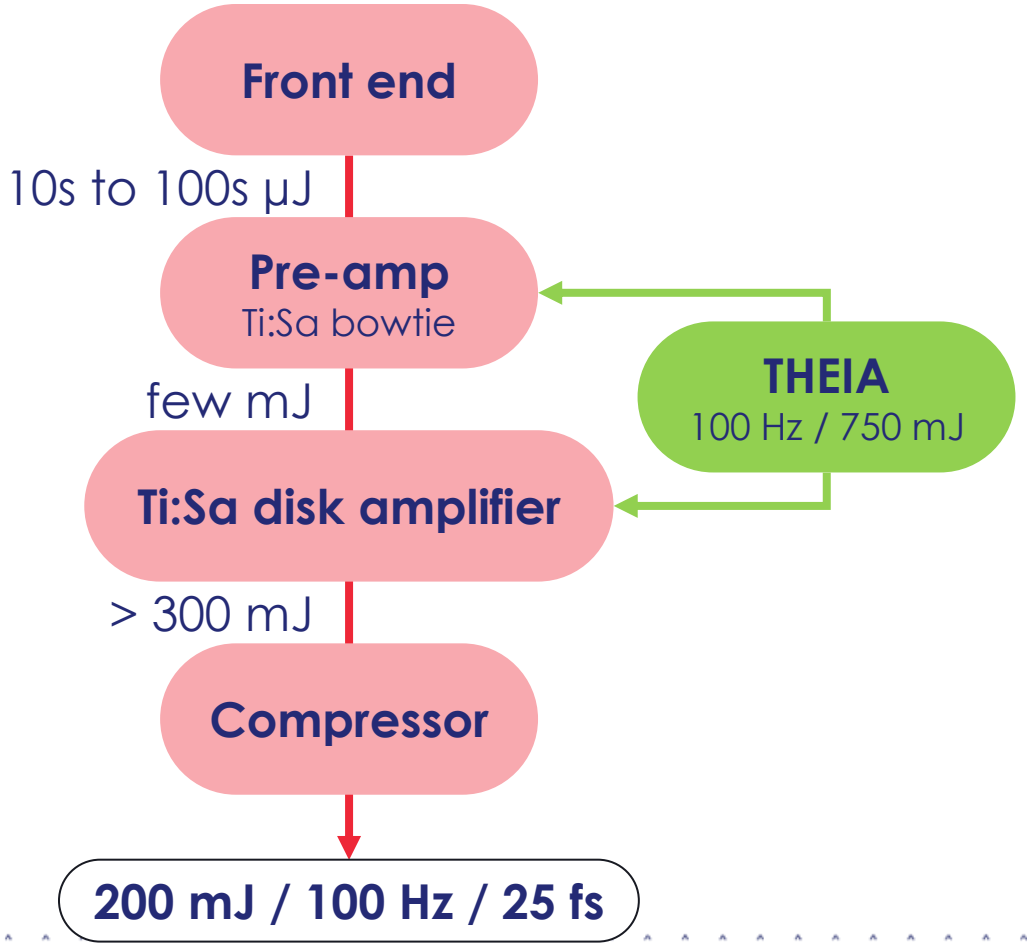
- **750 mJ** @ 532 nm, 100 Hz, ~10 ns

> New Ti:Sa disk amplifier at room temperature

- Active mirror configuration for effective cooling with **water @ 20°C**
- Fully qualified at **300 mJ**

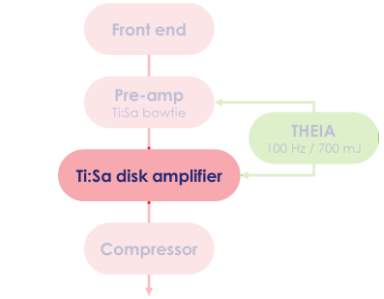
> "Standard" compressor

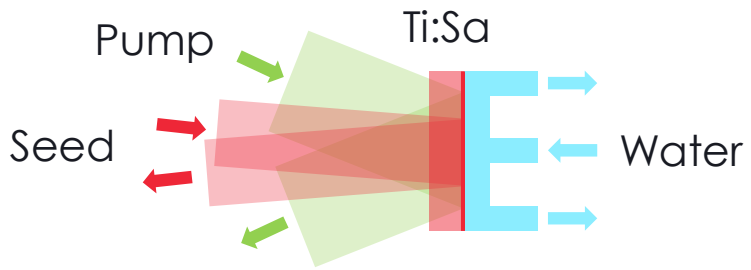
- No cooling required at this average power

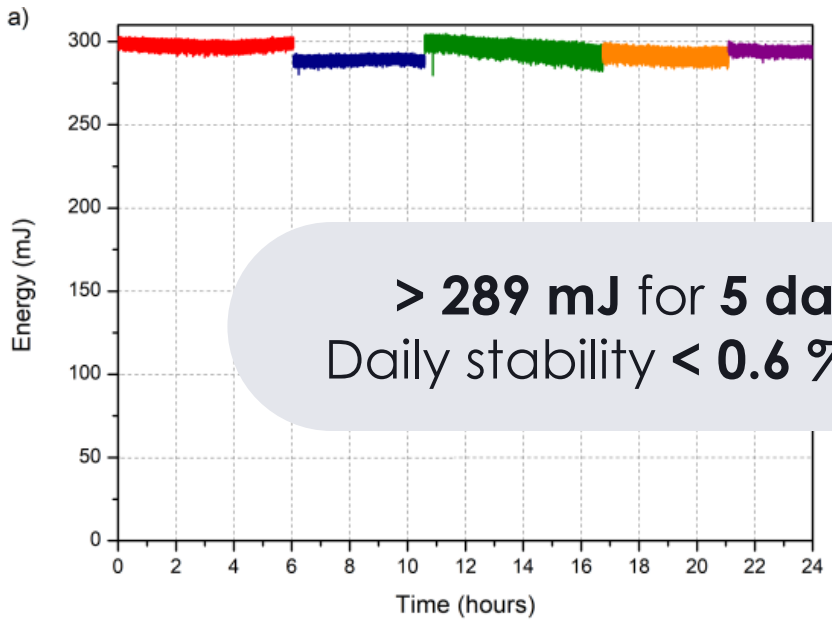


Ti:Sa disk amplifier

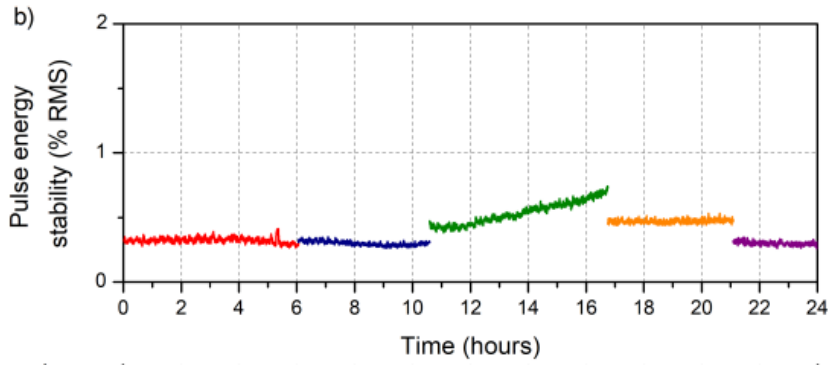
See more details in
Kabacinski & al, Optics Letters, 50, 18, 5630 (2025)

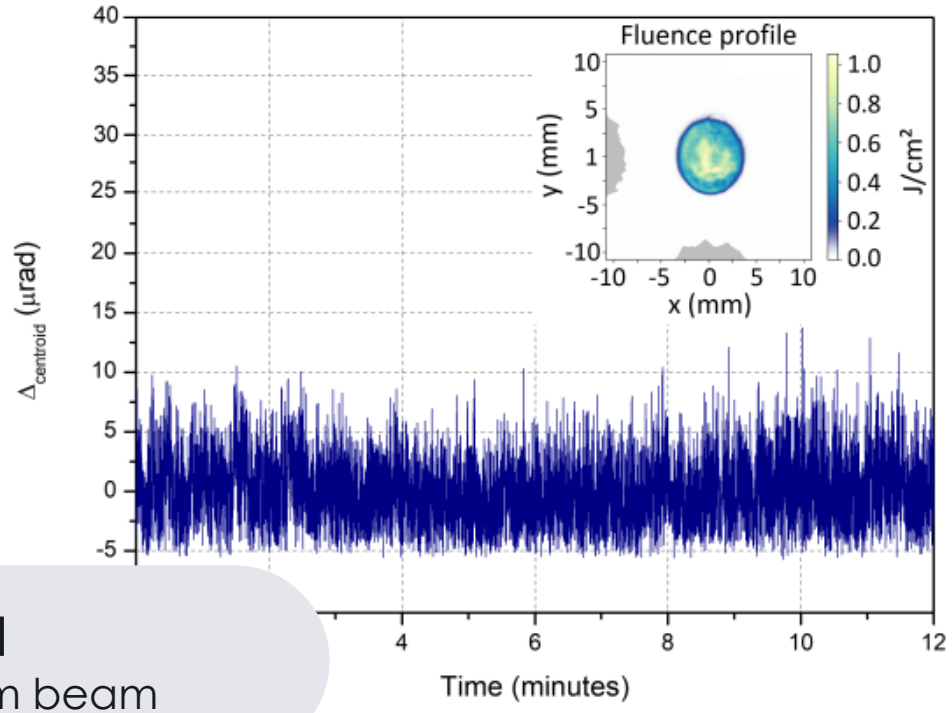






> 289 mJ for **5 days**
Daily stability **< 0.6 % rms**





< 3 µrad
12 min on Ø 8 mm beam

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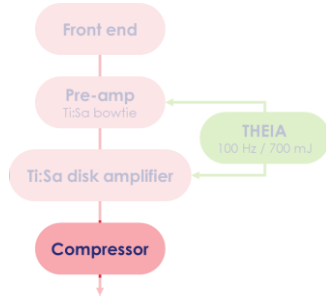
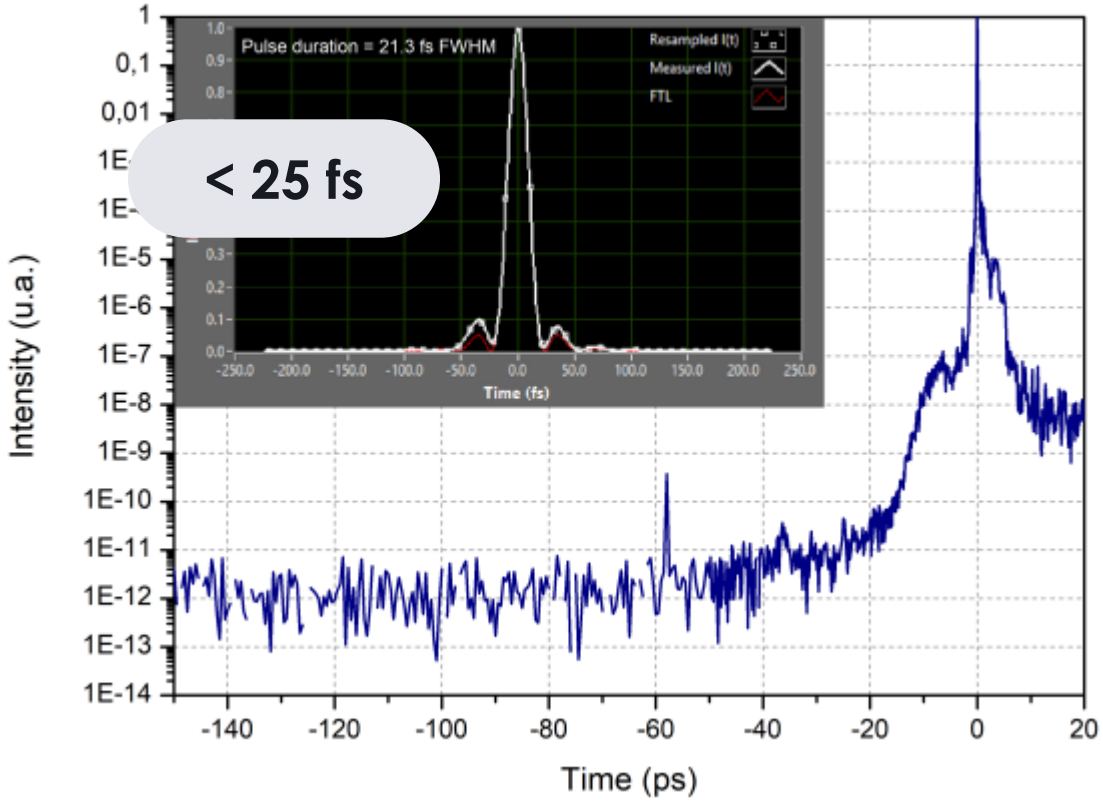
Compression

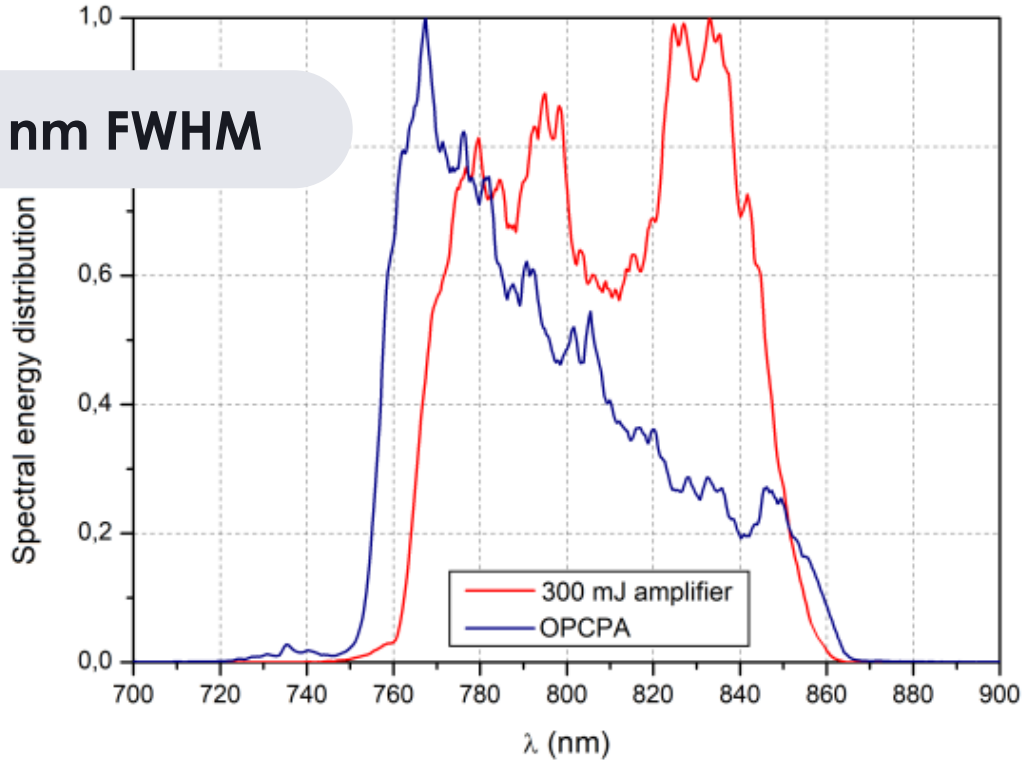


1 x 10^{-8} @ 10 ps
3 x 10^{-11} @ 30 ps

< 25 fs



80 nm FWHM



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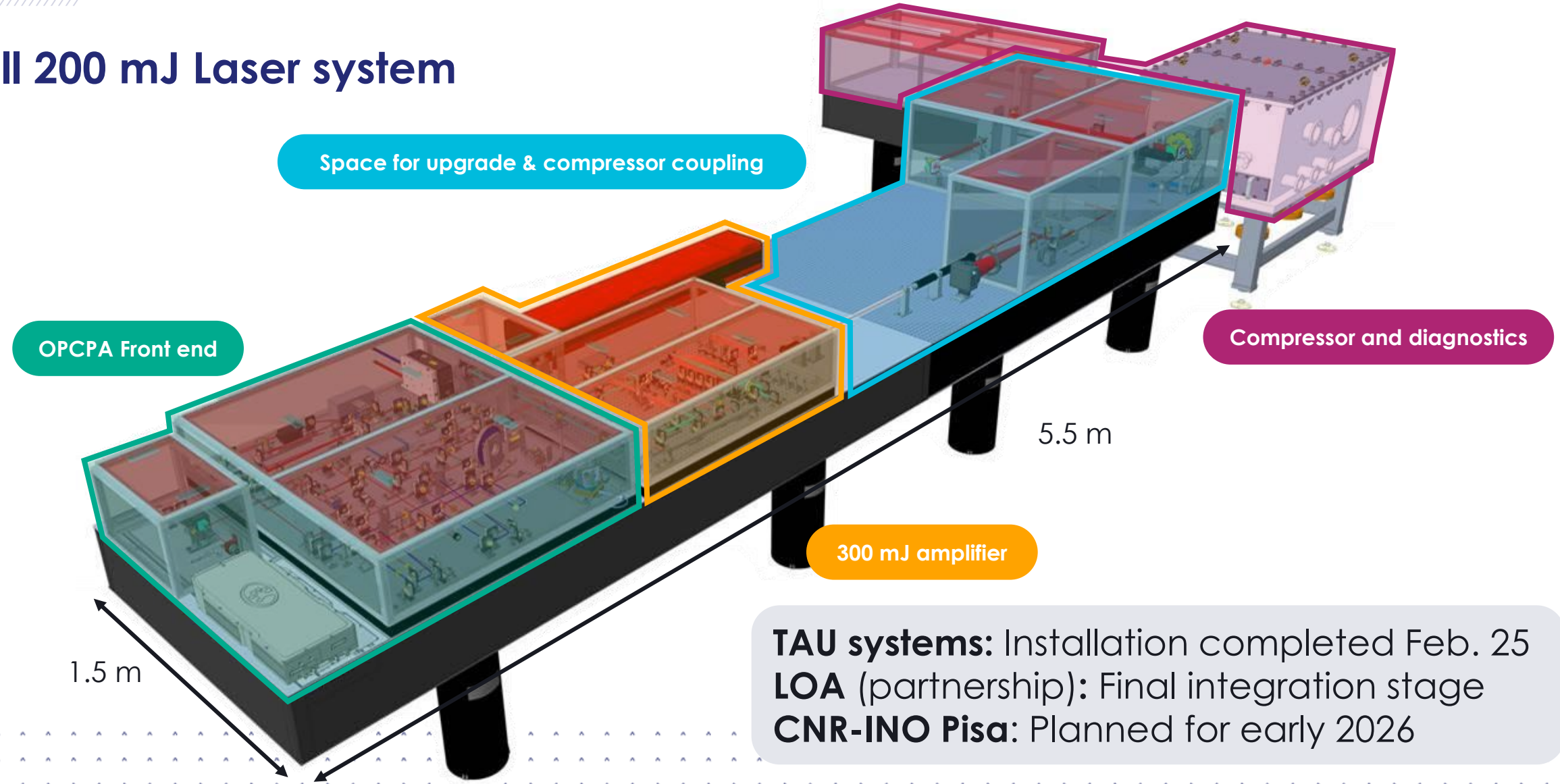
Full 200 mJ Laser system



TAU systems: Installation completed Feb. 25
LOA (partnership)**:** Final integration stage
CNR-INO Pisa: Planned for early 2026

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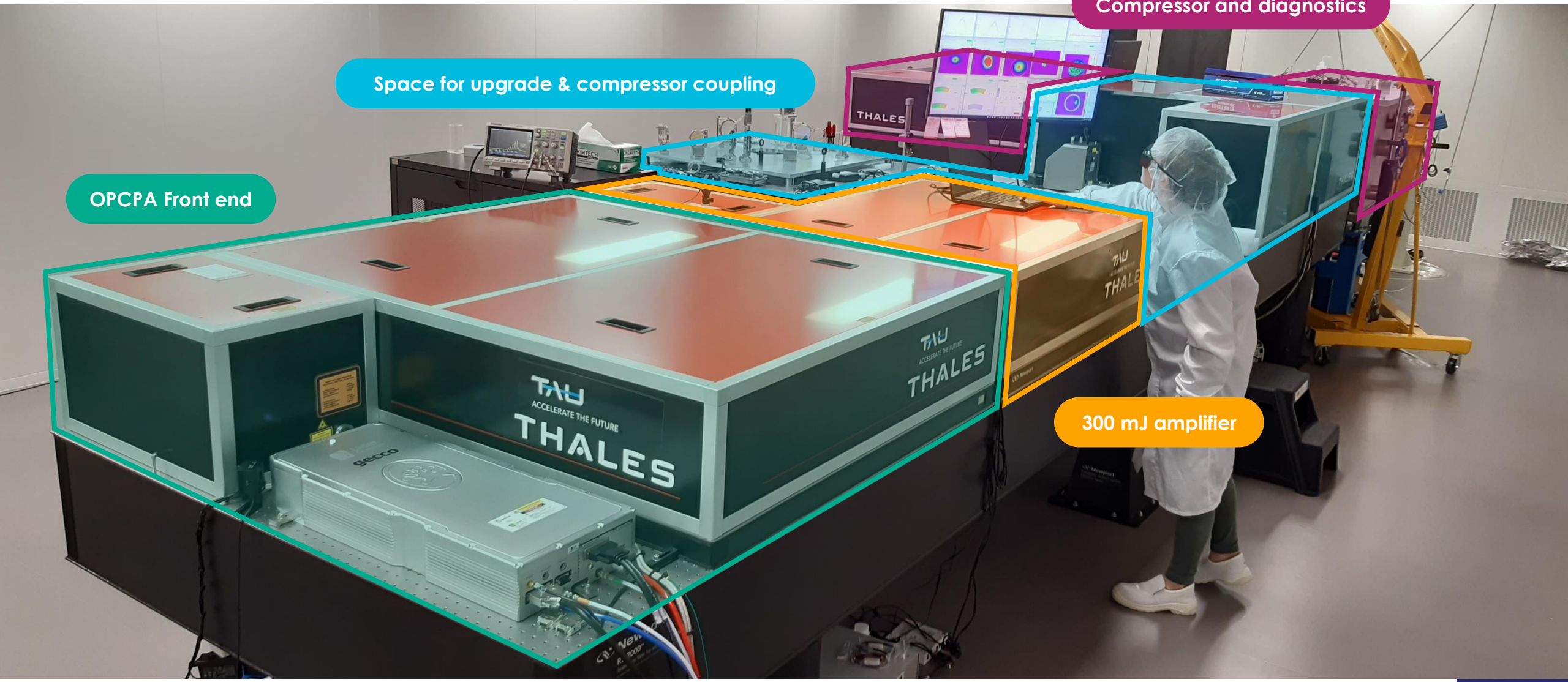
TAU systems: commisionned in Feb. 2025



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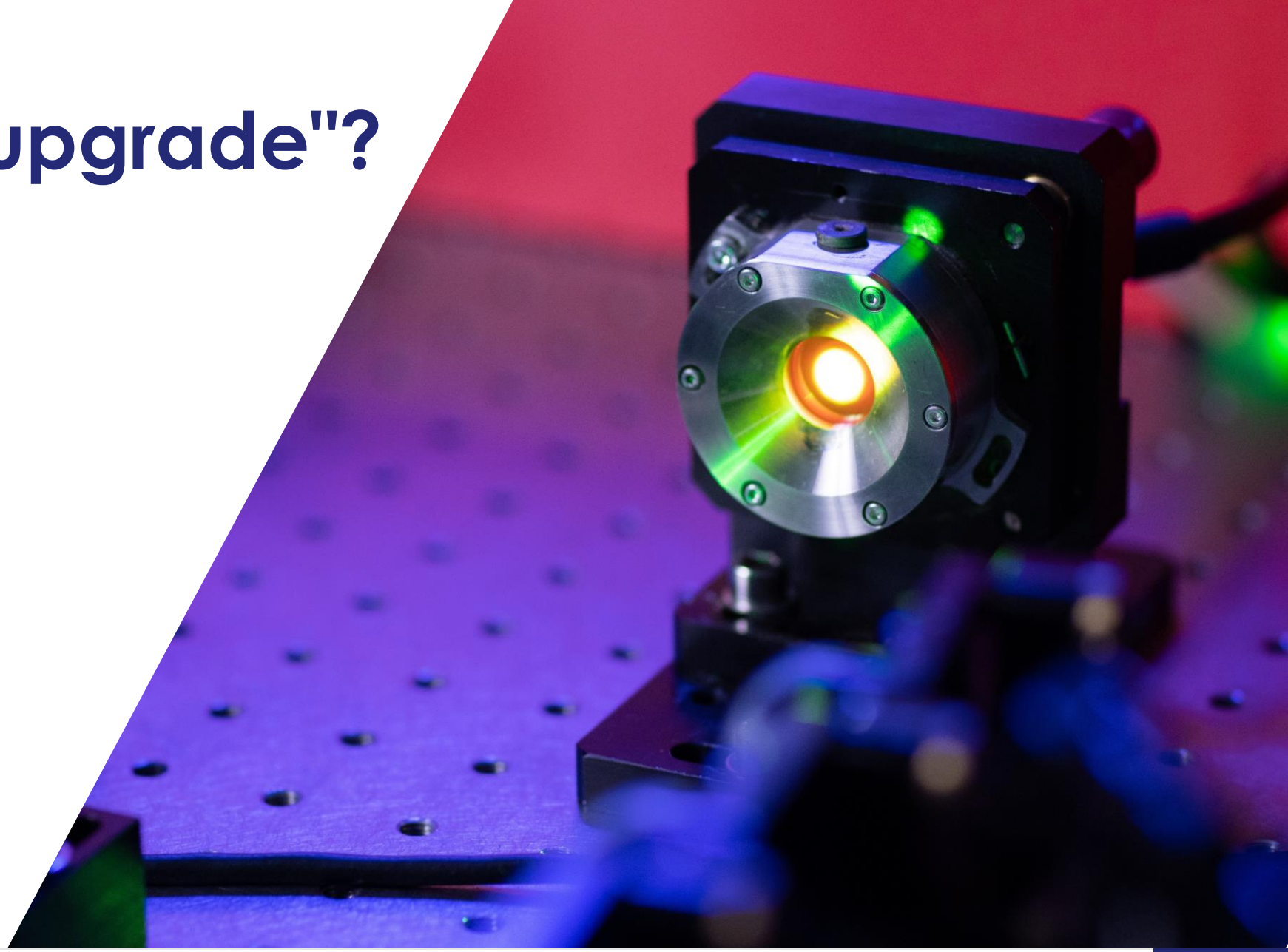
"Space for upgrade"?

1 J 100 Hz



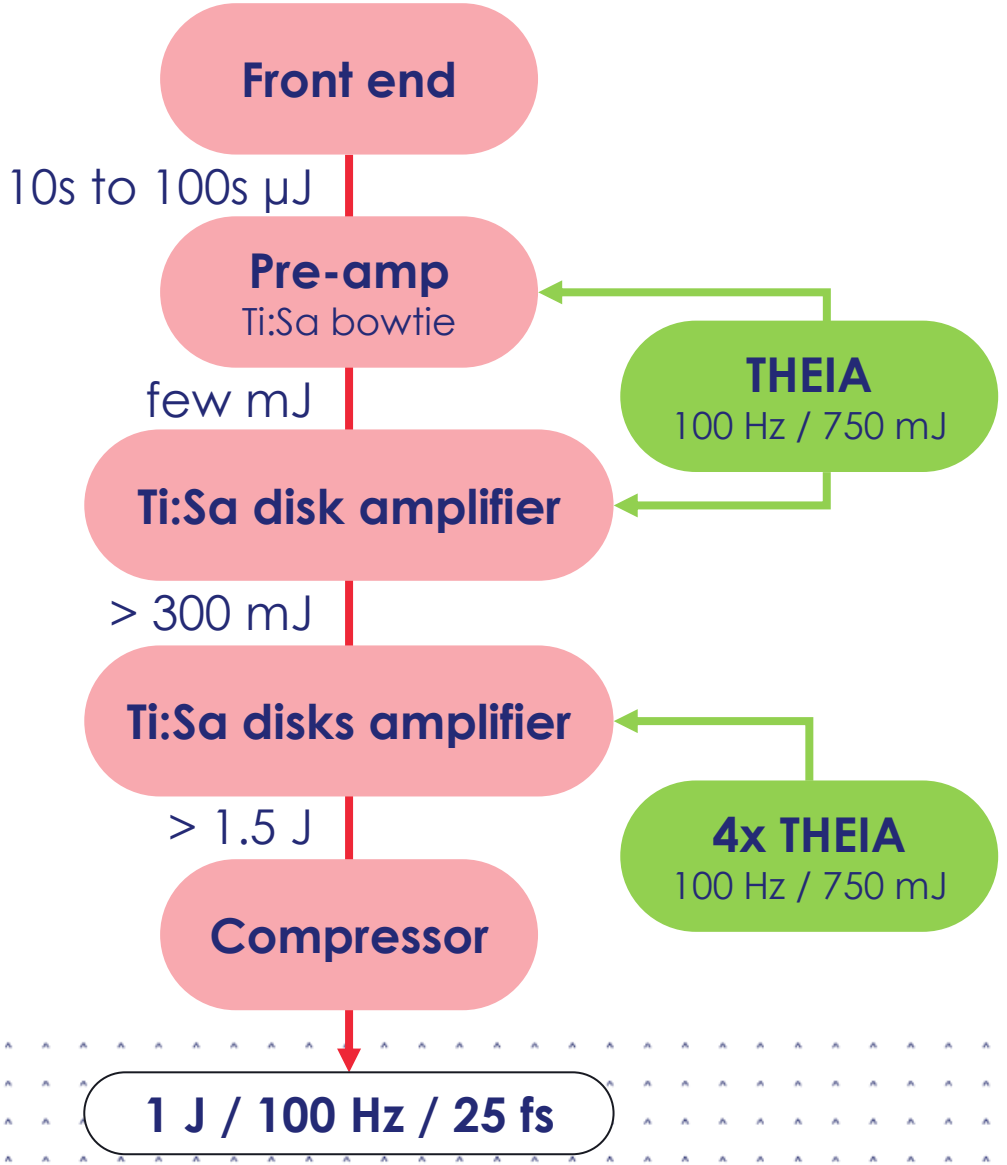
Upgrade to **1 J @ 100 Hz**

> Amplification with active mirrors

- > 850 mJ with 2 THEIAs on one crystal achieved (R&D)
- Thermal lens characterized
- ➔ Solution validated for integration

> Compression

- Simulation of grating heating and deformation to design cooling solution
- First tests on mirror substrate to validate solution



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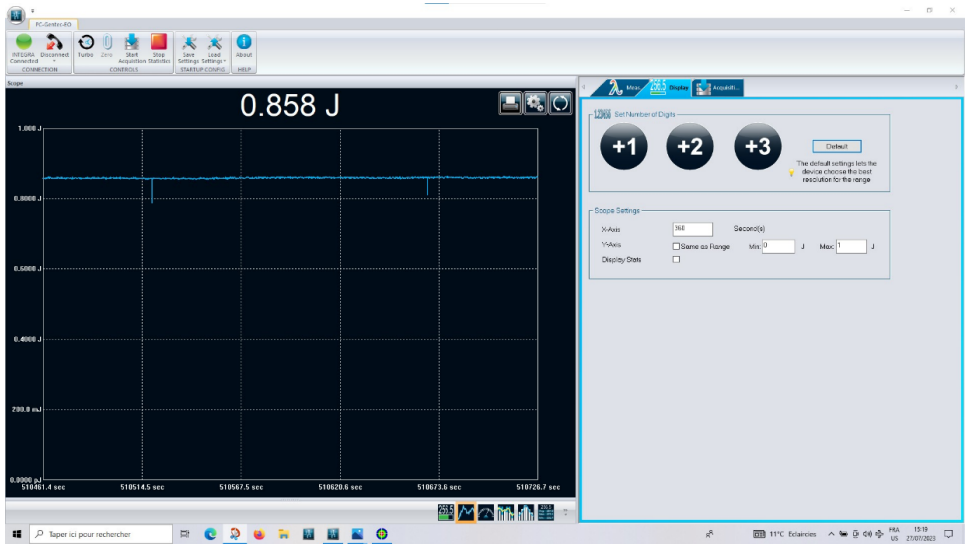
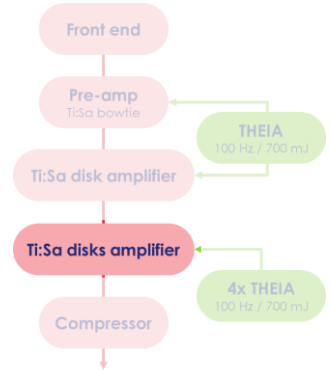
Upgrade to 1 J: Amplification

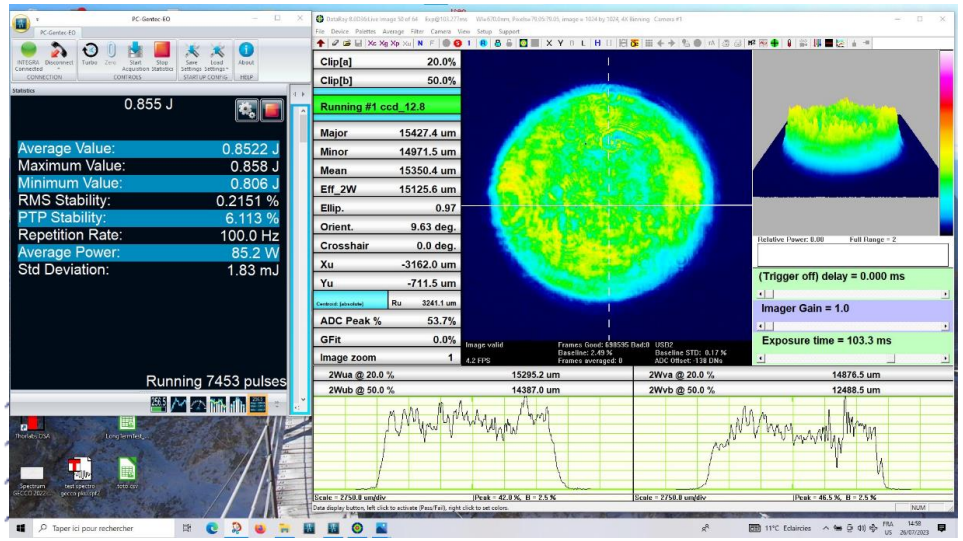
> R&D validation: ½ Joule amplifier

- Seeding with ~ 250 mJ
- Pumped by 2 THEIAs (1.5 J)
- 40 % extraction ➔ **> 850 mJ @ 100 Hz**, short-term stability < 0.3 % rms
- No ASE or transverse lasing
- 20°C water cooling, crystal temperature similar to 300 mJ amplifier
- Resulting total **thermal lensing > 20 m**

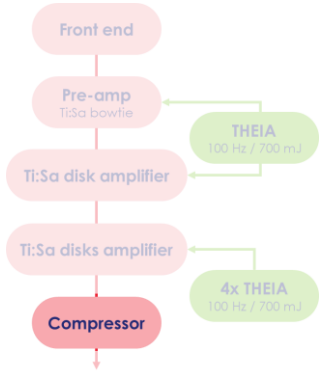




> 1.5 J amplifier ➔ 2 amplification stages



Upgrade to 1 J: Compression

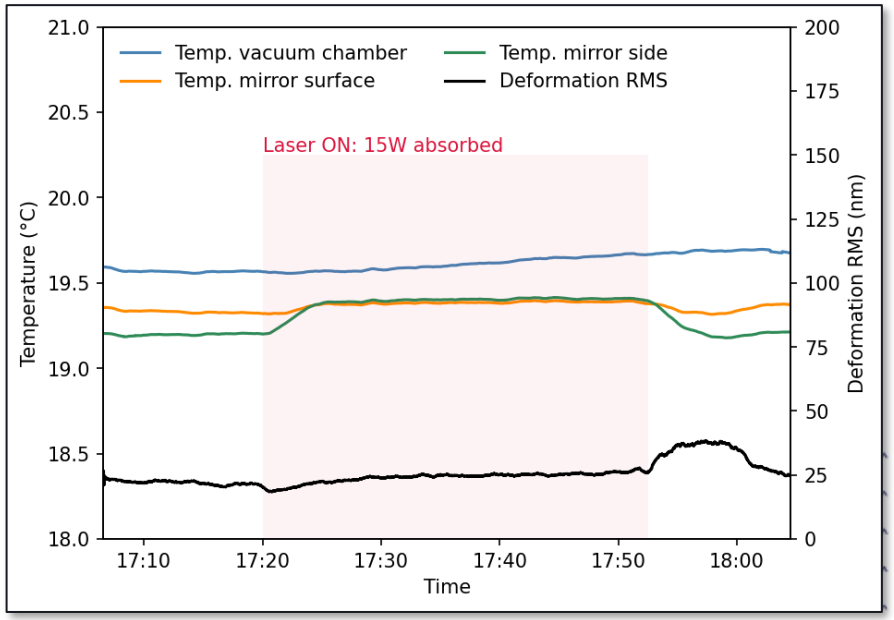


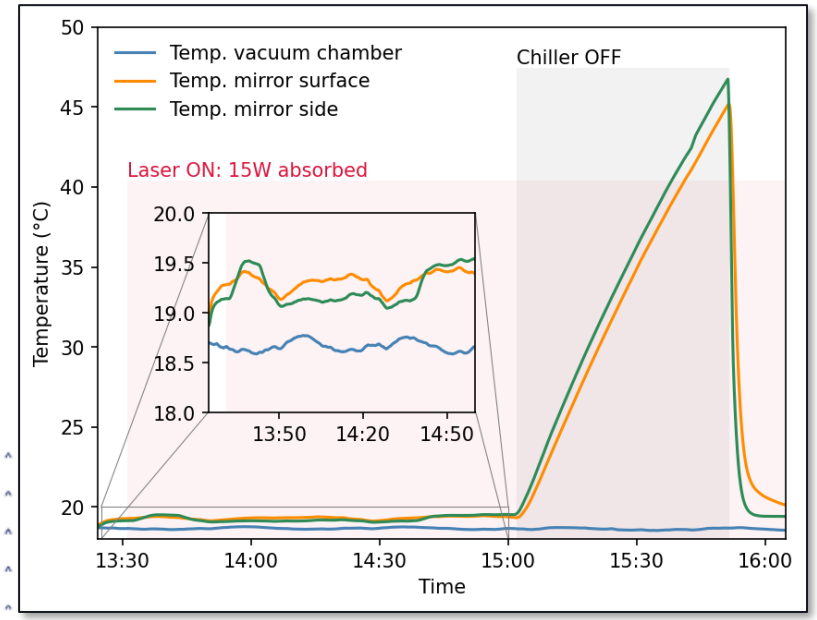
> Gold gratings for < 25 fs, ~ 12 W absorbed heat ➔ cooling required!

- Experiment on gold coated mirror, using THEIA as heating laser at LOA
- Monitoring of temperature and deformation

> 15 W absorbed ➔ ΔT < 1°C, RWFE < λ/30 rms

- Efficient and fast cooling





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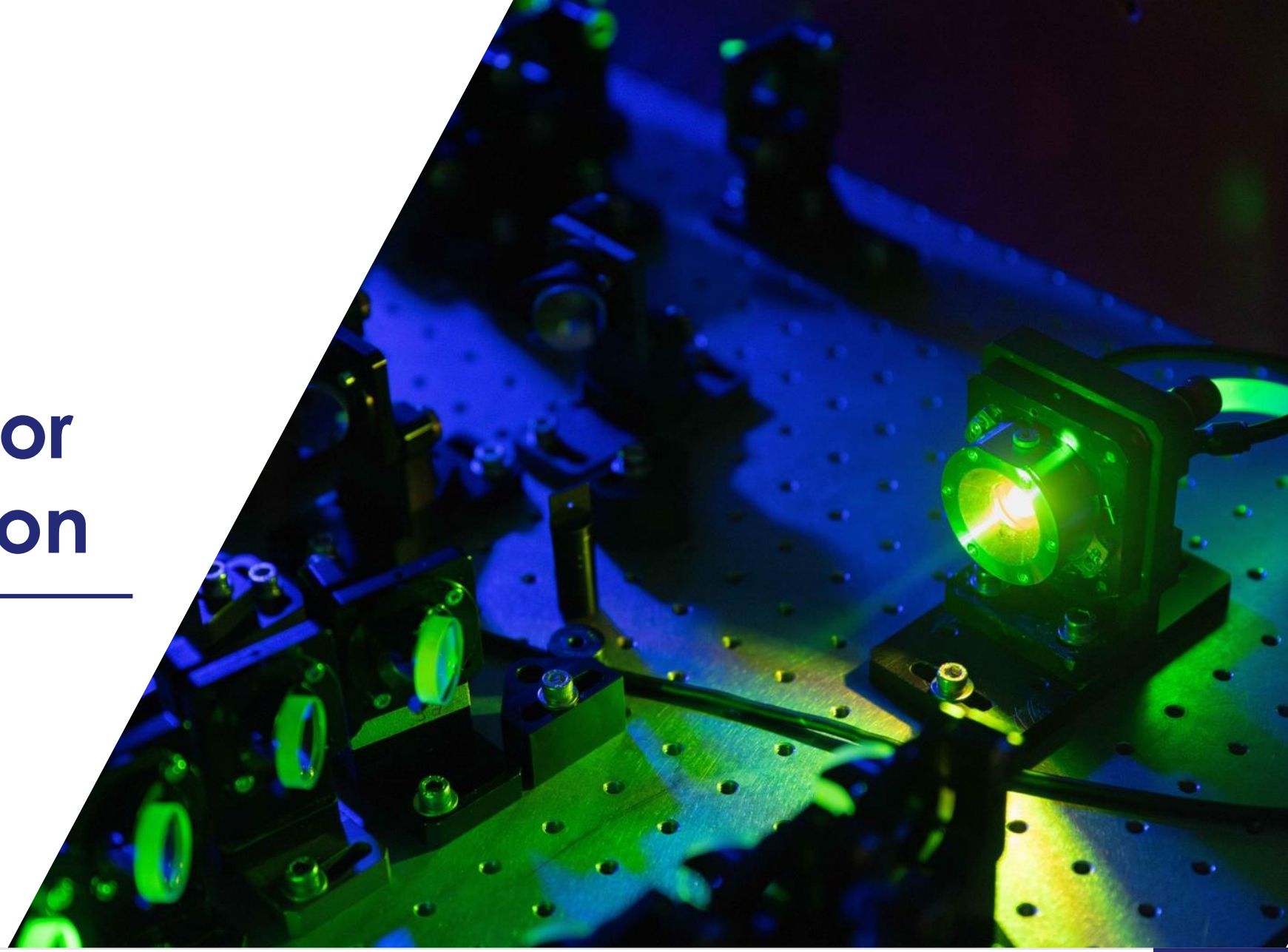
Thank you for your attention



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