THALES

PRESENTATION

2nd International Workshop on Proton-Boron Fusion

L. LAVENU

THALES GROUP

LAS

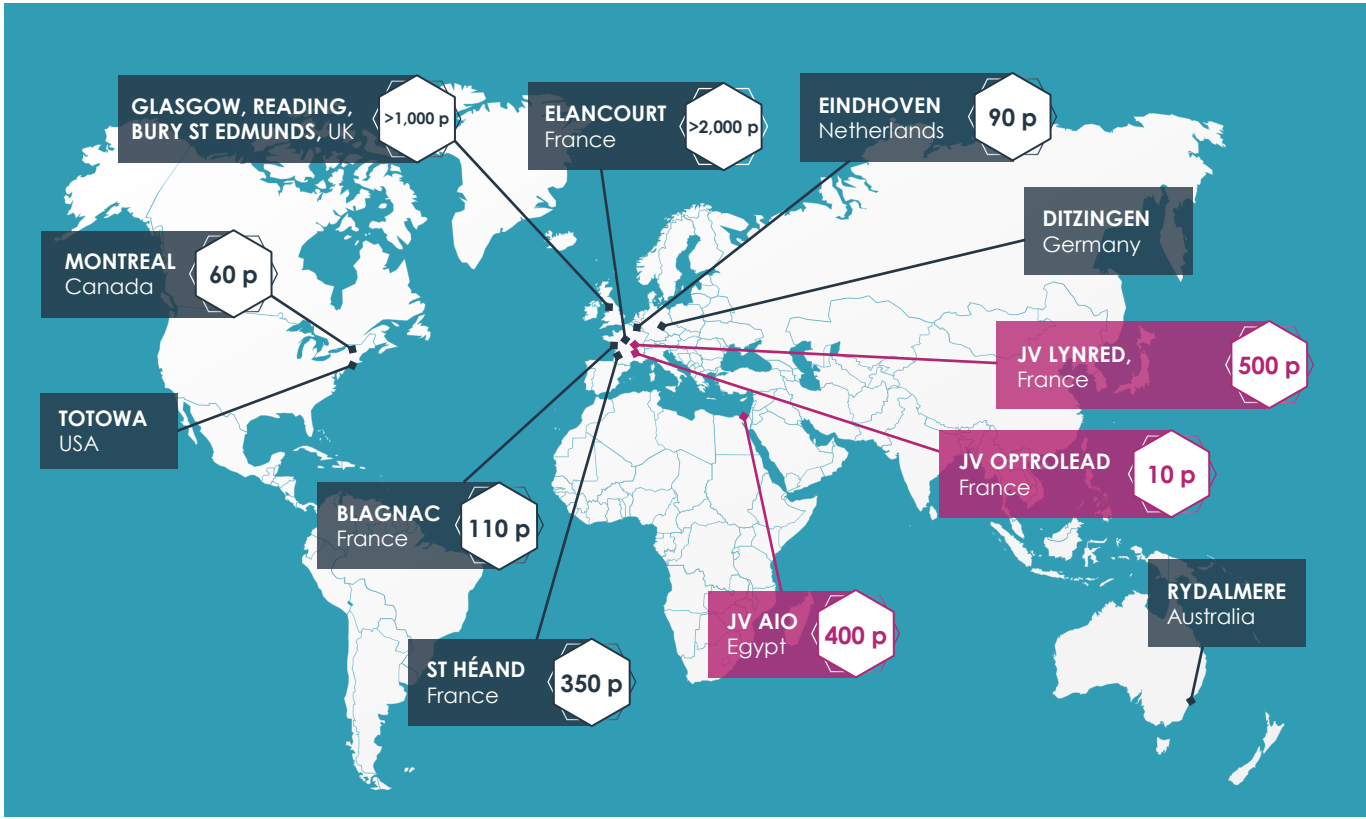
OME

OPTRONICS & MISSILE ELECTRONICS: INTERNATIONAL FOOTPRINT

11
Thales sites
+ 3 joint ventures

7
countries

> 4,500
employees



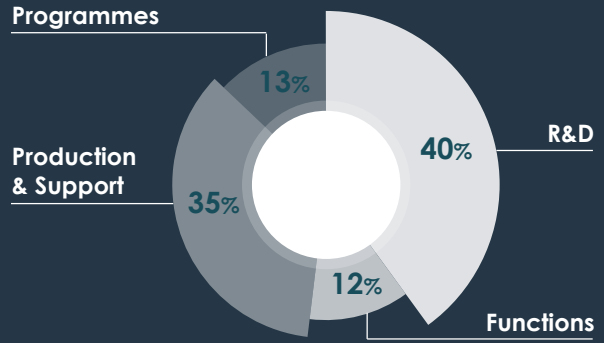
ACTIVITIES

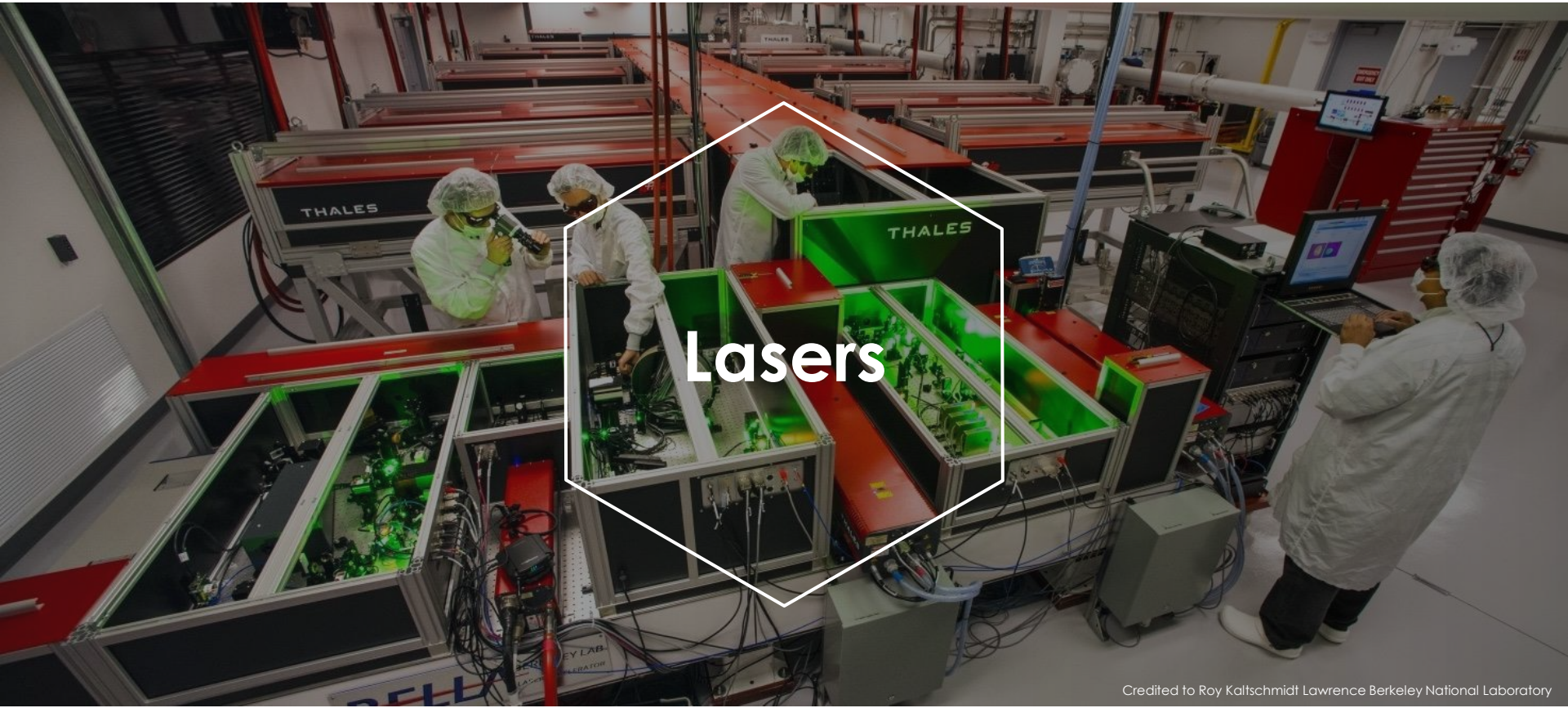
Elancourt
France

52,000 m²
floorspace
including 4,000 m² of clean rooms
Sight testing tower
Laser laboratories

2,000
employees

- **One site** developing, integrating and testing Thales optronics and missile electronics solutions in France
- **Image'Inn** technical and operational innovation laboratory for co-design by users
- **Europe's largest facility** of its kind

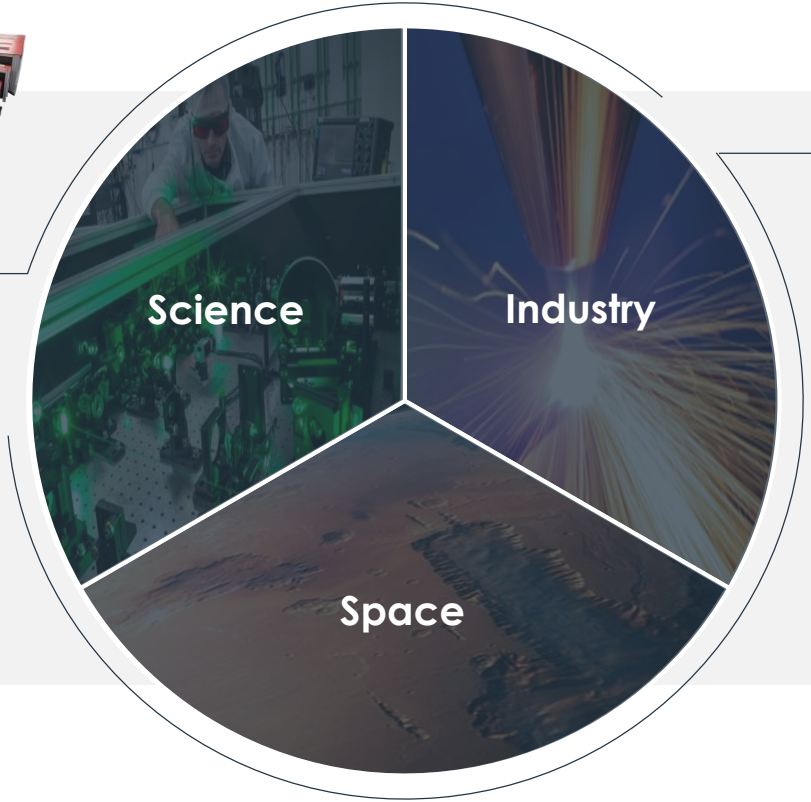




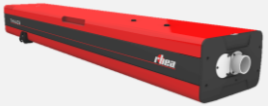
Credited to Roy Kaltschmidt Lawrence Berkeley National Laboratory

LASER ACTIVITY

Femtosecond

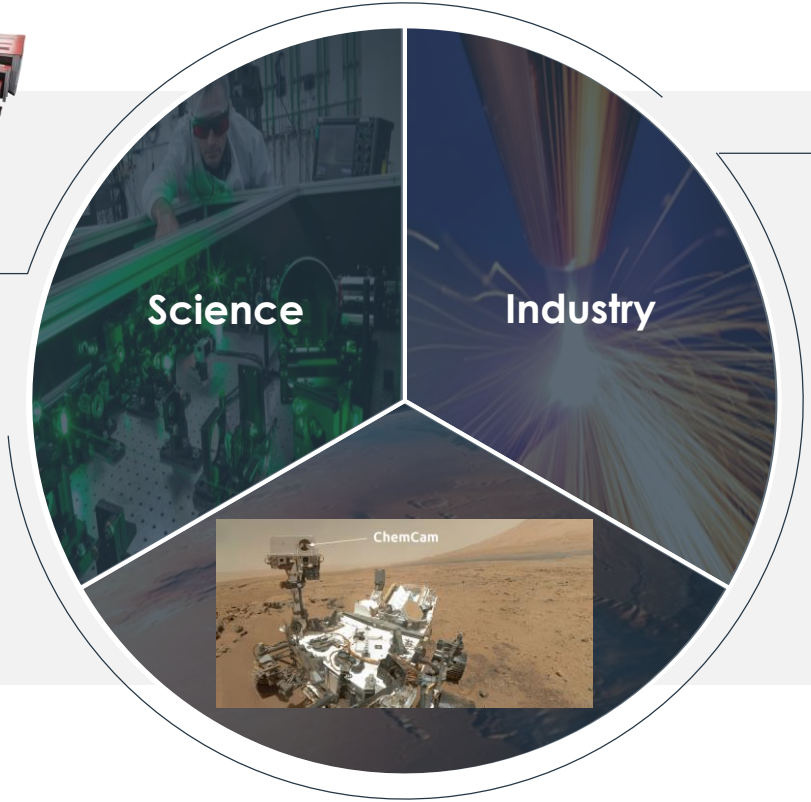


Nanosecond

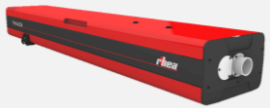


LASER ACTIVITY

Femtosecond

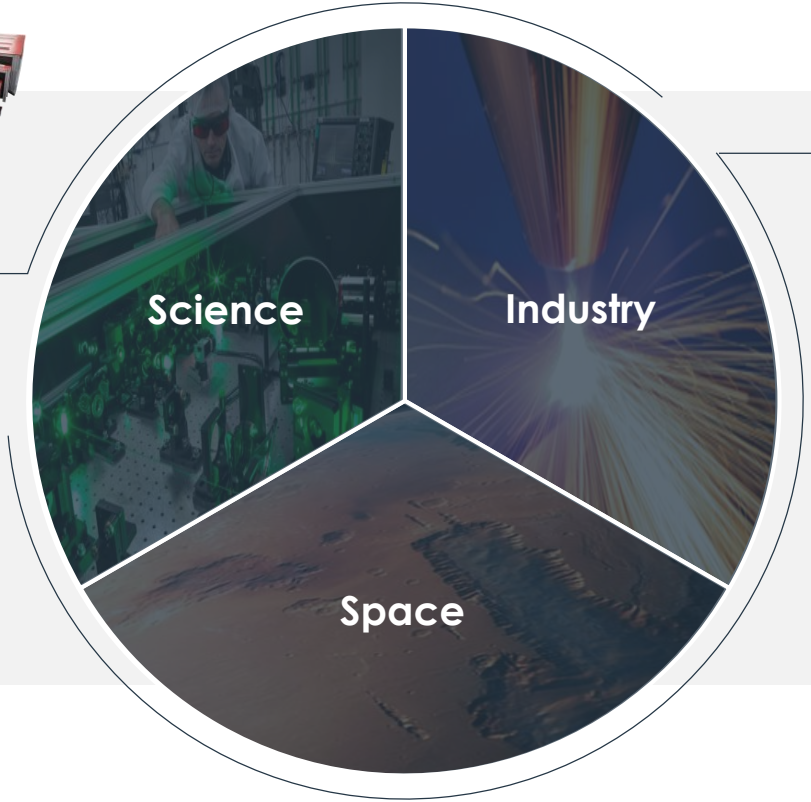


Nanosecond

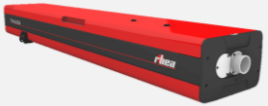


LASER ACTIVITY

Femtosecond



Nanosecond



MARKETS AND APPLICATIONS

SCIENCE

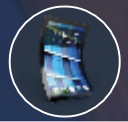
Pumping Laser Ti:Sa

Electrons & ions acceleration

Plasma Physics

X Ray generation

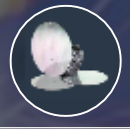
INDUSTRY



OLED Lift Off

Laser Shock Peening

Non Destructive Testing



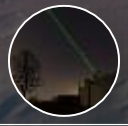
Silicon Annealing

Isotope production

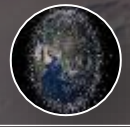
Particle therapy

SPACE/DEFENSE

LIBS Curiosity rover



Moon ranging



Space debris removal

Defense

Nanosecond products

THALES

NANOSECOND PRODUCTS

Diode pumped

THEIA
700mJ @200Hz

ETNA HP
170W @10kHz

Flashlamp pumped

SAGA HP
1,8J @5-10Hz

RHEA
5,5J @10Hz

GAIA HP
16J @1-5Hz

ATLAS
30J @0,1Hz
100J @0,017Hz

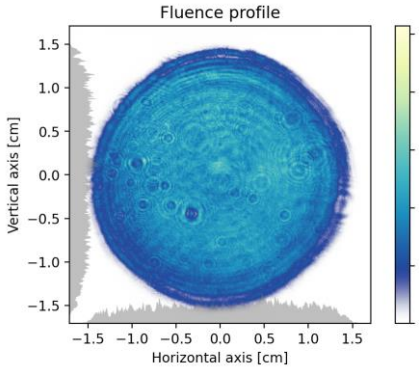
FOCUS ON RHEA

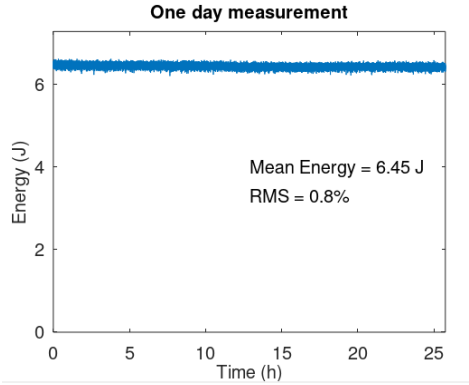
Pumping Laser
Ti:Sa

Laser Shock
Peening

Compactness
Robustness
Reliability

MODEL	RHEA
Repetition Rate (Hz)	5
Energy per pulse (J)	
-> At 1064 nm	≥ 8
-> At 532 nm	≥ 5
Pulse to pulse energy stability (% rms)	< 1.5
Pulse duration (ns)	5 to10

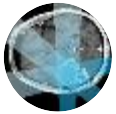




FOCUS ON RHEA

Non Destructive Testing

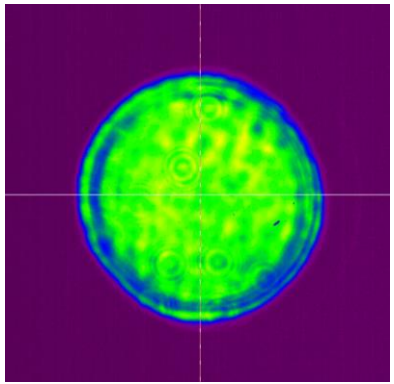
Pumping Laser Ti:Sa

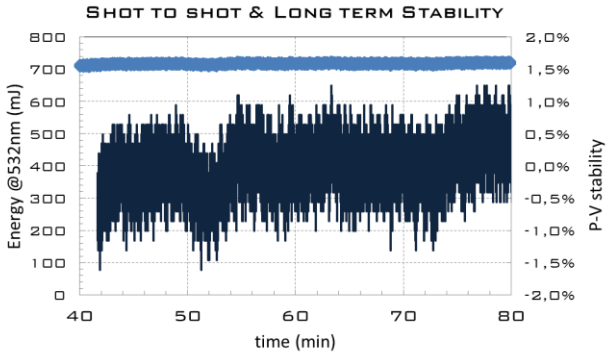


Particle therapy

Industry
Efficiency
Compactness

MODEL	THEIA
Repetition Rate (Hz)	Up to 200
Energy per pulse (mJ)	
-> At 1064 nm	≥ 1000
-> At 532 nm	≥ 700
-> At 355 nm	≥ 500
Pulse to pulse energy stability (% rms)	< 1
Typical pulse duration (ns)	10





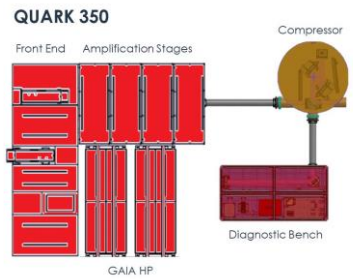
Femtosecond systems

THALES

QUARK FAMILY

Building Blocks

Custom system using our proven building blocks



Easy to use

User interface based on TANGO Software

Services

Range of customized services : Global service contract, Data monitoring, Hands on training, Qualification of critical components, Daily reliability

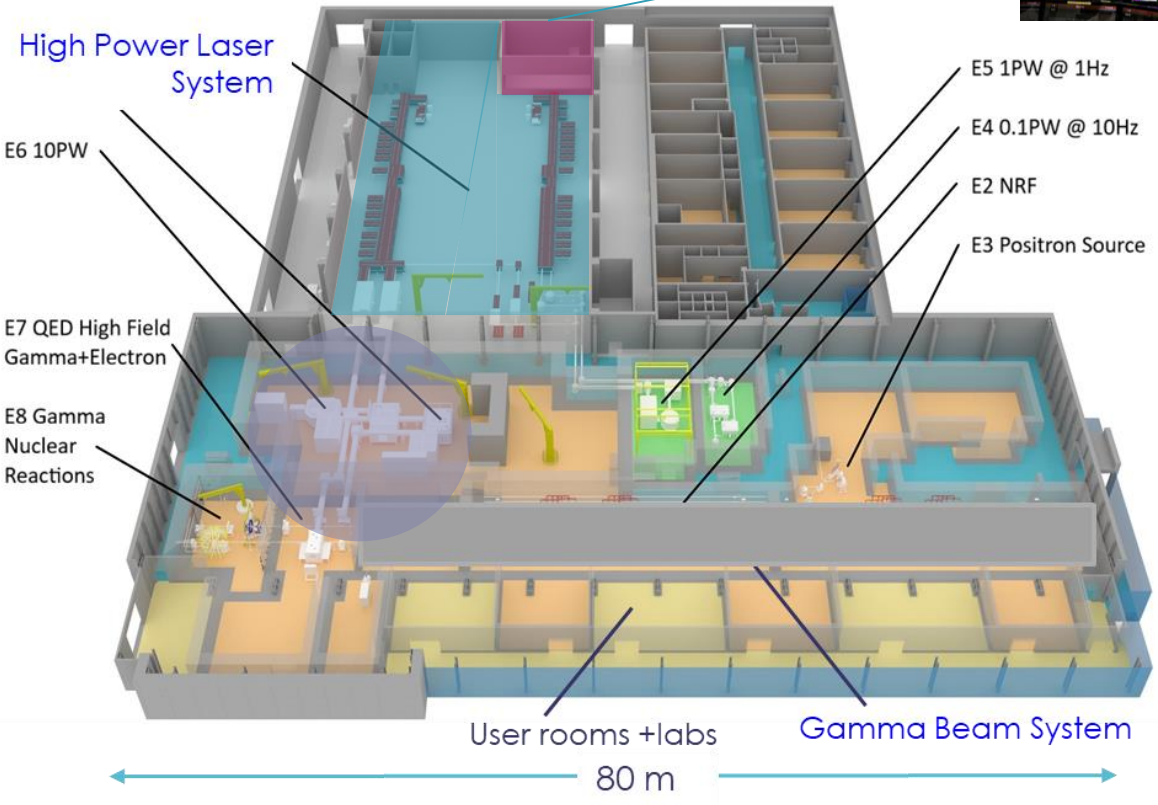
Advantages

- **Very high contrast** thanks to XPW filter
- **Patented solutions** to optimize laser performances
- **Room temperature cooling** system for highest reliability
- Optimized **embedded diagnostics** for easy operation
- **Versatile** and **evolutive software** architecture
- **Dedicated options** for experience optimization
- Be part of User **Community**
- **High level customer service** for training, maintenance and support for experimental campaign

ELI NP - INFRASTRUCTURE

Control
Diagnostics
Automatic start procedure

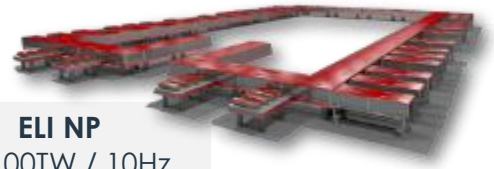
Beam Transport
Focusing



QUARK COMMUNITY

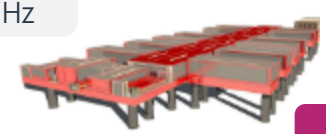
IPMA International Project Excellence Award GOLD WINNER 2013

CALA (3PW)
90J / 1Hz

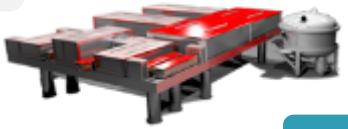


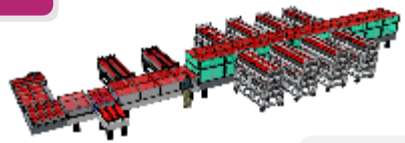
ELI NP
2x 100TW / 10Hz
2x 1PW / 1Hz
2x 10PW / 1sh/min

LBNL BELLA
1,3PW / 1Hz



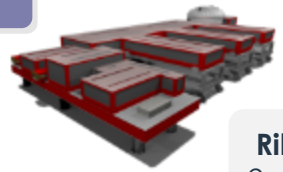
SCAPA
350TW / 5Hz



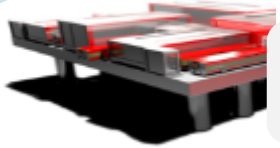


Peking Univ
2PW / 1Hz

USC
45TW / 10Hz



Riken Harima
2x 500TW / 1Hz



DESY 200TW/5Hz
Peking Univ 200TW/5Hz
Weizmann 2x100TW/1Hz

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

THALES

QUARK COMMUNITY

In operation


200 TW 5 Hz (DESY 2013)


1 PW 1 Hz (BELLA 2012)


90J 1 Hz (CALA 2018)


1 PW 0.1 Hz (CETAL 2013)


2x500 TW 1 Hz (Riken 2015)


45 TW 10 Hz (USC 2016)


350 TW 5 Hz (STRATHCLYDE 2017)

200 TW 5 Hz (Peking University 2016)

2X100TW 1Hz (WIS)

Recently commissioned

- 2x10PW 1 shot/min (ELI NP, Romania 2019)
- 200TW 1Hz (SW Jiao Tong University, China 2019)
- 1PW 0,1Hz (RRCAT India 2020)

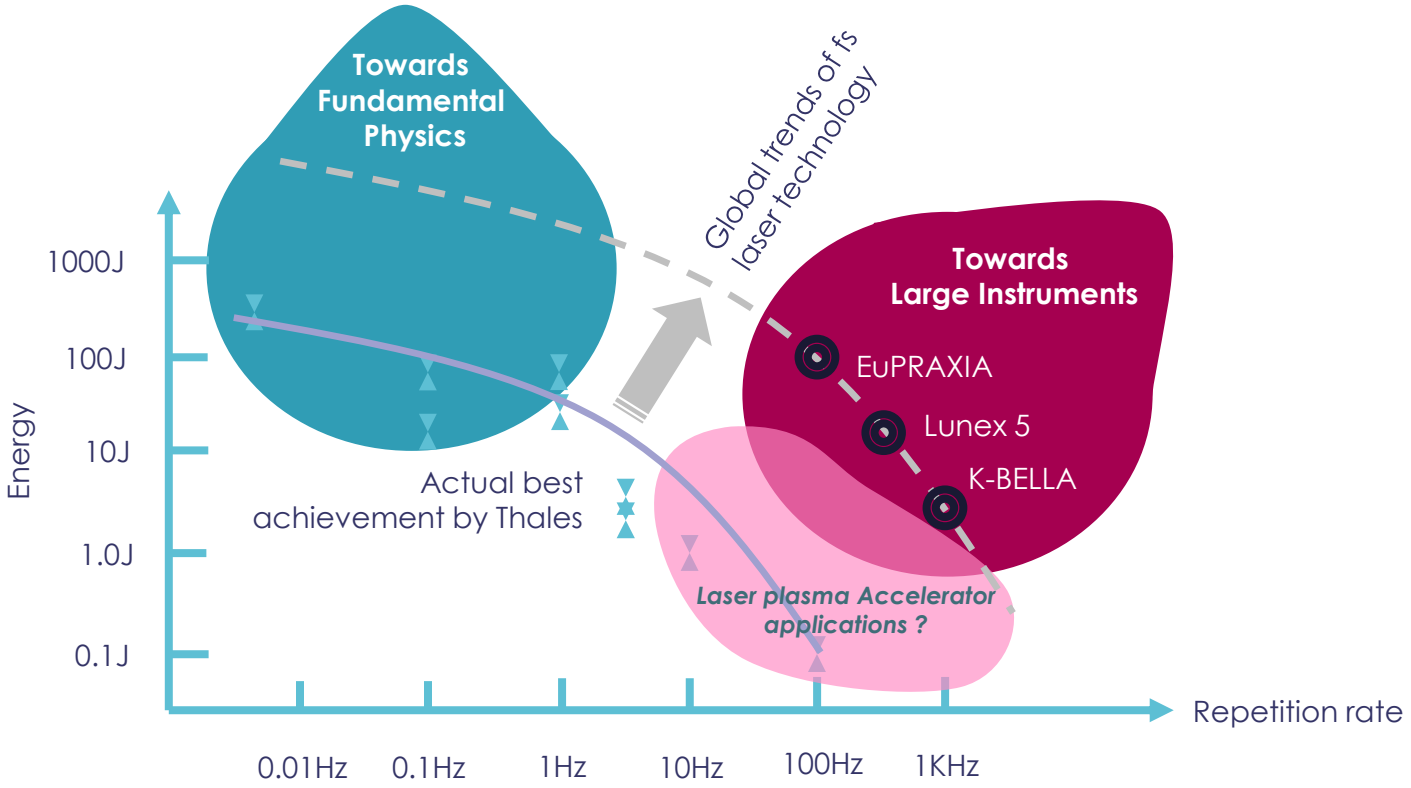
Under installation

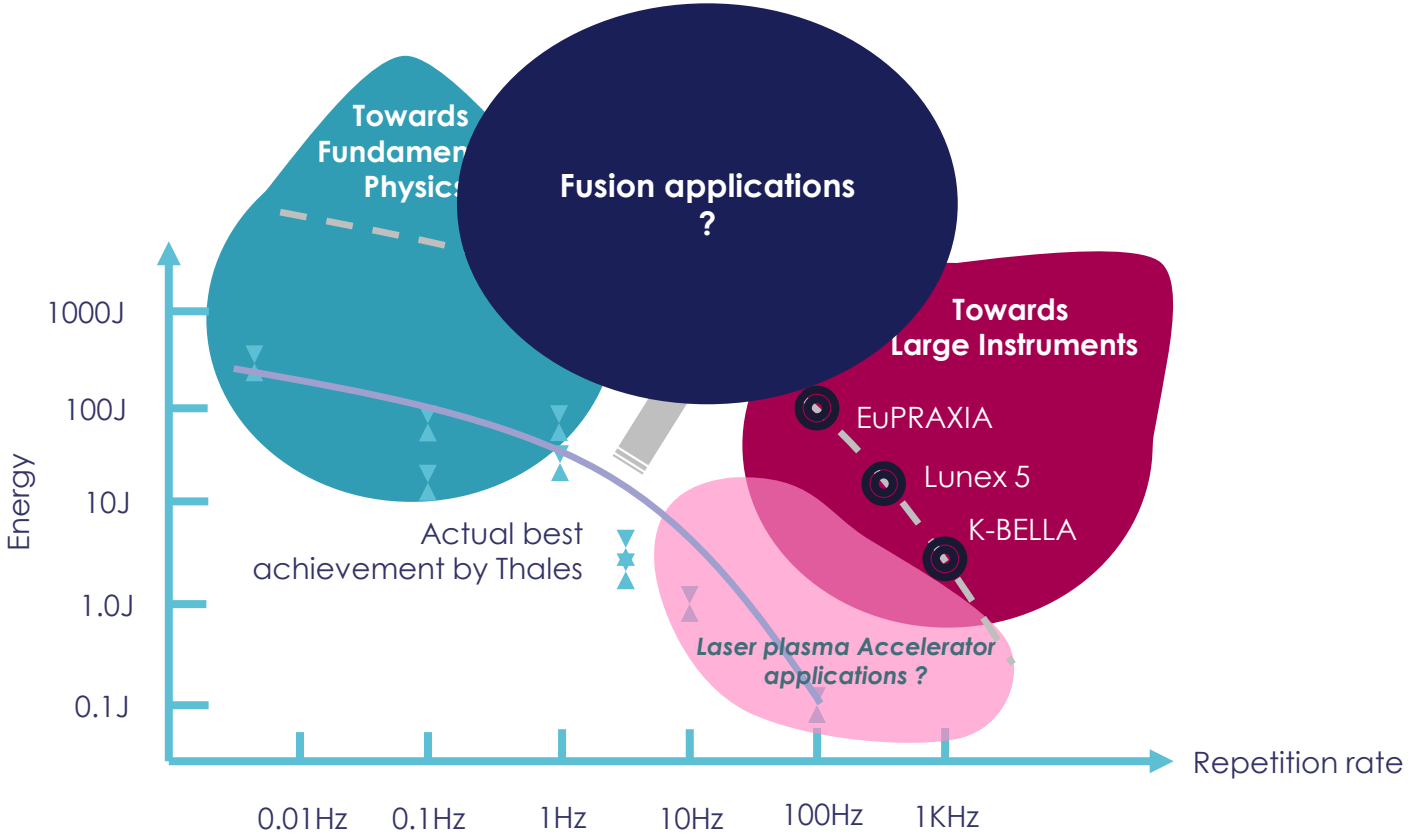
- 200TW 5Hz (Shenzhen University, China 2020)

Under integration

- 2PW 1Hz (Peking University, China 2020)
- 200TW 5Hz (Tsinghua University, China 2021)

THALES


Towards
Fundamental
Physics
Global trends of fs
laser technology
Towards
Large Instruments
EuPRAXIA
Lunex 5
K-BELLA
Actual best
achievement by Thales
Laser plasma Accelerator
applications ?
Energy
1000J
100J
10J
1.0J
0.1J
Repetition rate
0.01Hz
0.1Hz
1Hz
10Hz
100Hz
1KHz


Towards
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Actual best
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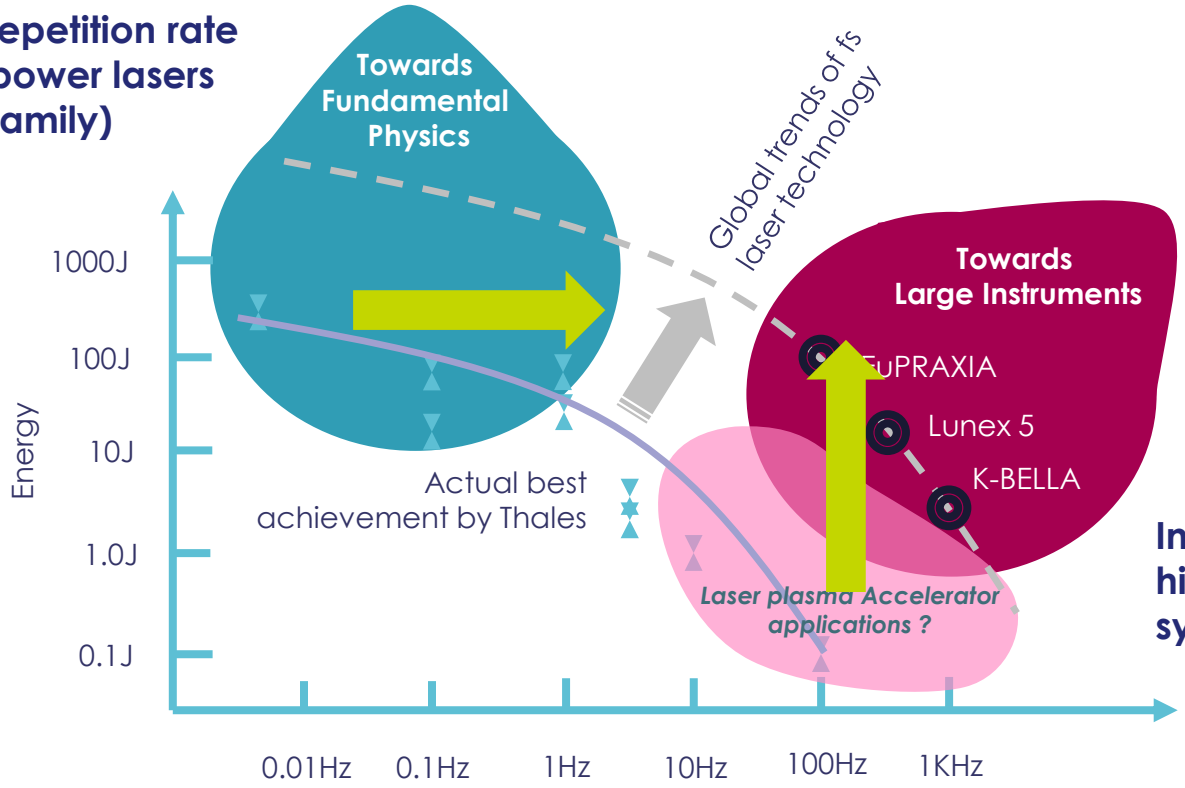
applications ?
Energy
1000J
100J
10J
1.0J
0.1J
0.01Hz
0.1Hz
1Hz
10Hz
100Hz
1KHz
Repetition rate

Increase the repetition rate of high peak power lasers (e.g. QUARK Family)



Increase the energy of high repetition rate systems

HERACLES 3

THALES

HERACLES3 JOINT LAB

THALES

- LAND & AIR SYSTEMS
- RESEARCH & TECHNOLOGY
- Avionics
- OPTRONICS & MISSILE ELECTRONICS
- MICROWAVE & IMAGING
- Laser activity
- Science activity

High energy lasers | Fiber lasers | Electron tubes and RF amplfiers

ACADEMIC PARTNERS

- **Institution**

INSTITUT POLYTECHNIQUE DE PARIS

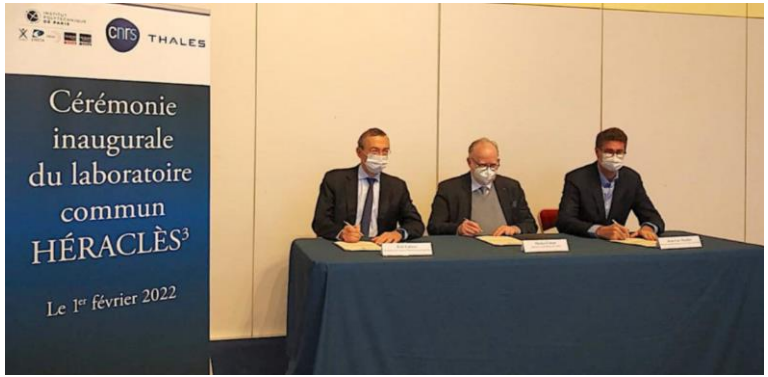
cnrs | École Polytechnique | ENSTA

- **Laboratories**

Cilex Apollon

loa

Xcan



OPTRONICS &
MISSILE ELECTRONICS

MICROWAVE
& IMAGING

RESEARCH &
TECHNOLOGY

loa

CilexApollon

THALES

Xcan

RESEARCH ACTIVITIES

Very high peak power > 1PW with Cilex Apollon

- Improvement of ps contrast
- Intensity stabilization on target

100Hz laser-plasma accelerator with loa

- Development of 1J, 100Hz, 25fs TiSa laser
- Compton, X-rays

Very high average power system with Xcan

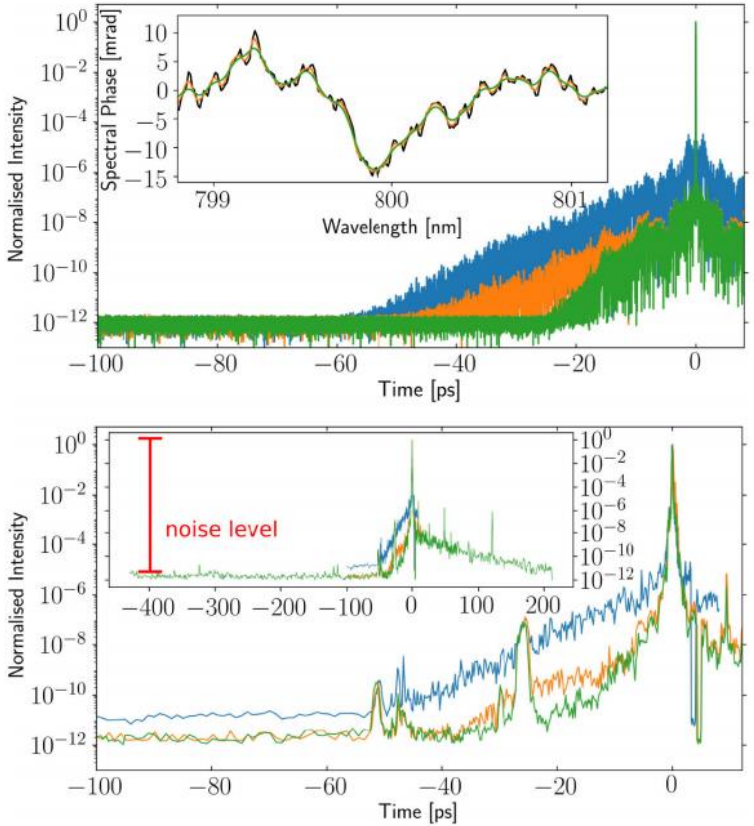
- >500W combined fiber laser @ MHz repetition rate
- Post compression of mJ class combined fiber laser down to < 40fs à 500kHz repetition rate

Increase laser pulse quality

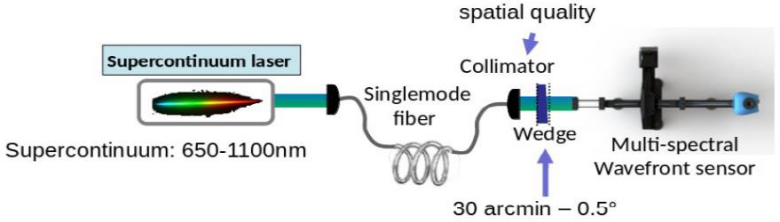
THALES

CONTRAST IMPROVEMENT

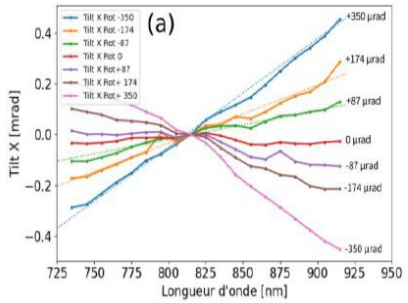
- L. Ranc PhD : Understand impact on temporal contrast ratio of optics roughness in Offner stretcher
- **Demonstration of improvement in the range of 10-100ps on Apollon facility**
- "Improvement in the temporal contrast in the tens of ps range of the multi-PW Apollon laser front-end", L. Ranc et al, Optics Letters, Vol 45, 16

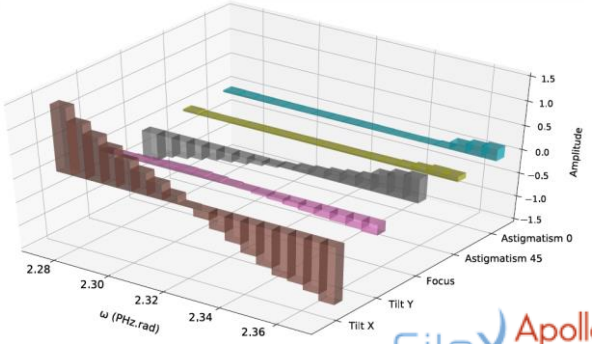


SPATIO-TEMPORAL DIAGNOSTICS



- **Measurement** of spatio-temporal couplings in ultra-intense laser chains, using calibrated state-of-the-art instruments.
- **Visualization & Interpretation** of laser pulses in 3D.
- **Compute & Understand** spatio-temporal effects on peak intensity at focus.



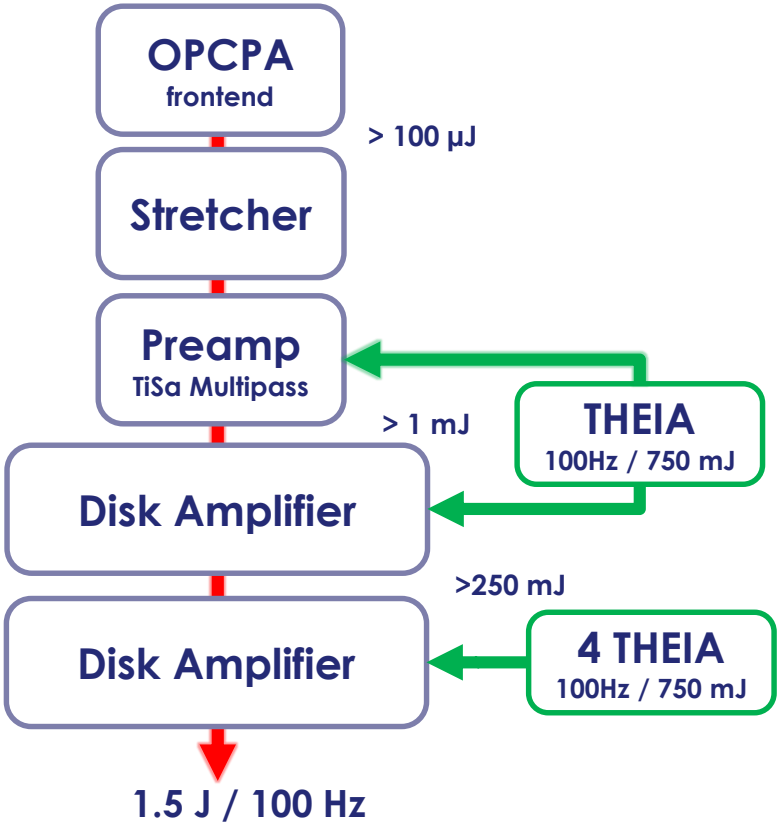


Increase repetition rate

FROM HIGH PEAK POWER TO HIGH REPETITION RATE

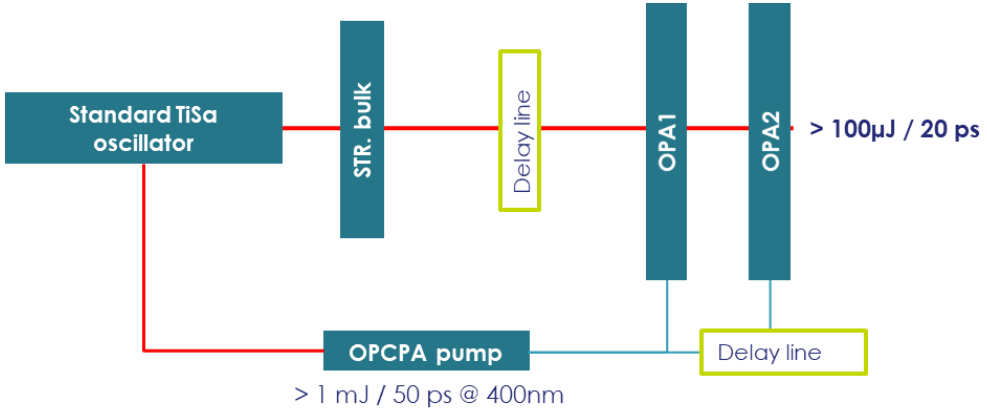
New TiSa laser architecture – In development

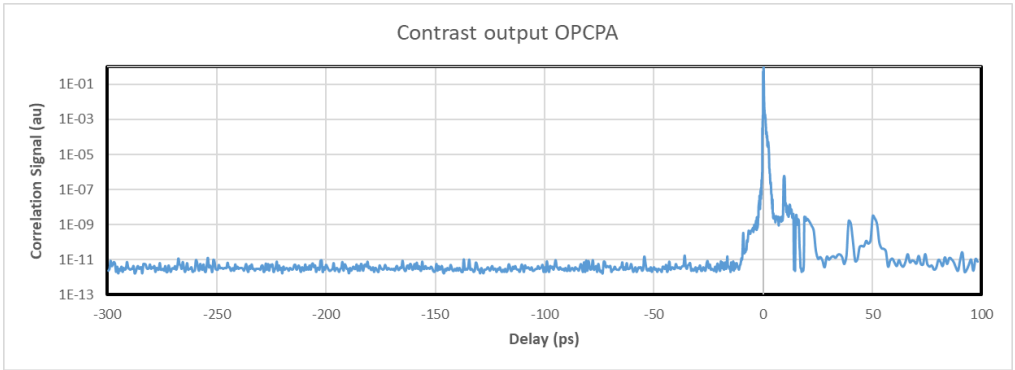
- **Robust OPCPA FE** : 100Hz / 300µJ demonstrated
- New ns diode-pumped laser : **THEIA family qualified**
- New TiSa amplifier architecture : **Qualification @ 300mJ 100Hz**

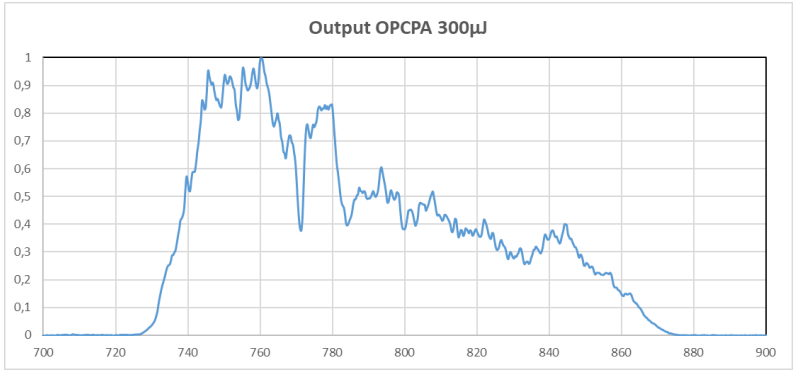


OPCPA FE

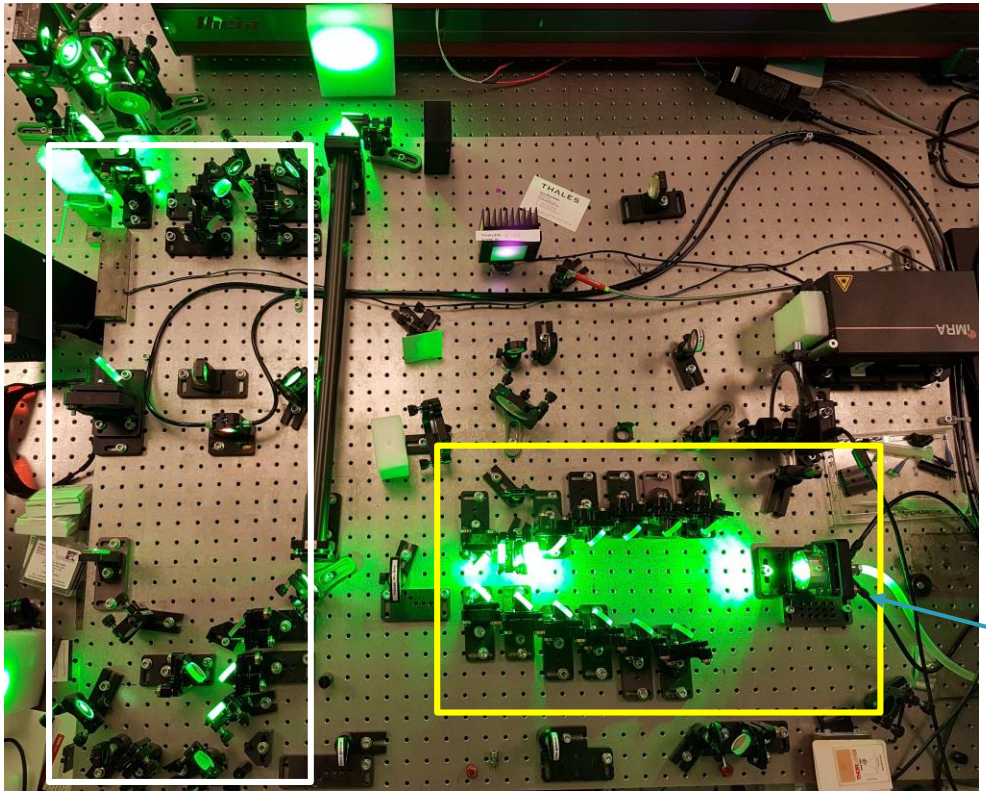
100Hz high contrast OPCPA
- **Energy > 100 µJ**
- **Pulse duration ~ 20 ps**
- **Bandwidth from 730 to 870 nm (FT ~ 20 fs)**
- **Short term stability < 1 % rms over 500 shots**





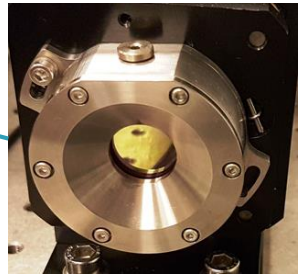


THICK DISK TISA PUMPED BY THEIA LASER



Multi-pass amplifier seed by XPW

- Seed 10µJ
- Standard 4 passes preamplifier : output energy 3mJ
- Thick-disk TiSa amplifier : output energy > 300mJ, stability < 0.5%rms for an hour



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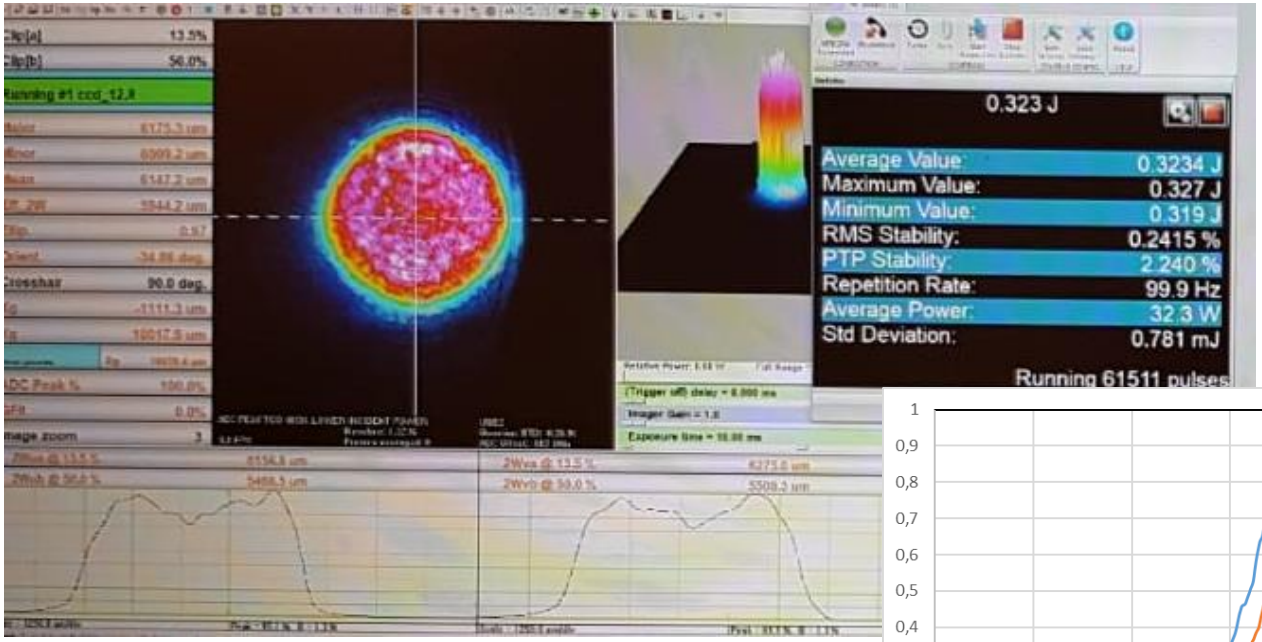
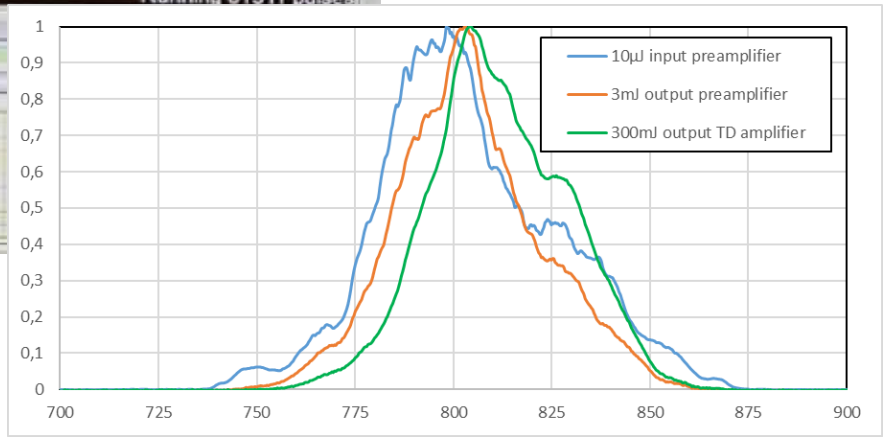
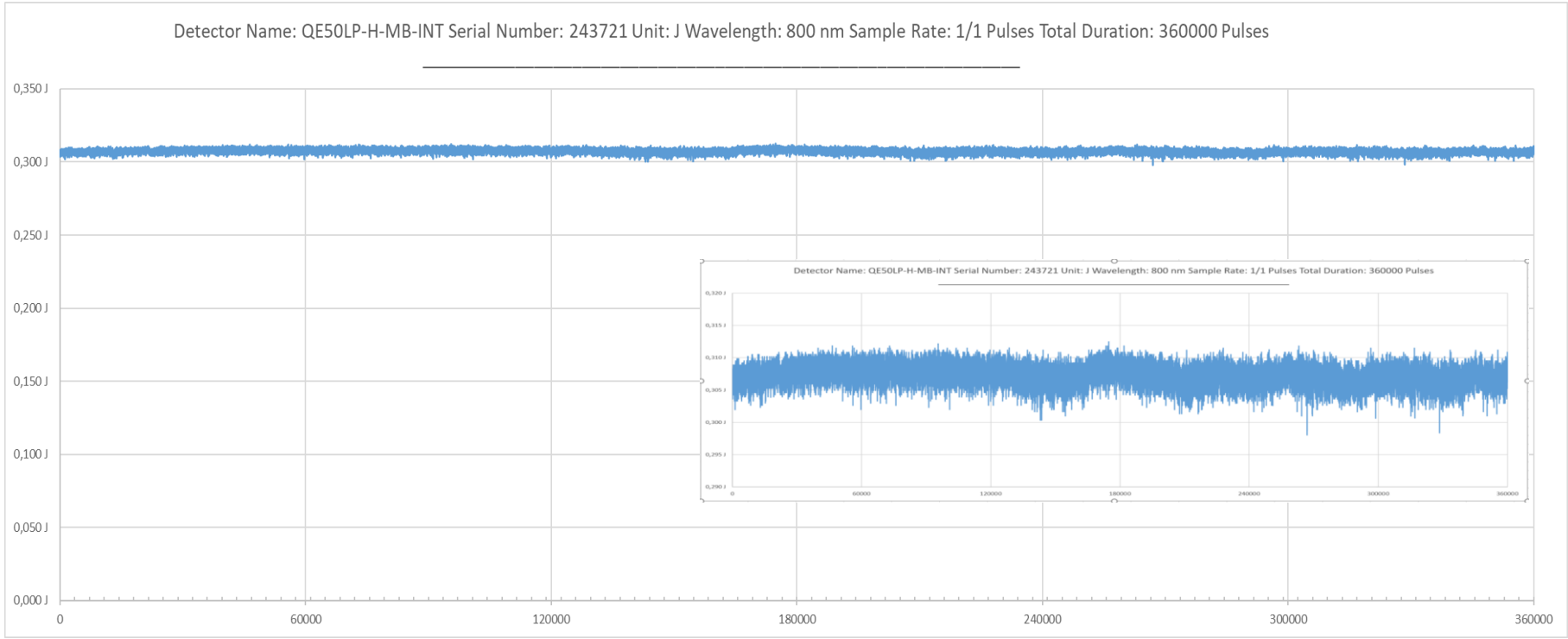
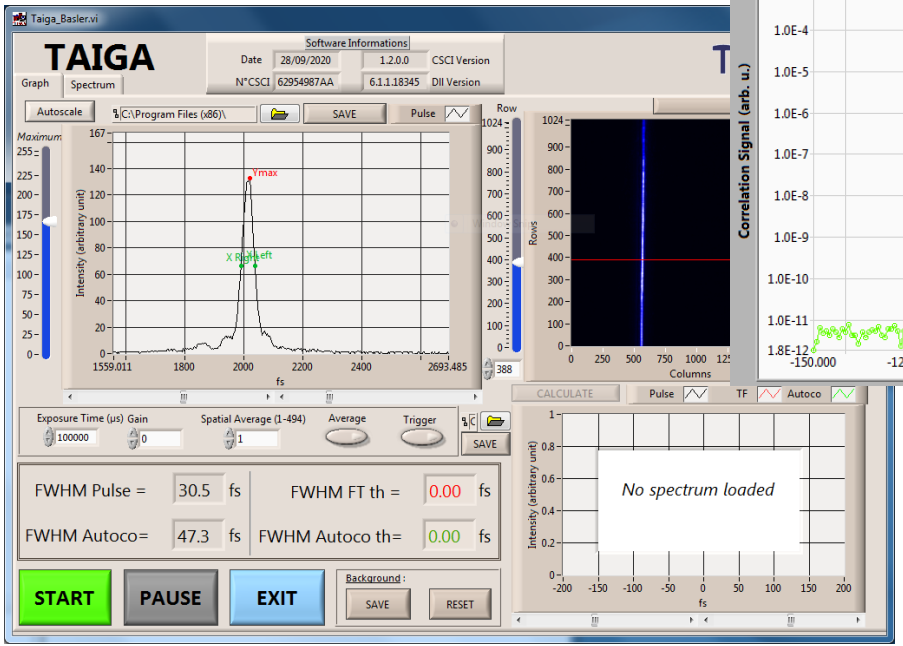


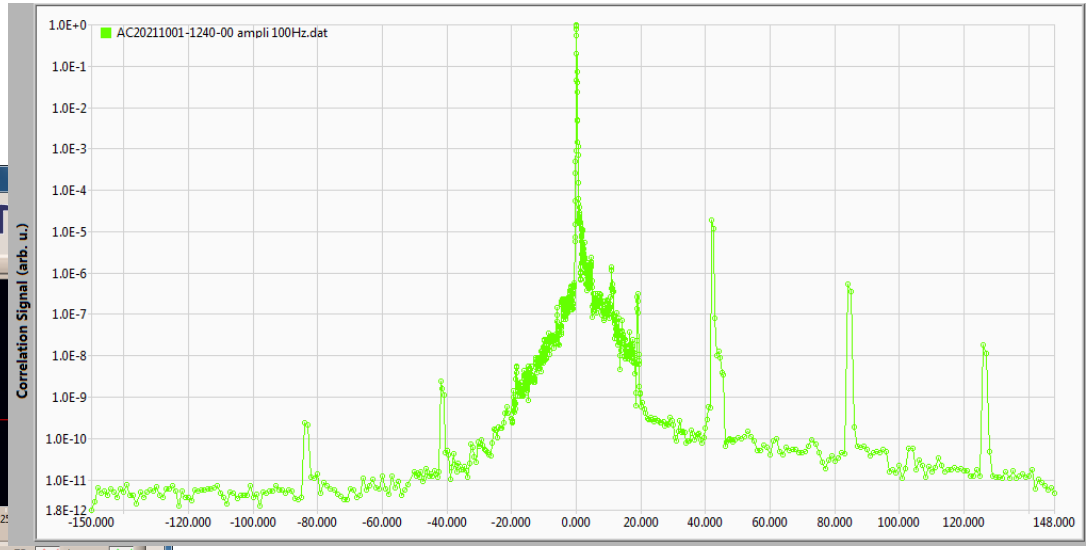


THICK DISK TISA PUMPED BY THEIA LASER : 1 HOUR OPERATION



THICK DISK TISA PUMPED BY THEIA LASER





- No dazzler in the laser

COMPRESSION

THALES

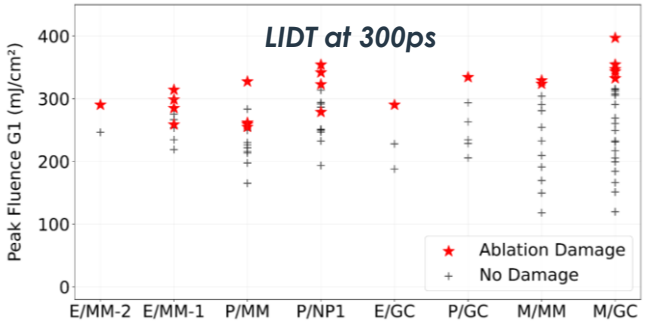
HORIBA FRANCE COLLABORATION

Work on ps and fs LIDT for gold gratings

- Different kind of samples

  - Tested samples are photoresist (P) or fused silica etched (E) gratings or mirrors (M). Evaporated coatings can be gold coating (GC), NP1 coatings, or mixture of metal coating (MM, different samples 1 or 2)

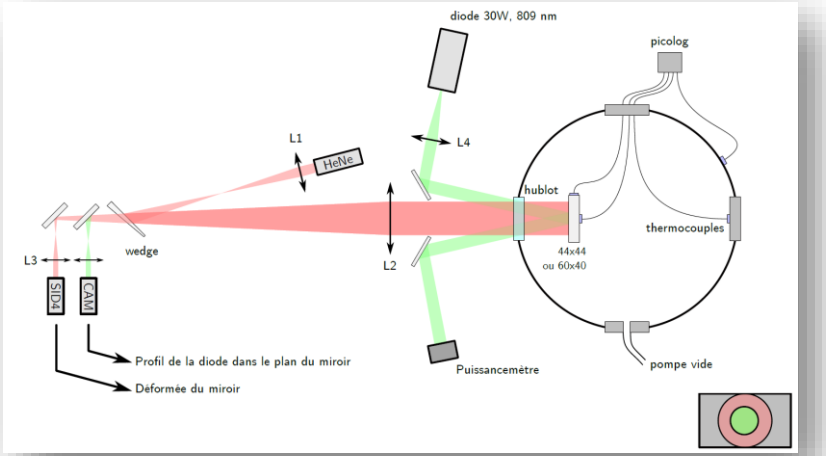
- LIDT tests at THALES under air :
  - 10 Hz Ti:Sapphire laser with a 800 nm central wavelength and 300 ps pulse duration and a 52° incidence angle
  - The beam surface is as large as 1.3cm².
  - Maximum fluence has been characterized at the test sample level.
  - N on 1 test with N=6000 has been selected to increase repeatability of the tests
- Fine characterization of damage at TRT and Horiba
- New design based on optimized gold coatings on photoresist grating proved to withstand up to 130 mJ/cm² average fluence for hundreds of kshots (Horiba France NP1 gratings) at 30fs
- LIDT characterization in picosecond regime :

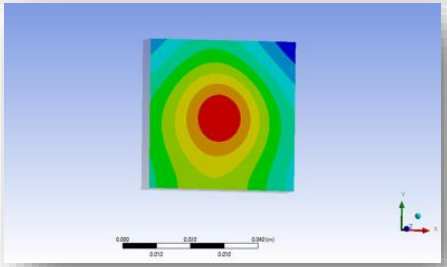


THERMAL MANAGEMENT IN HIGH-REPETITION SYSTEMS

Joule-class laser compression @100Hz is a challenge:

- **Experimental characterization** under progress in Thales laboratories.
  - Measure thermal deformations in experimental conditions using a test-bench under vacuum.
  - Understand the impact on wavefront, and criticity for end-user applications.
  - Develop thermal management systems for high repetition rate lasers.





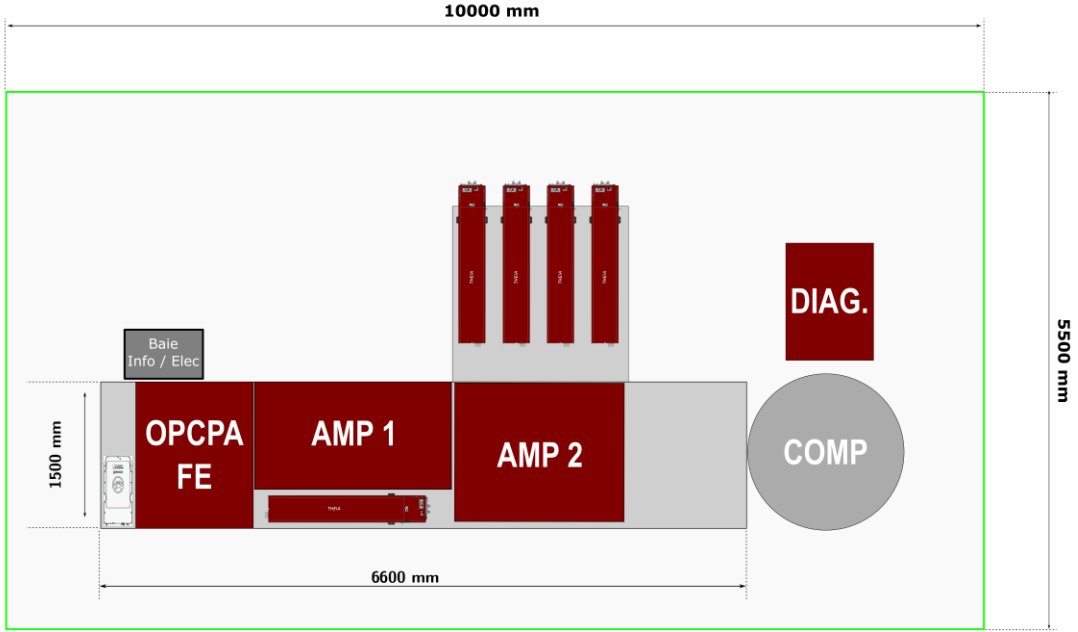
- Extrapolate our observations using **thermal system engineering and finite-elements simulations**

WHAT'S NEXT ?

THALES

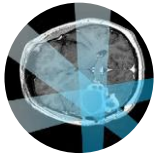
NEW LASER SYSTEMS : 1 J – 100 HZ

Laser to be installed in LOA



Parameters	Value
Repetition rate	100 Hz
Energy	> 1 J
Pulse duration	< 25 fs
Peak power	40 TW
Beam size	40 mm

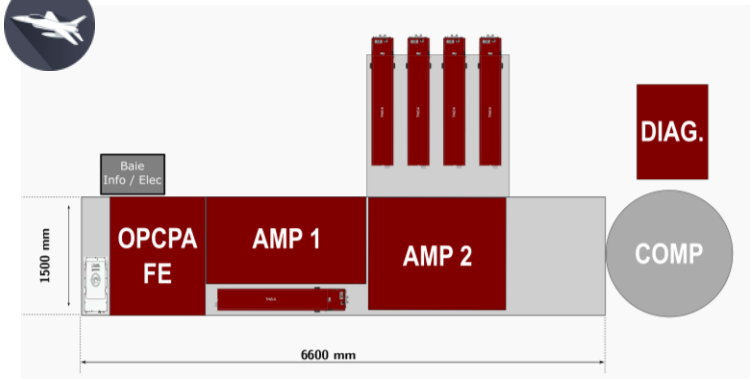
NEXT STEP : SOURCES FOR LASER PLASMA APPLICATIONS



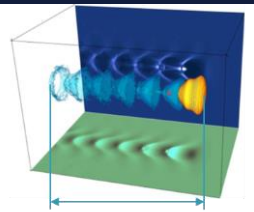
Particle therapy

Non Destructive Testing

Collaboration between THALES OME and THALES MIS

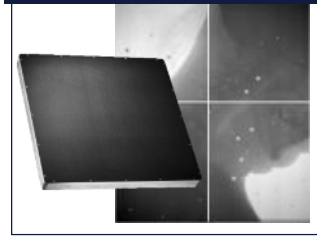


Laser plasma interaction

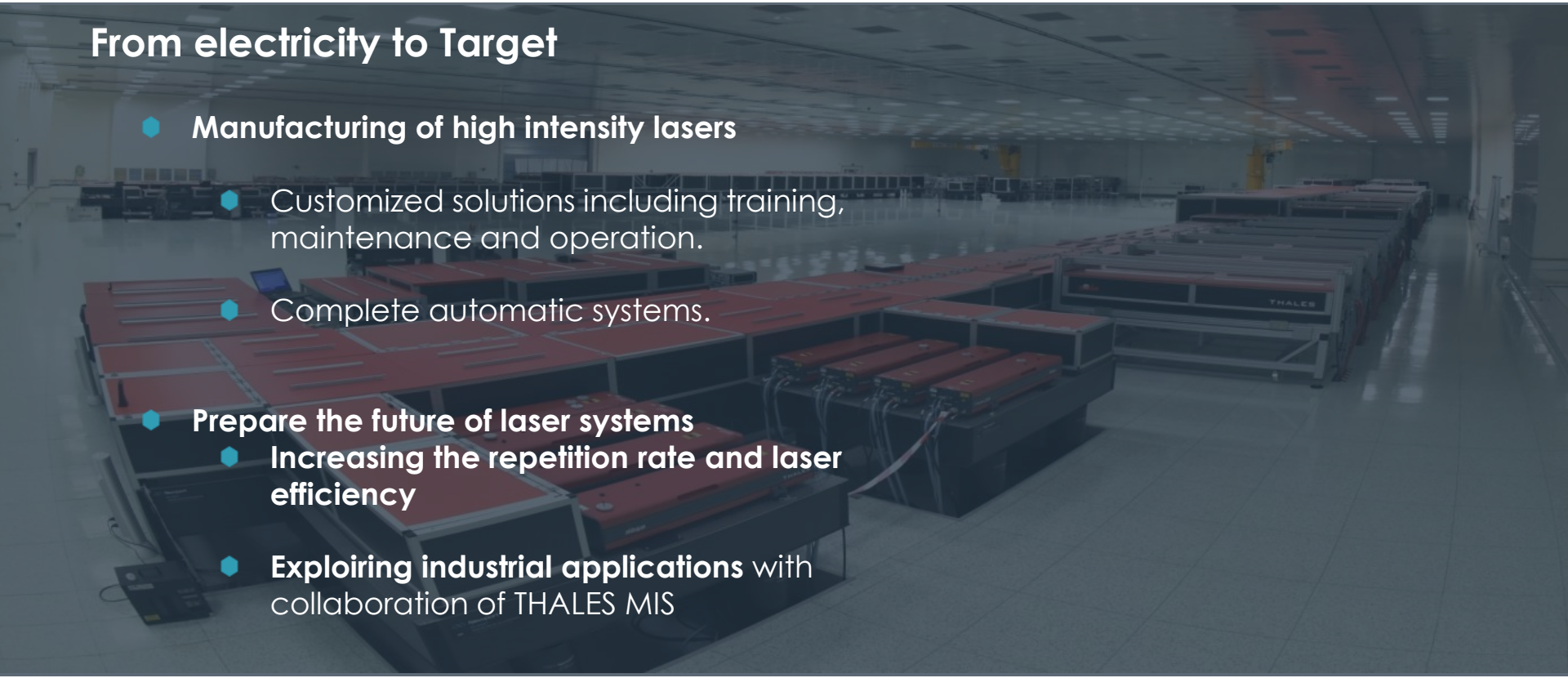


Electric field > 100GV/m

DETECTION
And DATA ANALYSIS



CONCLUSION



From electricity to Target

- **Manufacturing of high intensity lasers**
  - Customized solutions including training, maintenance and operation.
  - Complete automatic systems.
- **Prepare the future of laser systems**
  - **Increasing the repetition rate and laser efficiency**
  - **Exploiring industrial applications** with collaboration of THALES MIS

THALES