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Thales Optronique Laser Solution Department 30 years of expertise in High Energy Lasers



Dr. Marc Castaing,

HepTech Academia – Industry matching event on High Energy Lasers

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INTRODUCTION:

- An History of the laser activity
- Lasers at Thales Optronique

RECENT ACHIEVEMENTS

- Through Scientific collaboration to achieve high quality results
- 2012: 1st PW laser shot on earth and 1st laser shot on Mars
- 2013: 1st sub-25fs industrial PW laser, and demonstration of compact 200TW system

WHAT'S NEXT ?

- ELI NP manufacturing
- A compact solution for PW system ?

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1984: Creation of BM industries

- Activity centered on development of High Energy flashlamp pumped lasers
- 1992: Beginning of femtosecond laser activity

1994: Acquisition by Thomson CSF

2000: THALES LASER creation

2009: THALES LASER integrated in THALES OPTRONIQUE



7 companies + 4 JV



2800 people
Revenues 2011 : ≈ 700 M€

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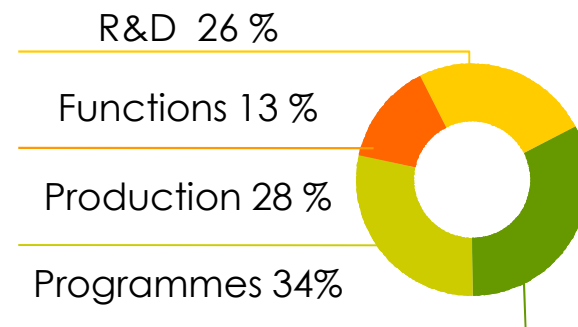
Élancourt



5 Main activities

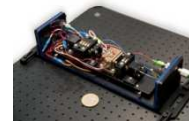
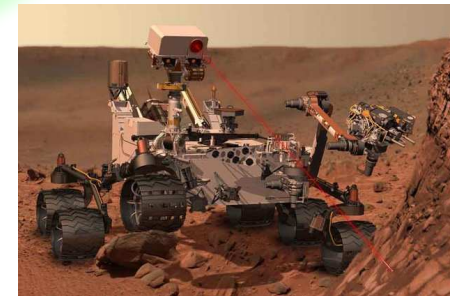
- ◆ Airborne Optronics
- ◆ Land & Naval Optronics
- ◆ Missile Electronics
- ◆ Laser
- ◆ Support & Customer Service

- ◆ **44,000 m² including**
 - 6,000 m² clean rooms
 - one sight testing tower
 - laser laboratories
- ◆ **1,300 employees**



- ◆ **Activity 2013:**
over 350 M€

Scientific lasers



Industrial lasers



Defense and Space

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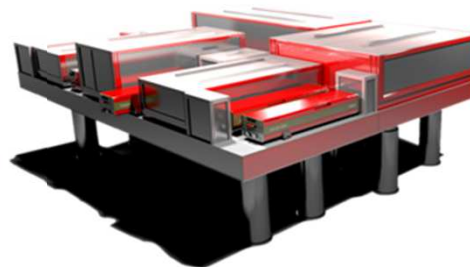
Laser systems from TW to PW



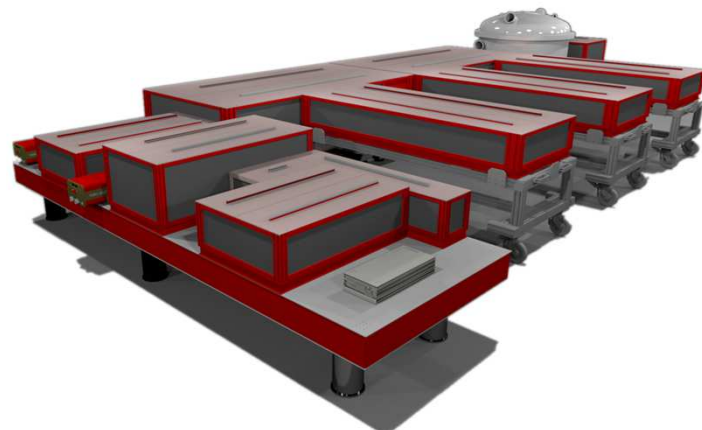
CETAL
1PW / 0,1 Hz



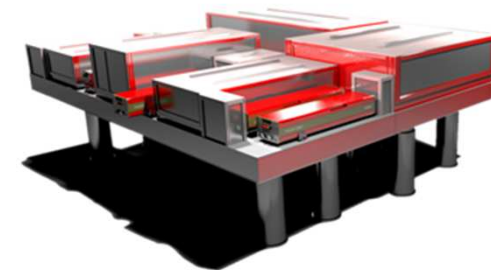
BELLA
1,3 PW / 1Hz



DESY
200 TW / 5Hz
(Upgradeable to 1 PW)



Riken Harima
2x 500 TW / 1Hz
(Upgradeable to 1 PW)



Peking University
200 TW / 5Hz
(Upgradeable to 1 PW)

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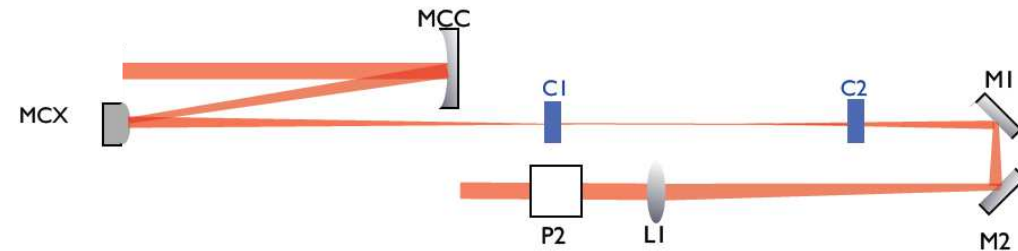
**Through scientific collaboration
& 30 years of experience
To achieve High Quality Results**

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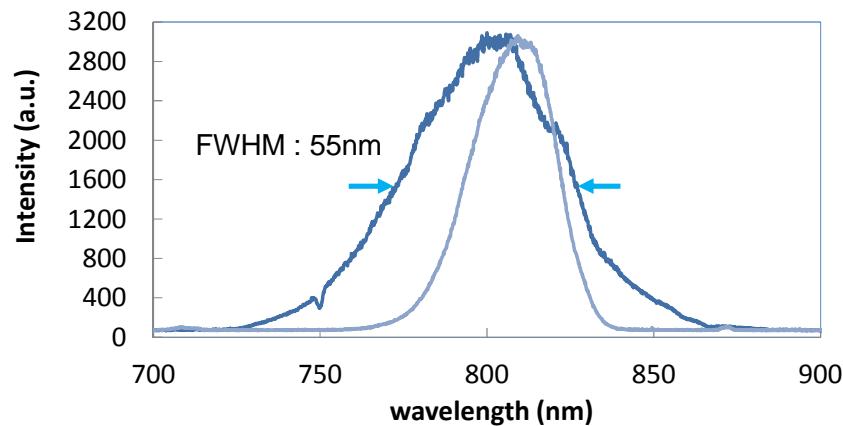
XPW (collaboration with LOA, Palaiseau)

◆ Two BaF₂ crystals generation

- Efficiency ~ 20 %
- FWHM Bandwidth ~ 55 nm
- Output Energy ~ 50 μJ
- Operation at ambient air

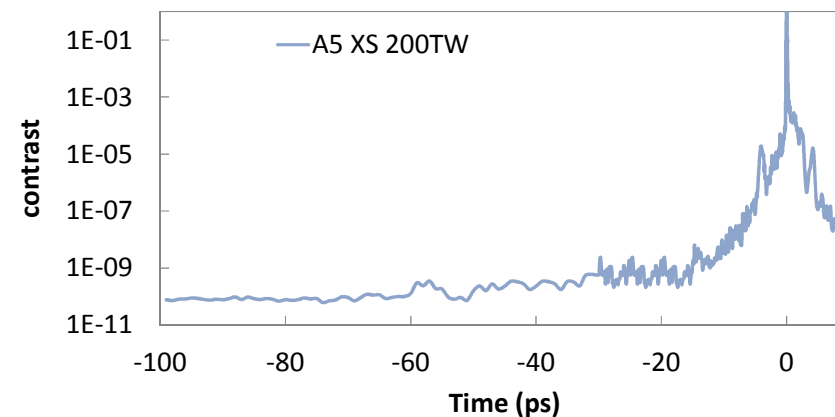


Spectrum before and after XPW



Spectrum Bandwidth Enhancement by $\sqrt{3}$

contrast at 5J / 25fs (200TW)



Ps Contrast Enhancement by 4 orders



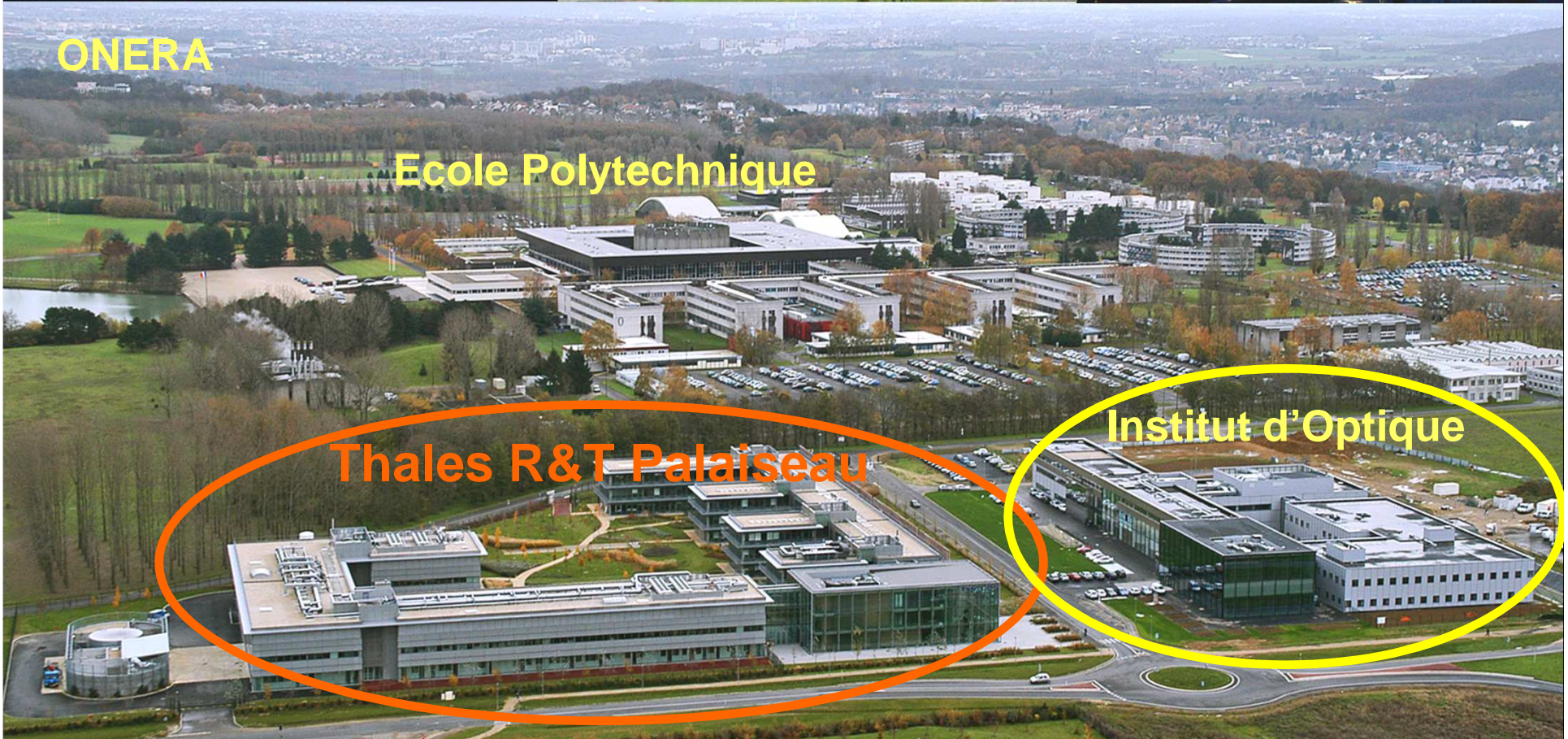
Thales R&T Reading



Thales R&T Delft



Thales R&T Singapore



ONERA

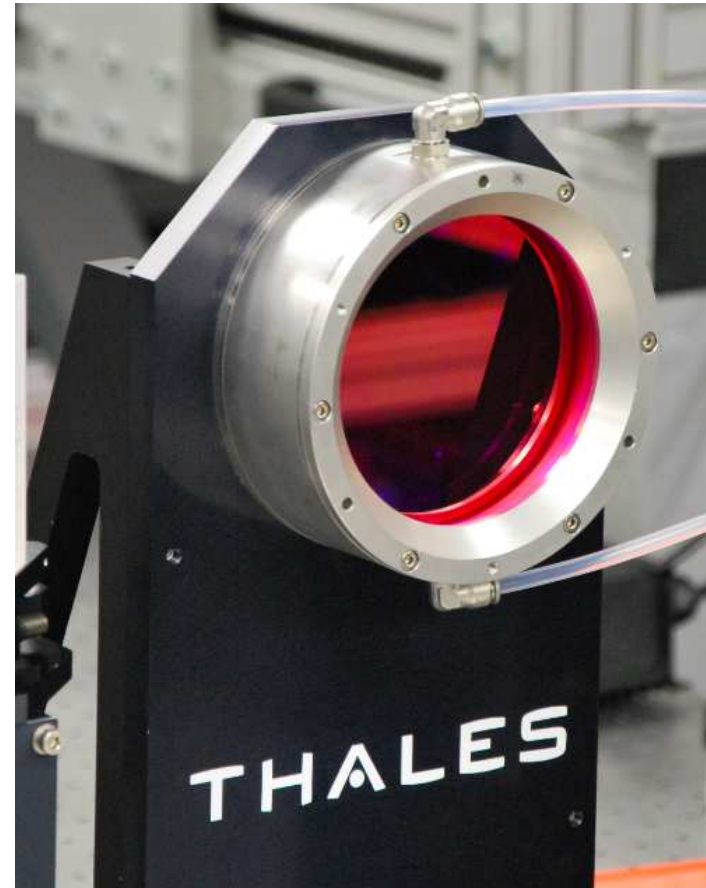
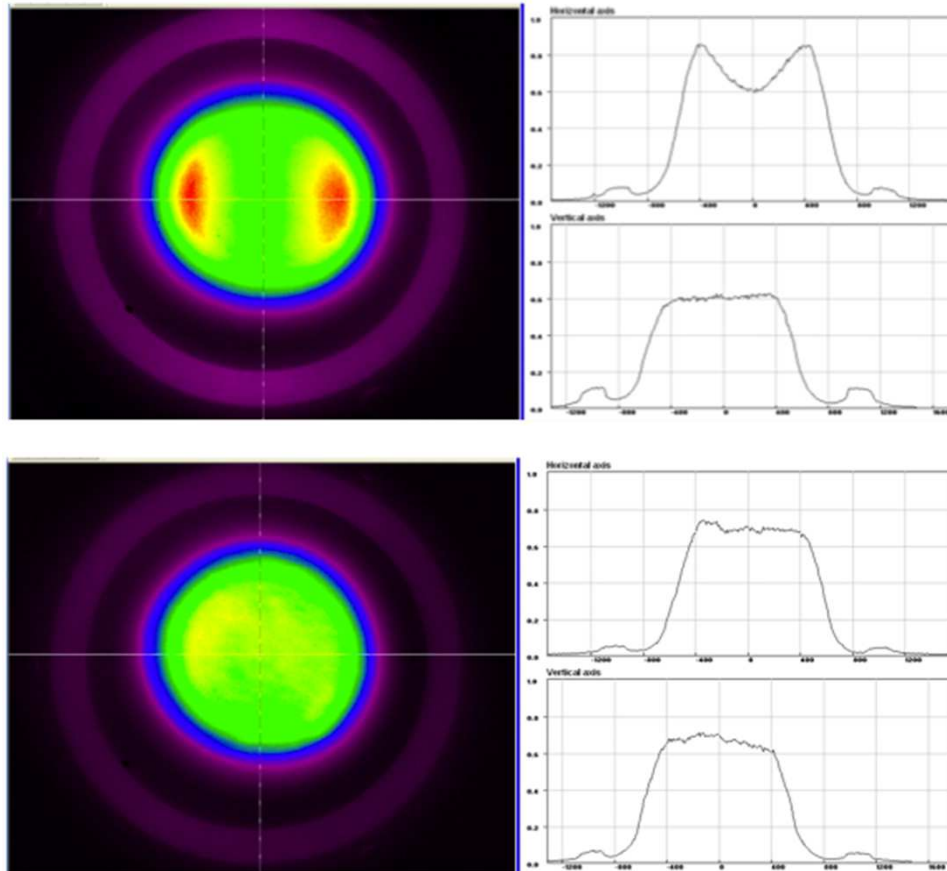
Ecole Polytechnique

Thales R&T Palaiseau

Institut d'Optique

Suppression of Transverse Lasing effect

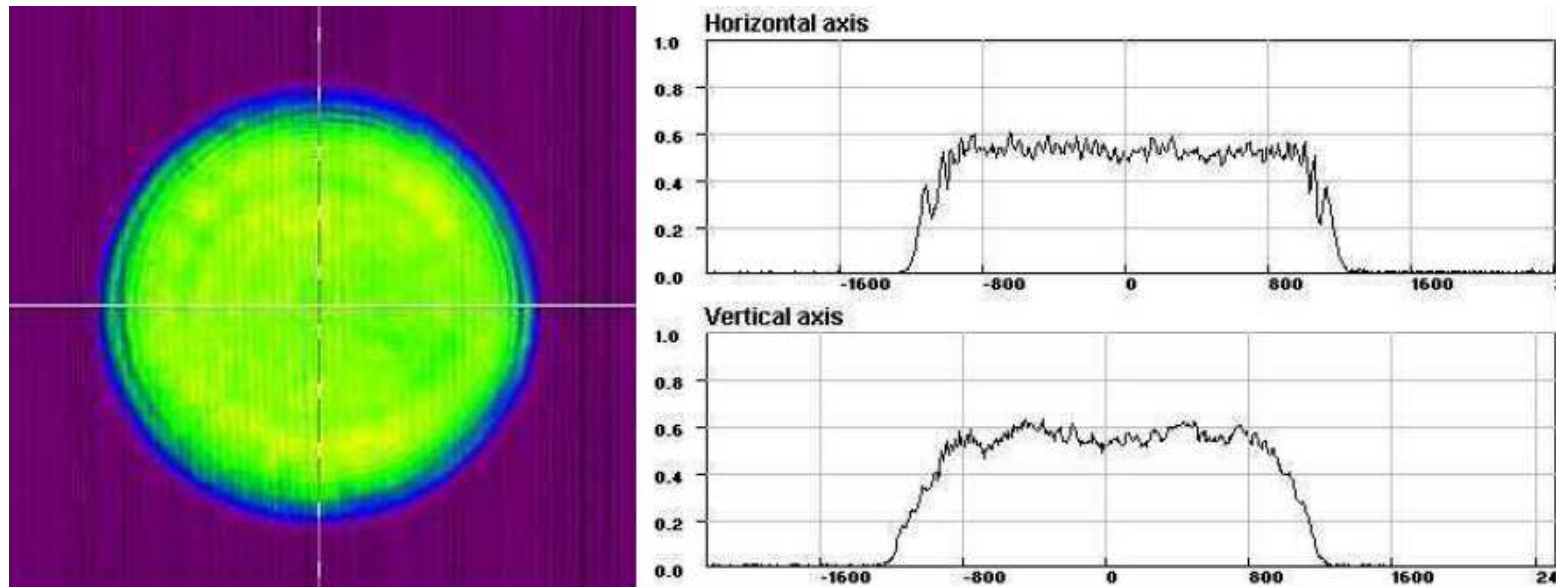
- ◆ Successful implementation of the liquid matching index (LMI) mount at the PetaWatt level (Pump Energy/facet : 30 J)



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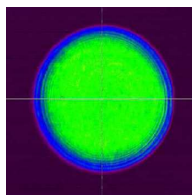
GAIA HP: high energy pump lasers designed for BELLA system

- ◆ $E > 14 \text{ J}$ @ 532 nm at 1 Hz (Now delivering up to 16J)
- ◆ Top hat profile without spatial shaping

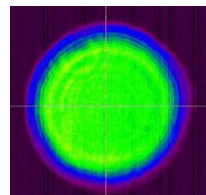


GAIA HP: high energy pump lasers designed for BELLA system

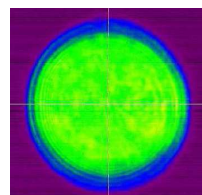
| GAIA HP | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Energy (J) | 15.2 | 15.4 | 15.3 | 15 | 14.7 | 14.7 | 14.9 | 14.6 | 14.4 | 15.2 | 14.9 | 15.3 |
| Energy Stability (rms) | 0.77% | 0.73% | 0.79% | 0.59% | 0.68% | 0.62% | 0.73% | 0.57% | 0.70% | 0.50% | 0.61% | 0.52% |



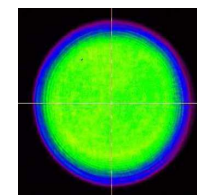
GAIA HP #1



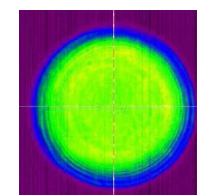
GAIA HP #2



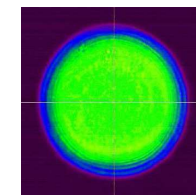
GAIA HP #3



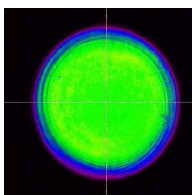
GAIA HP #4



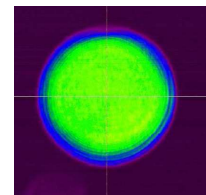
GAIA HP #5



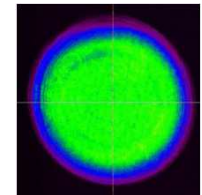
GAIA HP #6



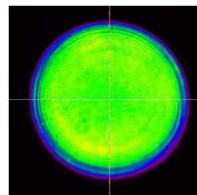
GAIA HP #7



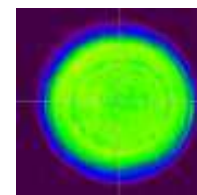
GAIA HP #8



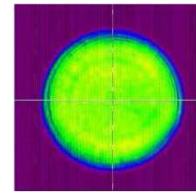
GAIA HP #9



GAIA HP #10



GAIA HP #11



GAIA HP #12

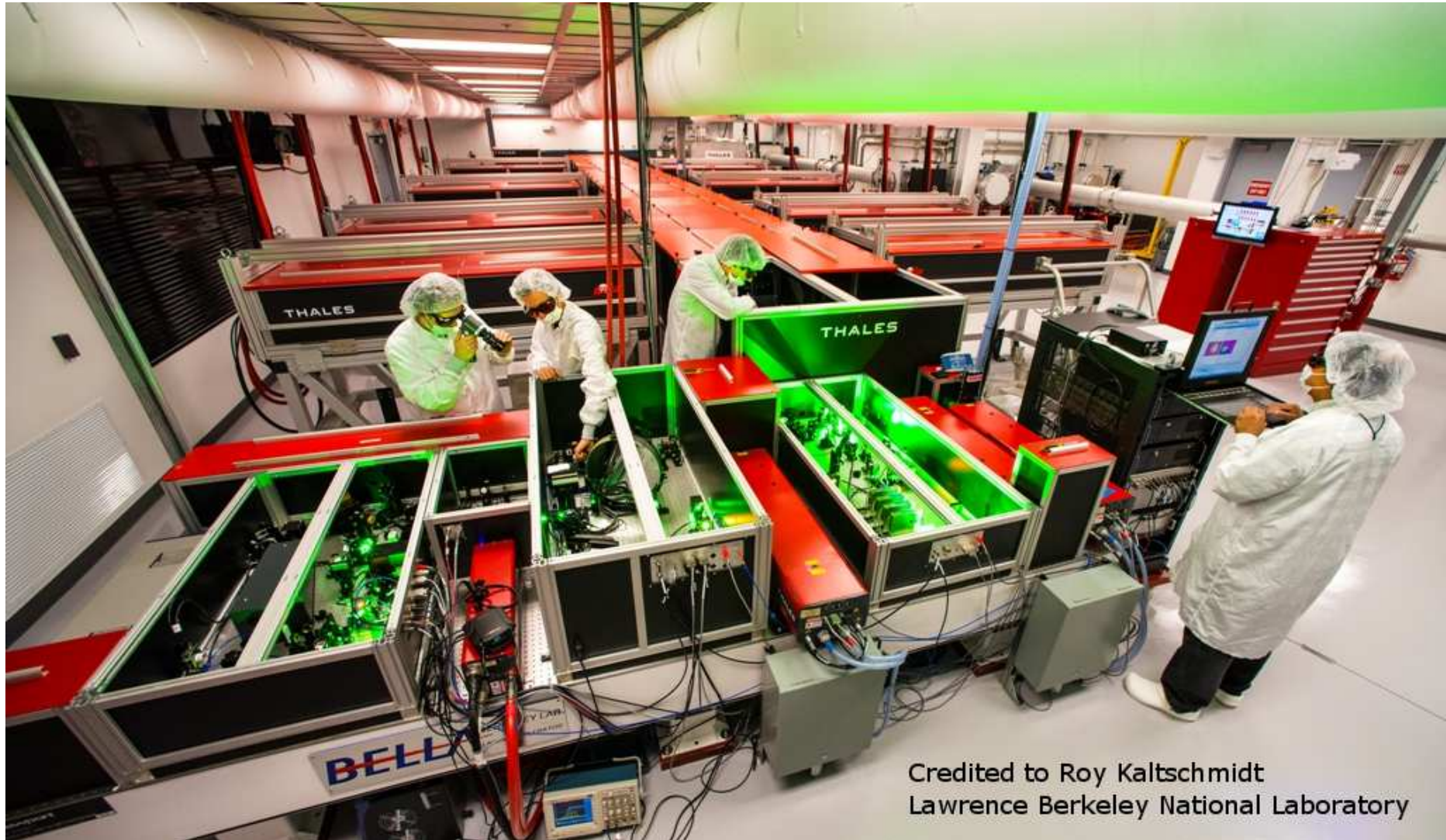
YEAR 2012
1st PW shot at 1Hz on earth
1st Laser shot on Mars

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BELLA system at Lawrence Berkeley National Laboratory

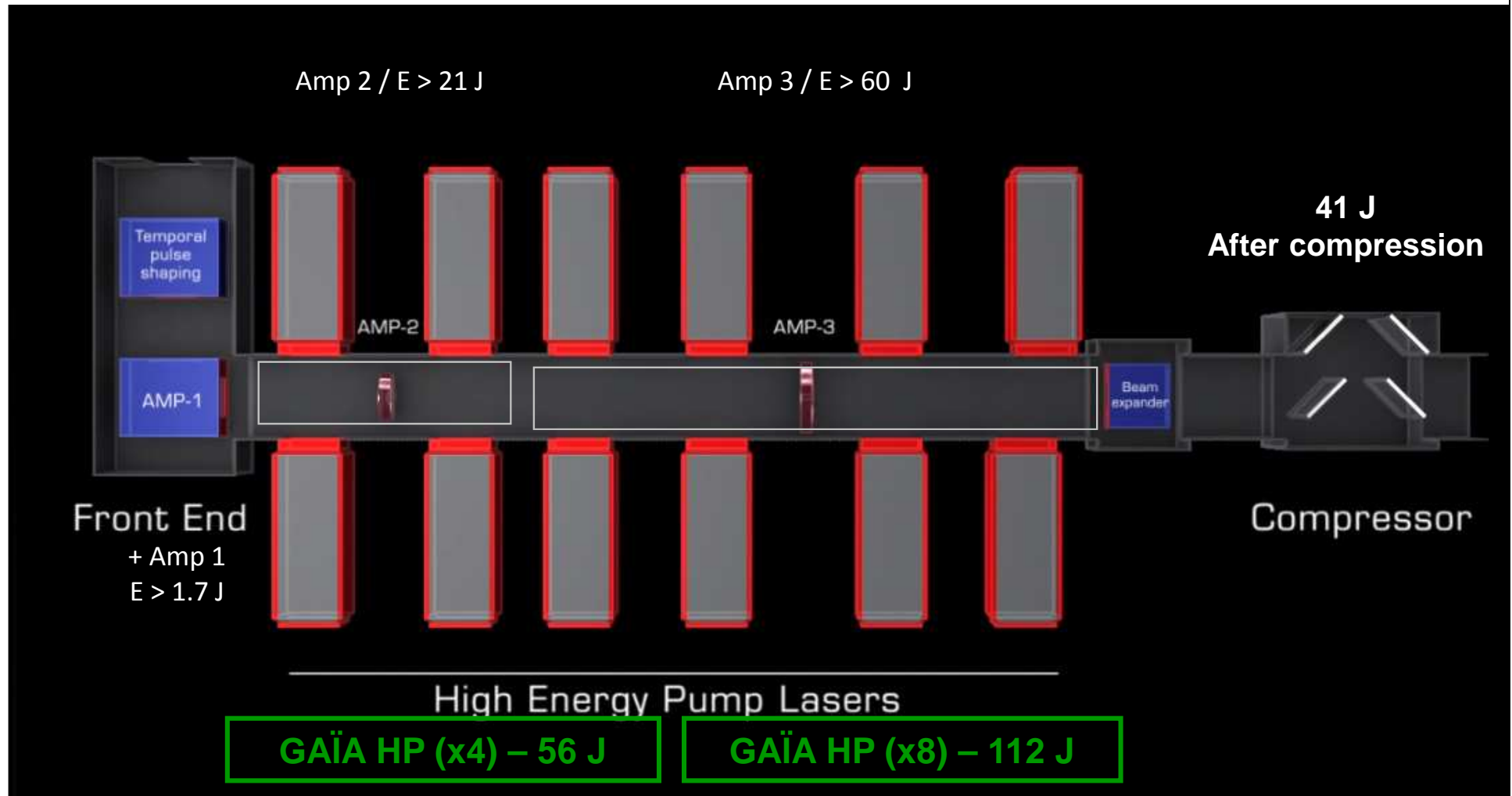
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BELLA laser system operational in July 2012

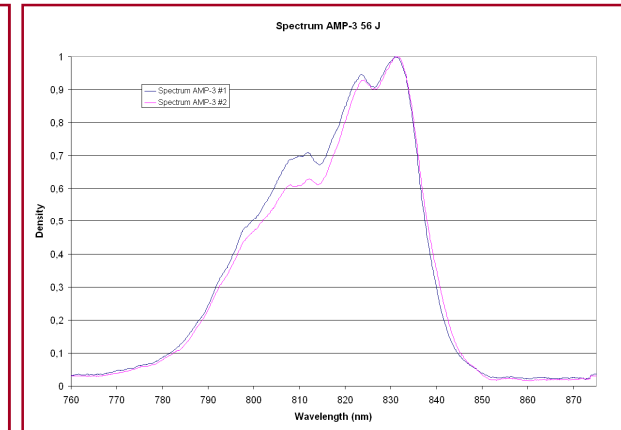
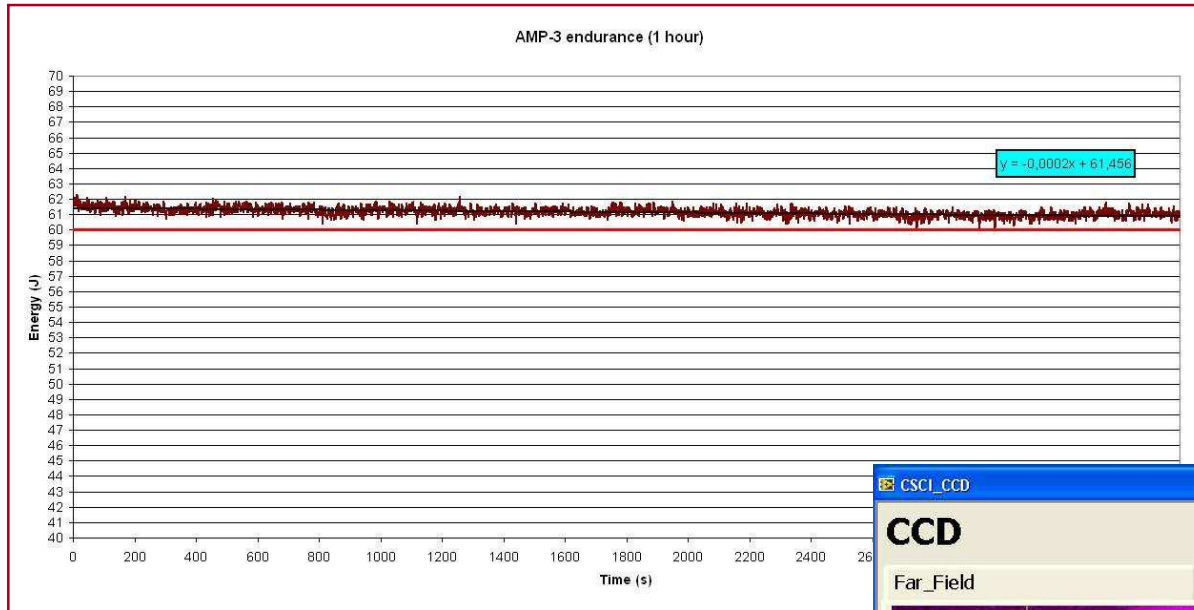


Credited to Roy Kaltschmidt
Lawrence Berkeley National Laboratory

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This

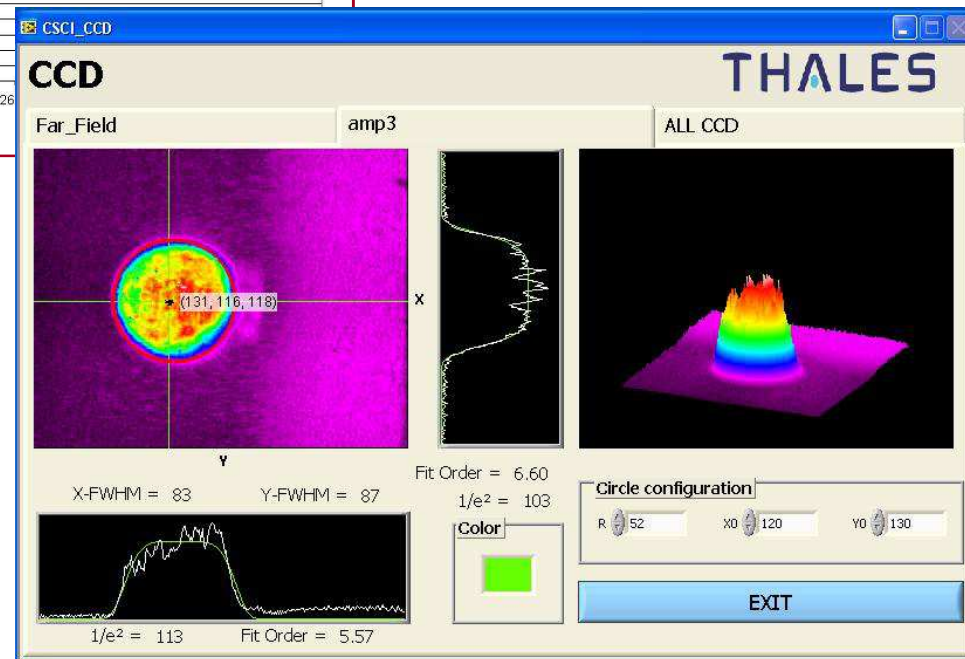


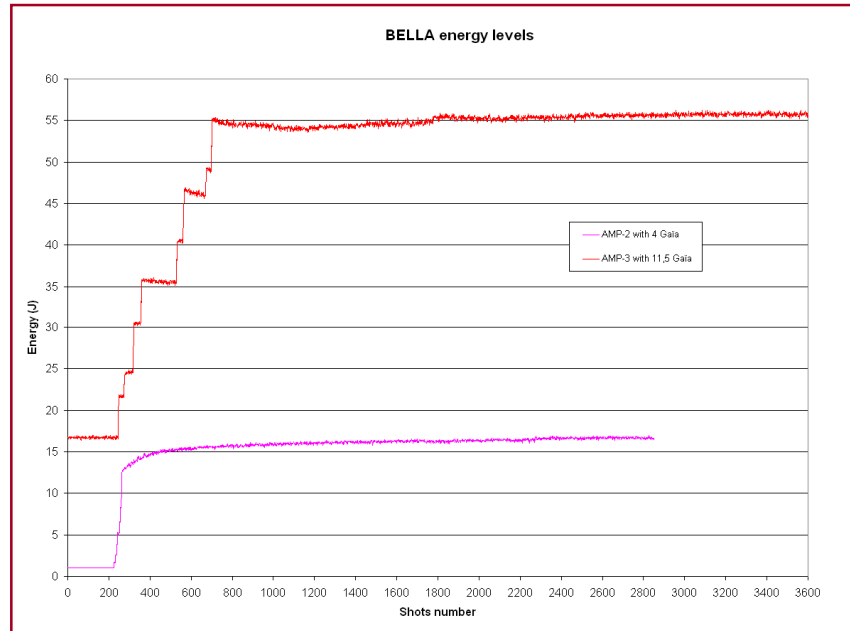
Energy:

- ◆ Average value : 61.2 J
- ◆ Stability : 0.30%

Spectral bandwidth:

- ◆ FWHM: 37 nm





Input energy:

- ◆ Average value: 55 J

Energy after compression:

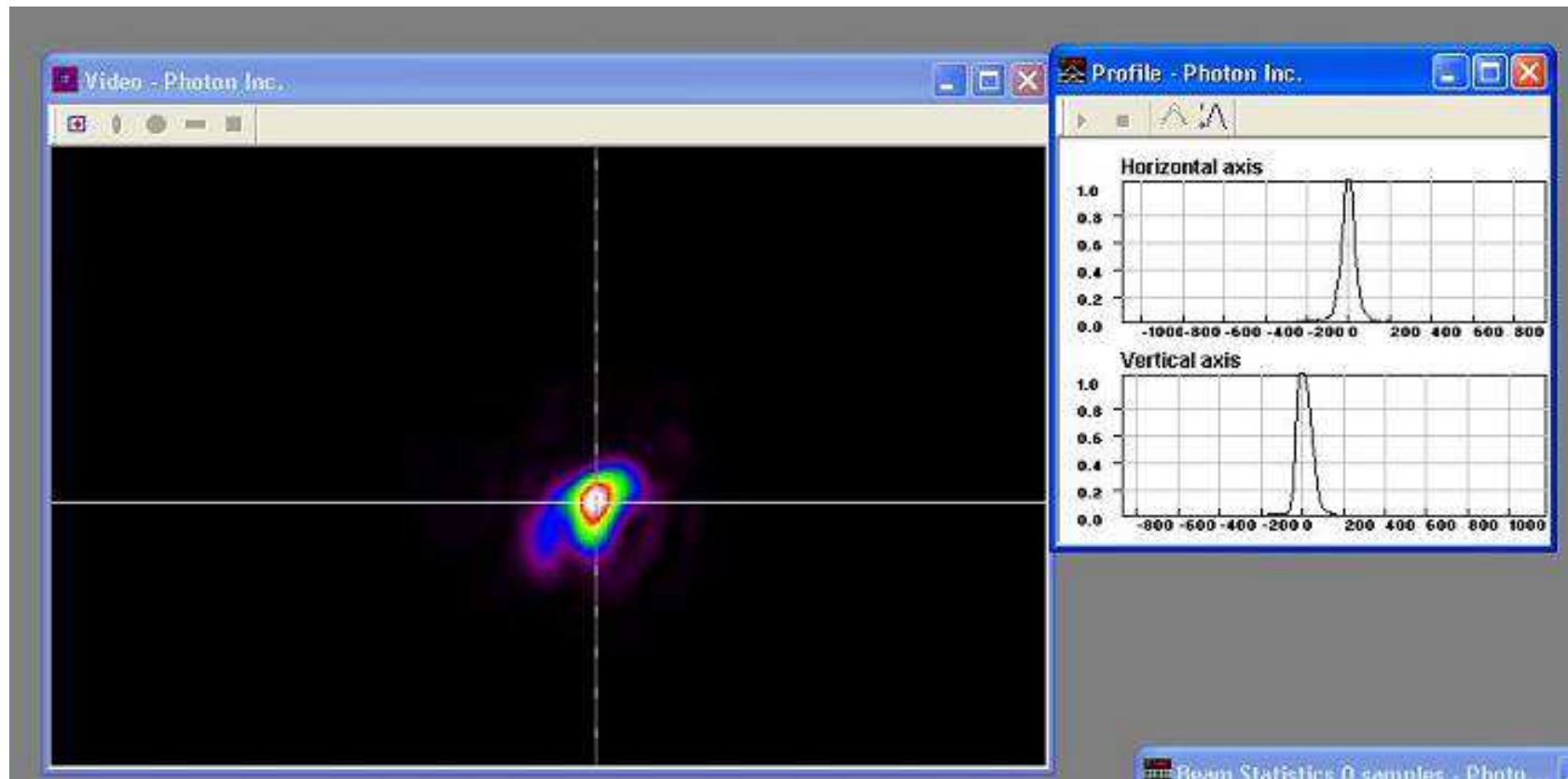
- ◆ Average value: 42.4 J

Compressor efficiency:

- ◆ 77%

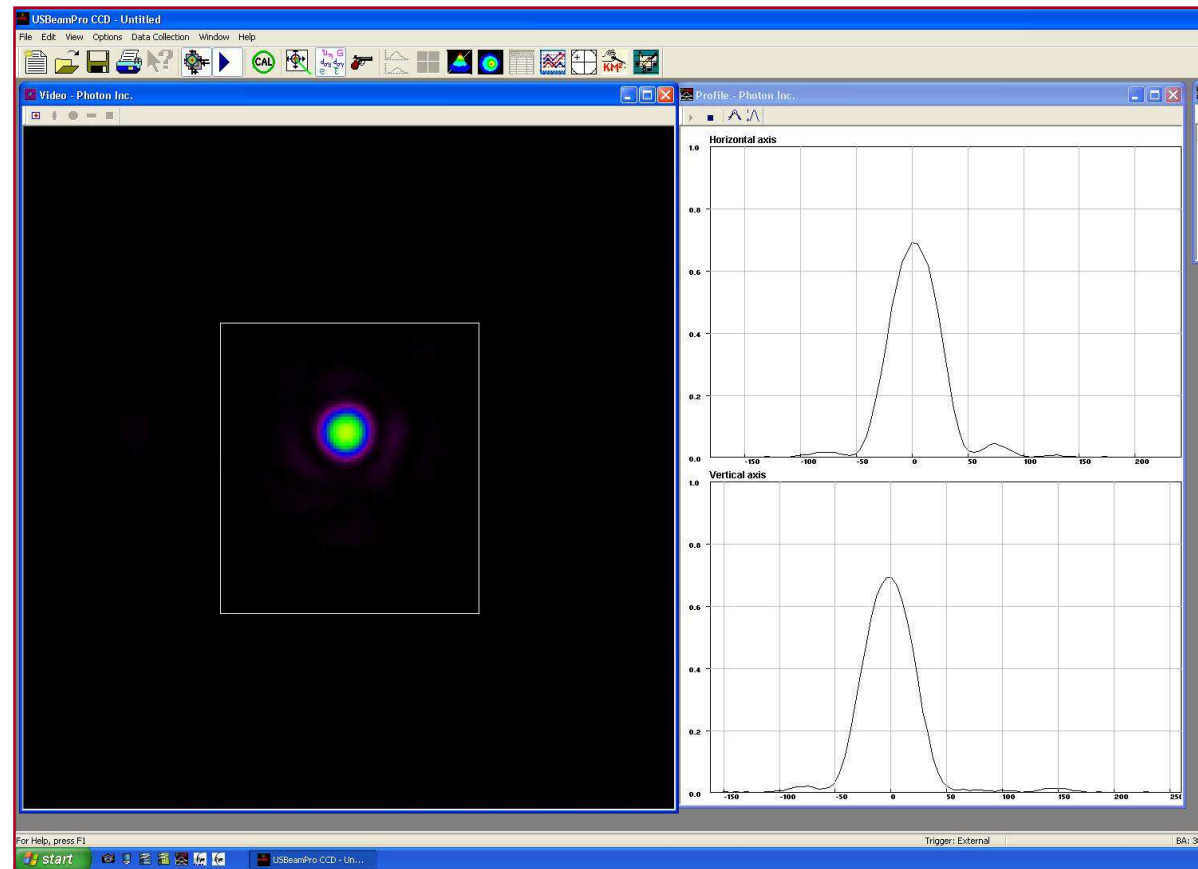
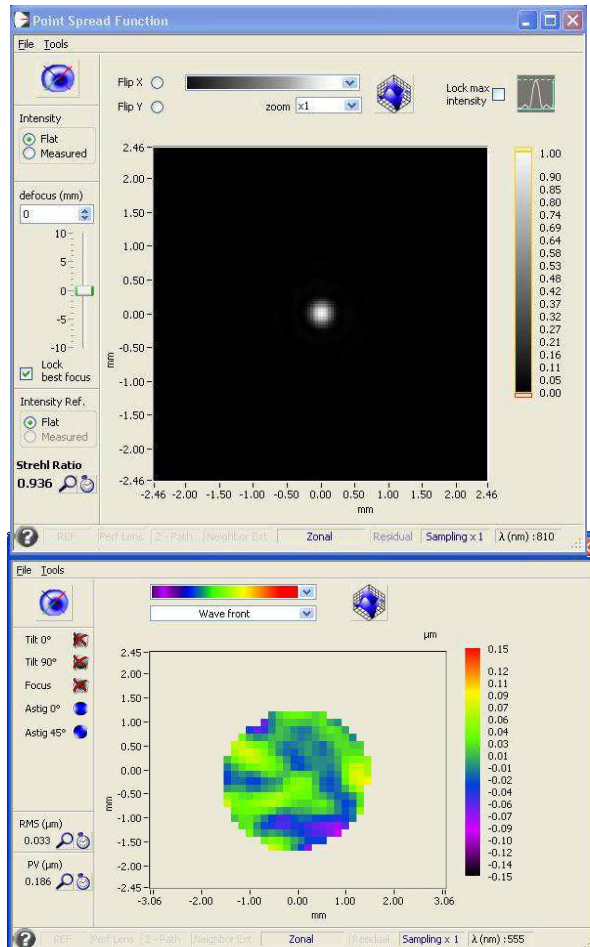


Far field beam profile with non-optimized correction



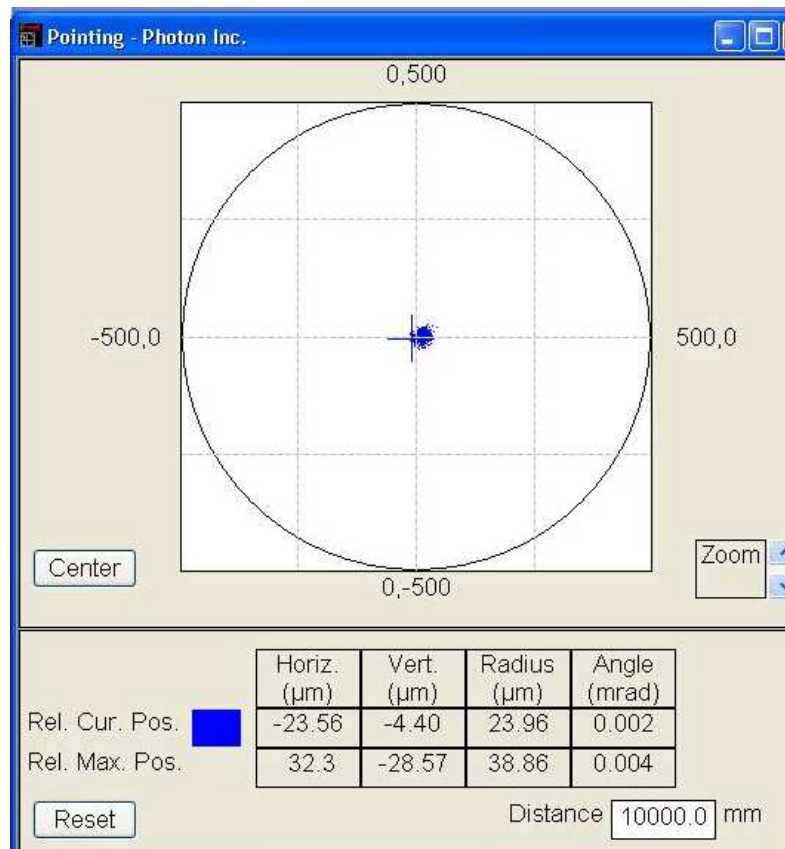
Farfield beam profile with correction performed by Deformable Mirror:

◆ Strehl ratio: 0.93

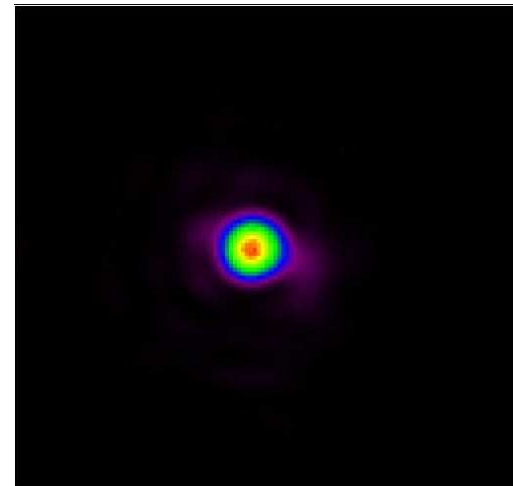


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Beam pointing stability (over 600 shots) < 1 μ rad r.m.s



| Parameter | Value | Mean | Min | Max | Std D... |
|----------------------------|-------|--------|-------|-------|----------|
| 86.5% Width (μm) | 202.6 | 212.44 | 192.8 | 228.4 | 6.36 |
| Pointing Position Hori... | -19.6 | -0.44 | -26.6 | 32.3 | 10.40 |
| Pointing Position Vert ... | -0.6 | 0.35 | -28.6 | 28.4 | 9.62 |
| Pointing Angle (mrad) | 0.002 | 0.0013 | 0.000 | 0.004 | 0.0006 |



The BELLA laser system:

- ◆ First industrial PetaWatt laser at 1Hz worldwide
- ◆ With exclusive technologies
 - XPW filter
 - High energy pump lasers
 - Anti-transverse lasing mount
- ◆ Delivered at customer site on time and in operation since July 2012
- ◆ Scientific program started in 2013 and production of high level scientific results



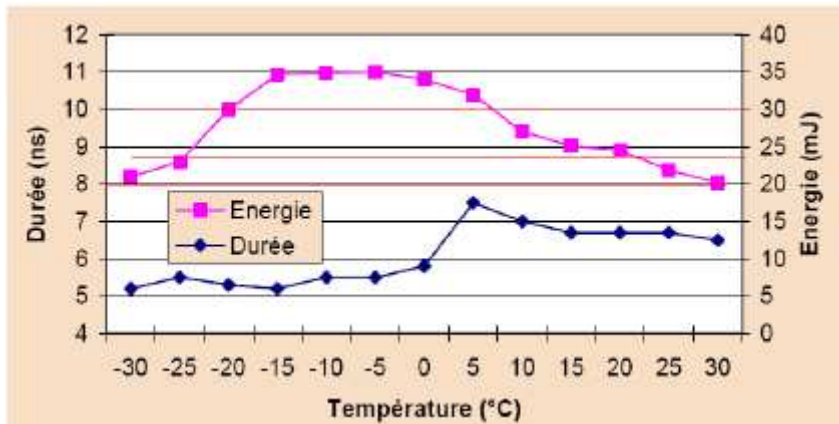
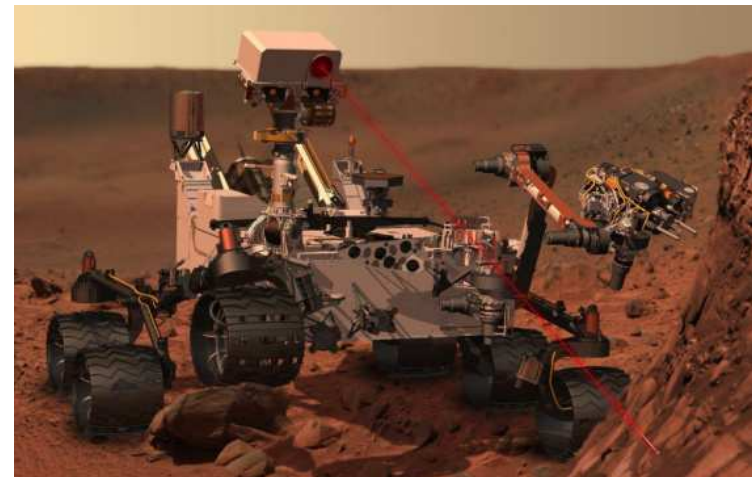
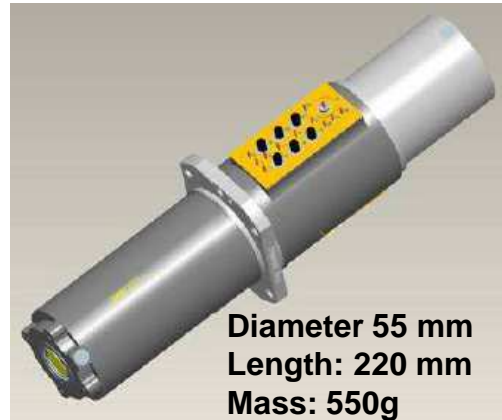
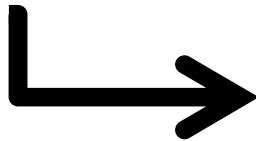
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At the same time on Mars...

THALES

From an industrial product to a space qualified laser



More than **24 mJ**
Pulse duration less than **8 ns**
Over **-20°C to +20°C** range

**YEAR 2013:
Sub 25fs industrial PW laser
&
Commissioning of highly compact
200 TW solution**

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CETAL system

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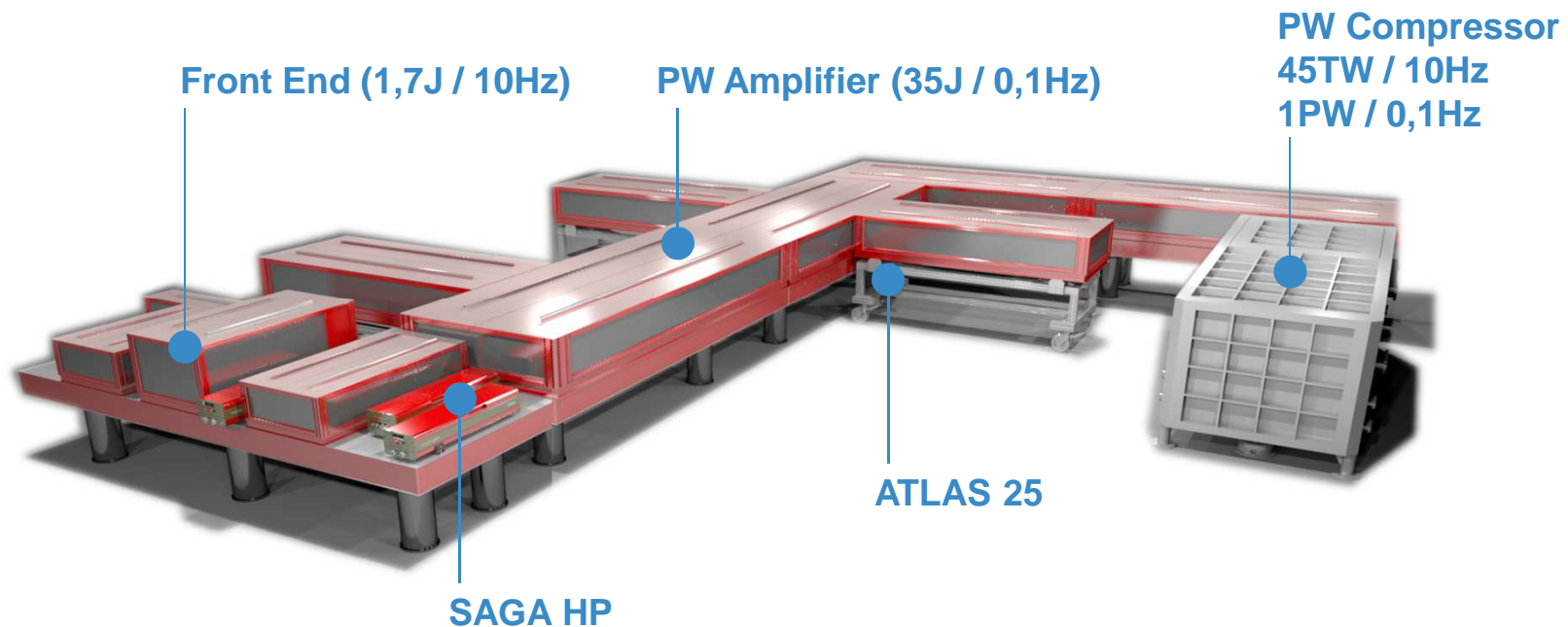
CETAL Specification

PW output specification

| | |
|-----------------------|--------------------------|
| Peak power | $\geq 1 \text{ PW}$ |
| Pulse duration | $< 25 \text{ fs}$ |
| Repetition rate | 0,1Hz |
| Ps pre-pulse contrast | $10^{11} @ 100\text{ps}$ |

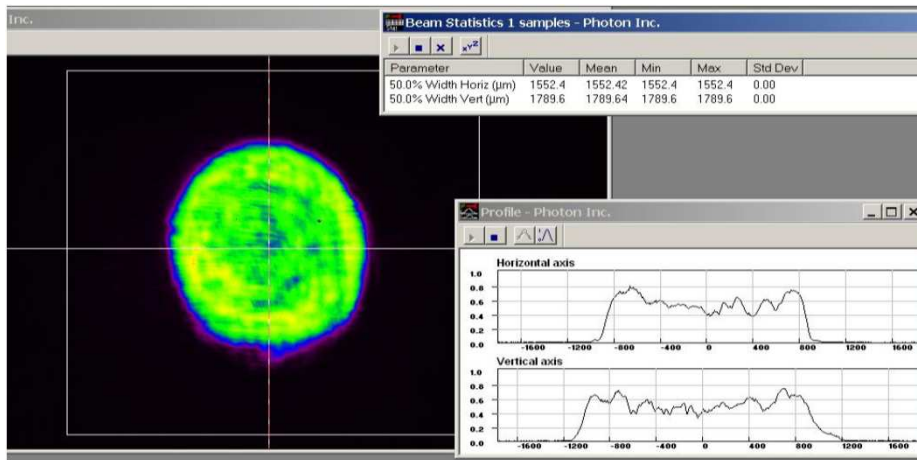
TW output specification

| | |
|-----------------------|--------------------------|
| Peak power | $\geq 45 \text{ PW}$ |
| Pulse duration | $< 25 \text{ fs}$ |
| Repetition rate | 10Hz |
| Ps pre-pulse contrast | $10^{11} @ 100\text{ps}$ |

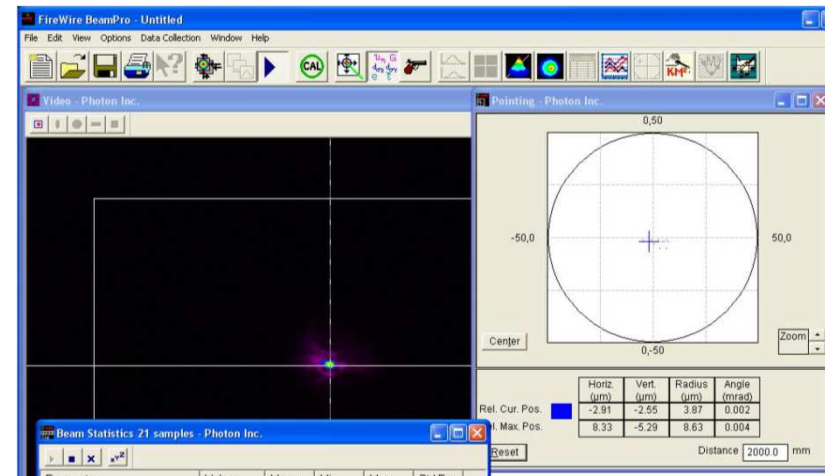


| Amplification results | | | | | |
|-----------------------|---------|---------|-------------|---------|-------------------------|
| Atlas 1 | Atlas 2 | Atlas 3 | Atlas 1+2+3 | E Ampli | Extraction (input 1.5J) |
| 25.1 J | 25.1 J | 25.2 J | 75.4 J | 33.5 J | 42.5 % |

Near field beam profile (33.5 J)



Pointing stability (1,2µrad rms)



| Parameter | Value | Mean | Min | Max | Std Dev |
|------------------------|-------|--------|-------|-------|---------|
| 50.0% Width Horiz (µm) | 63.4 | 66.24 | 54.8 | 89.2 | 8.94 |
| 50.0% Width Vert (µm) | 41.1 | 40.79 | 39.0 | 43.3 | 1.09 |
| Pointing Angle (mrad) | 0.002 | 0.0022 | 0.000 | 0.004 | 0.0012 |
| Pointing Radius (µm) | 3.23 | 4.470 | 0.52 | 8.63 | 2.339 |

Compressor overall optical transmission of 79% leads to an estimate of 26.5 J for output energy then a peak power of 1.12 PW

1PW system at 0.1 Hz



- ◆ Pulse duration: 25 fs
- ◆ Energy before compression: 34 J
- ◆ Compressor efficiency: 75 %
- ◆ ATLAS pump laser: 75 J
- ◆ Repetition rate: 0.1 Hz



Operational on site since November 2013

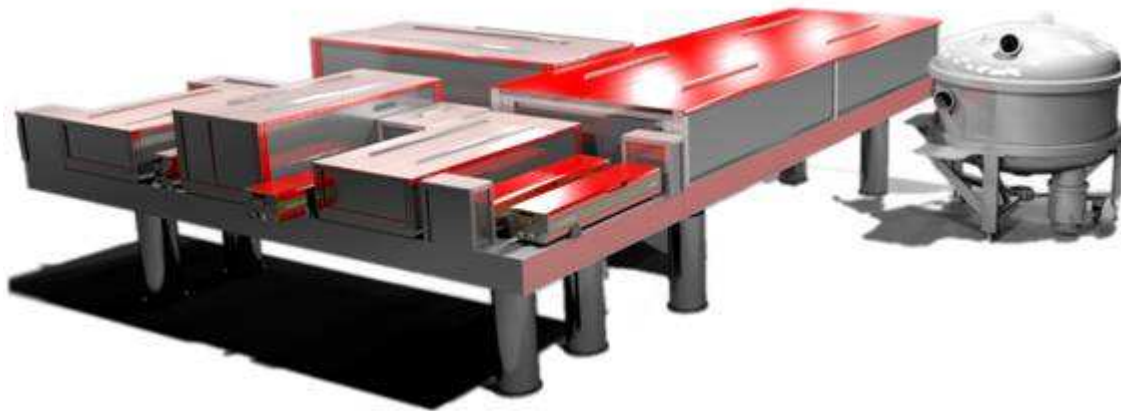
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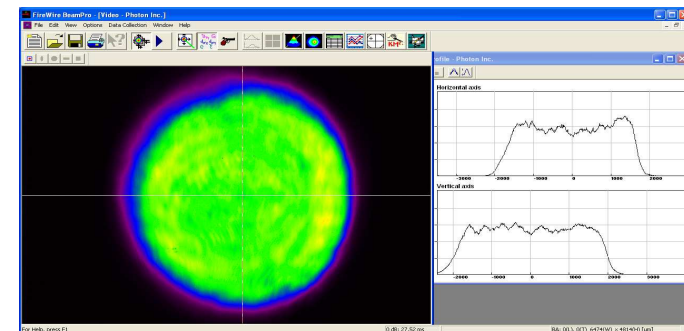
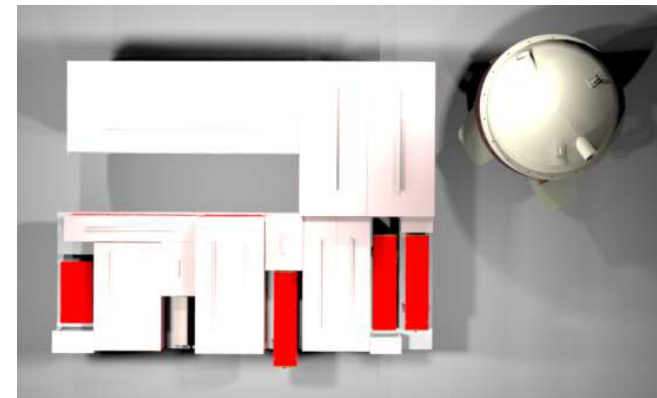
ALPHA 5XS – 200TW @ DESY

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Results of 200 TW system at 5 Hz

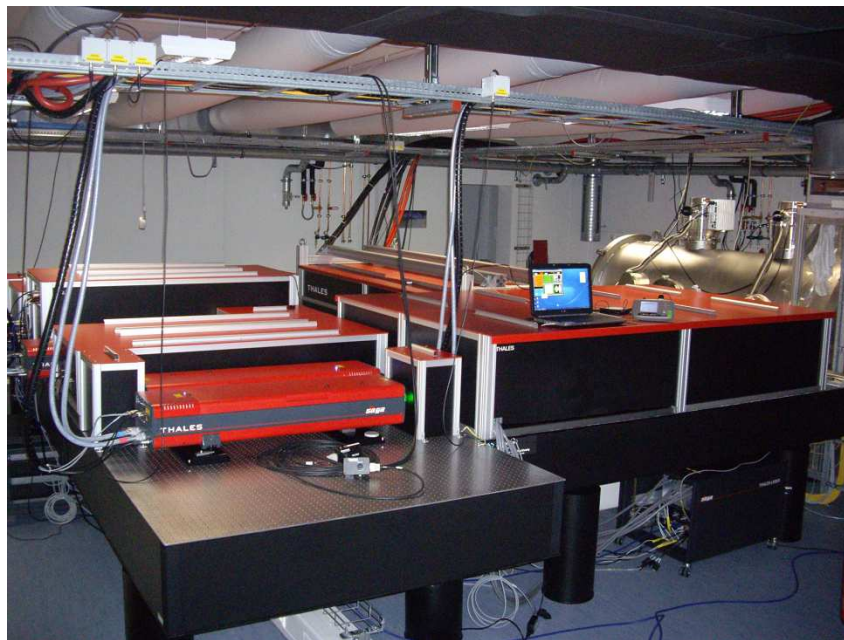


- ◆ Compact size 4m * 5 m (without compressor)
- ◆ Only one pump laser 15 J
- ◆ Water cooling
- ◆ Repetition rate 5 Hz
- ◆ Pulse duration: 25 fs
- ◆ Energy before compression: 7.2 J
- ◆ Strehl ratio: 0.92

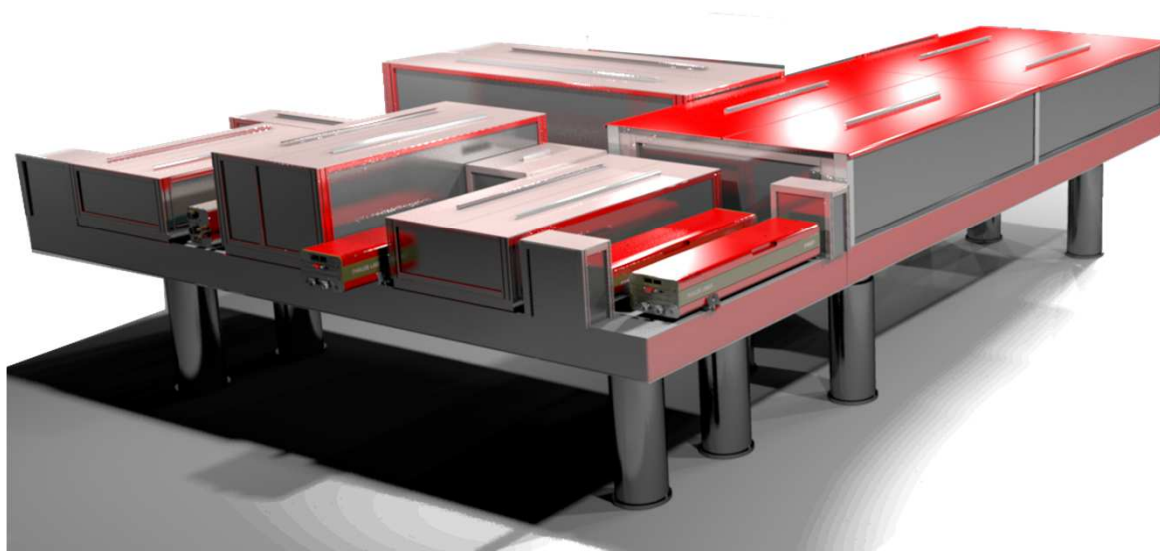


**Laser successfully
commissioned at DESY site**

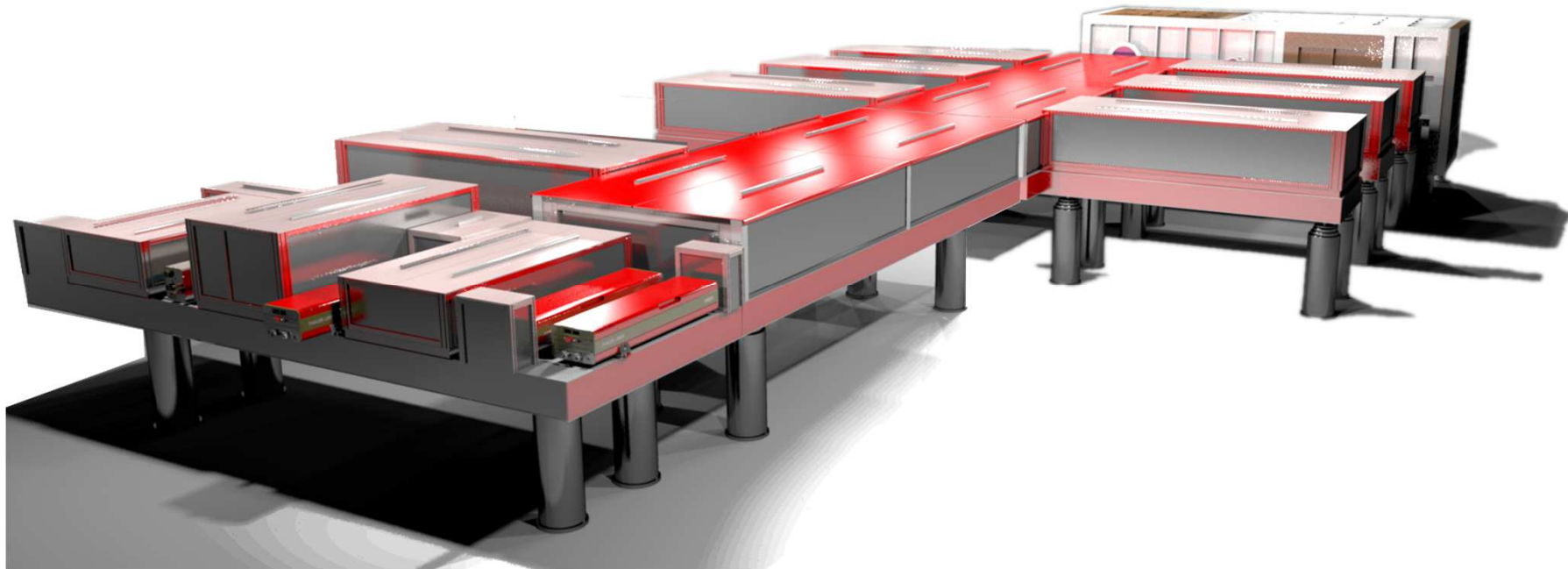
15th of November 2013 !!



Upgrade of the 200TW



To reach 1.2 PW (30 J, 25 fs)



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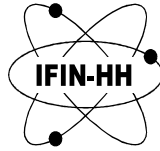
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CONCLUSION

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ELI-NP High Power Laser System - HPLS

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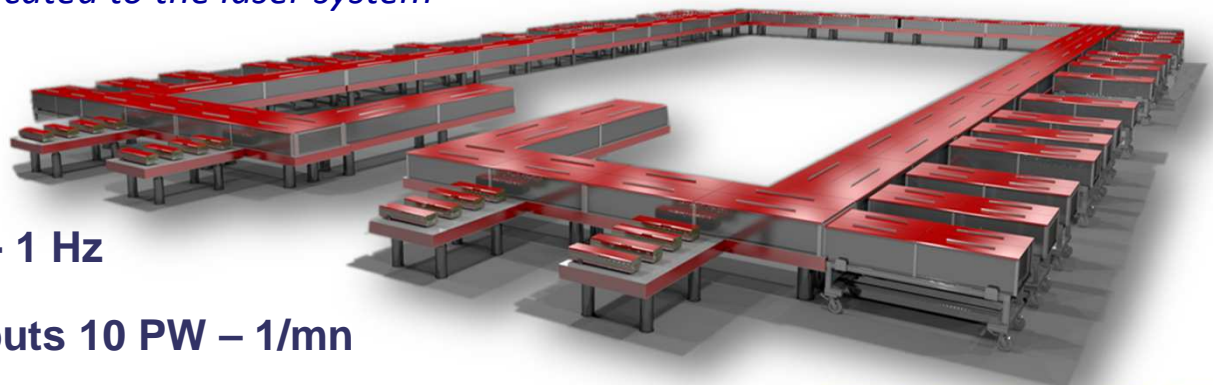


ELI-NP building with 1500m² allocated to the laser system

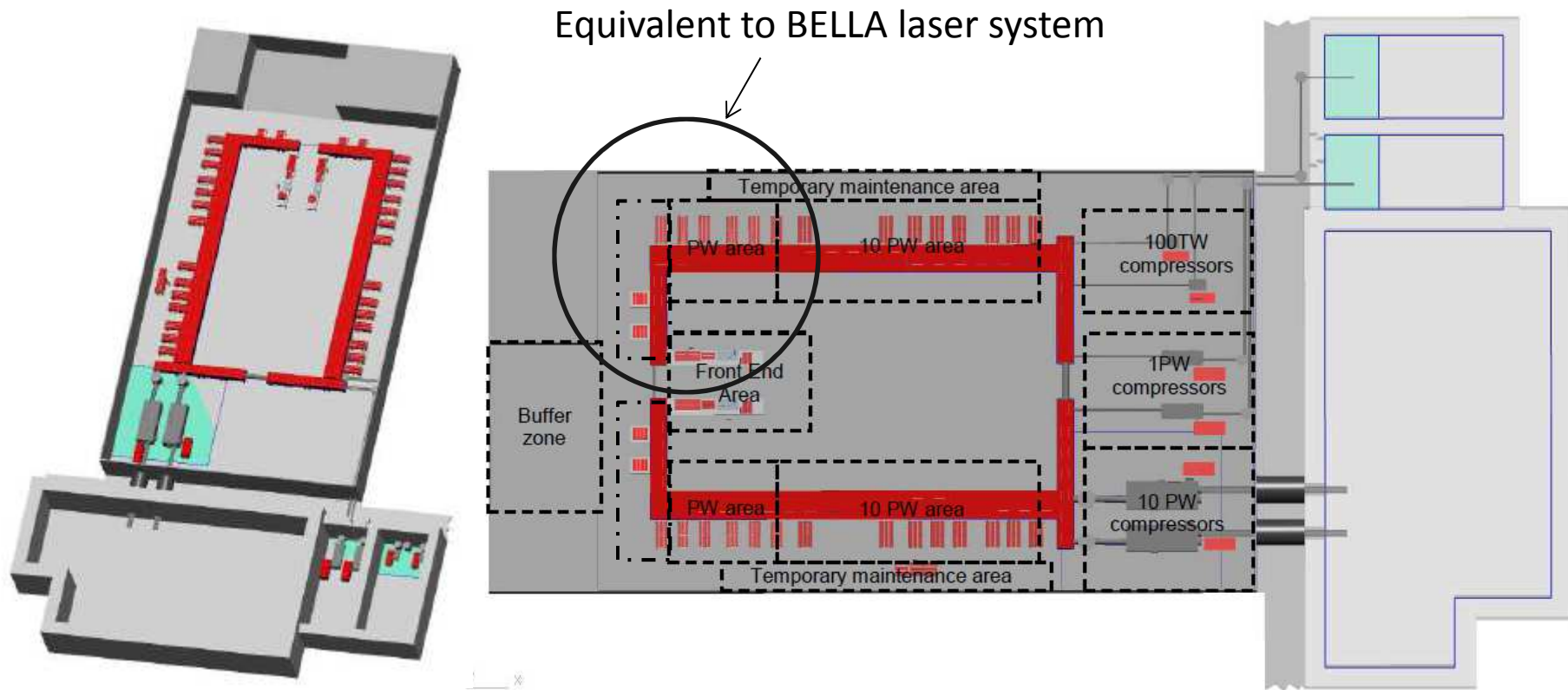


Contract awarded the 11th of July 2013

- ◆ 2 outputs 100 TW - 10 Hz
 - ◆ 2 outputs 1 PW - 1 Hz
 - ◆ 2 outputs 10 PW – 1/mn



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The High Power Laser Architecture

Hybrid double CPA configuration

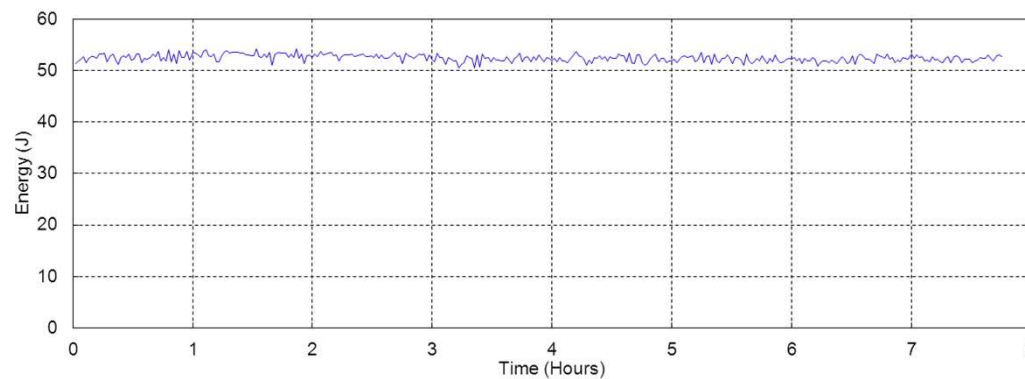
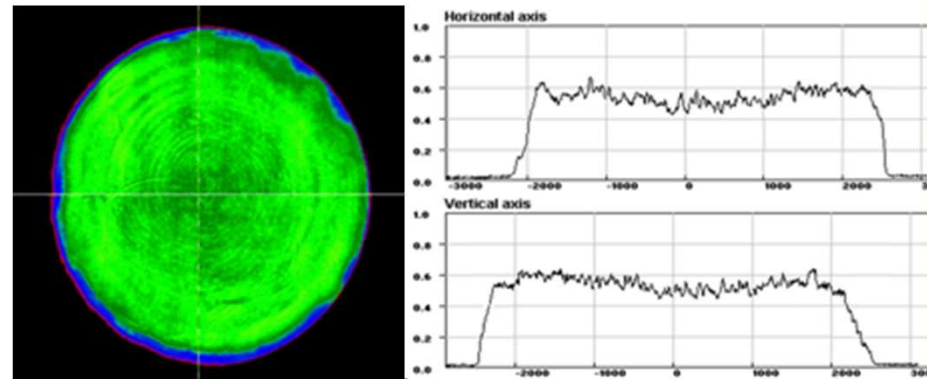
(collaboration with French project APOLLON through a technology transfer agreement)

- ◆ CPA 1 for beam stability
- ◆ XPW for contrast and spectrum enhancement
- ◆ OPCPA for contrast enhancement
- ◆ New high energy pump laser
- ◆ CPA 2 for energy and energy stability



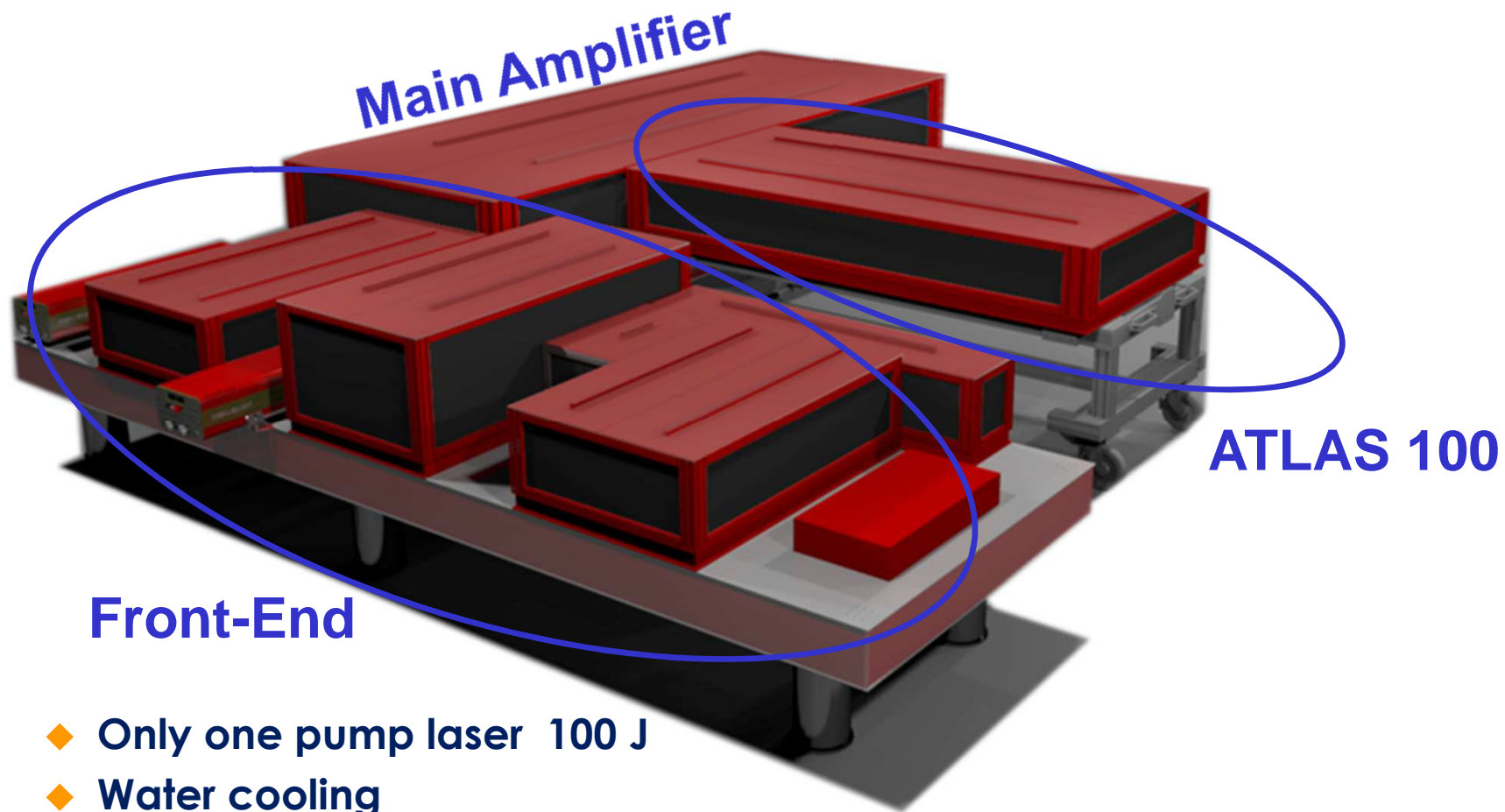
High energy improvement

- ◆ 100J green pump pulse in a single beam



Energy stability over 8 hours of operation

What about a compact PW class system ?



Front-End

- ◆ Only one pump laser 100 J
- ◆ Water cooling
- ◆ Repetition rate 1 shot/min
- ◆ Pulse duration: 25 fs
- ◆ Energy after compression: 25 J
- ◆ Strehl ratio: >0.9 (with deformable mirror)

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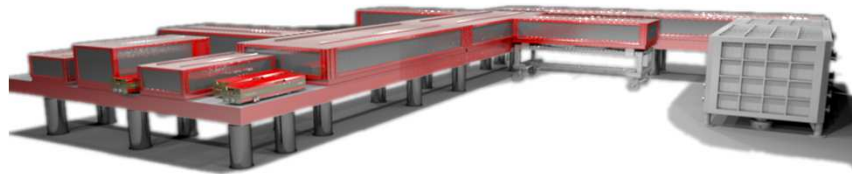
Thanks to 30 years of experience
&
through scientific collaboration

2x PW class laser successfully installed and commissioned at customer site

EXTREME PERFORMANCES have been achieved with critical laser parameters while keeping high **RELIABILITY** and **AVAILABILITY LEVEL** through robust **INDUSTRIAL** design.

BELLA system is daily used for science since **ALMOST 2 YEARS** and has already produced **OUTSTANDING SCIENTIFIC RESULTS**

We have now completed the design of the next generation which is 10 PW lasers and have started the construction of the two 10 PW beamlines of ELI-NP.



CETAL
1PW / 0,1 Hz



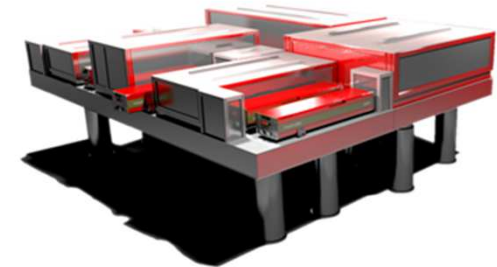
BELLA
1,3 PW / 1Hz

Thank you for your attention

Riken Harima
2x 500 TW / 1Hz
(Upgradeable to 1 PW)



DESY
200 TW / 5Hz
(Upgradeable to 1 PW)



THALES