



énergie nucléaire • énergies alternatives



# Overview of PETAL, the multi-Petawatt project on the LIL or LMJ facility

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France



# PETAL : objectives

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## Coupling of PETAL with Quads of LIL or LMJ 1 quad = 30 kJ / ns / 3 $\omega$

- Energy > 3 kJ,
- Wavelength > 1053 nm,
- Pulse duration between 0,5 and 10 picoseconds,
- Intensity on target >  $10^{20}$  -  $10^{21}$  W/cm<sup>2</sup>,
- Intensity contrast (short pulse) :  $10^{-7}$  at -7 ps,
- Energy contrast (long pulse) :  $10^{-3}$ .

# PETAL Project Phases

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Phase I  
Key issues



Front End  
Compression -  
Stage

Phases II and III

full power  
independent PW  
beam



Amplifier  
Section

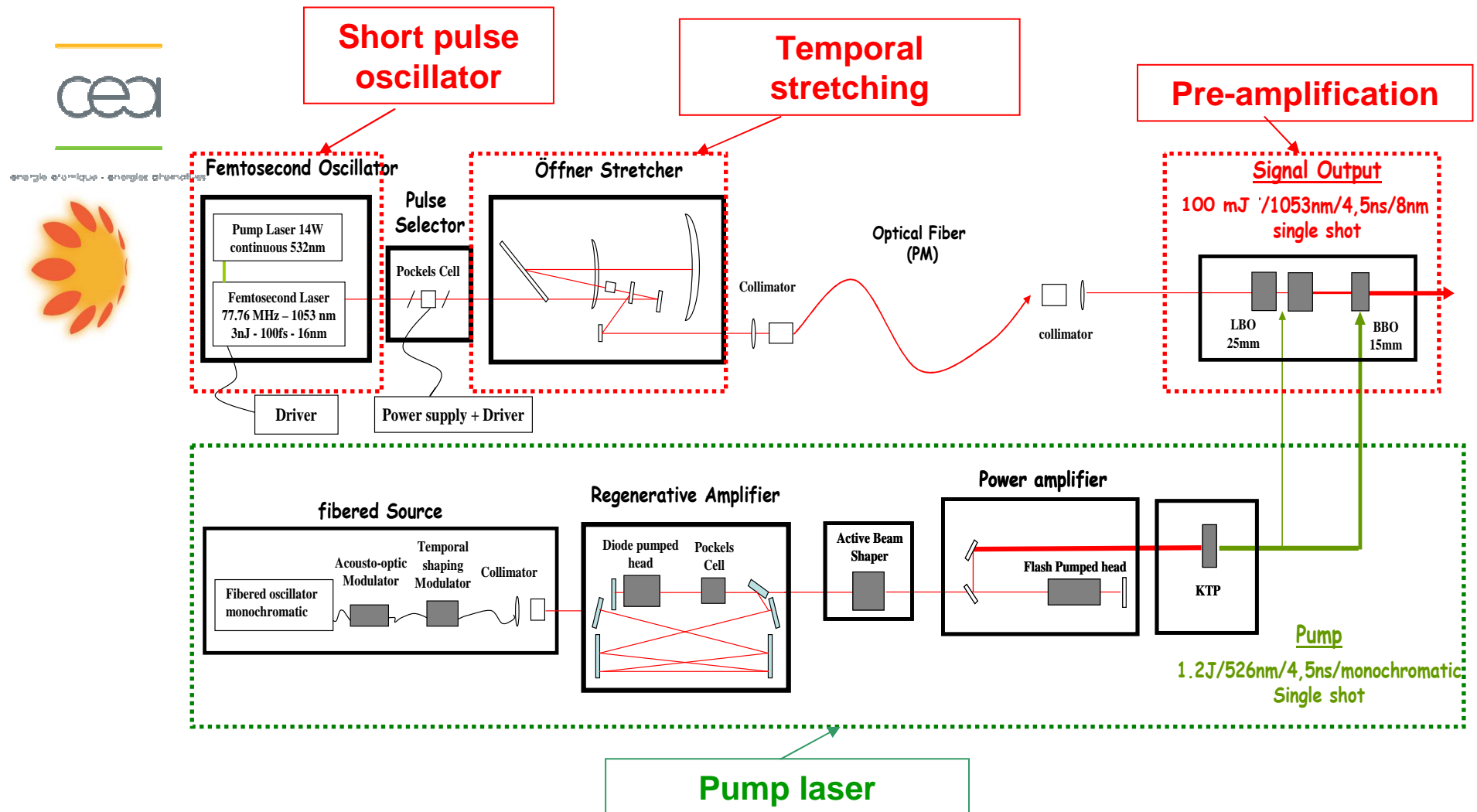
Phases IV and V

Coupling to the  
Quad



Transport  
Focusing

# Front-End Architecture\* : OPCPA Technique



\* E. Hugonnot et al., Appl. Opt. 45 (2006)

# PAM Performances

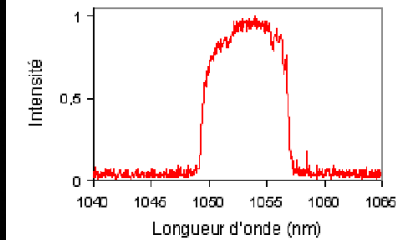
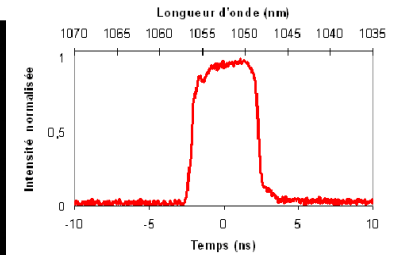
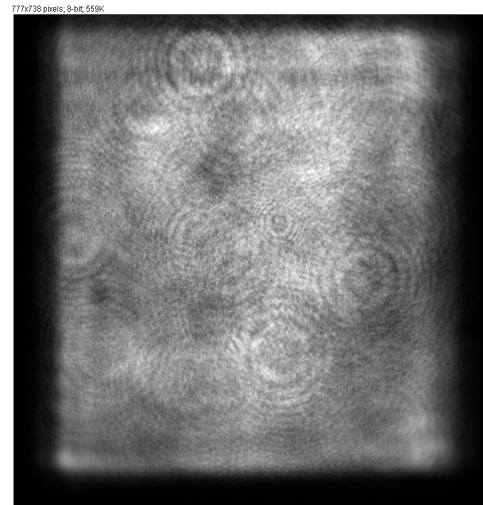


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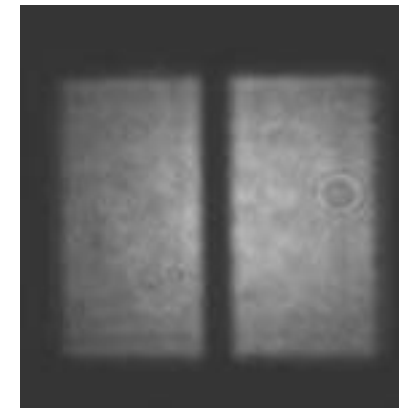
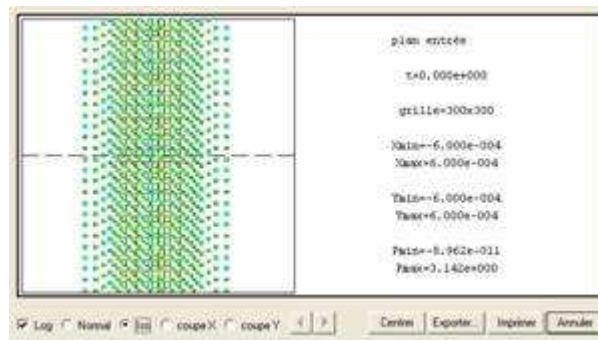
## PAM output\* :

- Flat top square beam
- Stretched pulse :  $\Delta t=4,5\text{ns}$ ,
- Spectrum  $\Delta\lambda=8\text{nm}$



## Beam shaping for compressor scheme :

- Phase plate + spatial filter



\* E. Hugonnot et al., Appl. Opt. **46** (2007)

# Integration of the PAM

Pump side



OPCPA side



PAM in the compressor room



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# Integrated PAM Performances

→ Long time and stable running under investigation for the integrated PAM

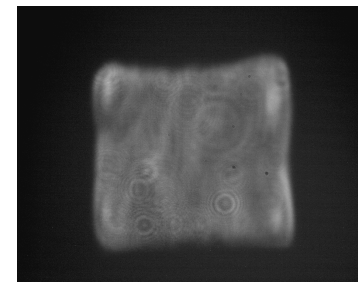
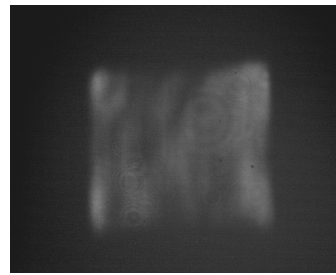
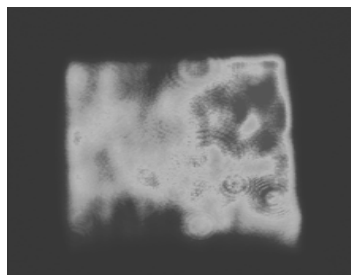


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Tilts of crystals in their neutral axis :  
OPG (optical parametric generation)

Vacuum tube in the 1st arm (pump)

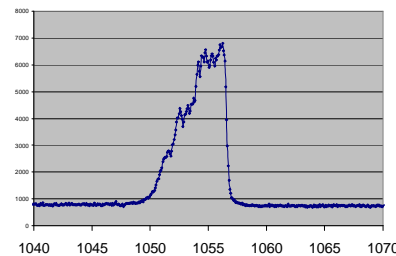


**E a = 58mJ**

E2w 1<sup>st</sup> arm = 127mJ

E2w 2<sup>nd</sup> arm = 551mJ

TIR N°22

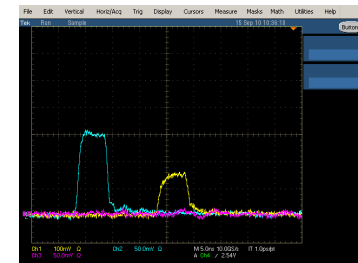
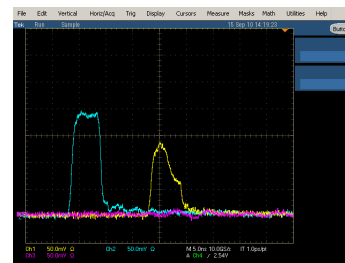
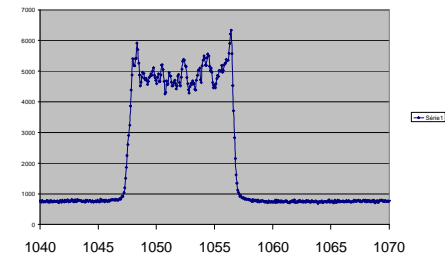


**E a = 81.7mJ**

E2w 1<sup>st</sup> arm = 161.1mJ

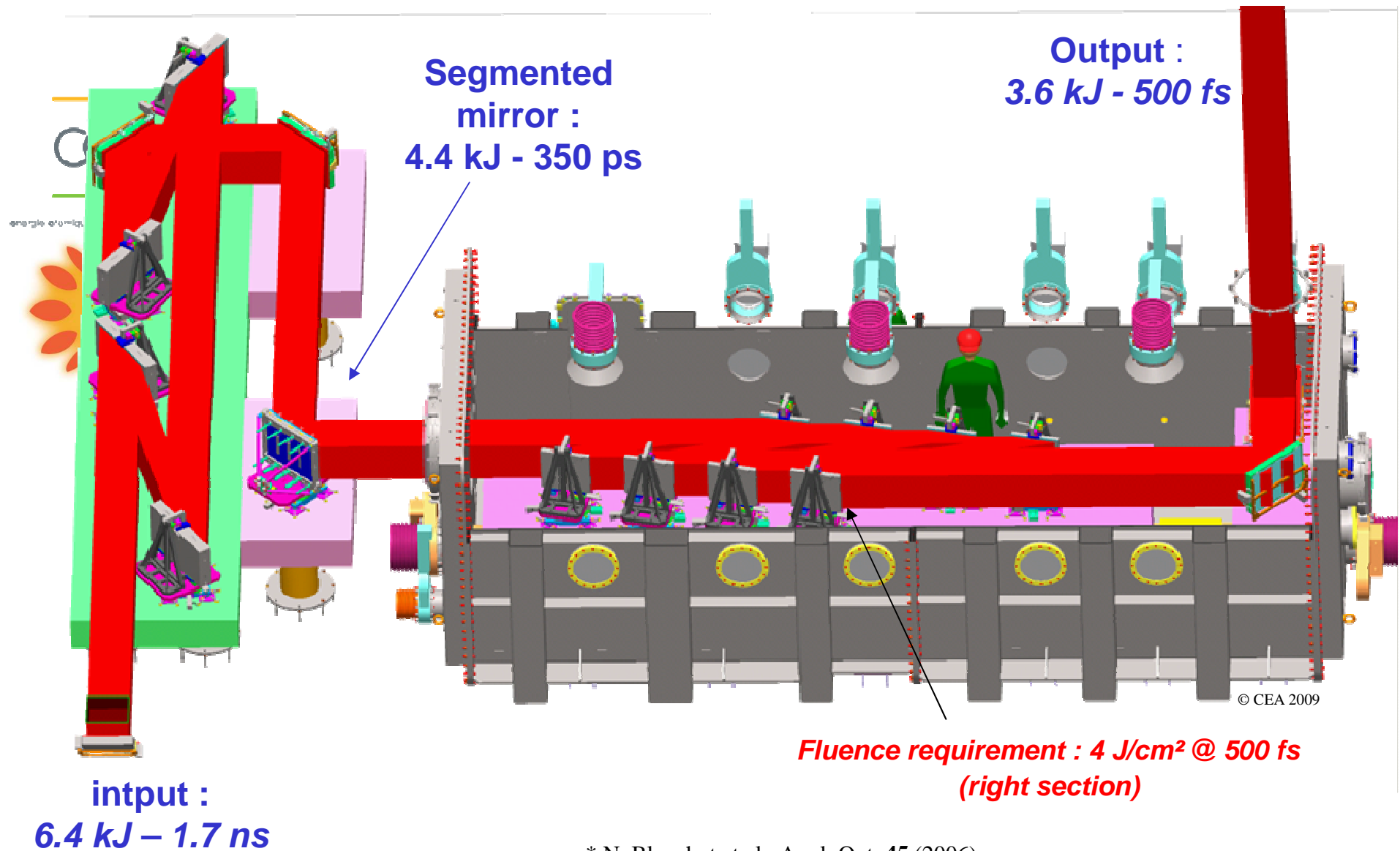
E2w 2<sup>nd</sup> arm = 484mJ

TIR N°6





# Segmented beam Compression Scheme



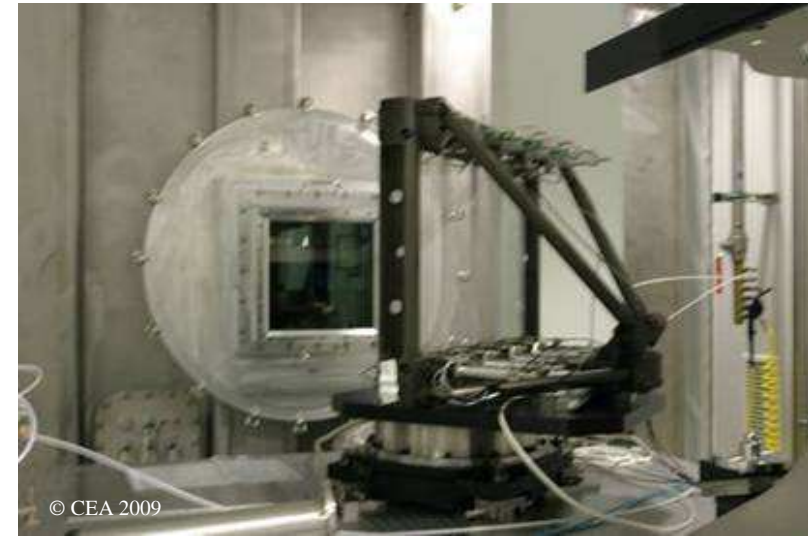
\* N. Blanchot et al., Appl. Opt. 45 (2006)



# Compression stages on the LIL facility

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# PETAL : 2D- Spectral Interferometry

PETAL : synchronization at 50 fs with 8 nm, sub-apertures, with longitudinal and transverse chromatisms



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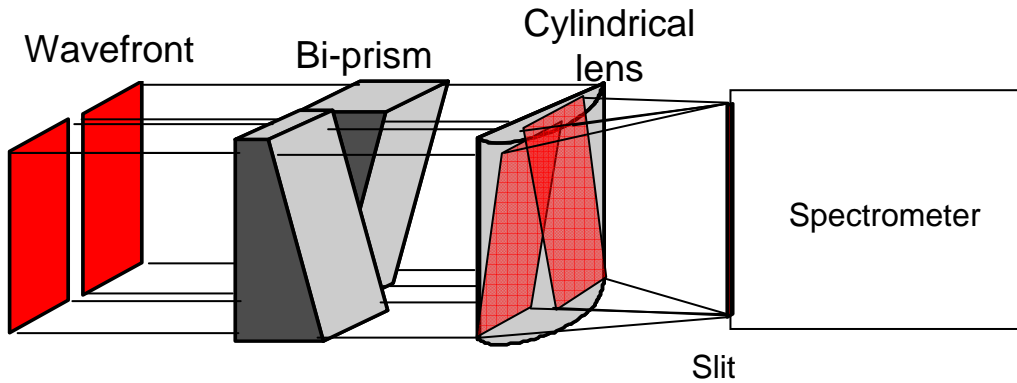
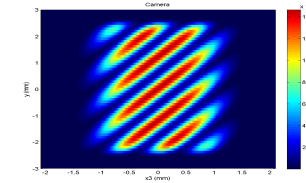
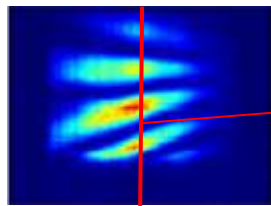


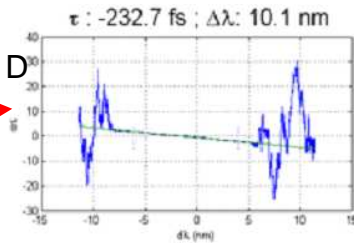
Image on the CCD



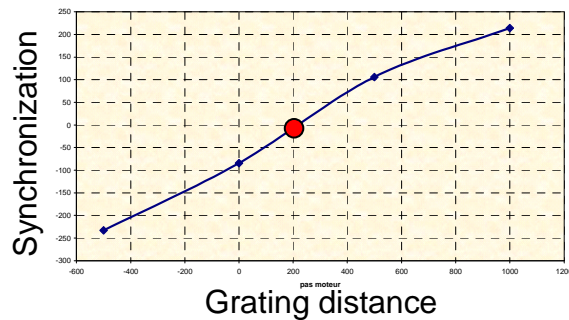
Delay = 3 ps



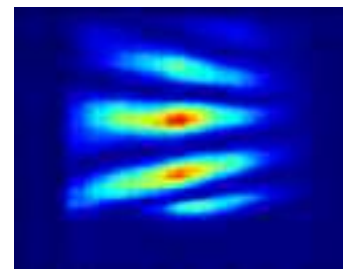
FFT-1D



→ 2D-SI, more than synchronization measurements : temporal distortion difference

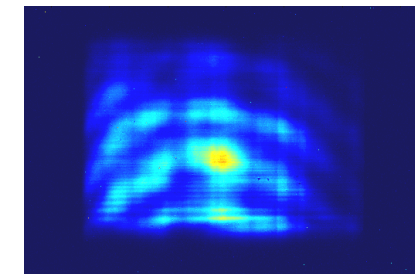


Groove rotation



Fan shaped fringes

Residual chirp



Curved fringes

\* N. Blanchot et al., Plasma Phys. Control. Fusion, **50** (2008) & N. Blanchot et al., Opt. Express **18**, 10088-10097 (2010)

# Sub-aperture beams phasing

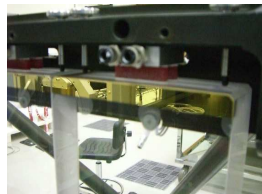
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PZT



Gold band for capacitive sensors

Action with Segmented Mirror

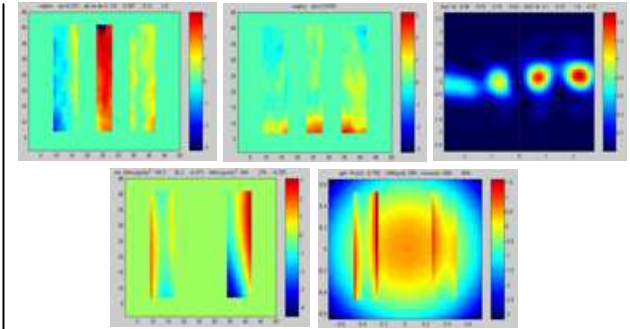
SID4\*



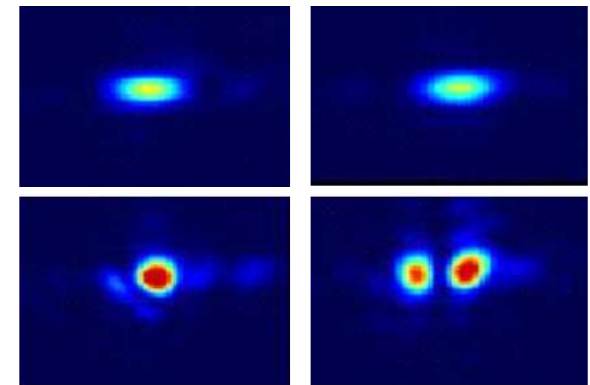
Far field

Diagnostics

\* S. Mousset et al., Opt. Lett. **31** (2006)



Focal spot\*\* after compression :  
 - each independent compressors  
 - Pistons of 0 nm and 500 nm



Results

\*\* S. Montant et al., Opt. Express **14** (2006)



# PETAL Project Phases

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Phase I  
Key issues

Phases II and III  
full power  
independent PW  
beam

Phases IV and V  
Coupling to the  
Quad



Front End  
Compression -  
Stage



Amplifier  
Section



Transport  
Focusing

# Laser bay



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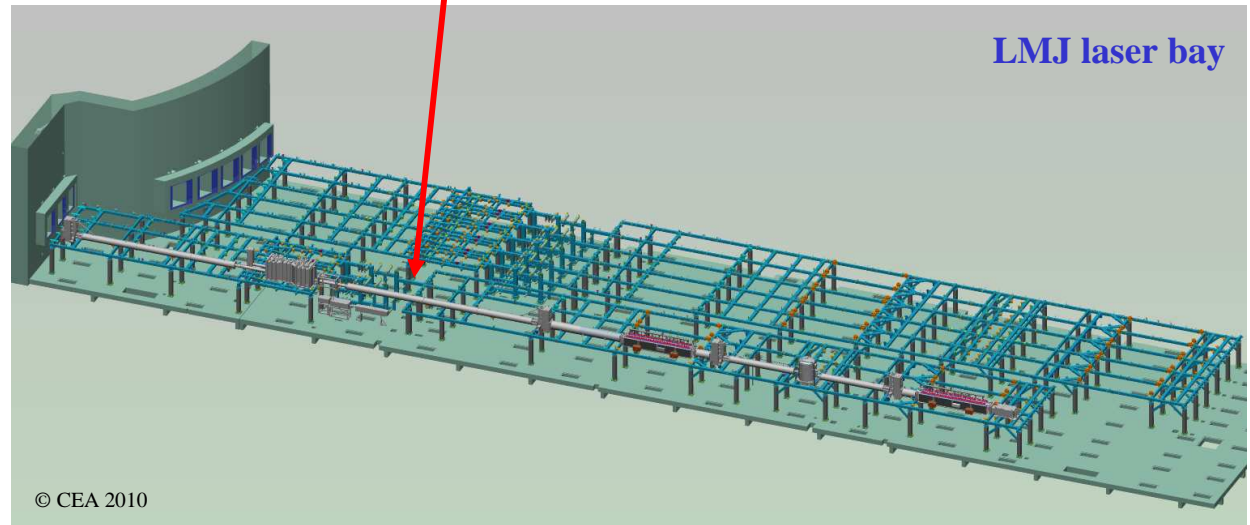
Centre de Recherches en Physique des Particules - GSI



LIL

© CEA

**PETAL  
PW beam**

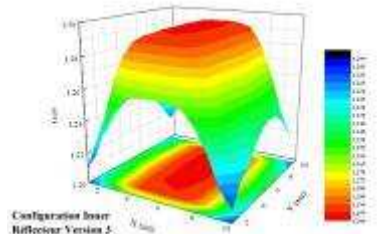
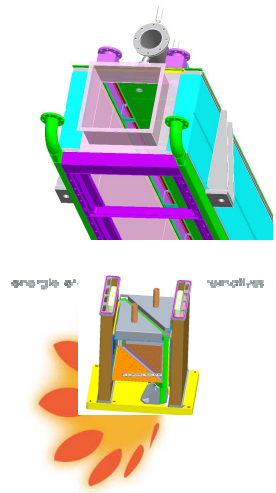


LMJ laser bay

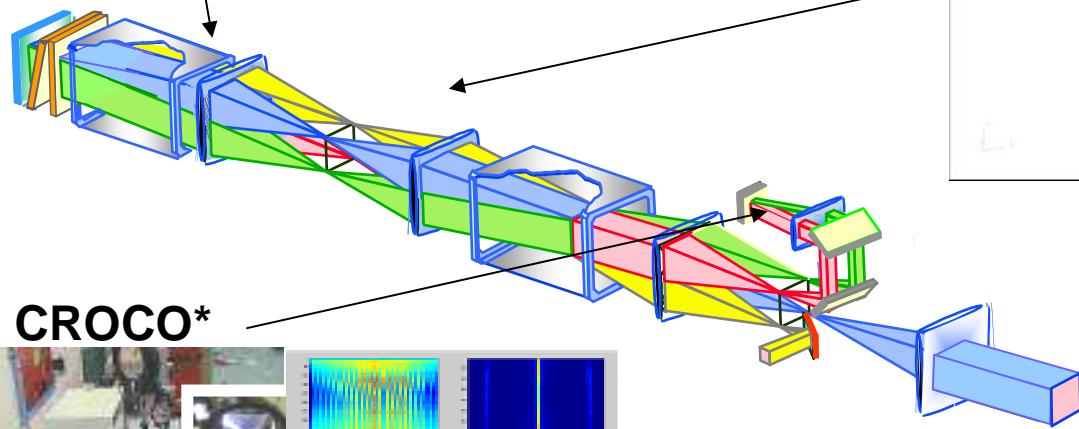
© CEA 2010

# PETAL amplifler section

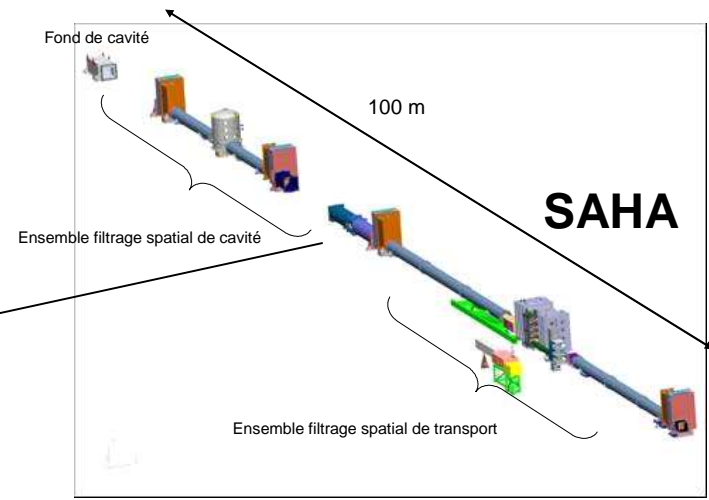
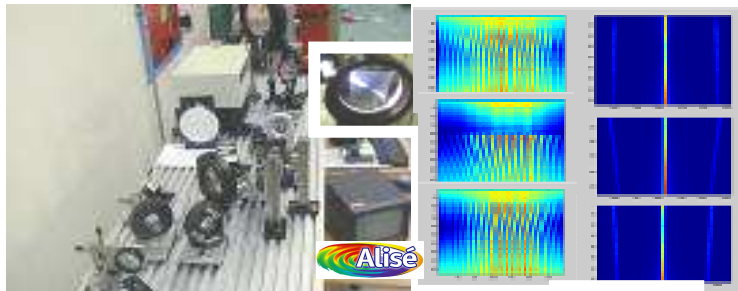
**LIL → PETAL : 4 x 2 → 1 x 1**



**Amplifieurs**



**CROCO\***



**SAHA**

**Mechanical supports**



\* C. Rouyer, Opt. Express **15**, 2019-2032 (2007)  
 J. Néauport et al, Appl. Opt. **46**, 1568-1574 (2007)

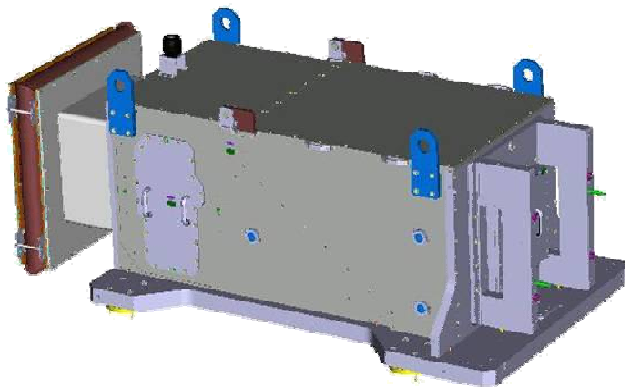
# Filtration chambers and cavity end

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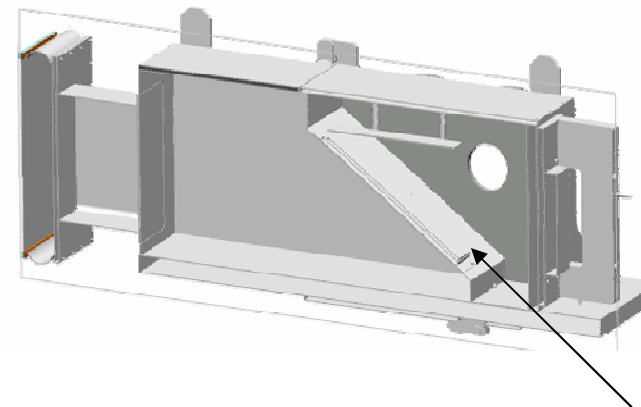
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## Cavity end with the polarizer



From cavity  
amplifier  
2% hygrometry



Polarizer  
35% hygrometry

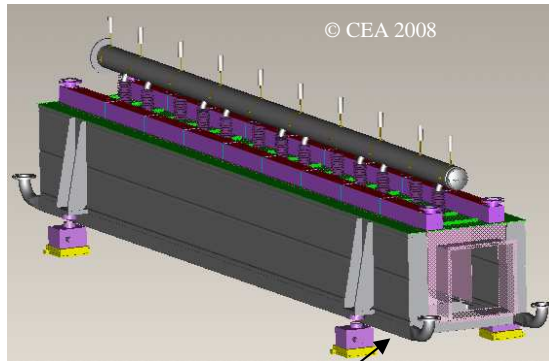


# Amplifiers : Fabrication in progress\*

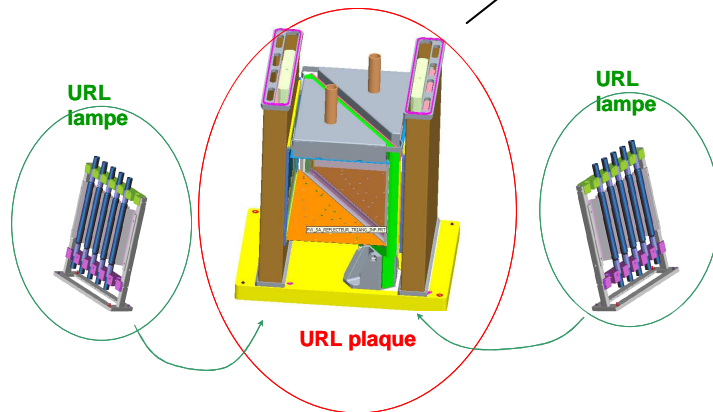
\* Prototype : tests in Q4 - 2009

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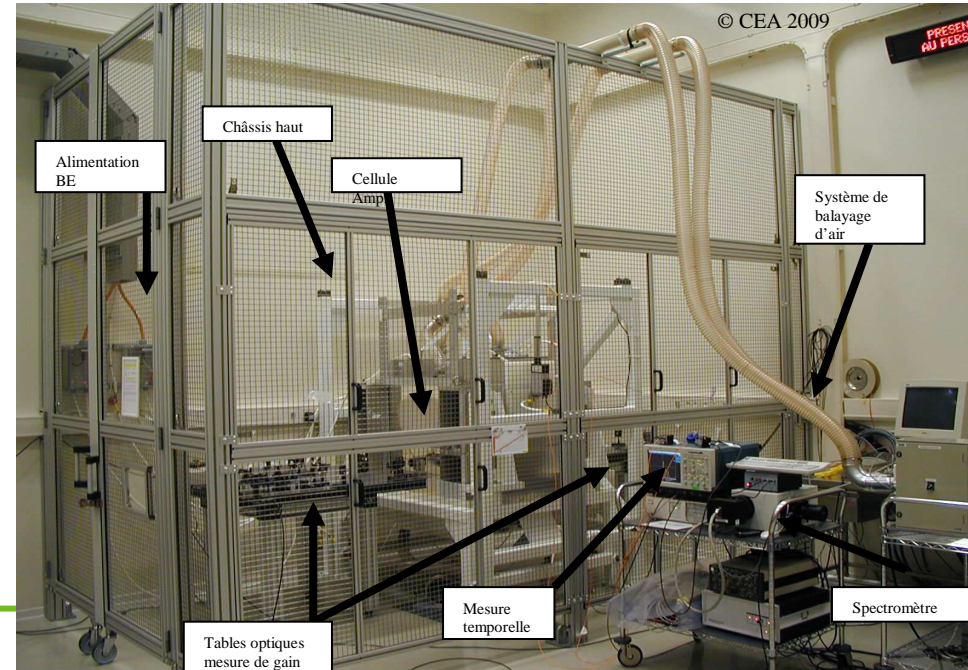
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- Transverse gain measurements
- Cooling system
- Contamination measurements



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Alimentation BE

Châssis haut

Cellule Amp

Système de balayage d'air

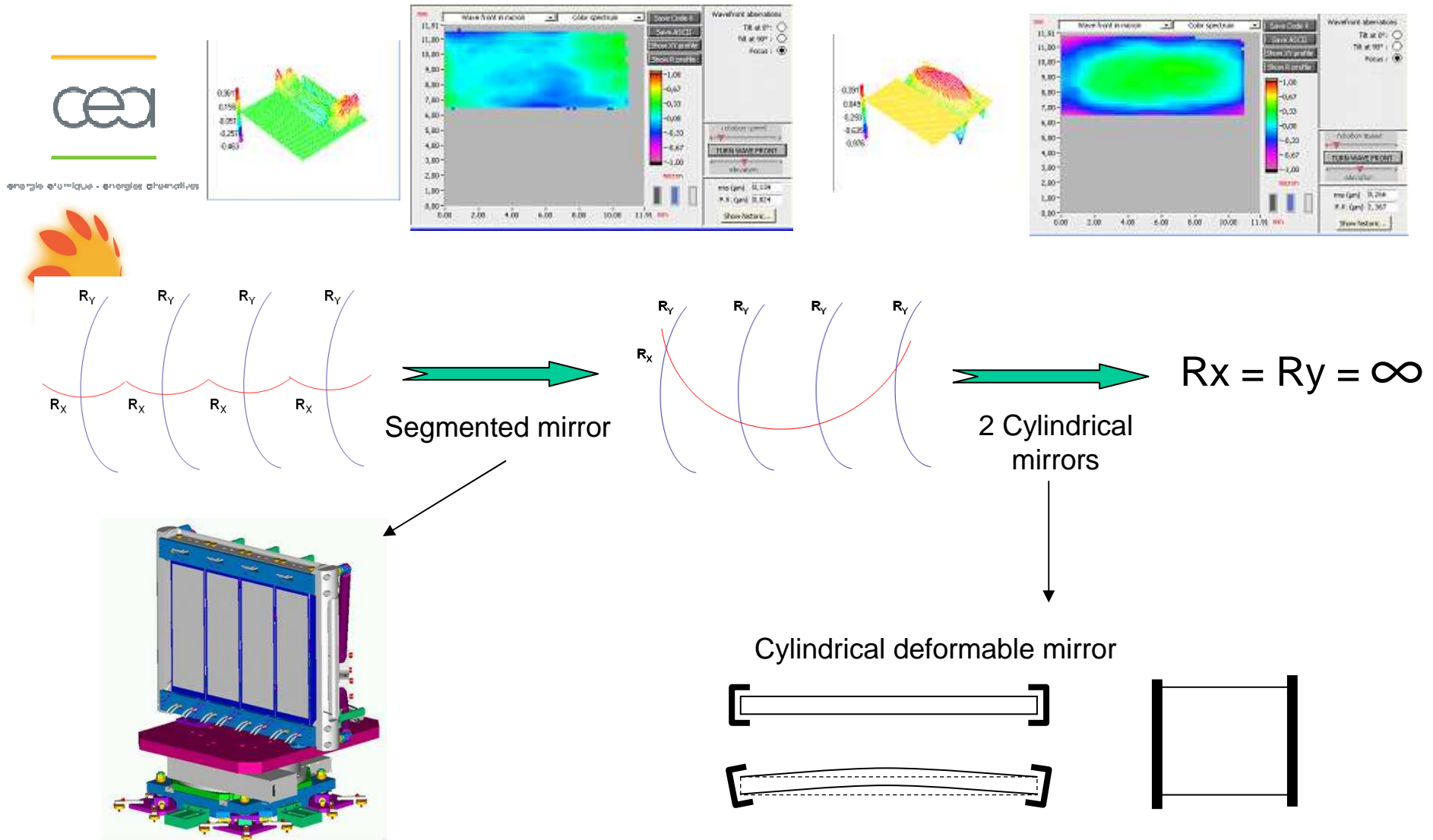
Mesure temporelle

Spectromètre

Tables optiques mesure de gain

# Compression wavefront correction

Wavefront deformation due to grating modification under vacuum : pre-correction in air

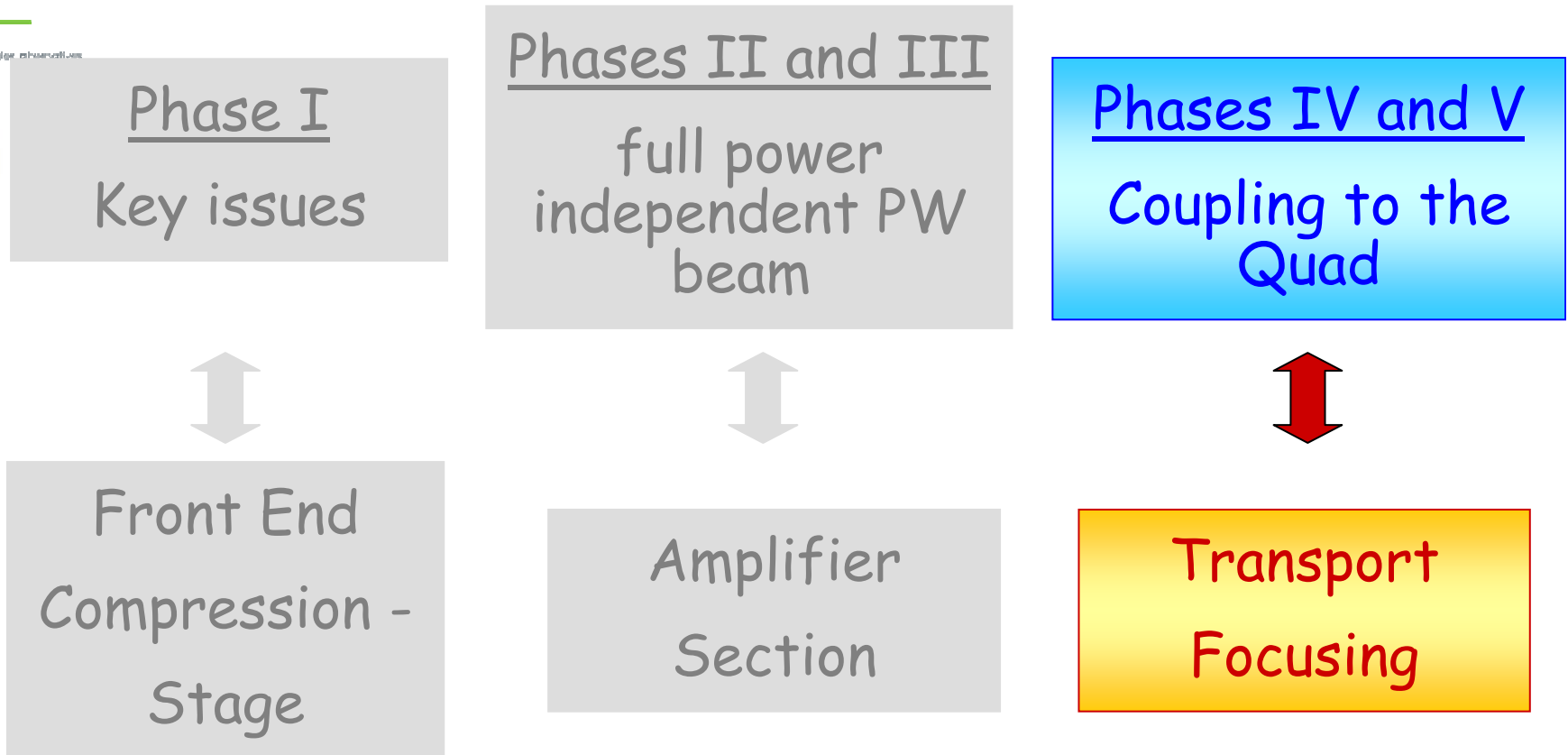


# PETAL Project Phases

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شركة الطاقة - شركة الطاقة



# Transport mirrors for compressed beam

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- **Mirror campaign :**

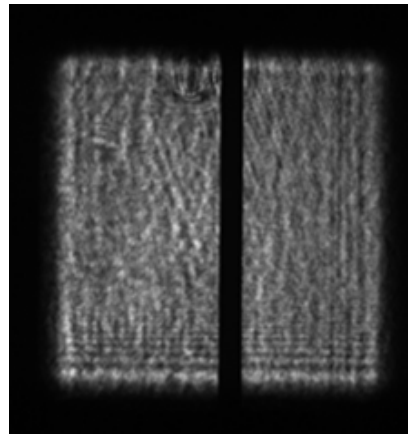
Mirror for future MLD gratings tested at 72° in polarization S > 4 J/cm<sup>2</sup> @ 500 fs

- **Extrapolation at 45° incidence angle for transport :**

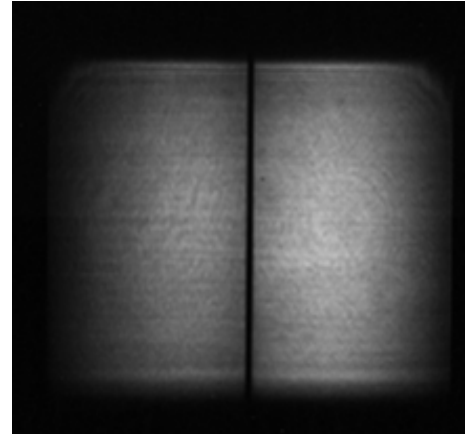
2.5 J/cm<sup>2</sup> at best... Spec at 4 J/cm<sup>2</sup> @ 500 fs

→ Efforts on the MLD (fabrication process) have to be done

- Specifications with the LIL modulations, **beam smoothing** for PETAL with transverse chromatism → decrease of the specification



Monochromatic pulses

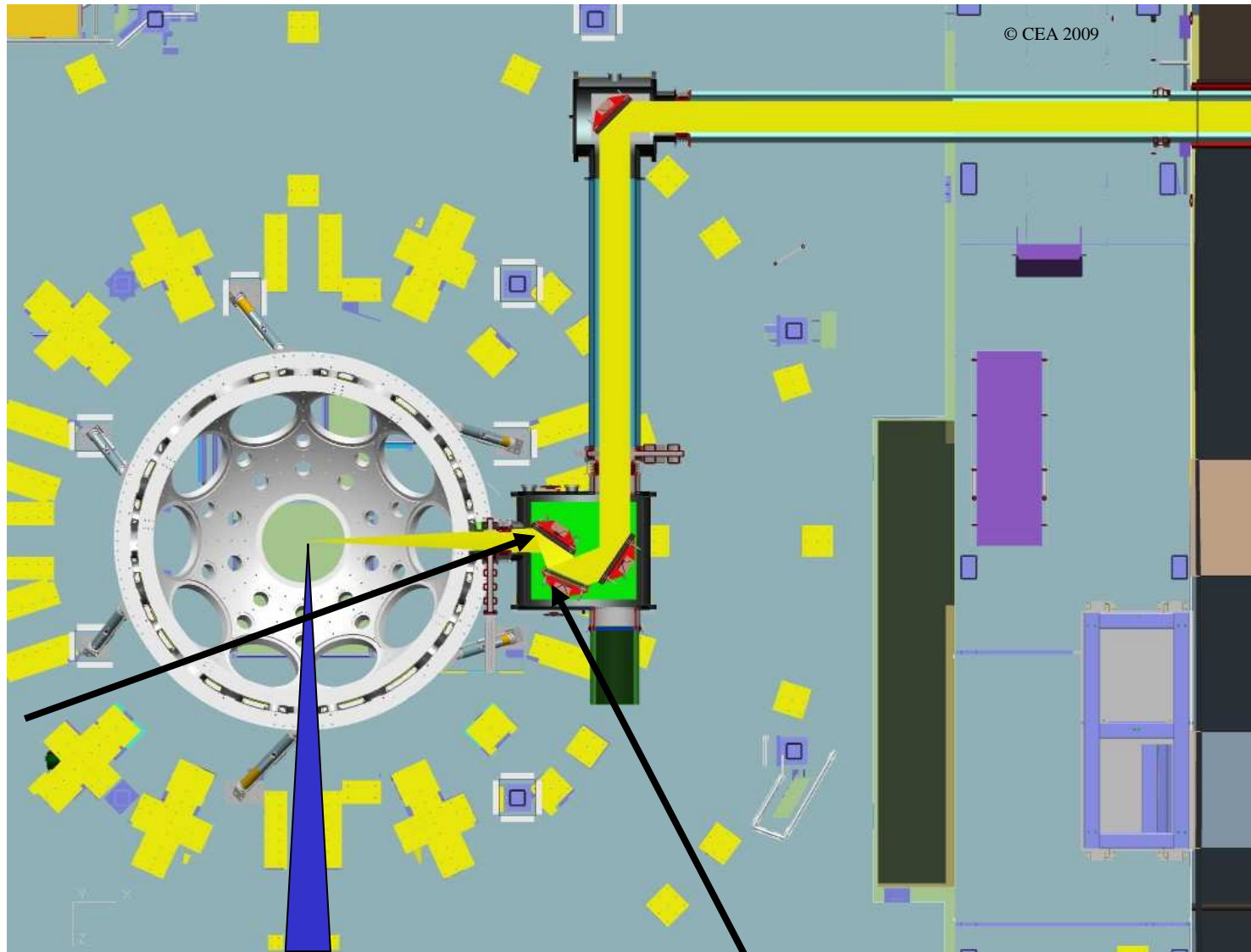


Femtosecond pulses

N. Bonod et al, Opt. Comm. **260**, 649-655 (2006), J. Neauport et al, Opt. Express **15**, 12508-12522 (2007),  
S. Palmier et al, Opt. Express **17**, 20430-40439 (2009)



# Focusing configuration : top view

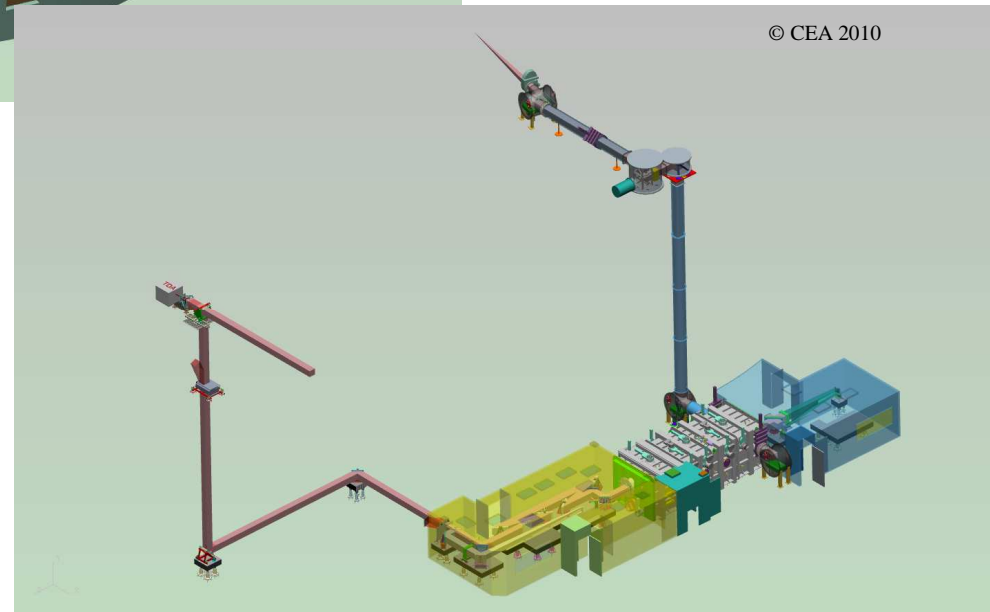
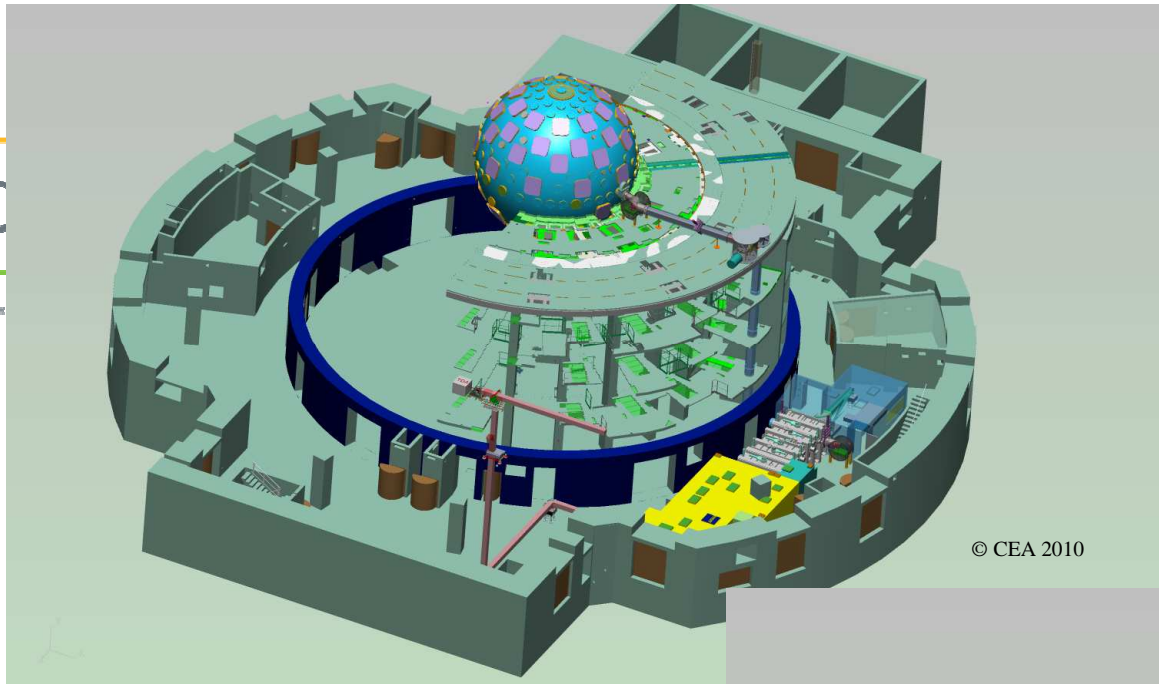


Pointing mirror

Quad LIL

Off axis Parabola : 90° deviation

# Transport Compression Focalisation in LMJ



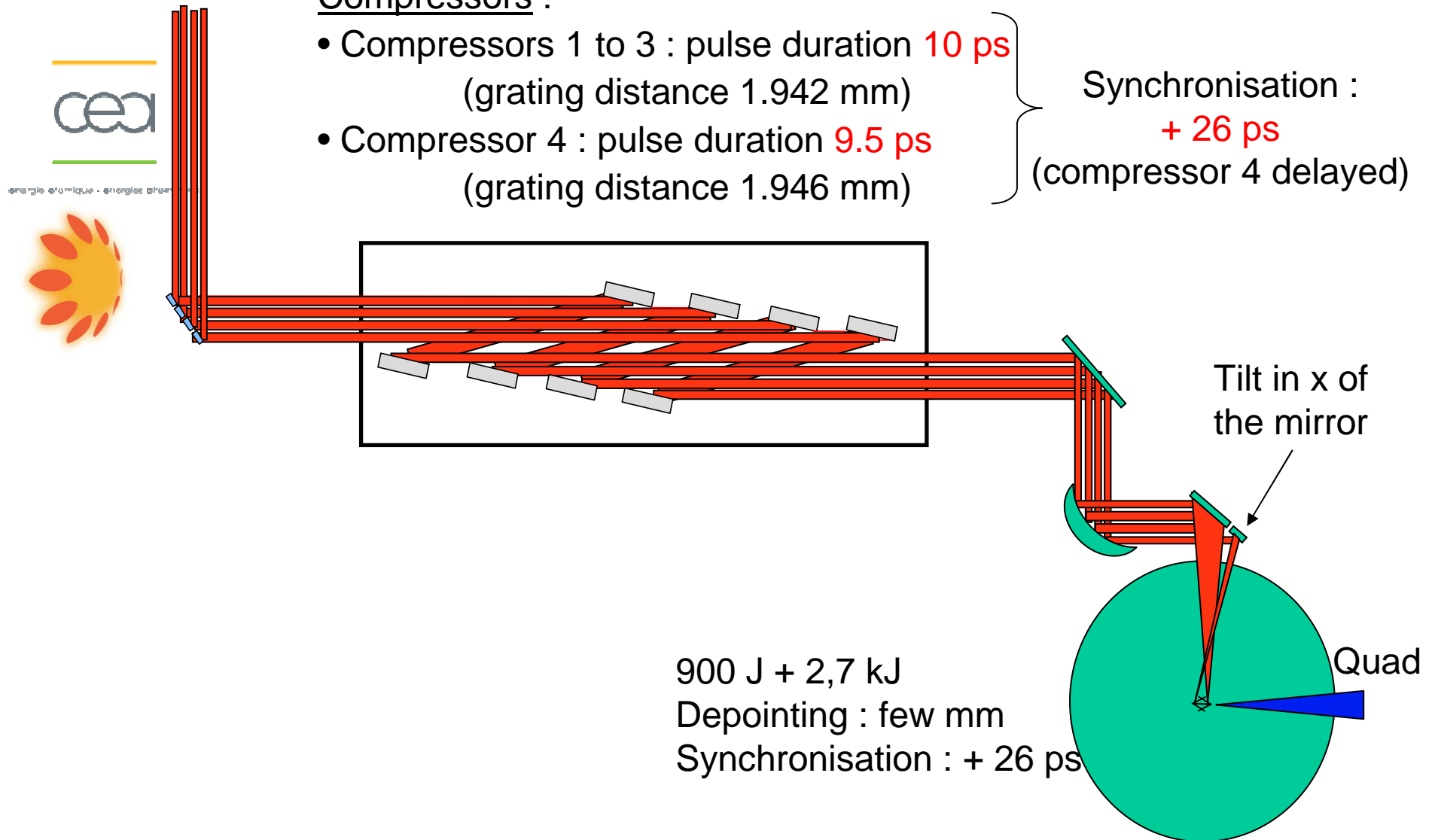
*Preliminary studies*

# Reservation for 2 beams configuration on target

## Compressors :

- Compressors 1 to 3 : pulse duration **10 ps**  
(grating distance 1.942 mm)
- Compressor 4 : pulse duration **9.5 ps**  
(grating distance 1.946 mm)

Synchronisation :  
**+ 26 ps**  
(compressor 4 delayed)





# PETAL contributors

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**And many other contributors !**