Power amplifier for Ti:Sapphire *multi* 100 TW and PW lasers:

Key Choices for quality…

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ICUIL 2008

Oct 27-31, 2008, Shanghai-Tongli, China

Amplitude Technologies

Leading Company in High Energy Femtosecond Lasers

100% market share in Europe !!

80% market share worldwide

Amplitude Group: 56 employees, 7 more persons in 2009

Amplitude Technologies: 30 employees

Total Turnover: 2008-2009 10 Millions €

Net profit :6 - 12 % from its beginning

Activities: > 90% Export

Amplitude TECHNOLOGIES

Amplitude Technologies 100 TW 10 Hz class Lasers

Customers references…

HAMAMATSU PHOTON IS OUR BUSINESS

NTLF

ALLS Advanced Laser Light Source

HEINRICH HEINE UNIVERSITÄT DÜSSELDORF

Forschungszentrum Dresden Rossendorf

MAX-PLANCK-GESELLSCHAFT

INFN

ACADEMIA OAMENILOR DE STIINTA DIN ROMANIA FONDATA 1936 ACADEMY OF ROMANIAN SCIENTISTS

IRAMIS

University of Strathclyde Glasgow

Amplitude TECHNOLOGIES

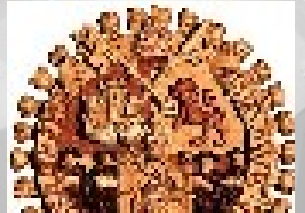
Amplitude Technologies 100 TW 10 Hz class Lasers

Customers references…

HAMAMATSU 100 TW

200 TW

20 TW



20 TW

100 TW

150 TW

Front-end 100 TW

MAX-PLANCK-GESELLSCHAFT

250 TW

INFN

20 TW

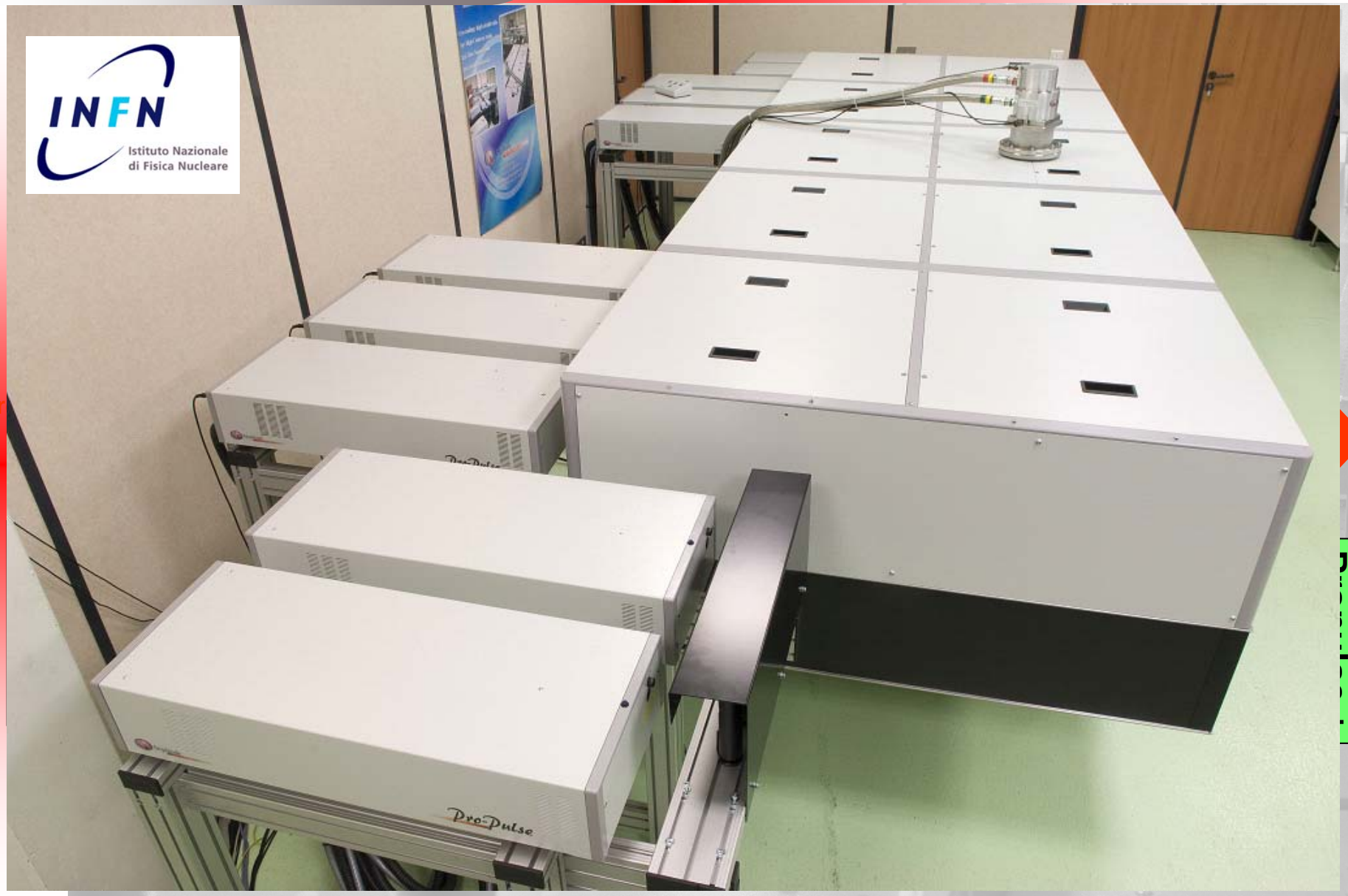
100 TW

IRAMIS

40 TW

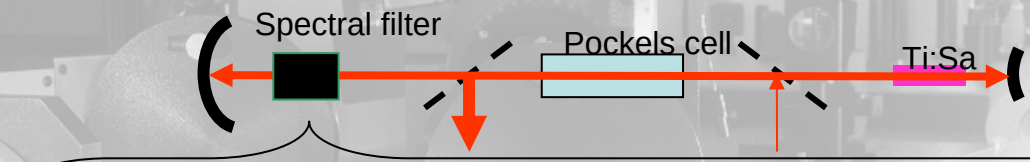
University of Strathclyde Glasgow

Amplifier set-up

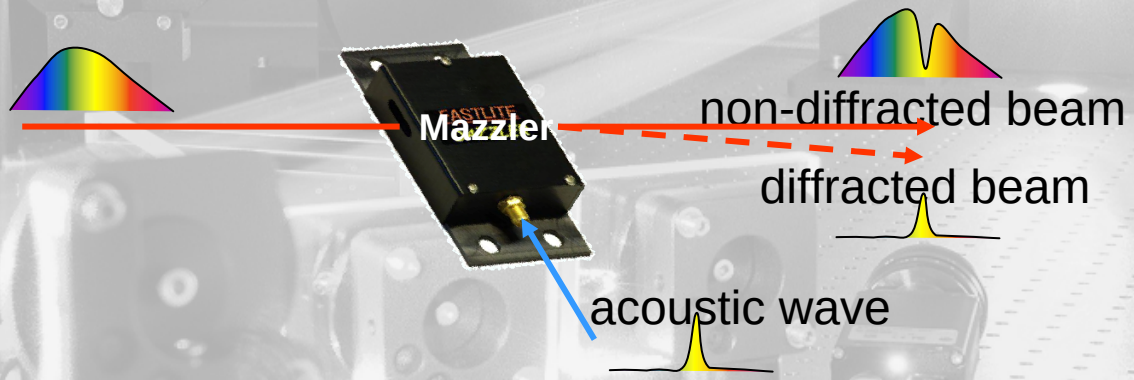


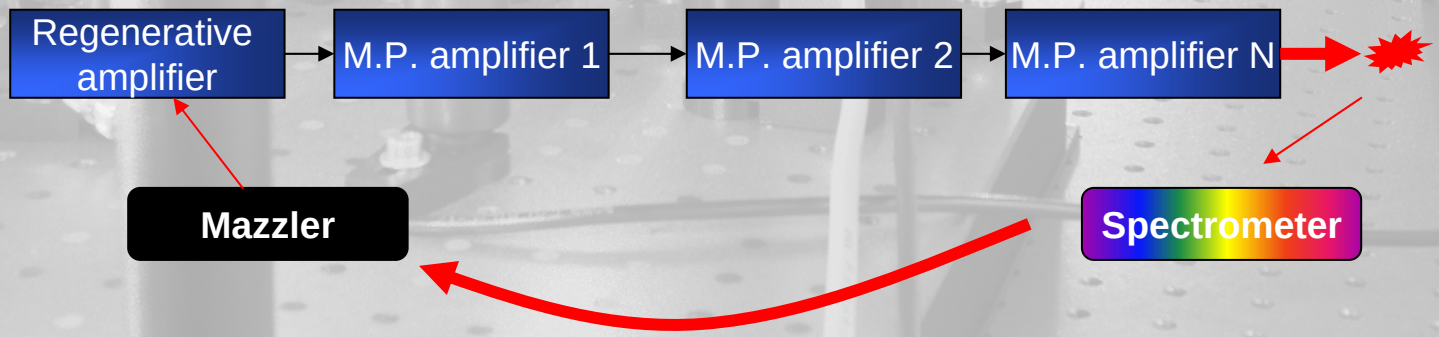
Gain narrowing control in power amplifier

Acousto-Optic Programmable Gain Control Filter (Mazzler)



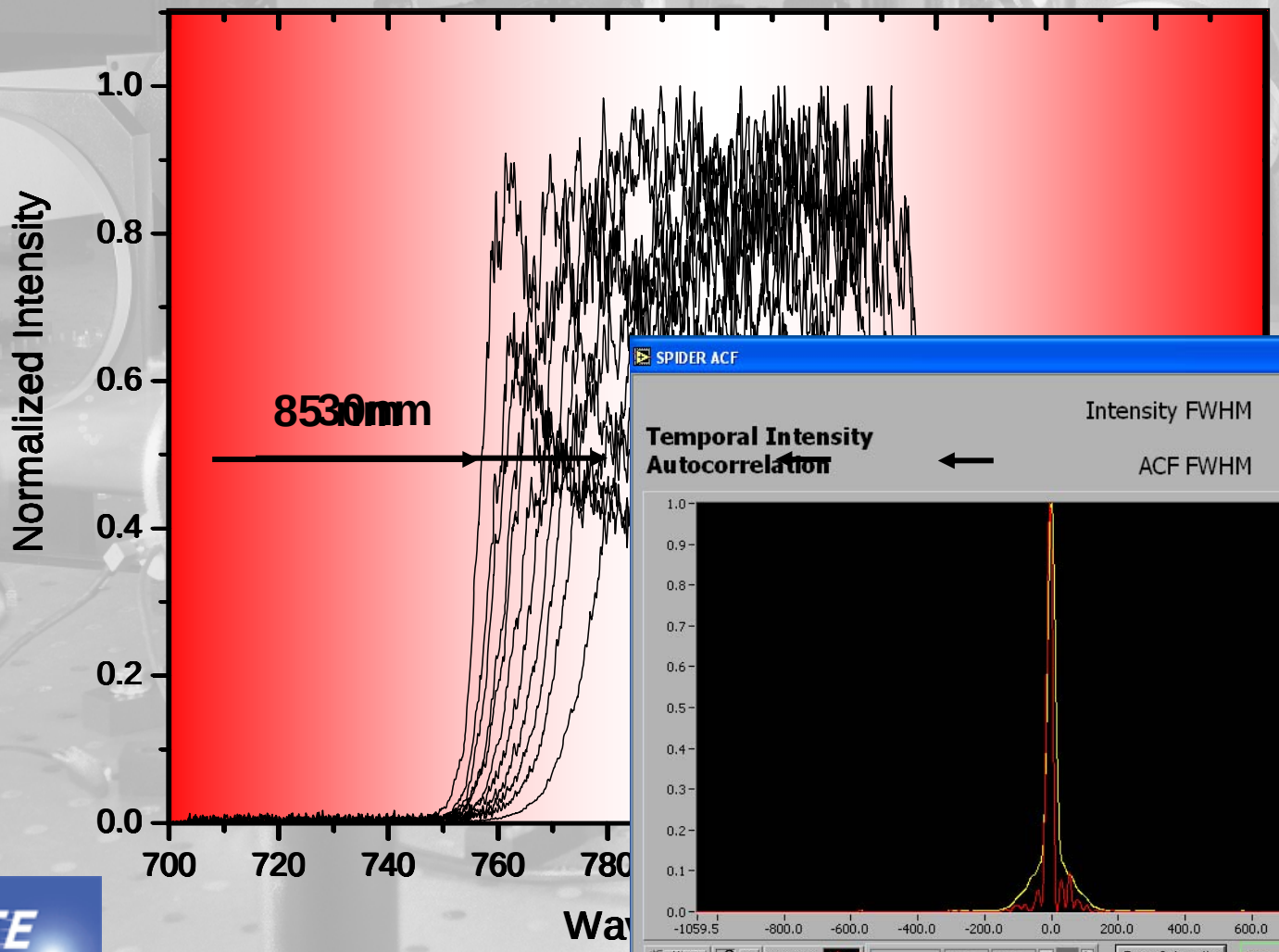
Acousto-Optic Programmable Gain Control Filter (AOPGCF)





Amplitude TECHNOLOGIES

Gain narrowing control in power amplifier



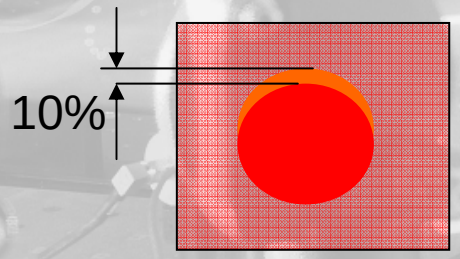
FASTLITE

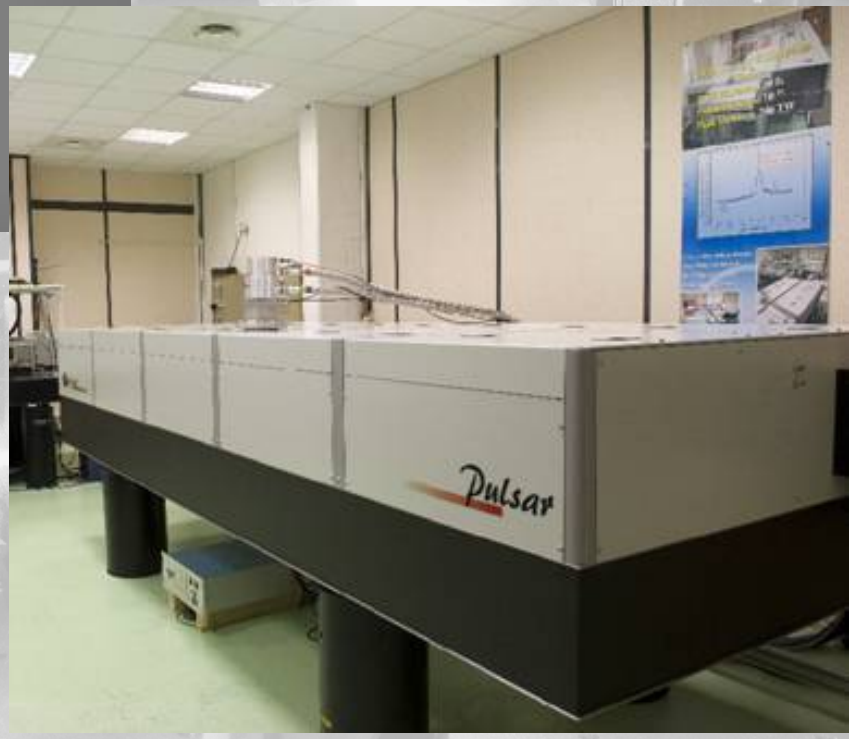
Sources of energy instabilities in power amplifier

-Input energy stability : $\sigma_{in\ 800\ nm}$

-Pump laser(s) (Nd:YAG) stability : σ_{pompe}

- alignment stability / beam pointing





$\delta\theta$ main amplifier : 200 µrad
$\delta\theta$ stretcher : 20 µrad

Improvement of energy stability

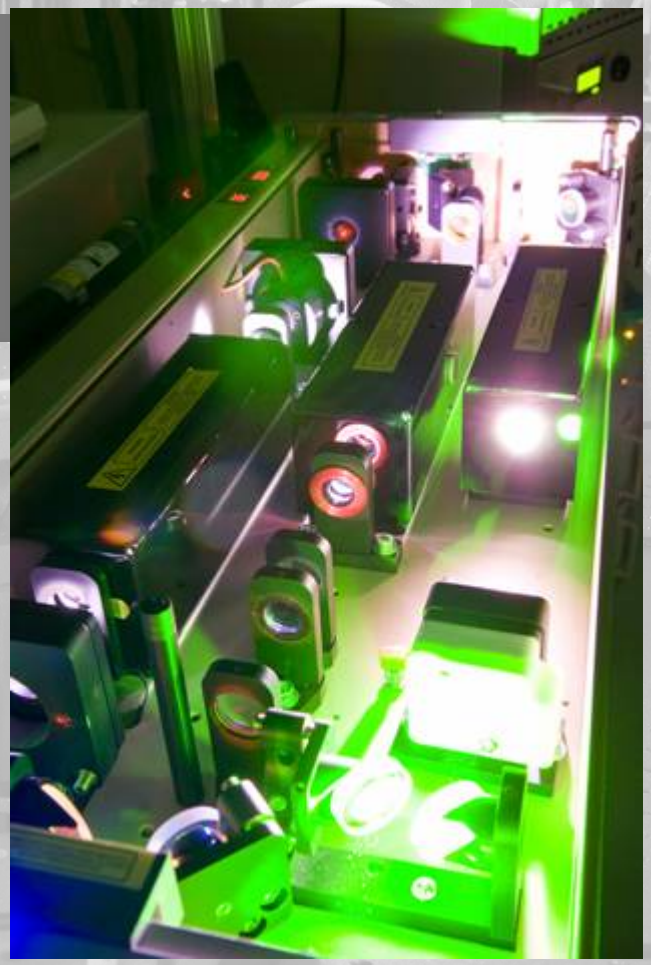
Pump lasers mixing

Nd:YAG pump stability : σ_{pompe} =1,2 % RMS

Mixing of N lasers :

Total pump stability : $\sigma_{\Sigma pompes} = \sigma_{pompe} / \sqrt{N}$

Calculated Values	
Number of lasers	**Shot to shot stability**
1	**1,2% RMS**
4	**0,6% RMS**
6	**0,5% RMS**
8	**0,4% RMS**



Energy stability
Impact of gain saturation

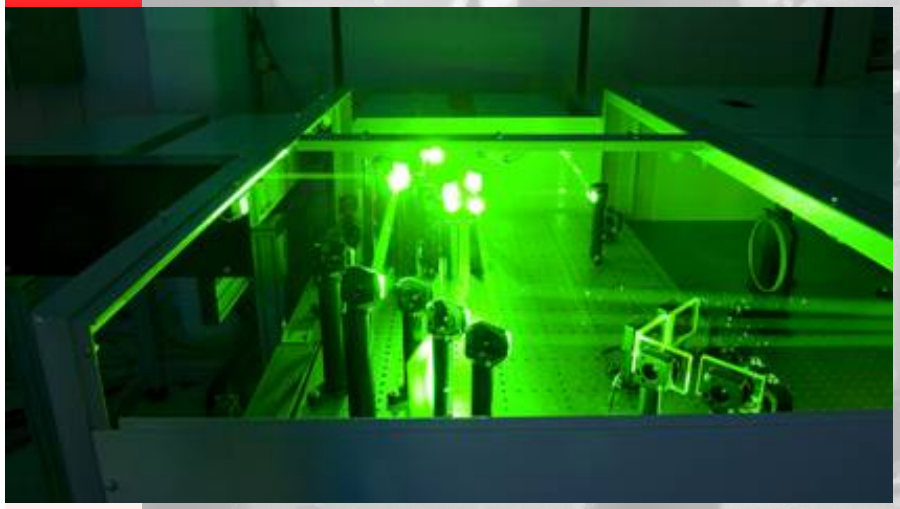
Modeling parameters :

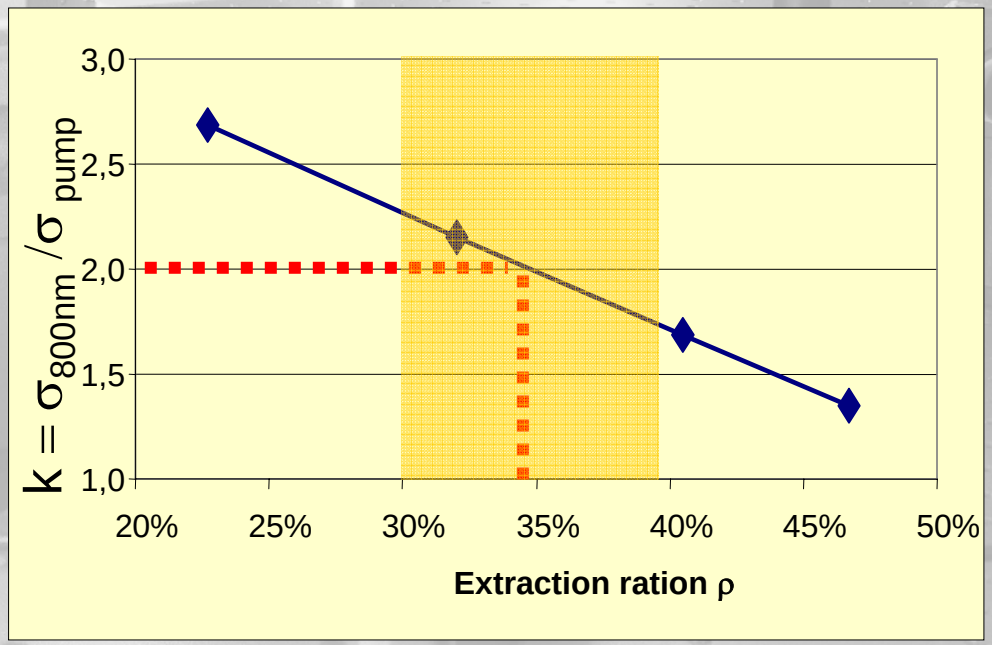
- 4 passes amplifier
- Maximum amplifier losses (FOM, geometric) 20%
- Single pass gain : 3
- Extraction ration : $\rho = E_{\text{extract 800 nm}} / E_{\text{Pump absorbed}}$

$$\sigma_{800\ \nu\mu} = k \times \sigma_{pompe} / \sqrt{N}$$

N=8, k=2 , σ_{pompe} =1.2% RMS

$\sigma_{800\ \nu\mu}$ = 0,84% RMS



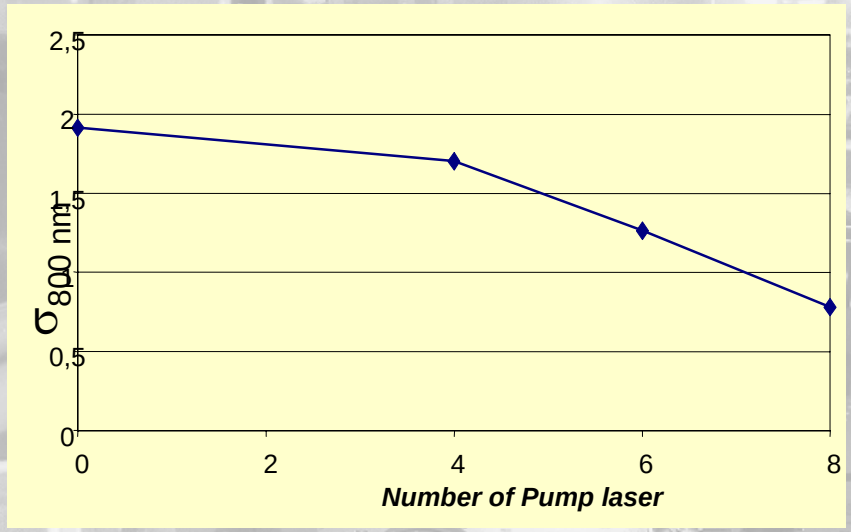


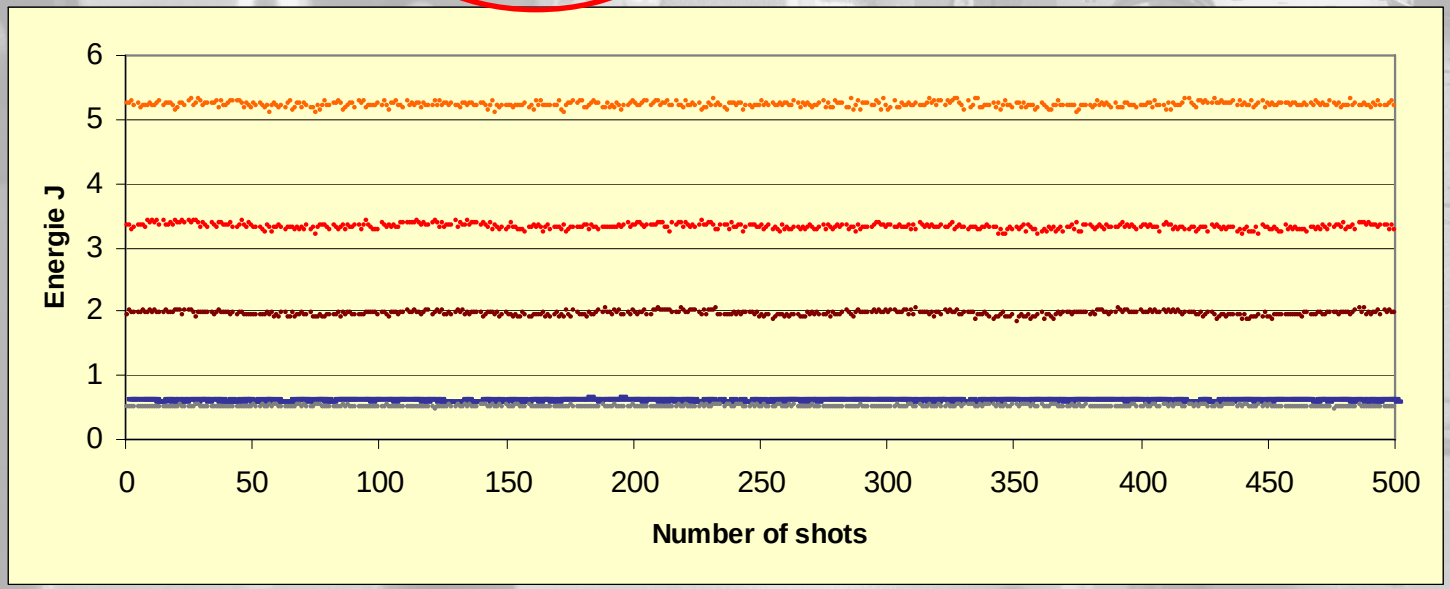
Energy stability
Pump lasers mixing

Experimental results

Measurement of energy over 500 shots.

Input energy stability:	1,9 % RMS
Input energy:	500 mJ
For N=8 :	
Total pump energy:	15 Joules
Output energy stability:	0,78% RMS
Output energy :	5,2 Joules



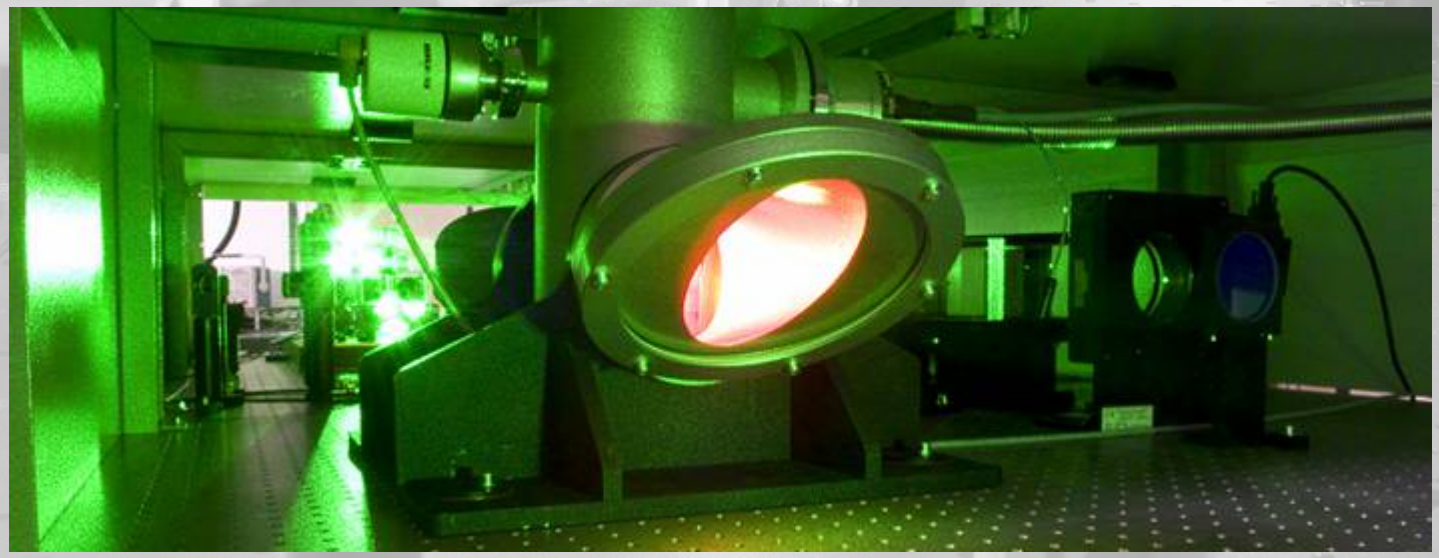


Spatial beam quality

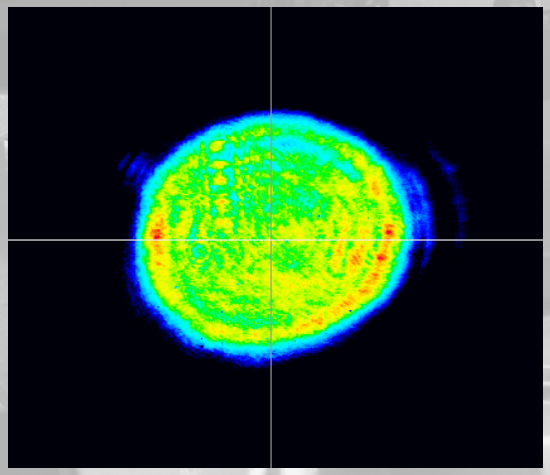
Sources of beam quality depreciation :

- Input beam quality
- Pump beam profile
- Optic quality (Ti: Sapphire)
- Thermal effects

-Beam quality :
- Amplitude defaults
- Phase defaults

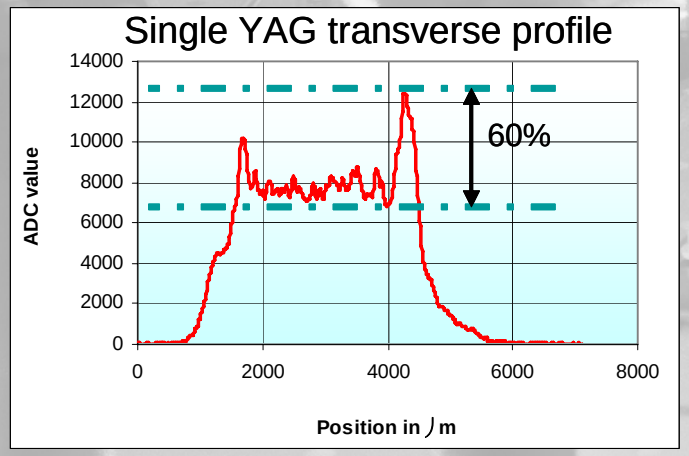


Solution to improve Spatial pump beam quality

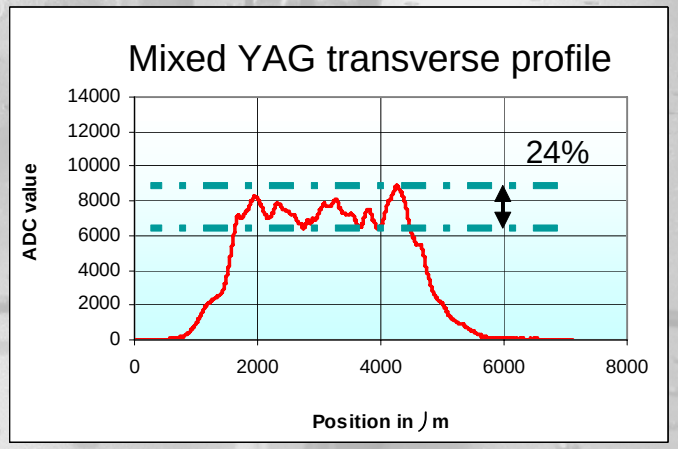


- Spatial filtering
- Beam homogenisation techniques.
- Smooth high energy pump beam profile
- **Pump laser beams mixing**

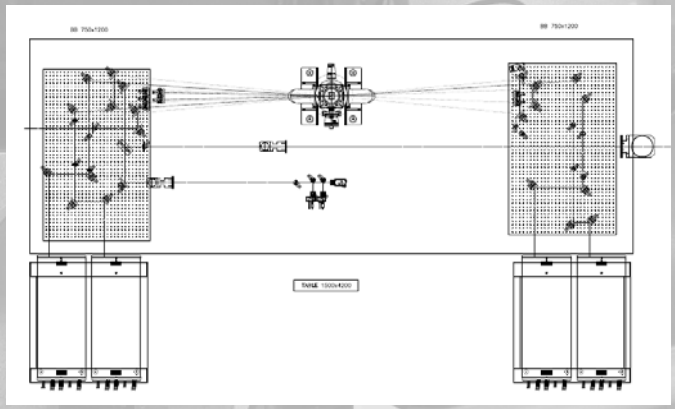
N=1



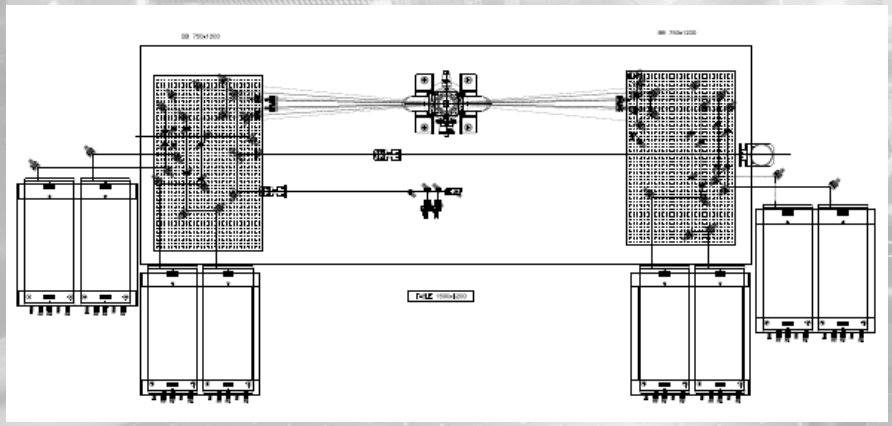
N=8



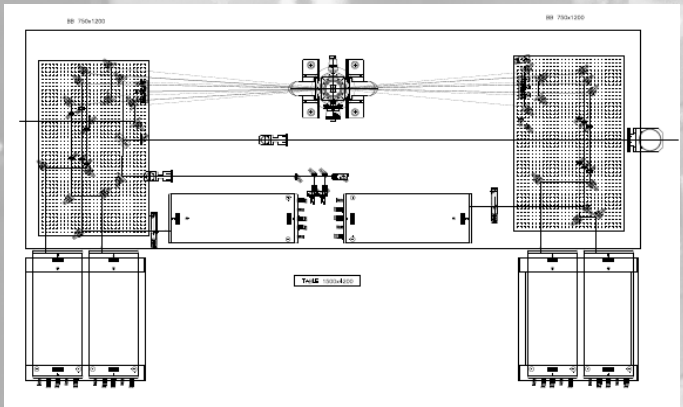
40 TW – 250 TW last amplifier



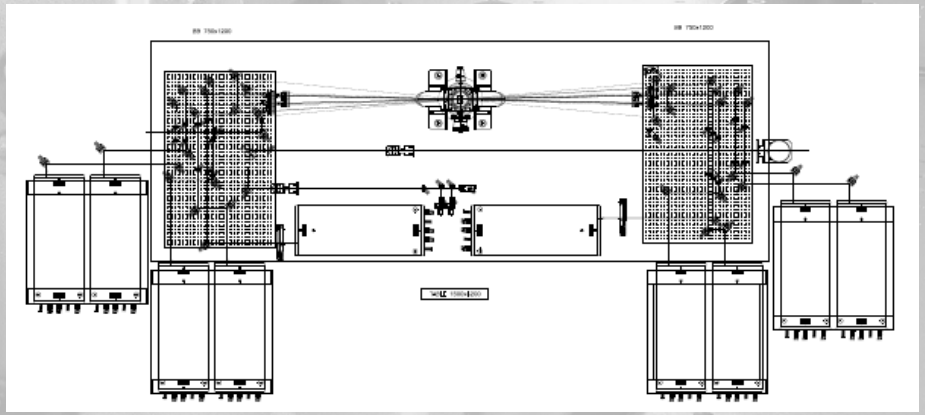
80 TW



175 TW



135 TW



250 TW

PW amplifier

Based on same approach of amplifier configuration, we have designed high repetition rate PW amplifier :

- 30J to 40J @ 800 nm output energy
- Total pump energy 100 J
- Repetition rate : 1 Hz

TITAN: The PETAWATT Pump Laser

- Energy up to 3.5J at 532nm
- Repetition rate 5Hz
- Stability < 1% RMS at 5 Hz and 1,03% at 1 Hz

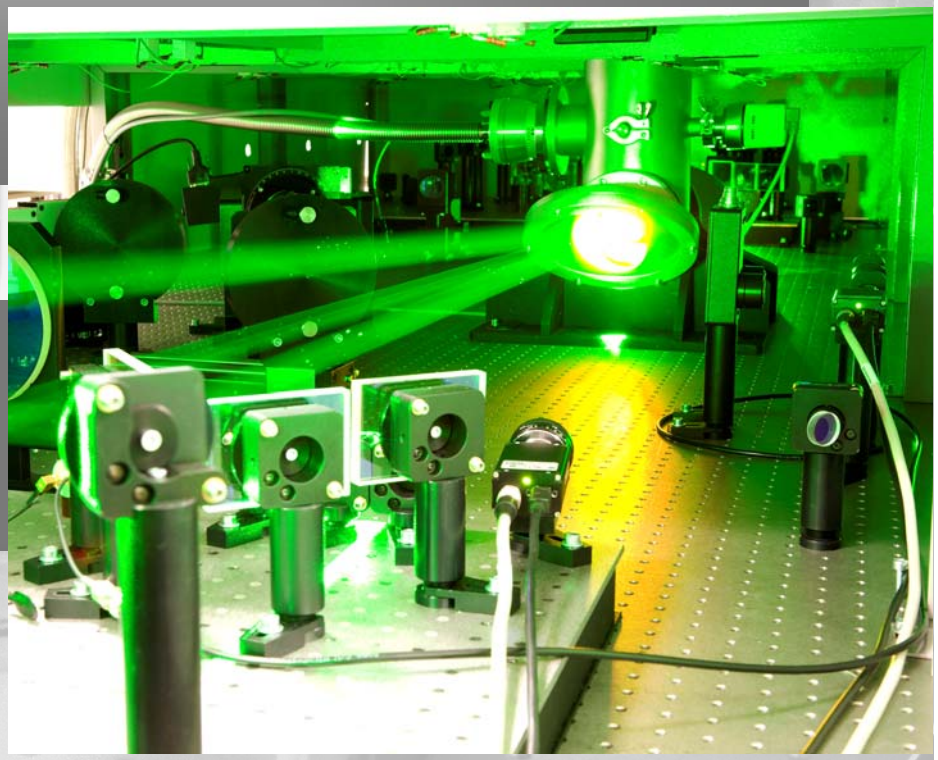
- Energy up to 5J at 532nm, 5 Hz in 2009….

Conclusion

We have demonstrated that power amplifiers laser using pump lasers mixing allow to obtain :

- Short duration (20fs -23fs)
- High energy stability (0.78 % RMS)
- Good profile

- High ASE contrast (10^{E-10})
- High ns contrast (10^{E-9})
- **Very good reliability**



Thanks to these performances, applications can be seriously considered (Protontherapy for Cancer treatment).