Generation of a 50fs/5J beam line for the new LULI laser facility ELFIE

J.-P. Zou, P. Audebert, X.-W. Chen*, L. Martin, C. Sauteret, C. Le Blanc

LULI, Ecole Polytechnique, CNRS, CEA, UPMC, 91128 Palaiseau, France
*Shanghai Institute of Optics and Fine Mechanics, Jiading, Shanghai, China

ICUIL2008 TongLi-Shanghai, China

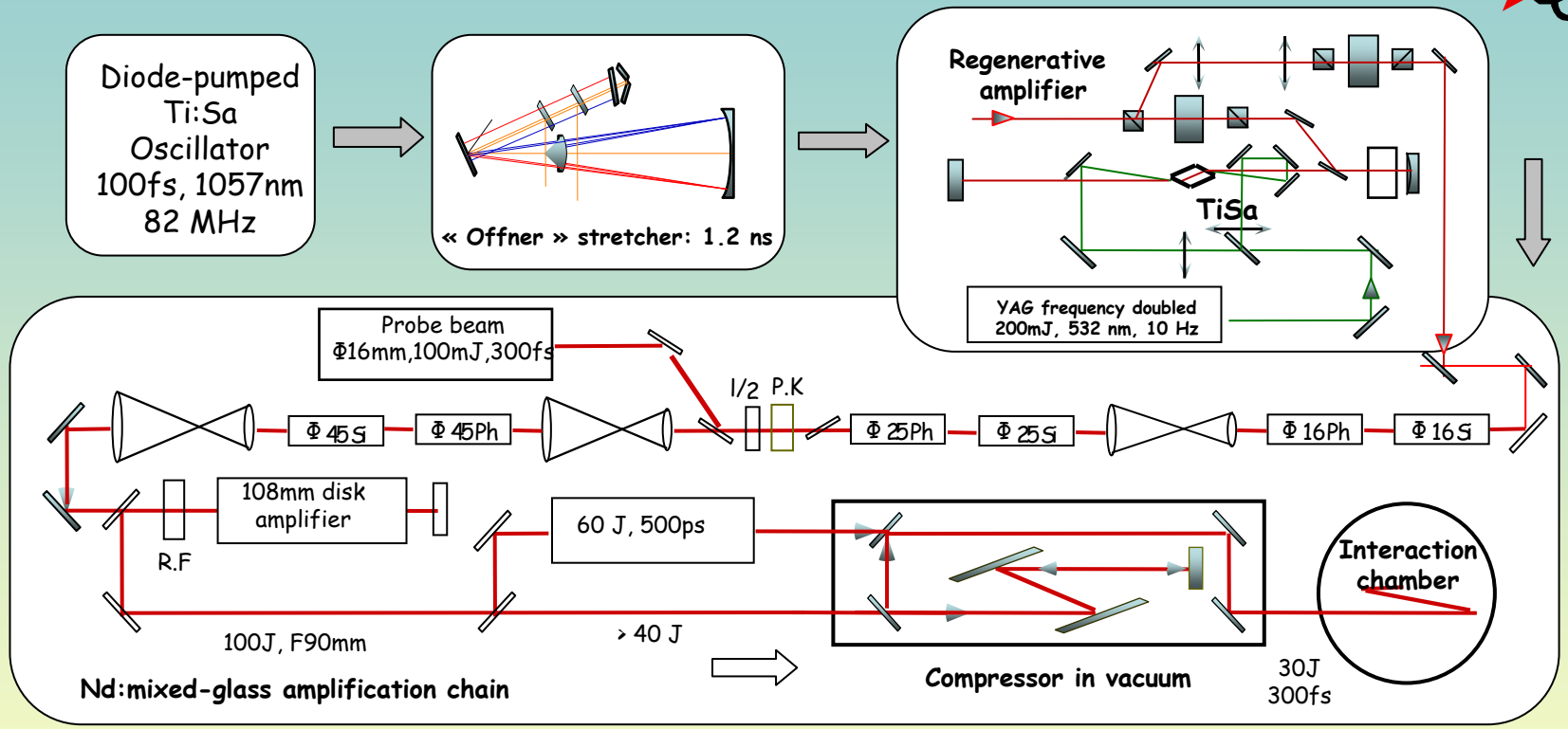
OUTLINE

- Overview of the 100TW facility
- ELFIE project description
- 50fs/5J beam line generation:

  laser scheme

  main technical issues

the 100TW facility: a versatile Ti:Sa and Nd:mixed-glass laser system



An ultra-intense **30 J /300fs** line **optically synchronized with**

(i) a **60J/~½ns** uncompressed (chirped) beam to produce long-scale length plasmas

(ii) an auxiliary **30TW (10J, 300fs)** [∅90mm] beam

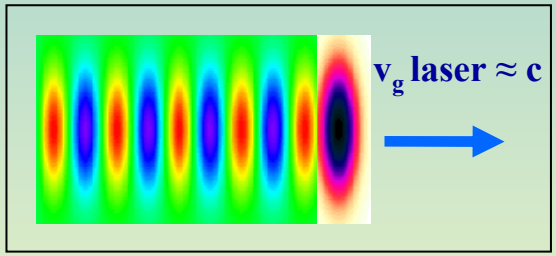
+ a ∅25mm **100 mJ short (0.3-a few ps)** tunable (ω→4ω) probe beam

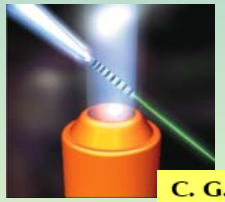
1 shot every **20 minutes** [**adaptive optics** ensuring shot-to-shot reliability]

ELFIE project : Upgrading the 100TW system

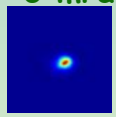
Higher energy & Larger pulse-duration scale

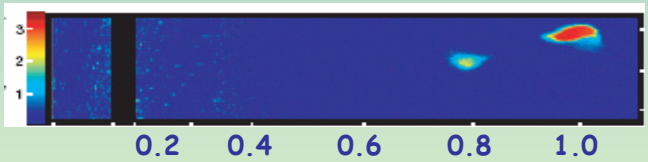
- Ultra-short laser pulses can produce plasma oscillations at vg≈c and accelerate collimated high-energy electrons (GeV)





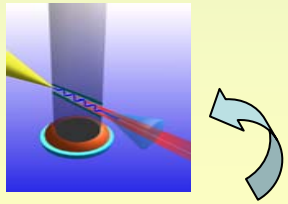
Divergence < 6 mrad



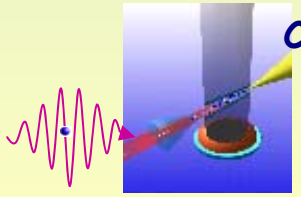


C. G. R. Geddes *et al.*, *Nature* 431, 535 (2004)
S. P. D. Mangles *et al.*, *Nature* 431, 538 (2004)
J. Faure *et al.*, *Nature* 431, 541 (2004)

-Intense & collimated X-ray pulses can be generated directly or indirectly high-brilliance source allows time-resolved radiography & coherent imaging

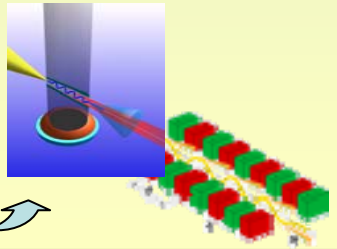


Betatron oscillations of e- in the plasma



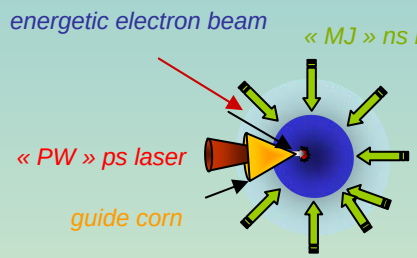
Compton scattering : e-& laser

FEL : e- & undulator

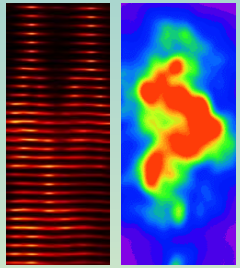


ELFIE allows to combine the ultra-short pulse features with the physical phenomena obtained with higher-energy, longer pulses

Energy production by controlled Inertial Fusion



Fast ignition concept

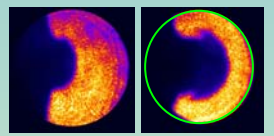


coalescence of the laser beam propagating in a plasma and parametric instability detected by Thomson diffusion

High energy density physics

laboratory astrophysics

Understanding of radiative hydrodynamics Phaenomena (radiatif choc, jets, …)

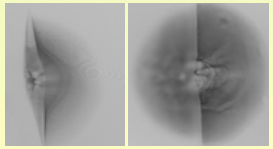


2D image of a choc propagating in under-dense matter

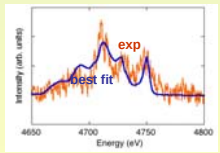
ZnS target and hohlraum for spectral opacity maesurements using LULI2000

Intense particle source generation & applications

proton beam focalized by an electrostatic micro-lens



auto-generated electromagnetic fields in a plasma visualized by proton radiography

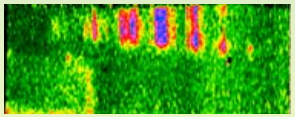


Te=0.35 eV, ne=2.5 10^{23} cm^{-3}, Z^*=2.9

Evidence of x-ray Thomson diffusion in a strong coupled aluminium plasma (Γ_i~240)

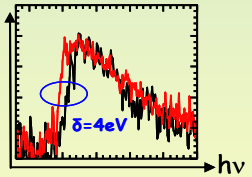
Warm dense matter

transitory plasma investigation near ETL



absorption spectrum of a non-stationnary aluminum plasma (ρ =0.3g/cc, Te=12-25eV)

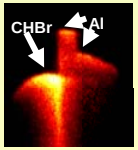
isochoric heating



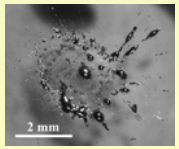
K edge displacement in solid aluminium after isochoric proton heating

Shocked matter

Equation of state



self emission during shock release



micro-spallation

Droplet ejection from the rear target surface of a tin target irradiated by a laser

J.-P. ZOU, LULI

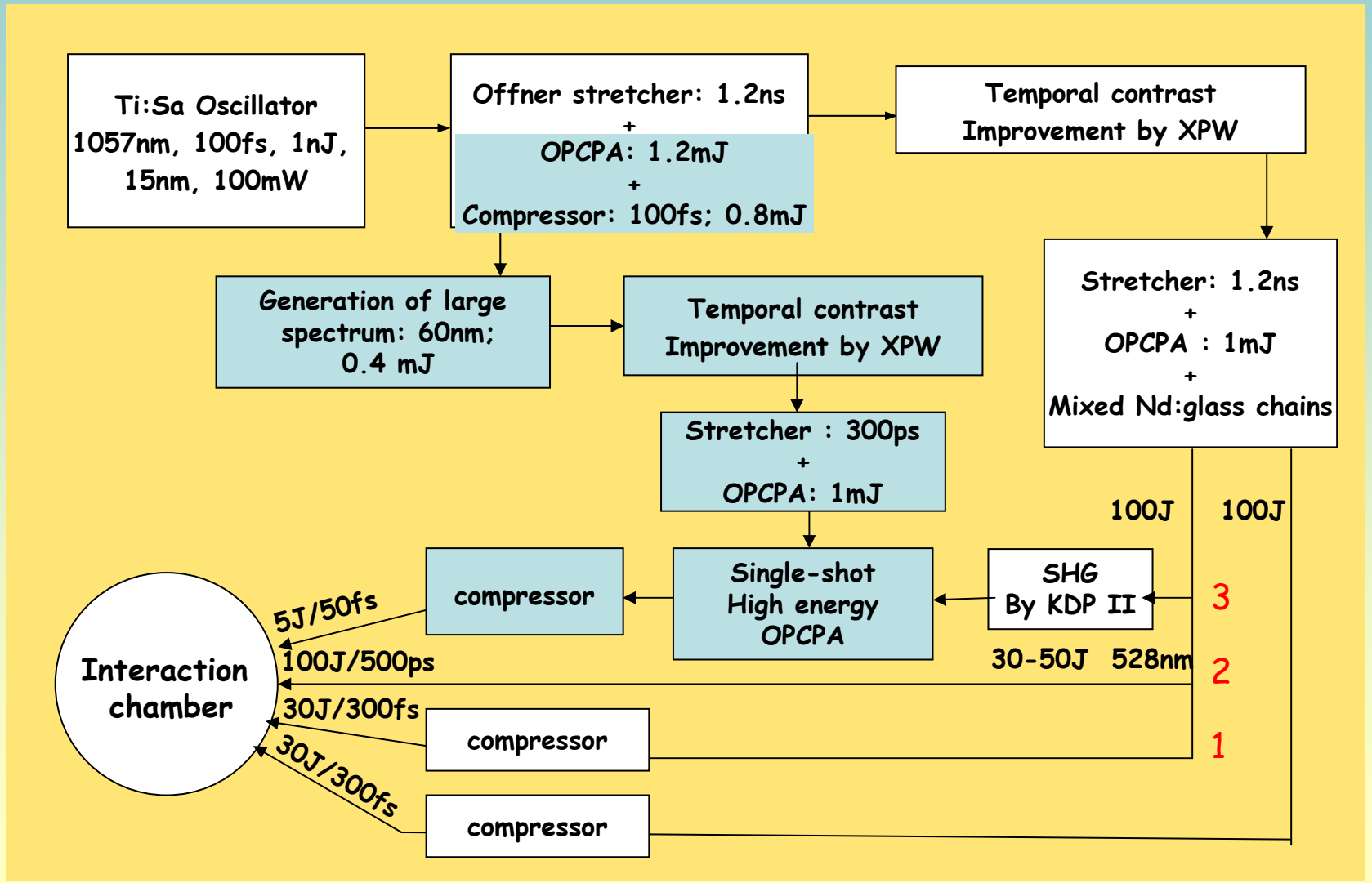
3 phases for ELFIE project :

1) laser and interaction chamber re-implementation
   - renovated laser & experiment areas (radio-protection, new command control system, new synchronization system, new compressor chamber design, ...)

2) output energy enhancement;
   the total amplified energy will be doubled : **200J** !!

3) development of a short-pulse high-energy beam line.
   non collinear OPCPA single-shot configuration
   => **50 fs / 5 J**

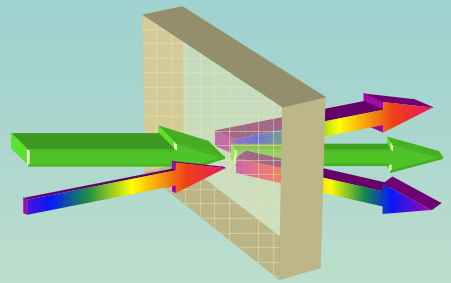
ELFIE scheme



Generation of 50fs/5J beamline

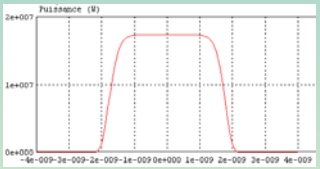
- 5 stages
  1) OPCPA pre-amplification
  2) Spectrum broadening by a hollow fiber
  3) Temporal contrast enhancement by XPW technique
  4) Broadband OPCPA single-shot amplification
  5) New compressor design

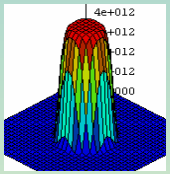
OPCPA pre-amplification

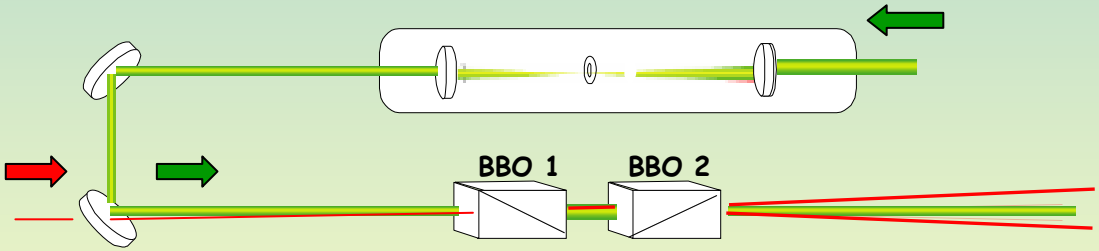


Pump:

532 nm, 60 mJ, 3.5ns

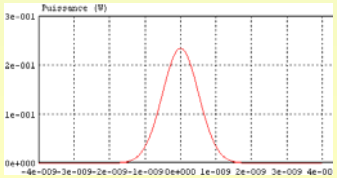


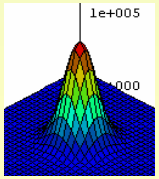




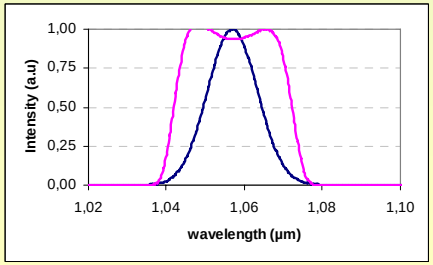
Signal:

1057 nm, 300pJ, 15nm, 1.2ns

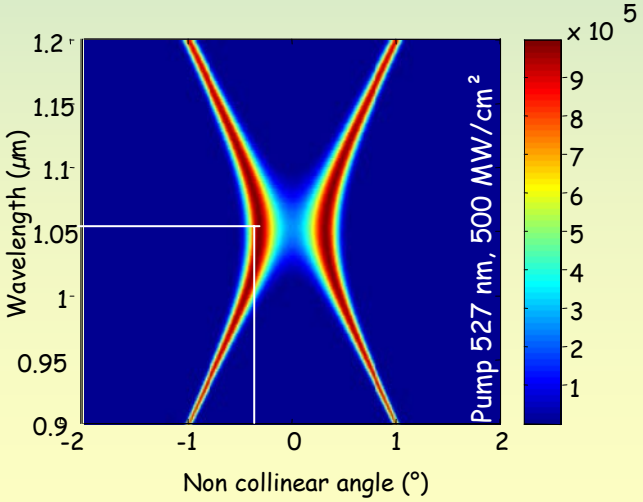




1057 nm, 2mJ, 29nm, 2.4ns



Parametric gain distribution



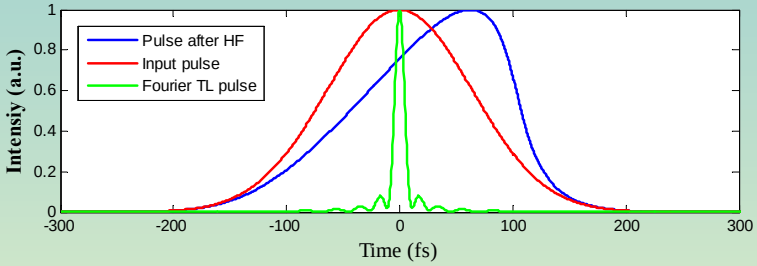
Calculated by N. Forget

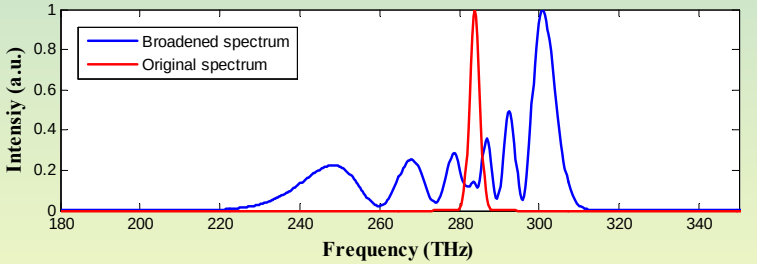
Spectrum broadening by a fused-silica hollow fiber filled with noble gas

Objectif: Δλ: >60nm

Few results exist at 1μm!!

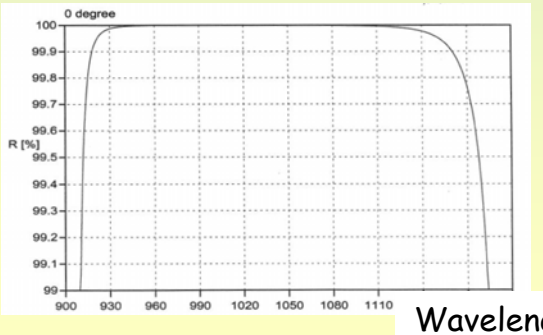
Input: 0.8mJ, 150fs @1057nm
250um inner diameter hollow fiber,
filled with 1.5bar Argon gas
L_{fiber}=1m, beta2=0.60411 fs^2/m



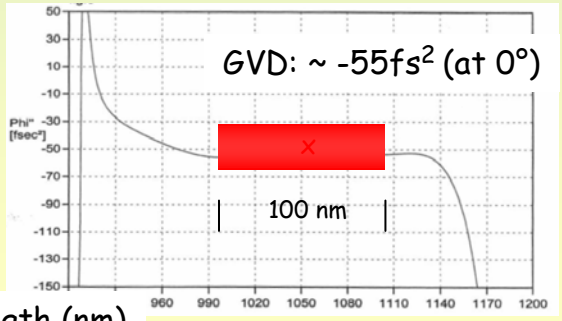


Quadratic and cubic phase compensation will be performed by two pairs of broadband chirped mirrors.

Calculated reflection (i~0°)



Calculated GVD



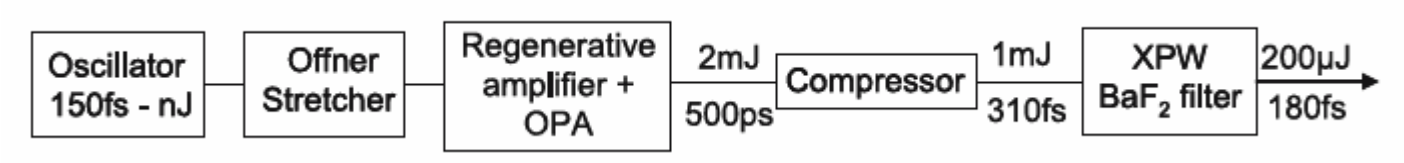
Wavelength (nm)

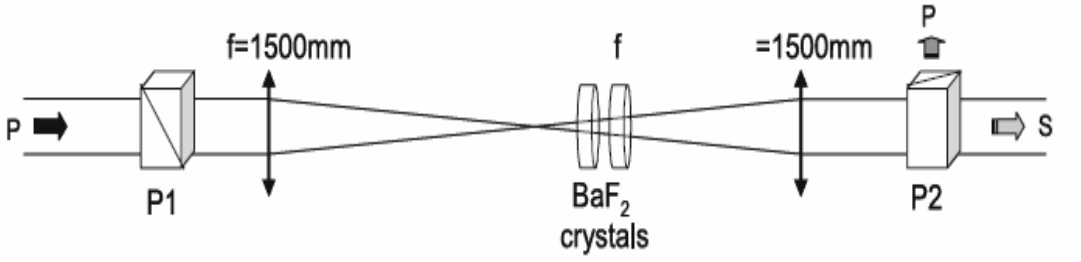
Experiment :
beginning of 2009

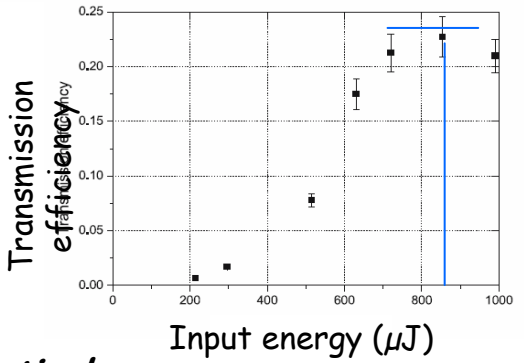
Temporal contrast enhancement by Crossed Polarized Wave generation (XPW)

For a CPA 100TW-class laser, ASE and pre-pulse/ main pulse : 10^{-7}

XPW experiment carried out in 100TW : ~ mJ and sub-ps pulse



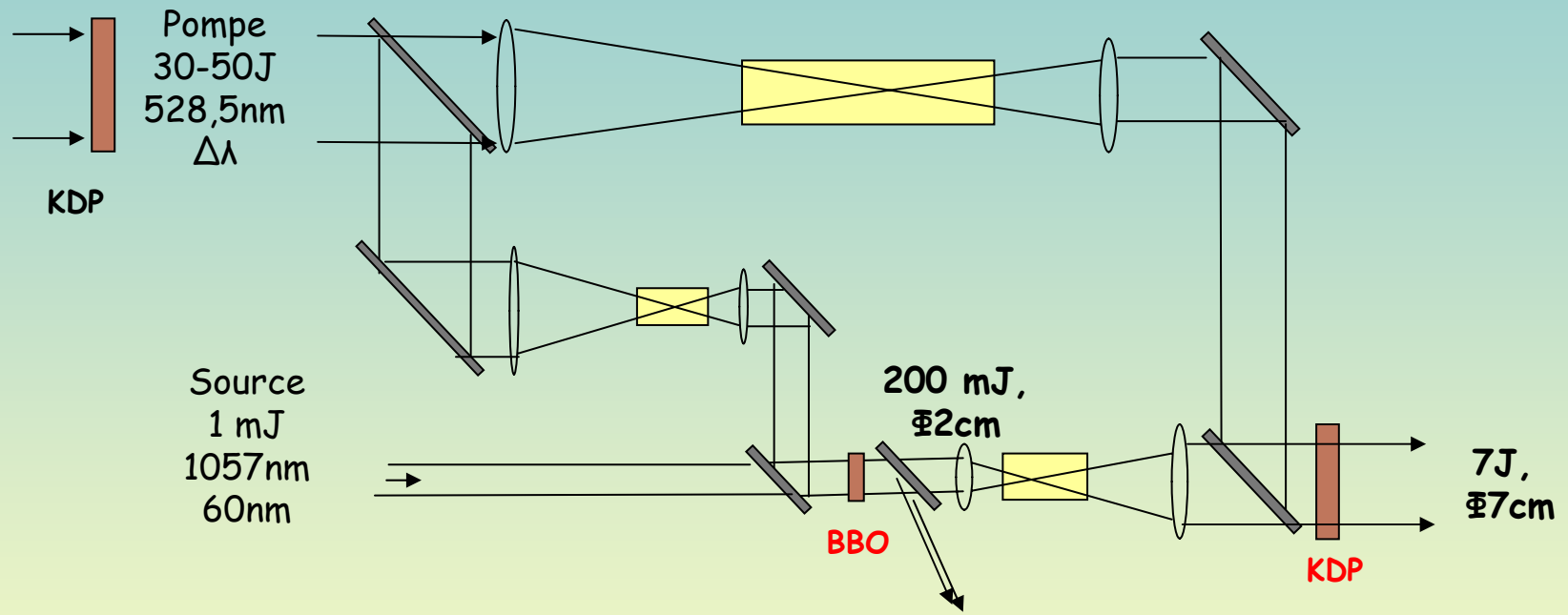




* **A. Cotel et al., *Nonlinear temporal pulse cleaning of 1-µm optical parametric chirped-pulse amplification system*, Applied Phys. B 83, 7 (2006)**

- Contrast enhancement by 3 to 4 orders of magnitude
- Spectral smoothing
- Spectral widening (x $\sqrt{3}$)
- Efficiency 22%

High-energy single-shot OPCPA configuration



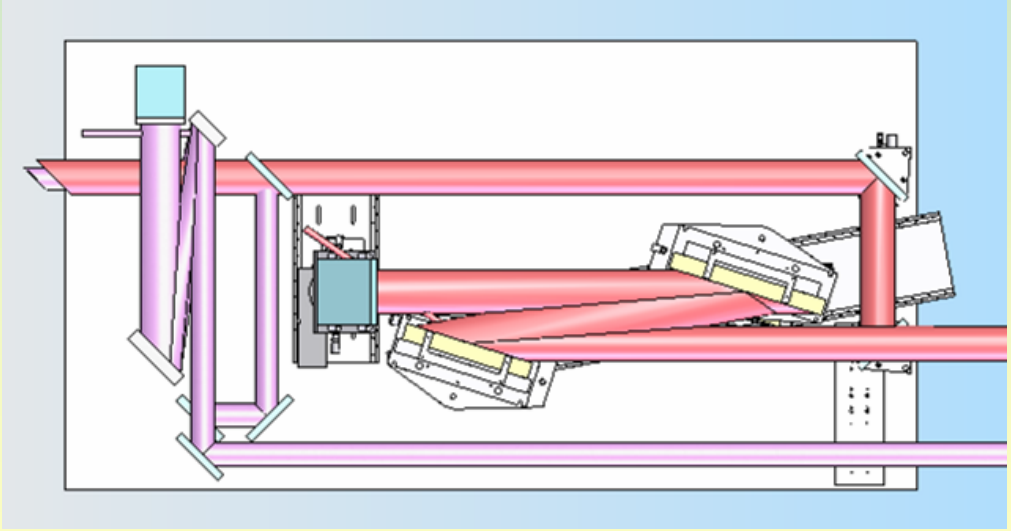
In the case where the signal and the pump have broad spectrum
⇨ parametric gain and amplified signal spectral bandwidth decrease dramatically

To improve the broadband parametric conversion:
3 parameters to link :spectral bandwidth, chirp, incident angle

New compressor design

3 compressors hosted in the same box:

- 2 compressors (1740l/mm) in two levels
  for **2x300fs** pulses;
- 1 compressor (1200l/mm), in the perpendicular direction
  for **50fs** pulse



High grating diffraction efficiency via. large bandwidth is needed

Conclusions

We have studied the laser scheme and the main technical issues of the 50fs/5J beam line for ELFIE

0) End of plasma experiments : mid of 2009

1) laser and interaction chamber re-implementation: end of 2009

2) output energy enhancement **(200J)**: end of 2009

3) development of a **50 fs / 5 J** beam line: mid of 2010

Experimental results will be presented at the next ICUIL