Recent results of optical smoothing on the Phebus Laser

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Introduction

Laser Mégajoules (LMJ) project requires new developments of smoothing techniques

➡ **We present Smoothing by Optical Fiber used on one power chain of Phebus Laser and study results in term of gain saturation**

➡ **We present also a new development of Smoothing by Transverse Spectral Dispersion which could improve frequency conversion efficiency**

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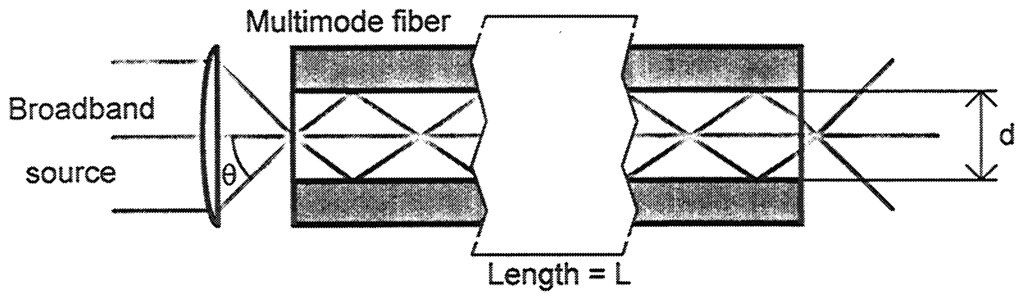
Spatial incoherence source and spectral dispersor

The multimode fiber induces spatial incoherence with a time delay between different spatial modes.



L=200 m

d=100 μm

θ=0.22 rad

λ=1.053 μm

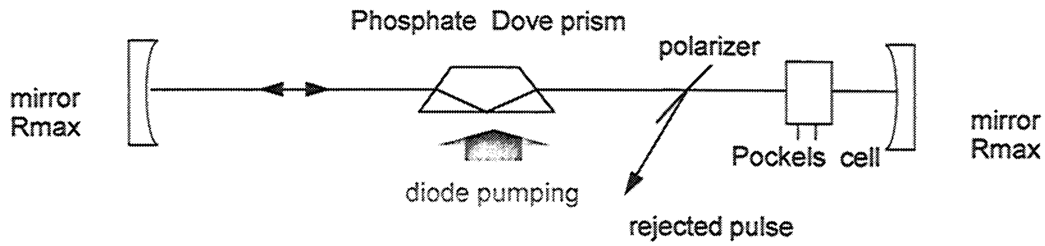
→

# of spatial modes $N_s = (2d\theta/\lambda)^2 = 1750$

Maximum time delay $T_d = L\theta^2/2nc = 9$ ns

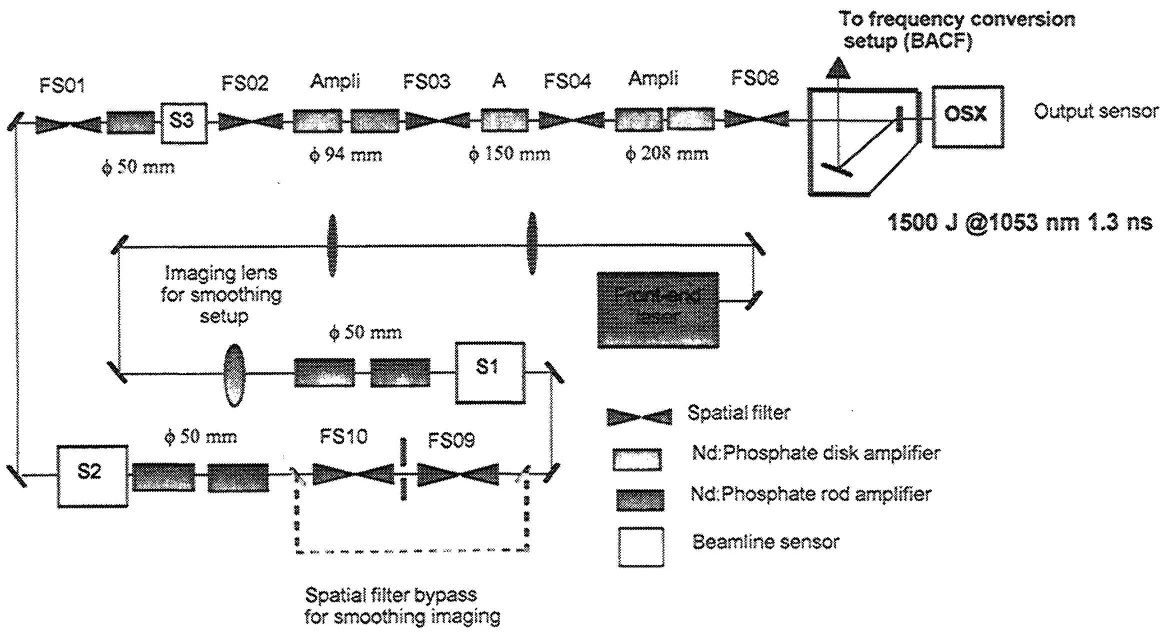
Dispersor resolution $\Delta\nu_{res}=2.73/2\pi T_d$

Temporal incoherent source



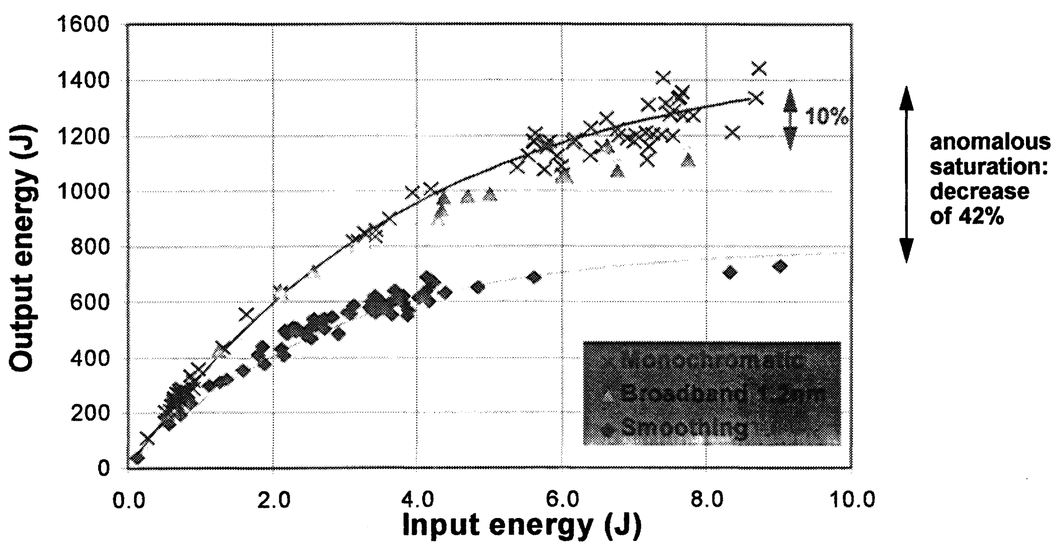
- Broadband Phosphate Cavity Dumping Oscillator ; E=1mJ; T=14ns; Repetition rate=1Hz; λ = 1054.5nm; $\Delta\lambda$ = 1,2nm
  +
  Spectral filtering with a mask in a grating pair
- Coherence time at 1ω : $t_c = 1/\Delta\nu$ =1.2-16ps

Phebus diagnostic chain



Amplification of fiber smoothed pulses

- **Comparison of the amplification gain between monochromatic, broadband and fiber smoothed pulses in the disk amplifiers.**



Explanations of the anomalous saturation

① **Self-modulation phase due to the temporal incoherence** *

- Non-linear losses $\approx 2 * \varepsilon^2 B^2$ with $B = \frac{2\pi}{\lambda} \int \gamma \; I(z)dz$

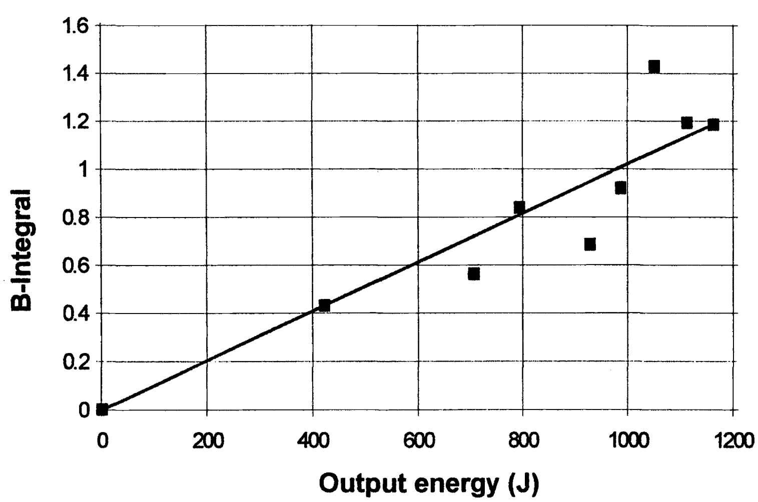
ε=0.08 for a coherence time of 1.2ps.

-Spectral broadening $\frac{\Delta\lambda_{output}}{\Delta\lambda_{input}} \approx \sqrt{1 + B^2}$

* "Amplification of broadband incoherent light in homogeneously broadened media in presence of Kerr nonlinearity" J.Garnier et al. To be published

② **Low level of smoothing of the laser beam in the amplifier disks.**

Spectral broadening of broadband pulses as a function of energy



$$B = \frac{1}{2}\sqrt{\left(\frac{\Delta\lambda_{output}}{\Delta\lambda_{input}}\right)^2 - 1}$$

It can only explain a loss of 10% in the amplification

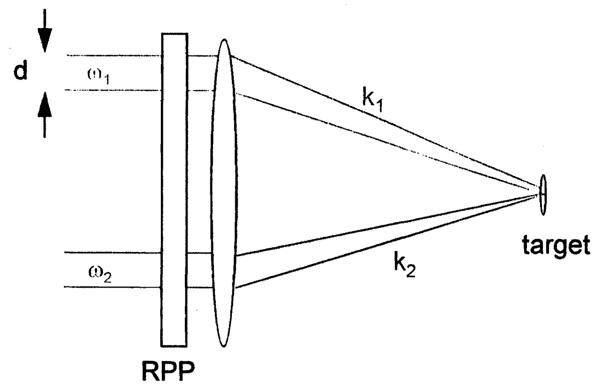
Smoothing by Transverse Spectral Dispersion (S.T.S.D.)

Principle
Mixing different frequencies with different angles.

$$E(x,t) = A_1 \exp[i(\omega_1 t - k_1 x)] + A_2 \exp[i(\omega_2 t - k_2 x)]$$

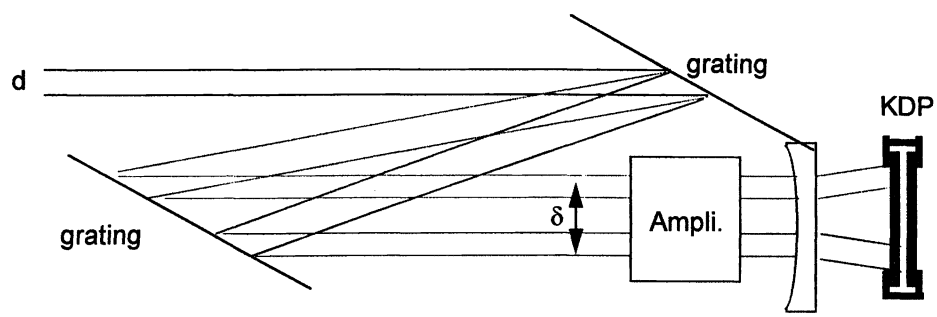
Fringes move in time

$$I(x,t) = |A_1|^2 + |A_2|^2 + 2A_1A_2\cos[\Delta\omega t - \Delta k x]$$



Originally proposed by LLE REVIEW N°36

STSD
Locally narrow bandwidth



1. Creation of a transverse spectral dispersion in the Phebus front-end.
2. Angular dispersion after a divergent lens $\theta_{PM}(\lambda) = \theta_{PM}(\lambda_0) + \beta.\lambda$
3. Frequency conversion is improved if $\beta = \left.\frac{d\theta_{PM}}{d\lambda}\right|_{\lambda_0}$

Conclusion

- We have observed an anomalous gain saturation with a fiber smoothed pulse.
- The self-modulation phase only explains a part of the drop.
- Next step
  - → research of other explanations, for instance a poor smoothing in the amplifier disks.
  - → experimental test of different smoothing techniques (Smoothing by Transverse Spectral Dispersion).