



**CEA/SPAM**  
*(Atoms, Photons and Molecules Laboratory)*  
**Activity in EUROFEL /DS3**

D. Garzella, P. Hollander



# SPAM

Femtosecond Laser Servers

- LUCA (20 Hz, 2 TW)
- UHI 10 (10 Hz, 10 TW) => upgrade 100 TW
- PLFA (1 KHz, 0.2 TW)

Daily Operation up to 10 Beamlines for Users

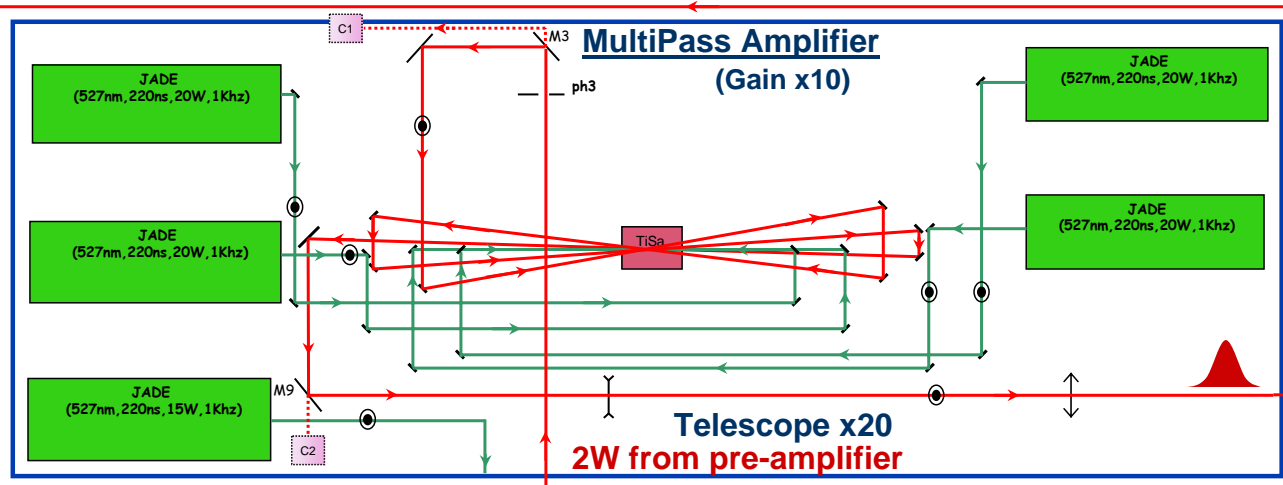
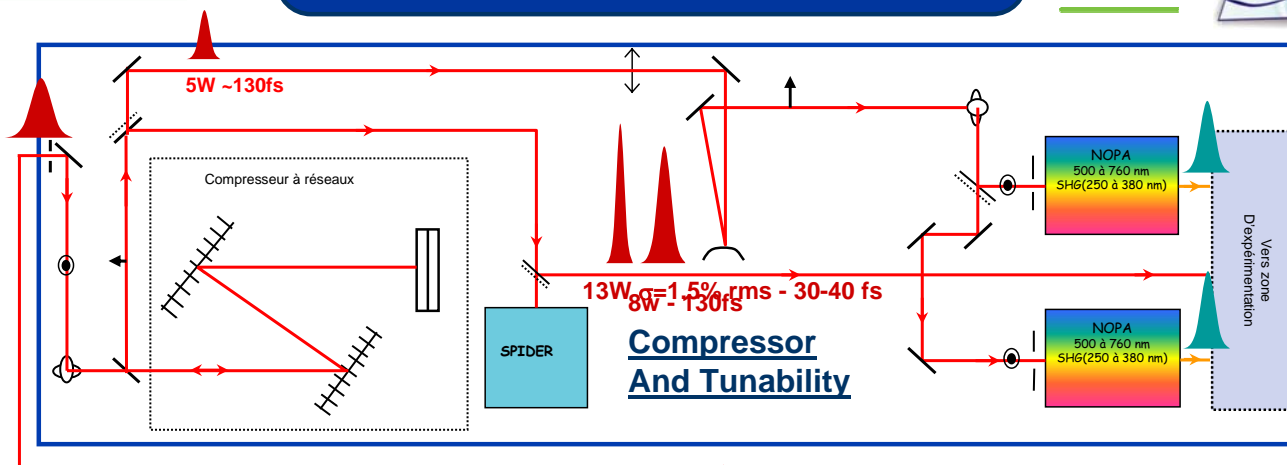


## EUROFEL Staff

D. Garzella	Permanent Position 30-50 %
O. Gobert	Permanent Position 10 %
J. F. Hergott	Permanent Position 5 %
P. Monot	Permanent Position 5 %
P. Hollander	18 Months (DS1, DS3)
O. Tcherbakoff	18 Months (DS3, DS4)

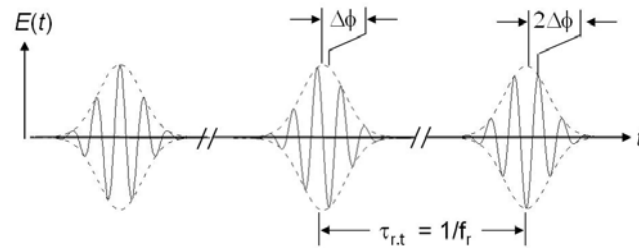
Up to now, limited R&D activity on DS1  
And CEP stabilization !





## Electric Field from a Femtosecond Mode-locked Laser

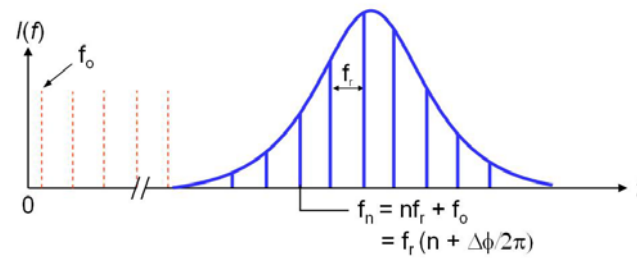
Time domain



Carrier-envelope  
phase slip from pulse  
to pulse because:

$$v_g \neq v_p$$

Frequency domain

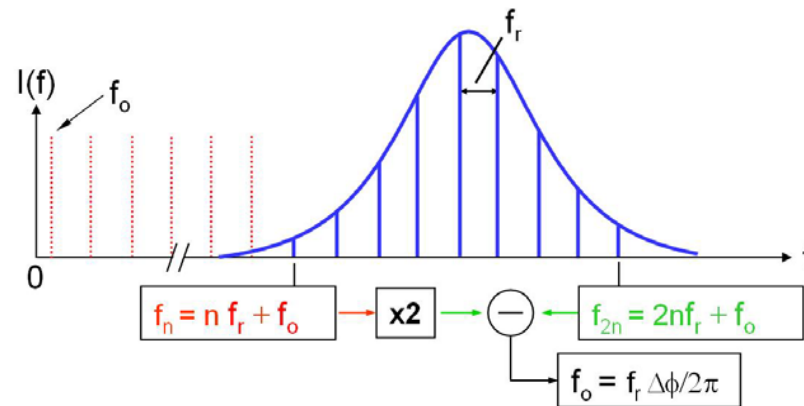


Modes are offset from  
harmonics of  $f_r$  by:

$$f_0 = f_r \Delta\phi/2\pi$$

Original ideas: Hänsch, Wineland, Udem

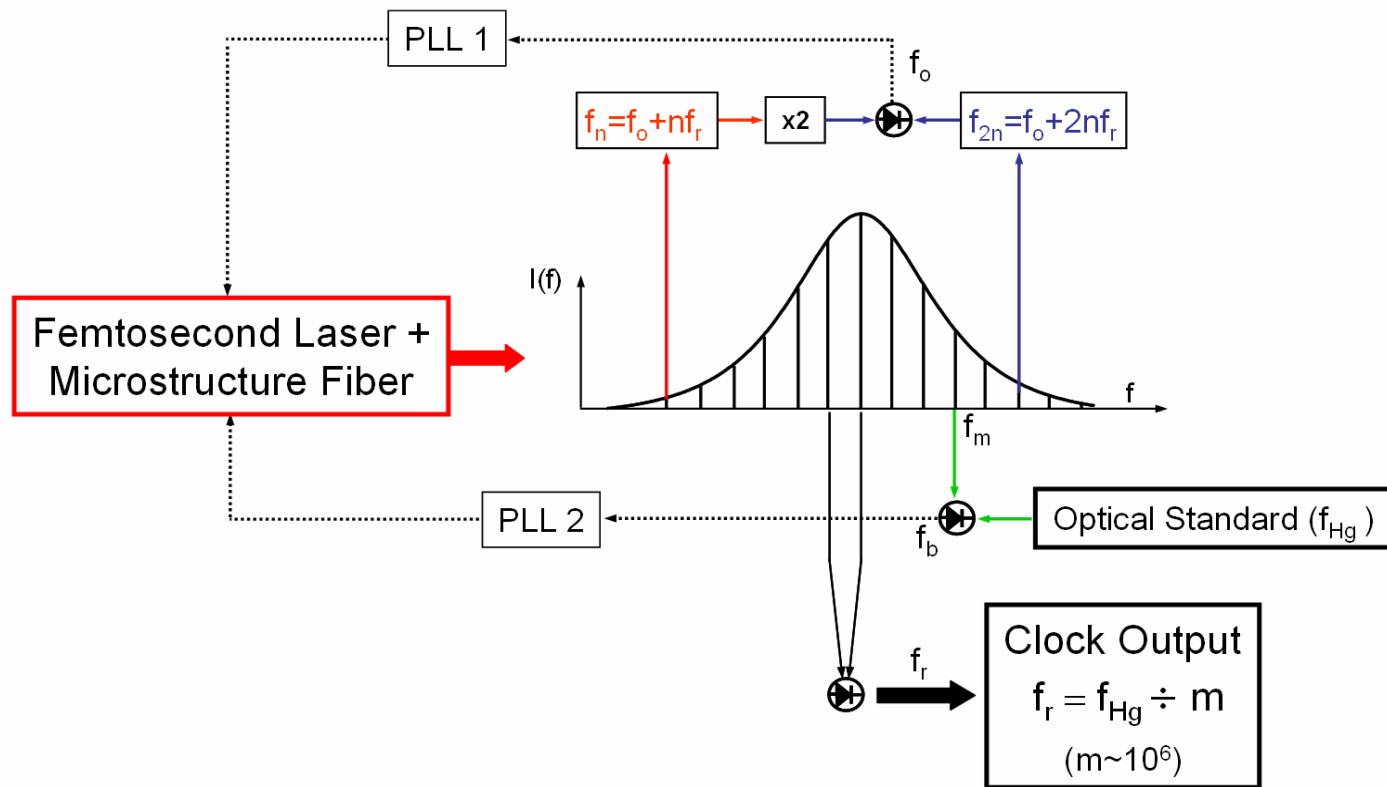
## Self-Referenced Optical Frequency Synthesizer



- $f_0$  is generated from a heterodyne beat between the second harmonic of the  $n^{\text{th}}$  mode and the  $2n^{\text{th}}$  mode.

- Once  $f_r$  and  $f_0$  are referenced to a frequency standard (optical or microwave), all the frequency modes of the fs comb are fixed.

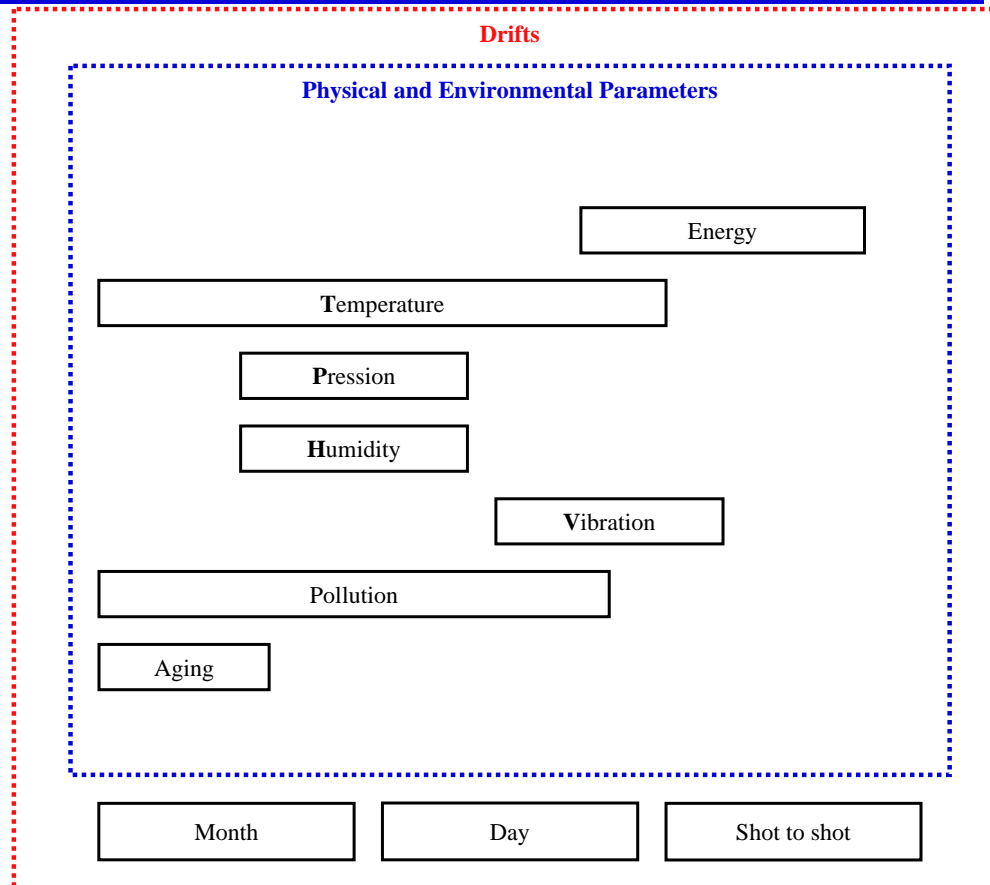
# Optical → Microwave Synthesis (schematic)



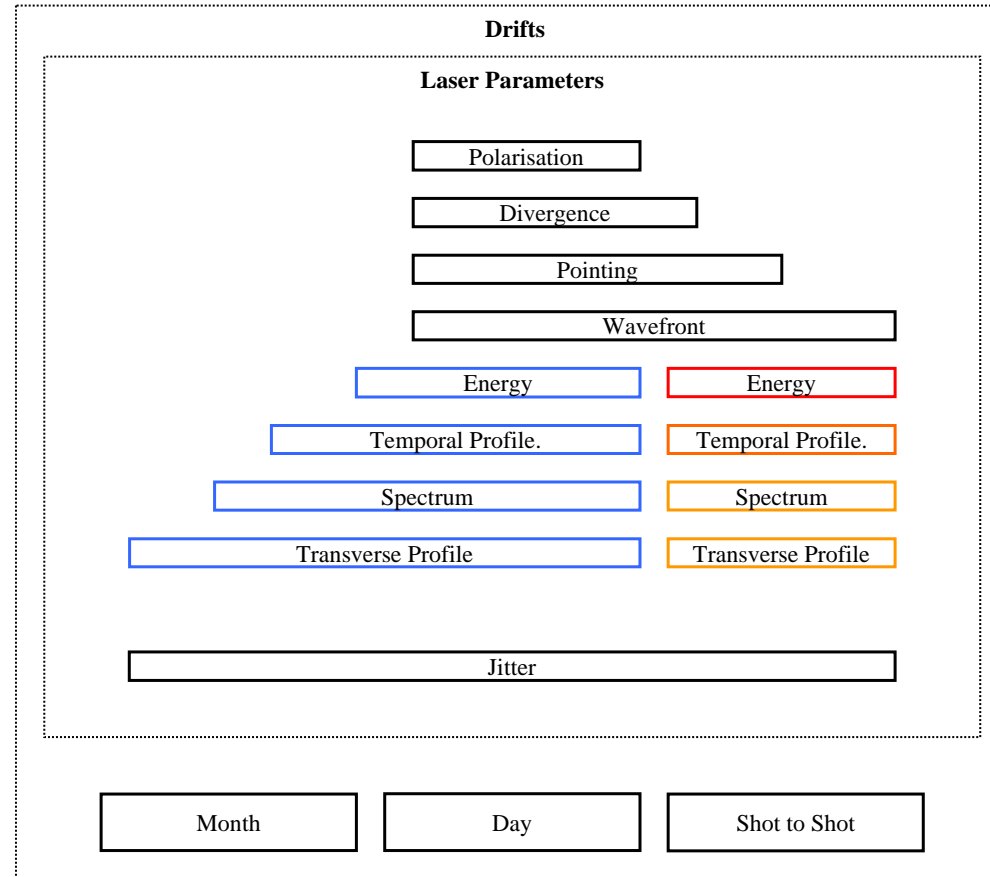
S. Diddams, *et al.* Science **293**, 825 (2001)



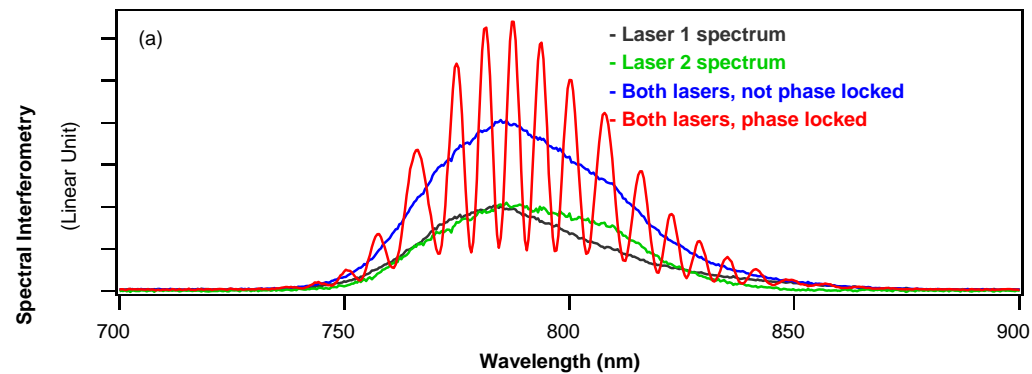
Temporal Scales for jitter and drifts of physical and environmental parameters



## Illustration : Typical temporal scales for laser Drifts

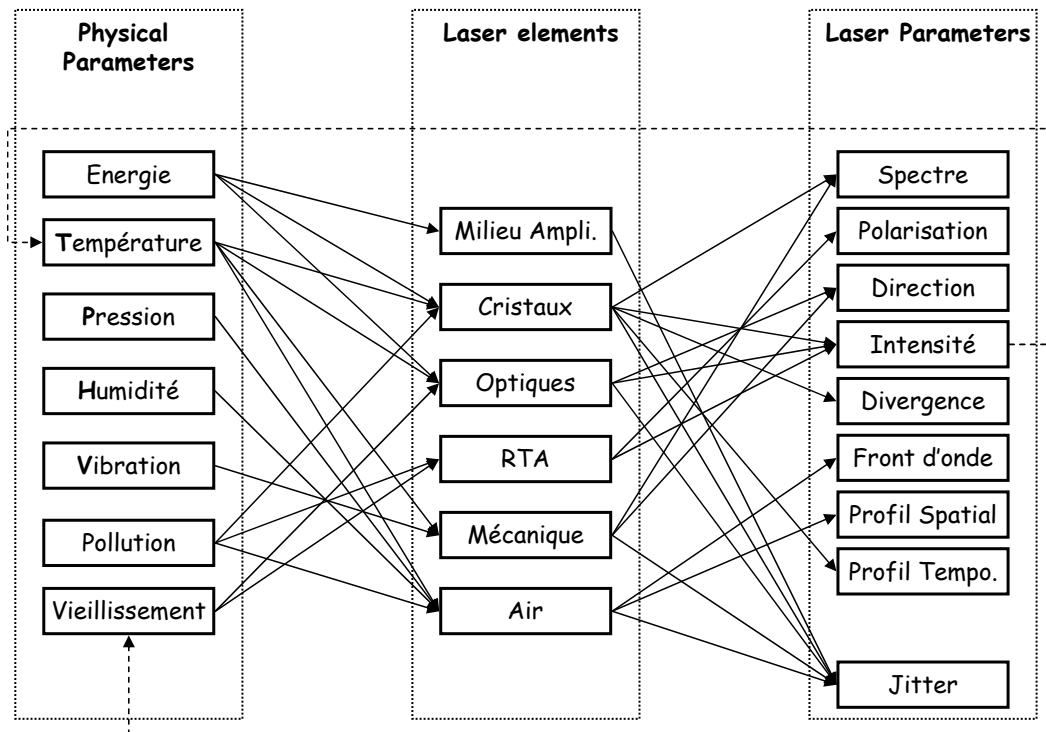


## Spectral Interferometry



- *High Accuracy (get sub-fringe information ~2 fs)*
- *No sensitivity to pointing fluctuations*
- *Different spectra (no contrast reduction)*
- *Analysis of different chirps (different fringe contrast)*

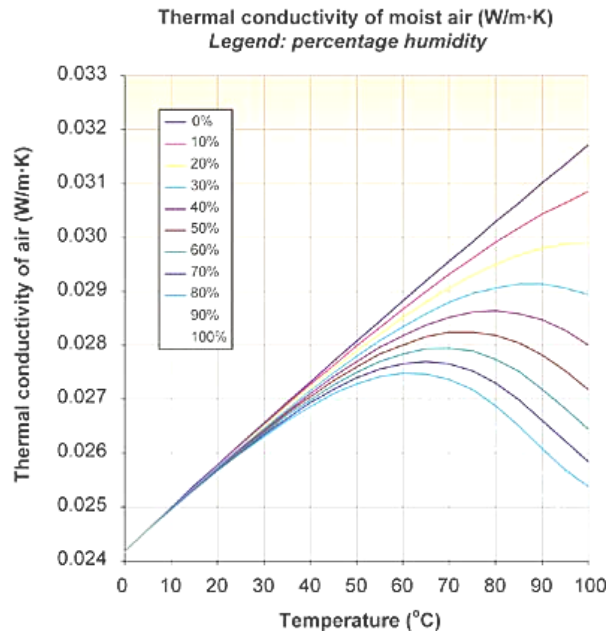
### Laser System





## Paramètre Physique : Illustration (dérive lente)

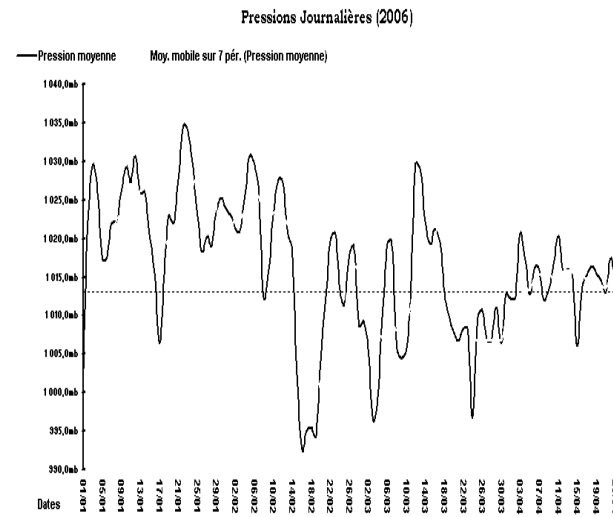
@ 25°C variation de 260 à 263 mW/m.K soit ~ 1%



[http://www.electronics-cooling.com/html/2003\\_november\\_techdata.html](http://www.electronics-cooling.com/html/2003_november_techdata.html)



Pour 100 m parcours : ~ 200 fs /  $\Delta p$  1%



Variation Pression atmosphérique sur 6 mois à Anthony (source : Web)



Paramètre Physique : Illustration (dérive lente) suite...



### Thermique – Mécanique

Coefficient de dilatation thermique typique pour acier  $\sim 5.10^{-6}/K^{\circ}$

Optiques séparées de  $L = 1 \text{ m}$  :  $\sim 5 \mu\text{m} / K^{\circ}\text{m} \sim 15 \text{ fs} / K^{\circ}\text{m}$

REGEN 20 passages cavité de 4 m :  $4 \times 20 \times 15 \text{ fs}/K^{\circ} \sim 1200 \text{ fs} / K^{\circ} \sim 1 \text{ ps} / K^{\circ}$

### Pour illustration : Jitter attendu entre sortie oscillateur et fin de chaîne

Thermo-Mécanique ( $1^{\circ} / \text{jour}$ ) + Pression ( $2 \% \Delta p / \text{jour}$ )  $\sim 2 \text{ ps} = 20 \times 100 \text{ fs}$



## CEA/DS3 Synchronization, Jitter and Drift

**Main Goal : Systematic Analysis**

**How really large is the jitter in KHz laser systems ?**

- **Averaged on different timescales**

  - Pump Laser Stability**

  - Mechanical stability (two amplified beams)**

  - Air Flow dynamics**

  - Non Linear effects in short pulse propagation**

- **Shot to Shot**

  - Pointing**

  - Oscillator and Pump Laser Stability**

**What about the drift ?**

- **Thermal Stability**