

SPARC laser progress

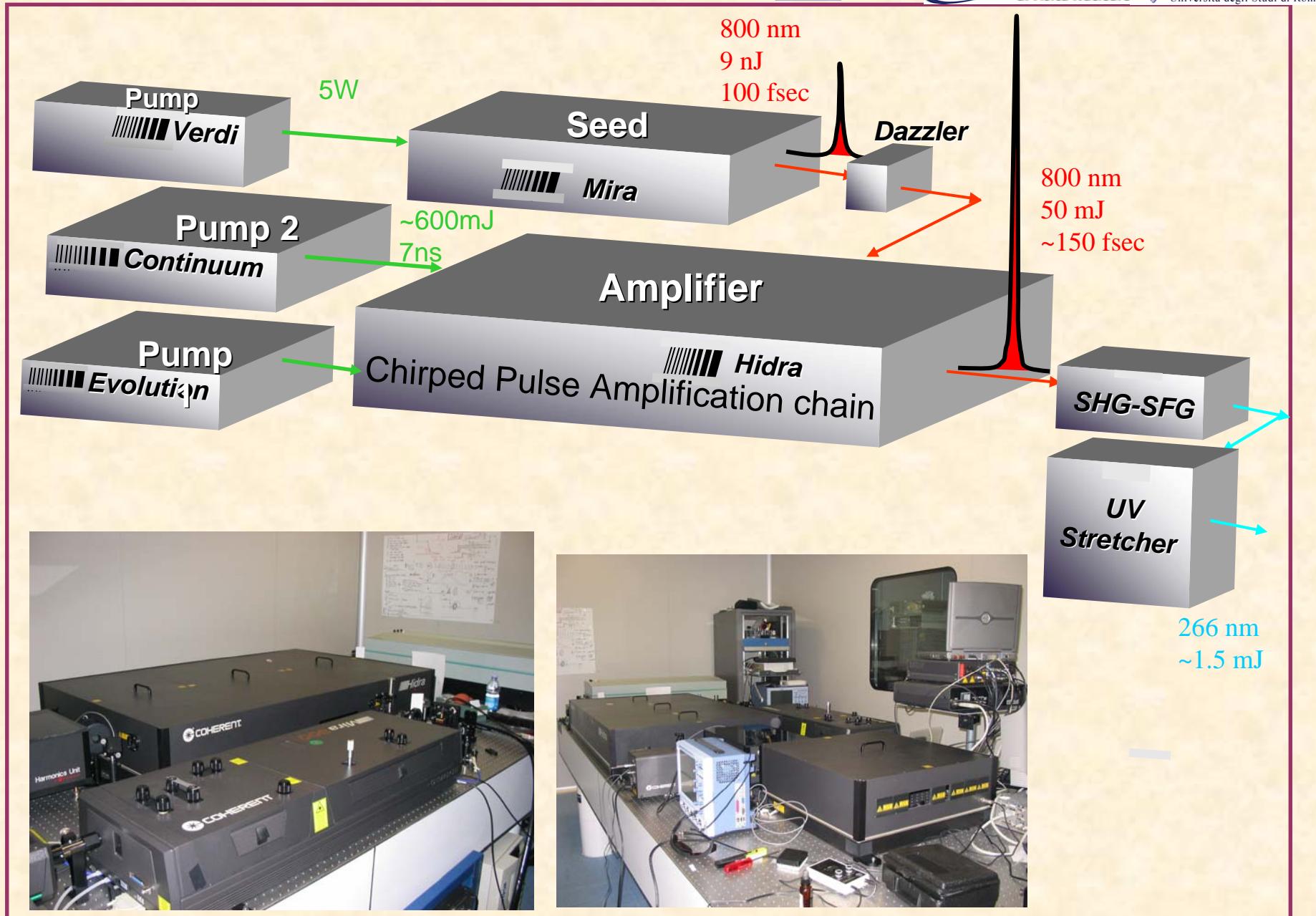
Overview:

- SPARC laser overview
- Pulse Shaping (Temporal)
- Diagnostic
- Synchronization

SPARC laser Team:

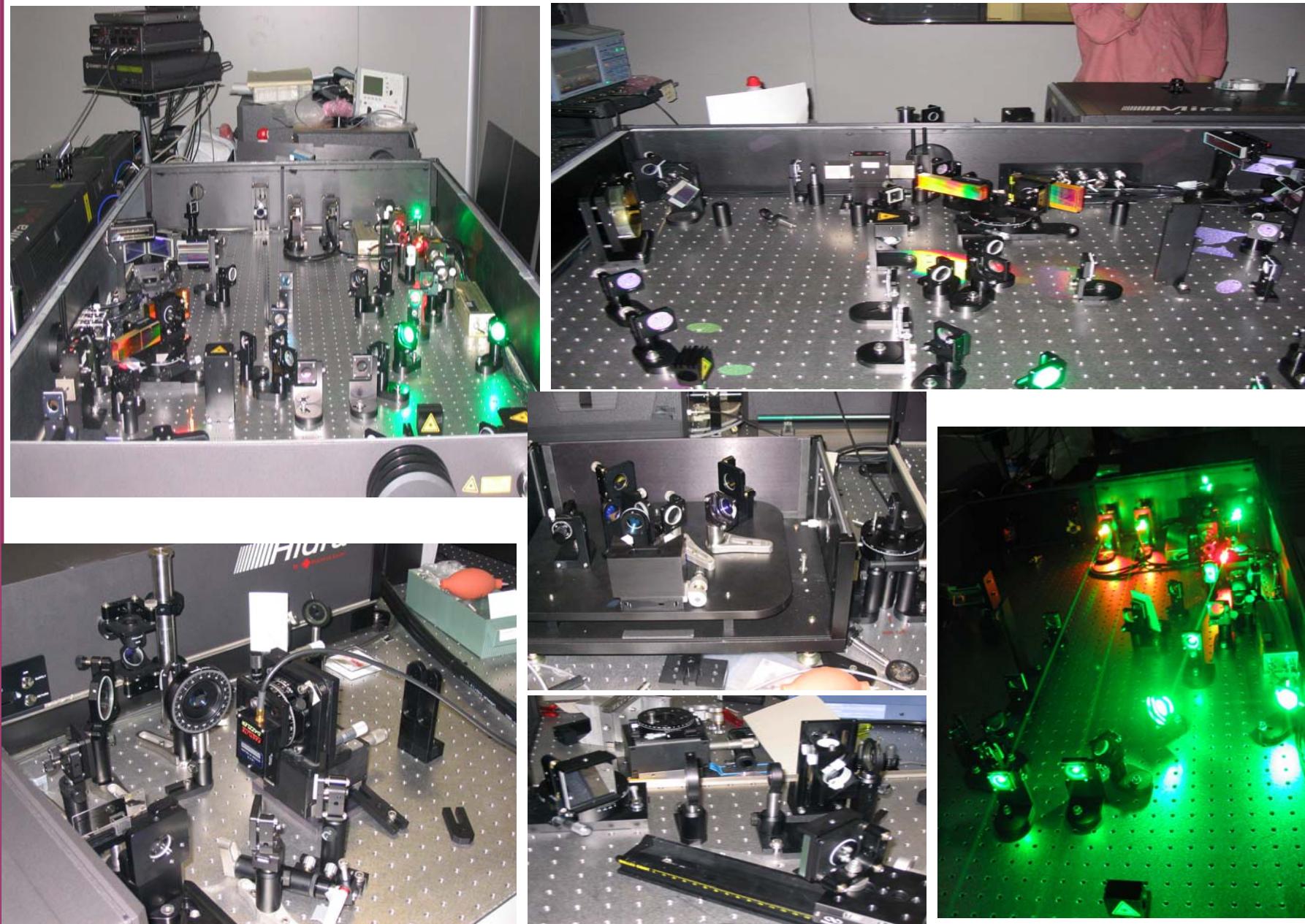
Massimo Petrарca
Carlo Vicario
Giancarlo Gatti
Pietro Musumeci
Simone Cialdi

Group leader:
Andrea Ghigo



Energy & Power measurements

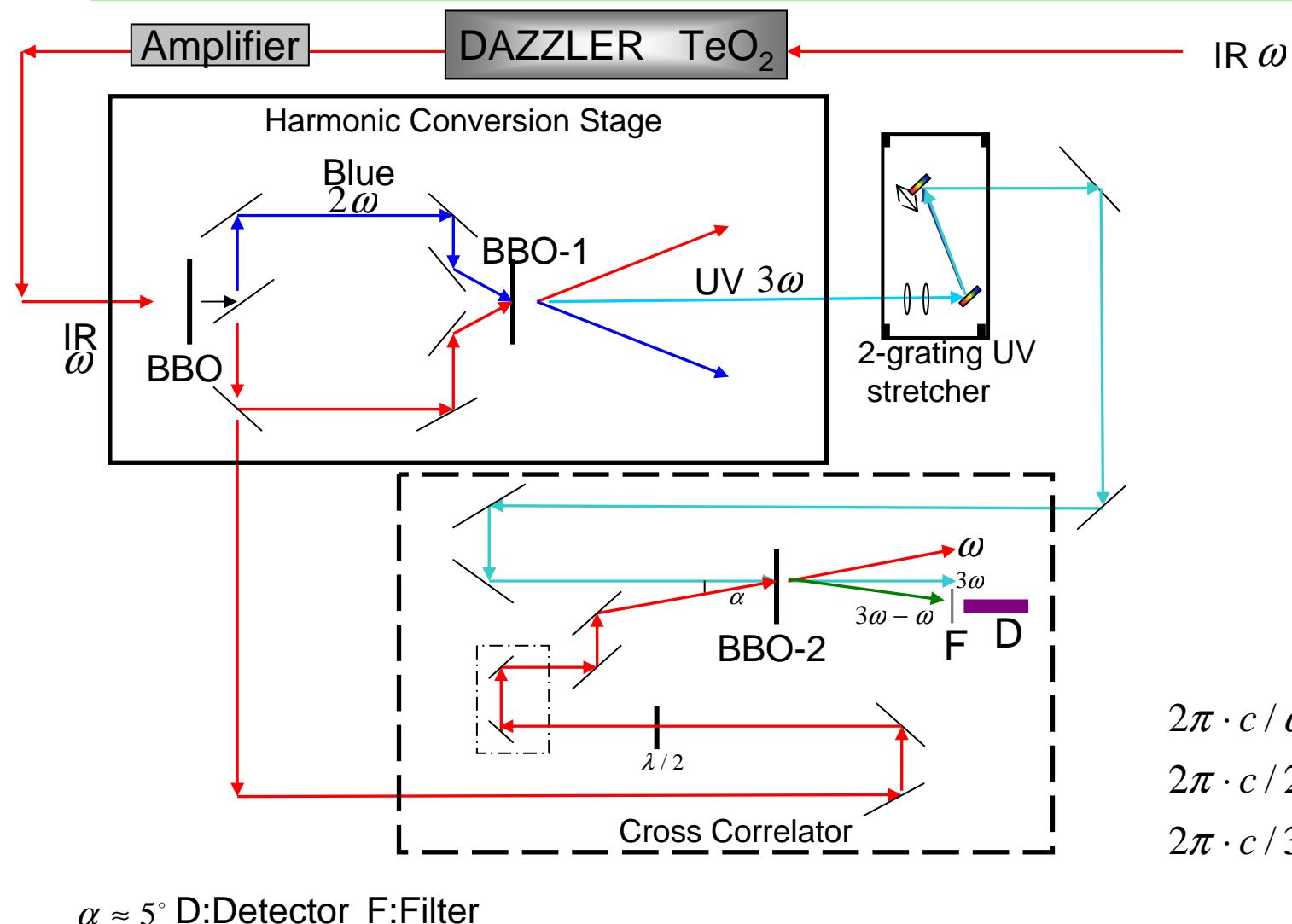
	measured value	unit
Oscillator [79,3 MHz]	>800	mW
Regen amplifier [1kHz]	2	mJ
Regenerative pump @ 532 nm	15	W
First pass amplifier [10 Hz]	10	mJ
Second pass amplifier [10 Hz]	65	mJ
Multipass pump @ 532 nm	720	mJ
Compressed pulse [10 Hz]	>50	mJ
Second harmonic	20	mJ
UV un-stretched	3.5	mJ
UV stretched	1.4	mJ



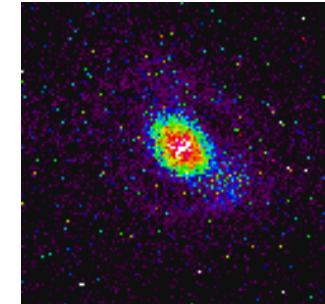
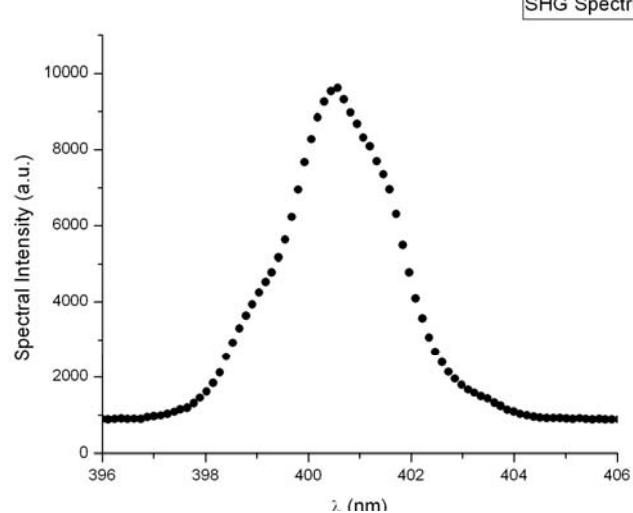
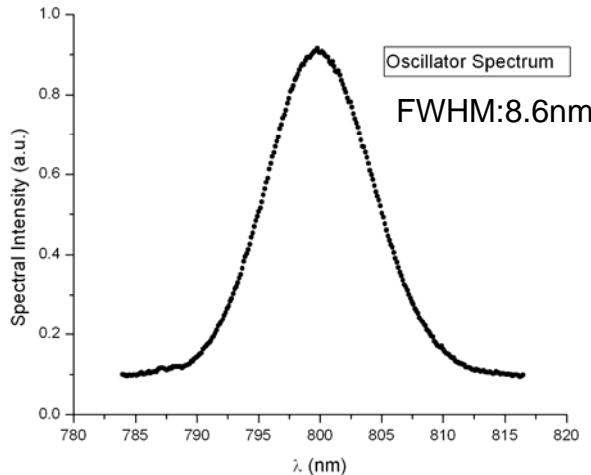
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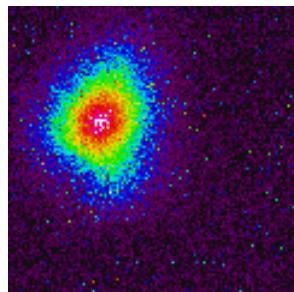
Frequency Process Scheme



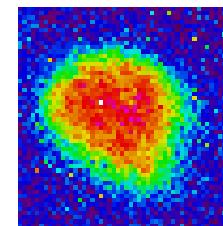
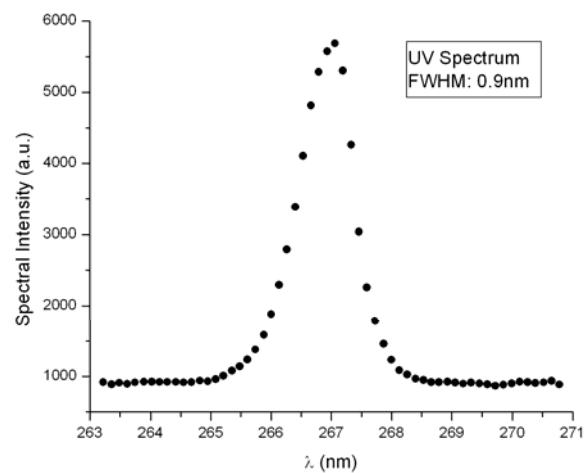
Laser Characteristics



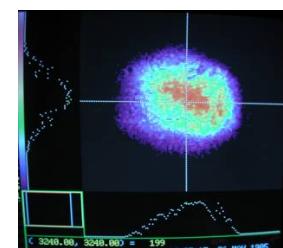
Blue
beam spot
Full Energy
20mJ



IR
beam spot
Full Energy
50mJ

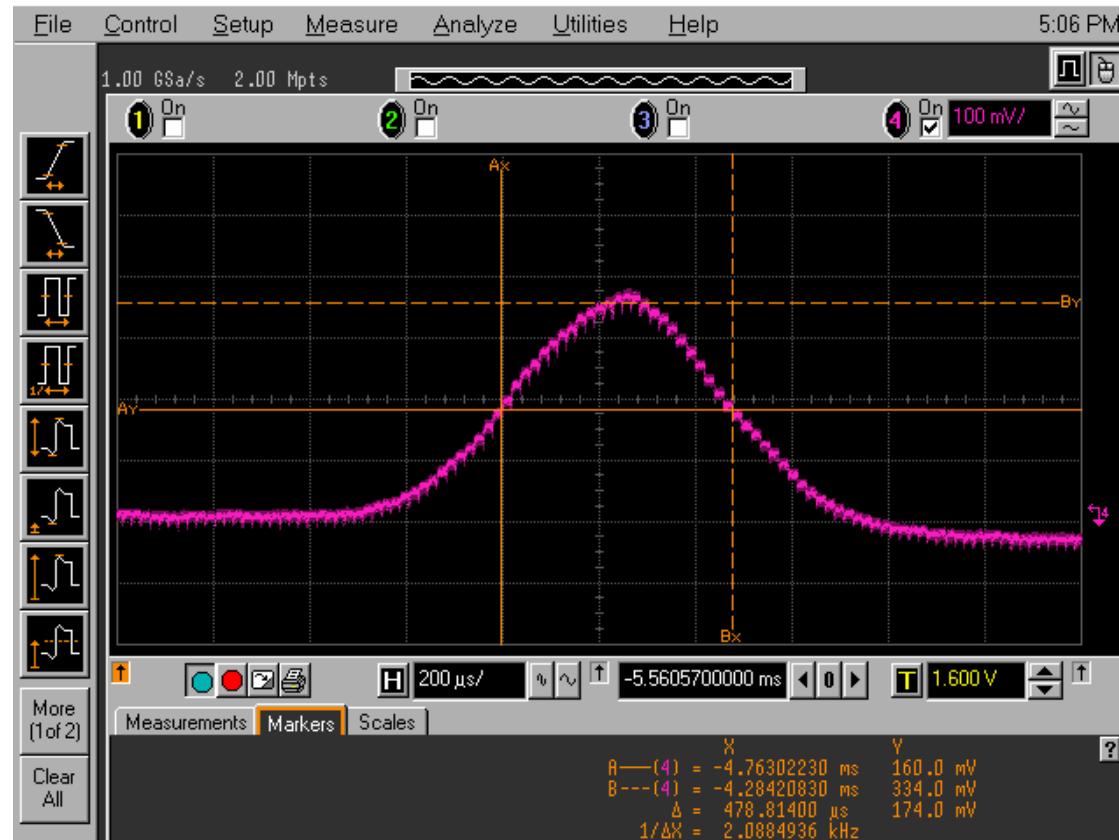


UV
beam spot
Full Energy
3.5mJ



Single Shot Amplifier Autocorrelation Trace

Autocorrelation FWHM T~ 200fs --> Gaussian Shape T ~160 fs



Temporal Pulse Shaping: “DAZZLER”

- Birefringent crystal TeO₂ → 2 preference polarization directions (allowed)

Matching Conditions

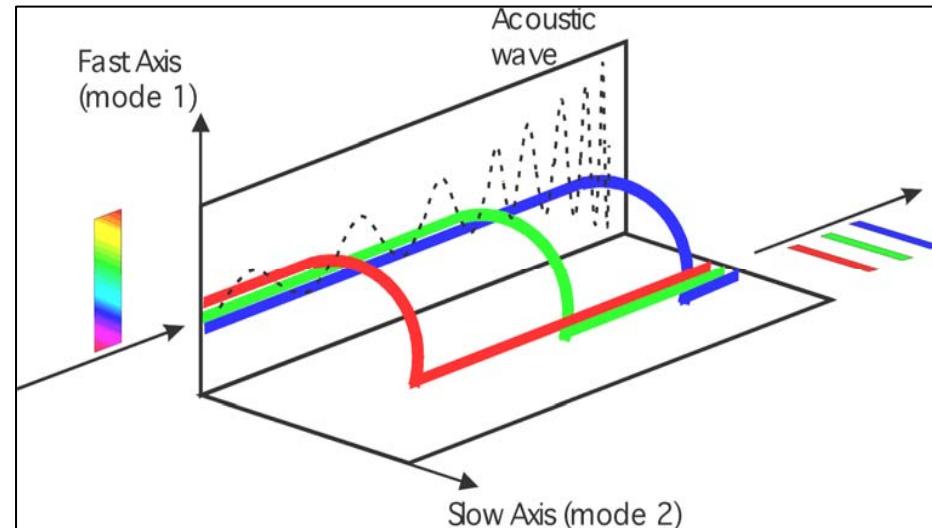
$$\omega_2 = \omega_1 + \Omega_{ac}$$

$$\vec{K}_2 = \vec{K}_1 + \vec{K}_{ac} \quad \text{---} \quad \frac{n_2 \omega_2}{c} = \frac{n_1 \omega_1}{c} + \vec{K}_{ac}$$

L : crystal length

z : scattering position for ω_i

Group velocities for Fast and Slow modes



- Output group delay depends on the frequency scattering position along the crystal

$$\tau_g(\omega) = \frac{z(\omega)}{v_{g1}(\omega)} + \frac{L - z(\omega)}{v_{g2}(\omega)}$$

Maximum delay
achievable in single passage:

$$\frac{L}{v_{g2}(\omega)} < \tau_g(\omega) < \frac{L}{v_{g1}(\omega)}$$

DAZZLER FILTER

P. Tournois, Opt. Comm. **140**, 245, 1997

$$E_{out}(\omega) = E_{in}(\omega) T_{ac}(\alpha\omega)$$

$\alpha = (n_2 - n_1)V_{ac} / c \cong 10^{-7}$ for TeO_2

- Complex equation but no phase infos. about initial pulse: $\phi_{in} = 0$

Amplitude & Phase

- Dazzler driven by a computer through FASTLITE software:
Phase up to 4th order & Amplitude mod.
- Resolution: ~0.3nm.
- Maximum Delay ~ 7ps.
- Crystal damage threshold: 100MW/cm²
- Efficiency in single passage: ~50%.
- Easy to align.
- Possibility to read from a data file for external Phase & Amplitude modulation

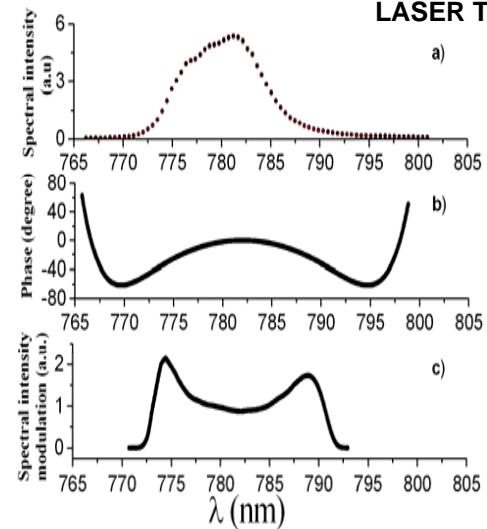
Polynomial expansion
of even order (symmetry)
up to 8th order required
to reduce rise time

Amplitude filter transfer function
to obtain output
Super Gaussian spectrum:

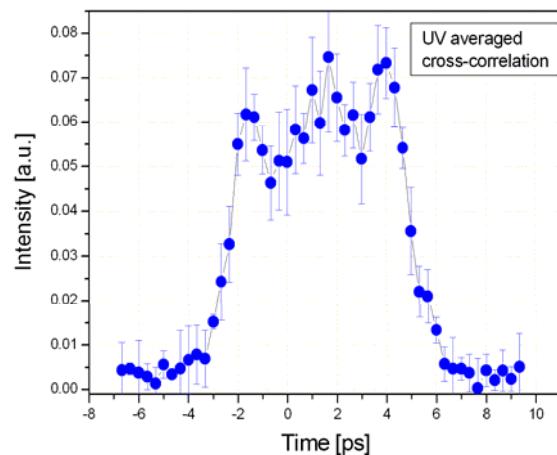
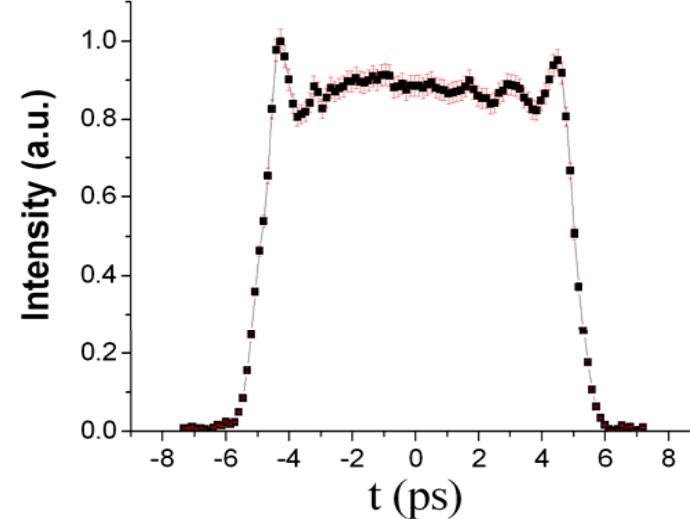
Old IR pulse shaping measures

Proceeding EPAC 2004:

LASER TEMPORAL PULSE SHAPING EXPERIMENT FOR SPARC PHOTINJECTOR

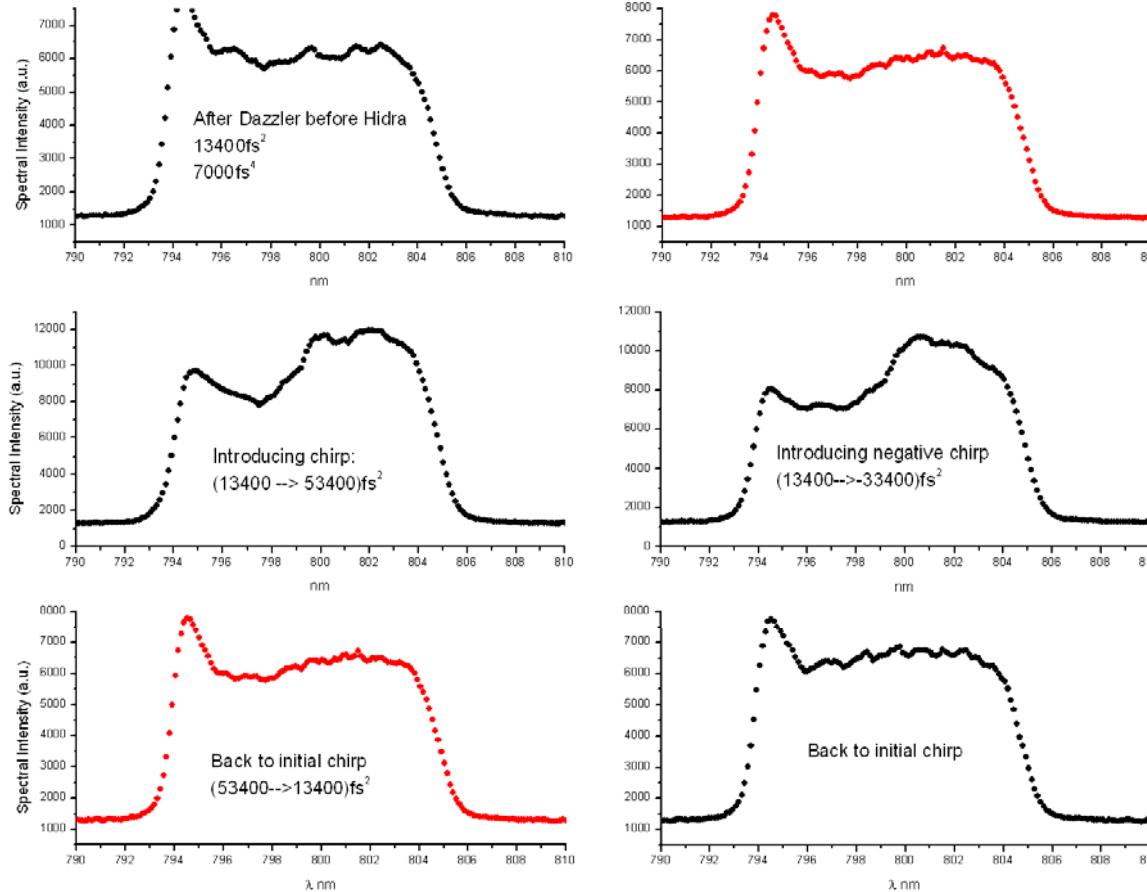


IR



UV:
BNL measure

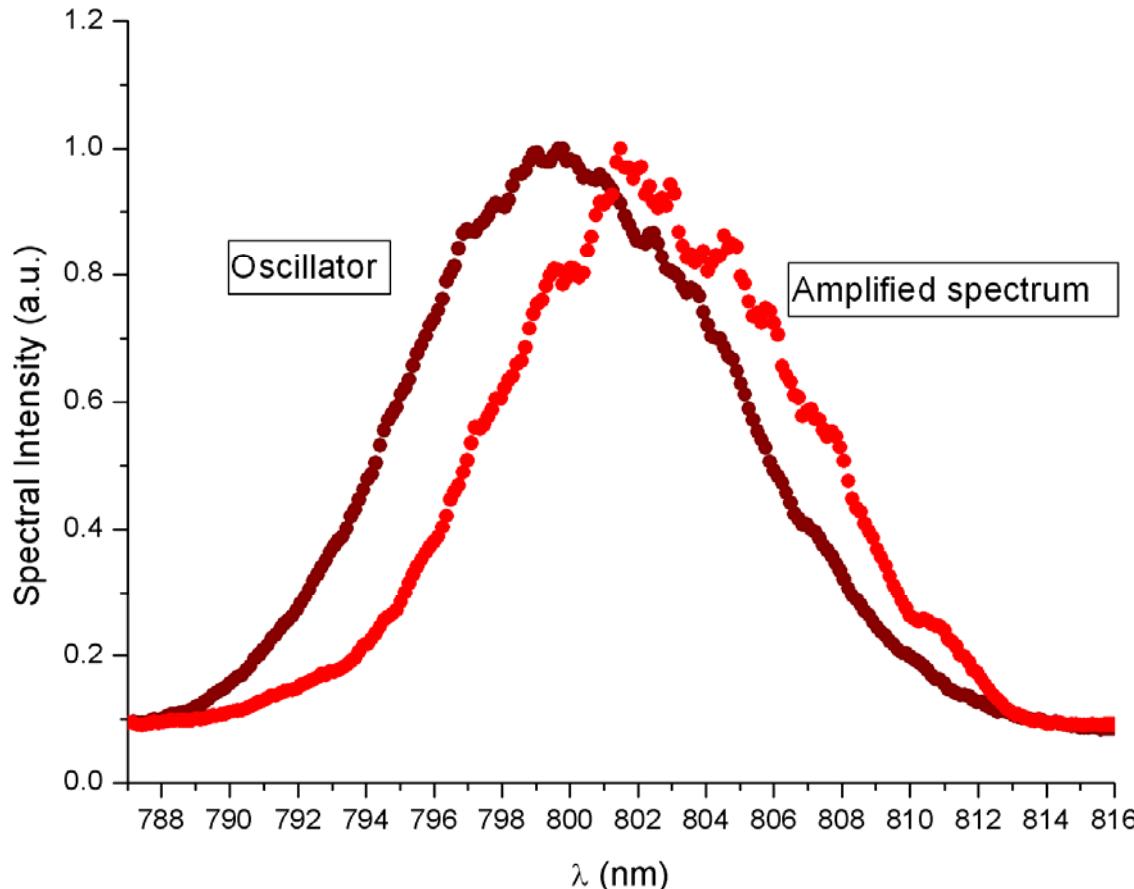
Phase & Amplitude modulation [@LNF]



By changing the phase
ONLY;
the amplitude
is affected too:
they are coupled

Phase modulation is coupled to Amplitude modulation in Dazzler

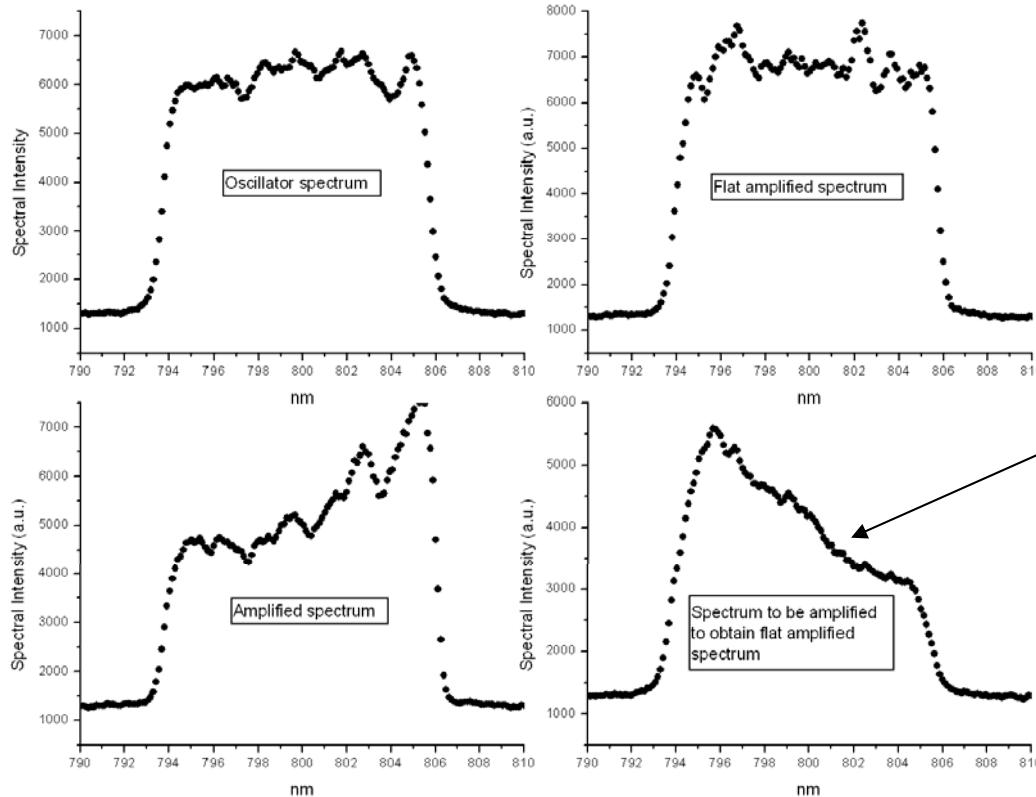
Amplification spectral distortions on Gaussian shape @LNF



The amplifier introduces a distortion on the oscillator spectrum shifting the central wavelength to higher wavelength.
For a Gaussian shape spectrum the distortion does not modify the shape

For a non amplified flat spectrum this distortion is too bad to maintain the flat spectrum profile.

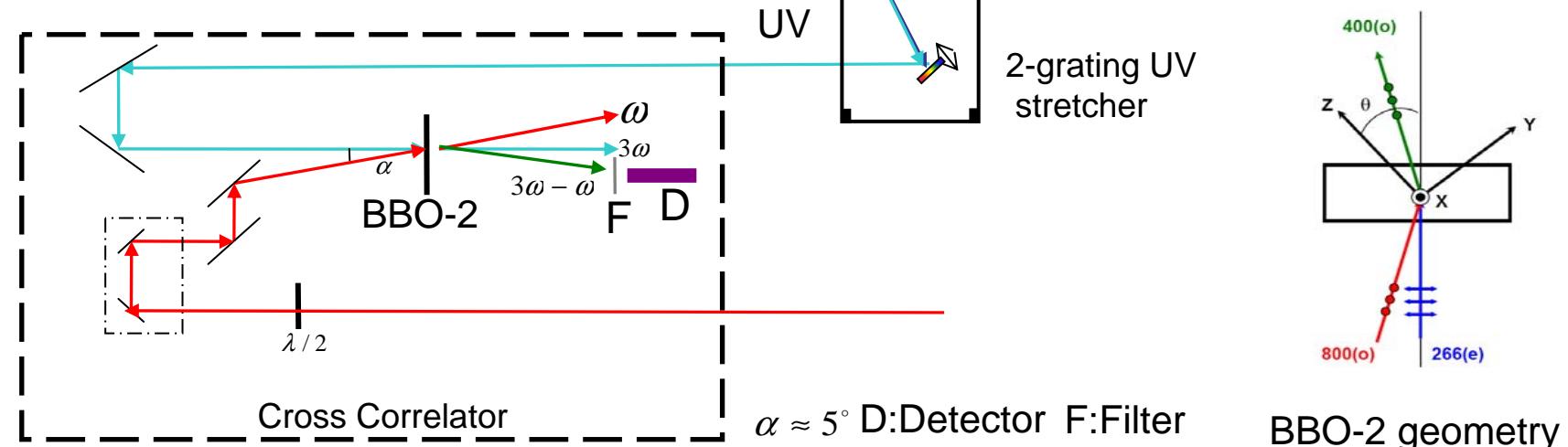
Amplification spectral distortions on a flat spectrum @LNF



The distortion introduced by the amplifier can be compensated using the DAZZLER:
spectrum we need to produce before the amplifier to obtain flat spectrum after

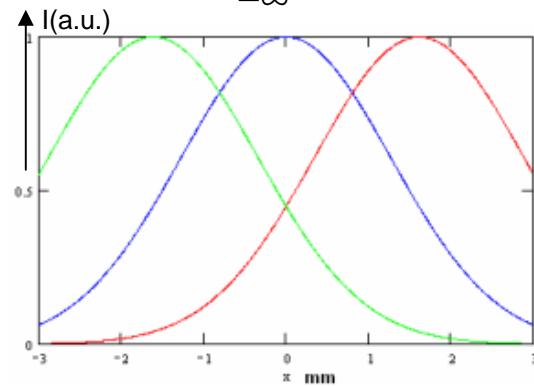
The amplifier introduces distortions in the spectrum so:
IT is better to look at the amplified spectrum as a reference
to start the pulse manipulation for the flat spectrum or other spectral shapes

Cross Correlator:



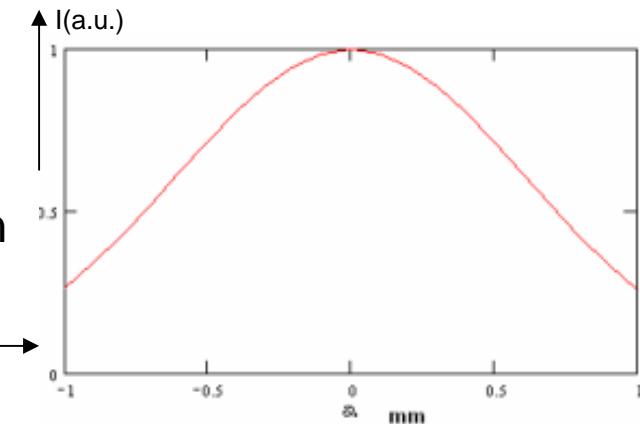
$$A_2(\tau) = \int_{-\infty}^{\infty} I_1(t) I_2(t - \tau) dt$$

Cross correlation signal



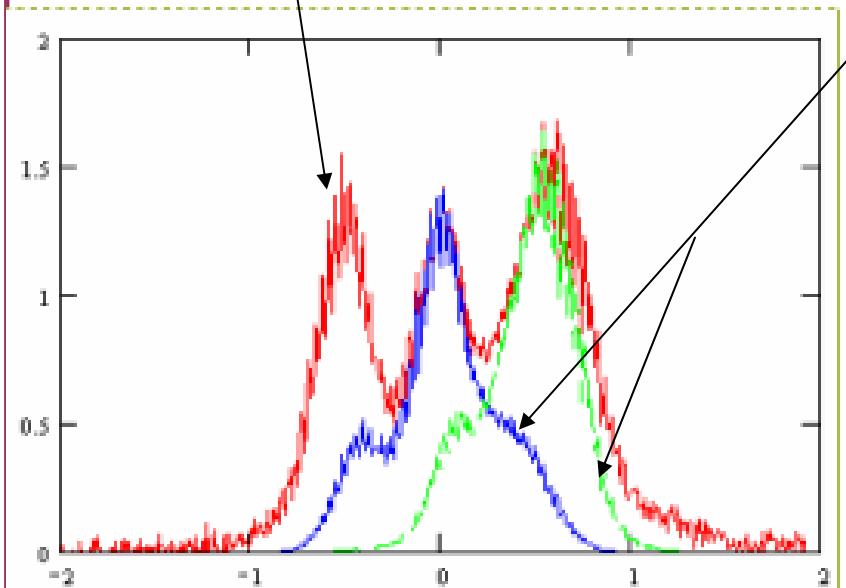
Spatial chirp effect

Amplitude modulation
Due to spatial chirp

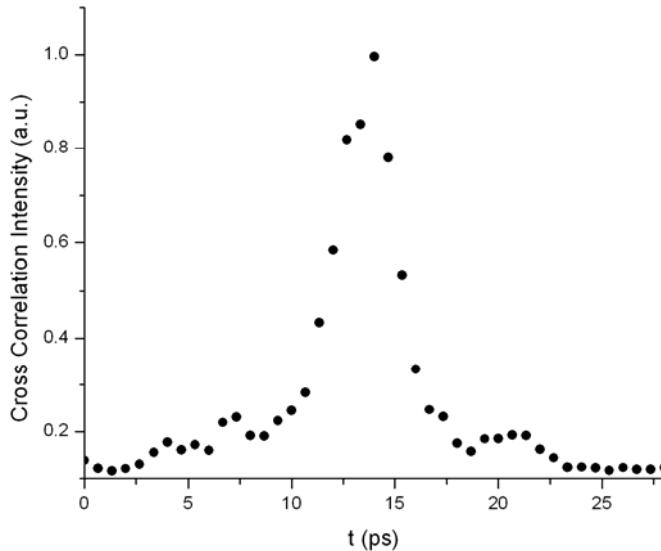


Cross correlator measure vs Alignment @LNF

UV spectrum



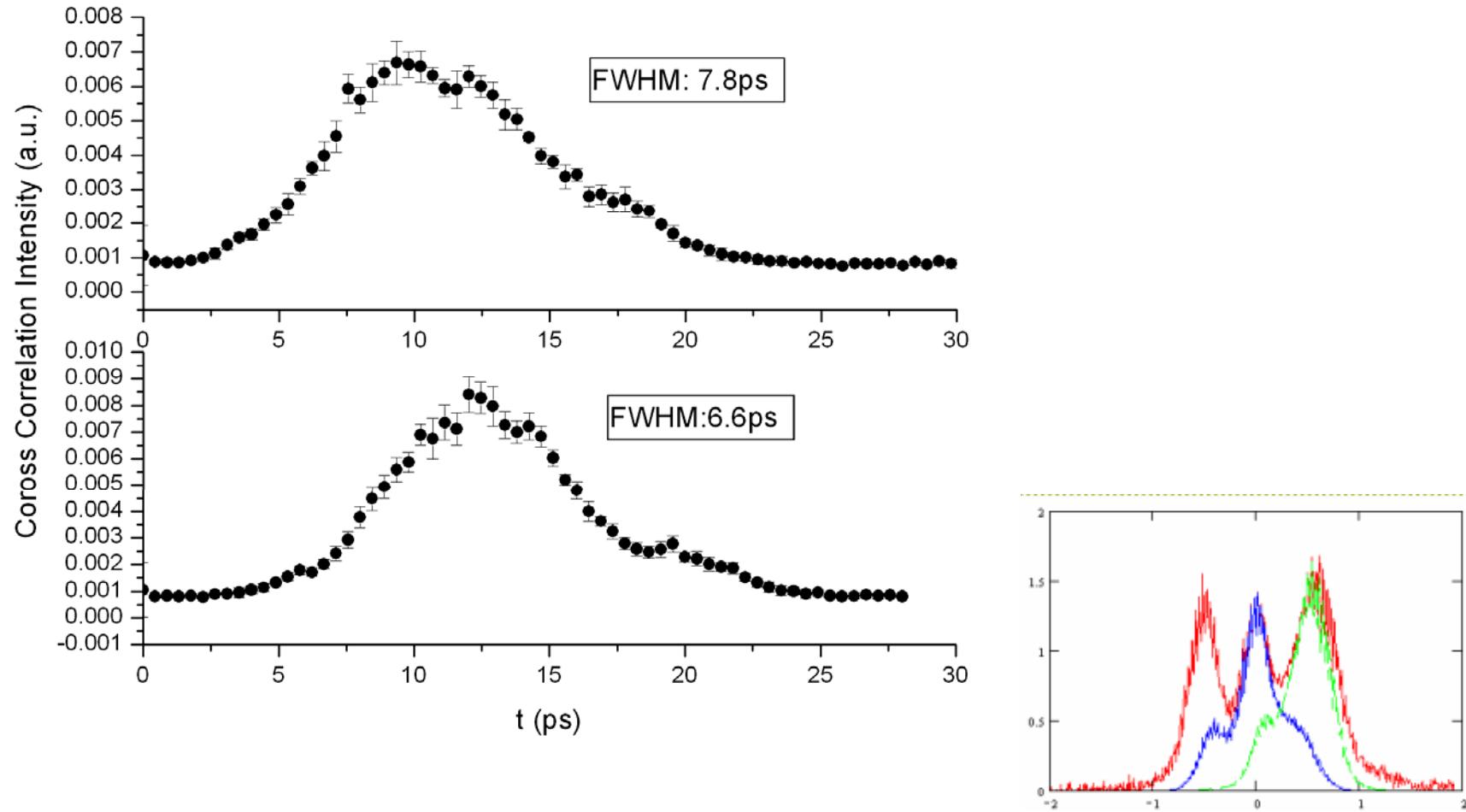
UV spectrum multiply by amplitude modulation due to spatial chirp



It is possible to verify experimentally with the cross correlator the spatial chirp introduce by the UV stretcher

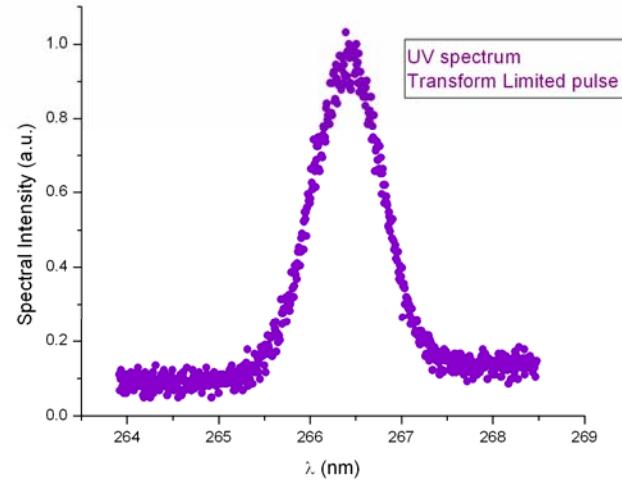
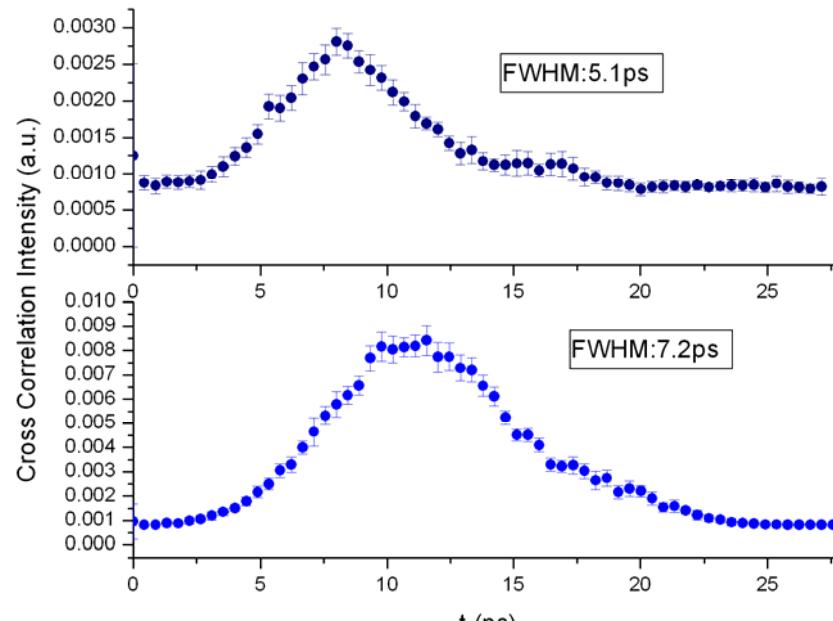
Cross Correlation measure relative to the spectrum: **UV spectrum**

Changing the alignment the measure changes because of Spatial Chirp @LNF



Cross correlator measure vs UV spot dimension @LNF

The spatial chirp effect can be seen also by cutting the beam spot trough a iris. In fact in this way the iris behaves like a filter. In the data it is possible to see a change of 2.1ps.



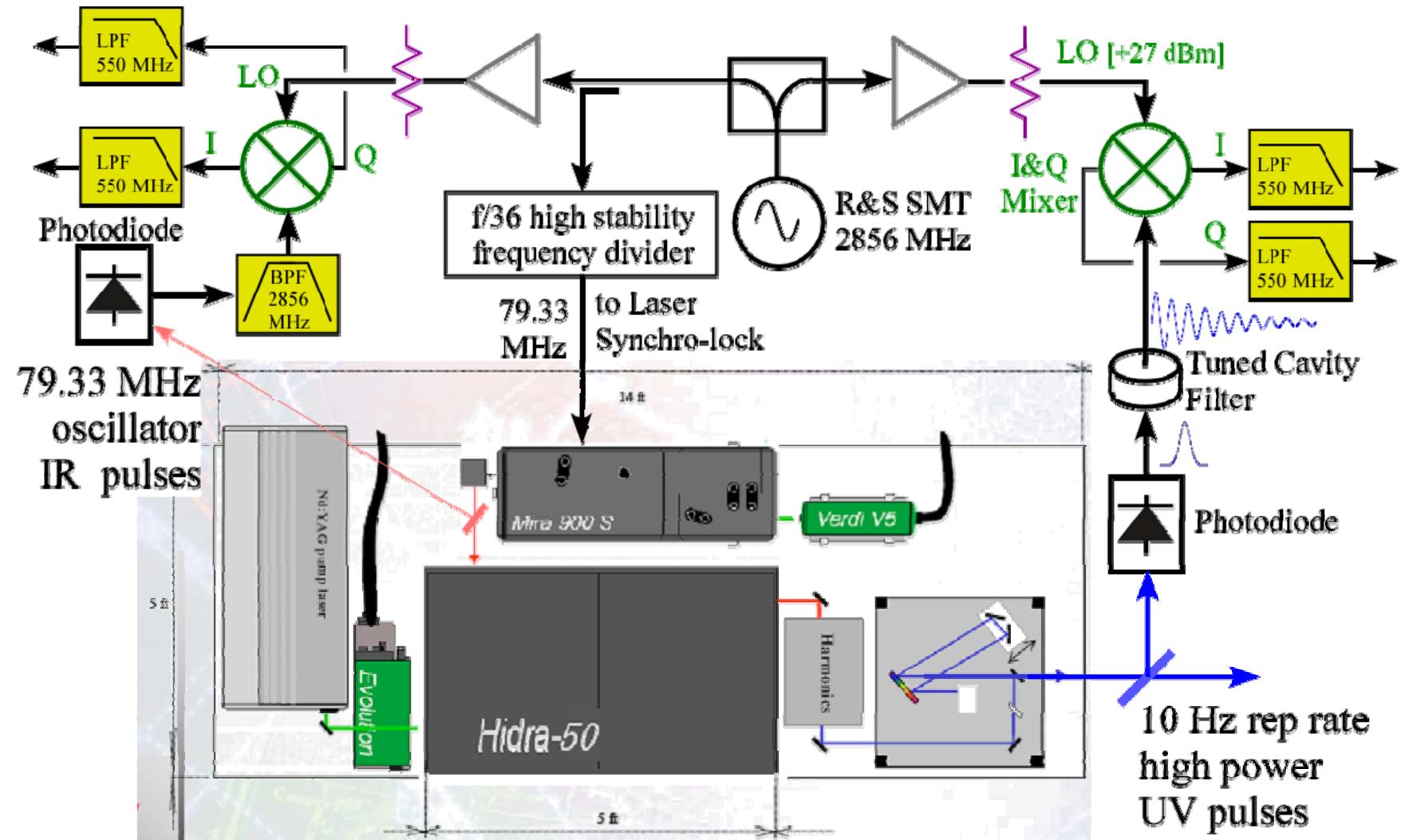
Synchronization system

Thanks to



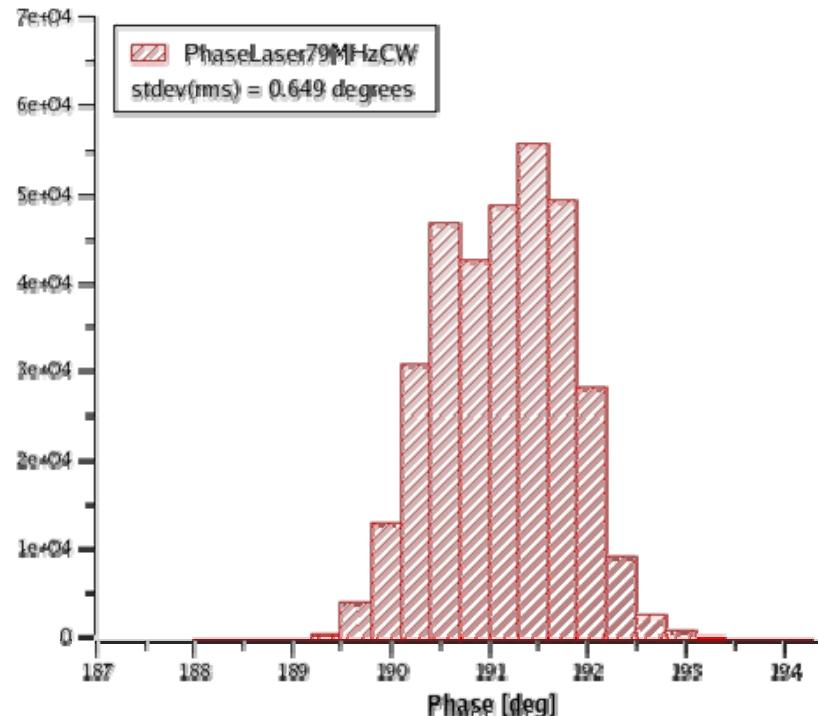
M. Bellaveglia A. Gallo L. Cacciotti

Laser time jitter measurements set-up

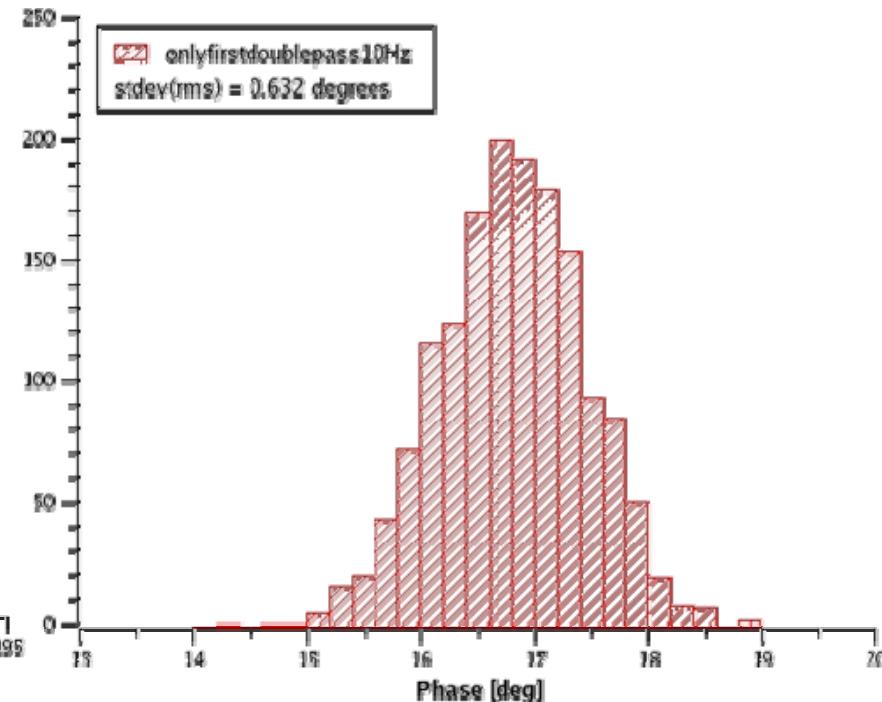


Laser time jitter measurements

Proceedings PAC05: RF SPARC synchronization system.



Laser oscillator phase noise
IR pulses, 79.33 MHz rep rate
Measured phase noise
 $650 \div 750 \text{ fs}$ rms



Laser output phase noise
UV pulses, 10 Hz rep rate
Measured phase noise
 $630 \text{ fs} \div 1 \text{ ps}$ rms

Summary

To perform pulse shaping using the Dazzler
it is not possible to change
the phase without changing
the spectral amplitude too

The Dazzler can compensate for the
distortions introduced by
the amplifiers and the harmonic conversion

To achieve correct information about the pulses
temporal width using
cross correlation technique
it is necessary to eliminate the
spatial chirp.



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