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Central Laser Facility

Temporal and spectral characterization of Ultra-Short High Power Laser Pulses

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Within a collaboration with SPARC_LAB

IN SUPREMÆ DIGNITATIS 1343

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Summary

- Measurements' Importance
- Laser Diagnostic: *GRENOUILLE*
- Previous Algorithm: *BASIC FROG*, *GP*, *COMPOSITE*.
- The *DEVELOPED ALGORITHM*
- Characterization of *VULCAN DATA*
- Characterization of *FULL POWER GEMINI DATA*
- Conclusions

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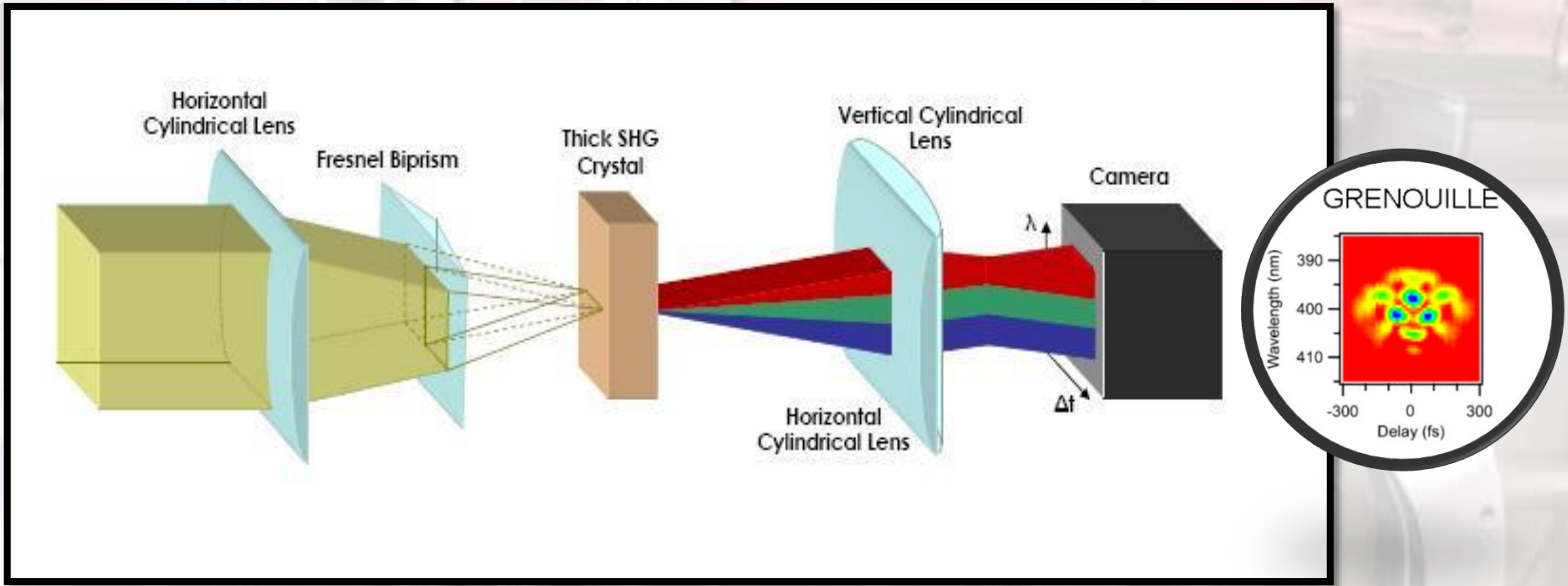
Measurements' Importance

The characterization of the laser pulse is essential for studying many physical process:

- ✓ The *PHOTO-DISSOCIATION* is more efficient in the case of using a chirped pulse;
- ✓ The *NON-LINEAR PHENOMENA* like self-focusing, self-phase modulation, etc. which modify the laser beam;
- ✓ The *TEST OF THEORETICAL MODELS* about the laser physics and the *PRODUCTION OF SHORTER PULSES;*
- ✓ The detection of the laser paramenter, after passing a material, for understanding its *STRUCTURAL CHARACTERISTICS*;
- ✓ The *VALUATION OF THE PULSE TEMPORAL SHAPE* (pedestal,pre-pulses,etc.) for the employment of this type of pulses in plasma physics (laser-plasma interaction, fusion, etc.).

GRating-Eliminated No-nonsense Observation of Ultrafast Incident Laser Light E-fields



GRENOUILLE IS A SPECTRALLY RESOLVED AUTOCORRELATION.

Patrick O'Shea, Mark Kimmel, Xun Gu, and Rick Trebino,
Highly simplified device for ultrashort-pulse measurement,
OPTICS LETTERS / Vol. 26, No. 12 / June 15, 2001

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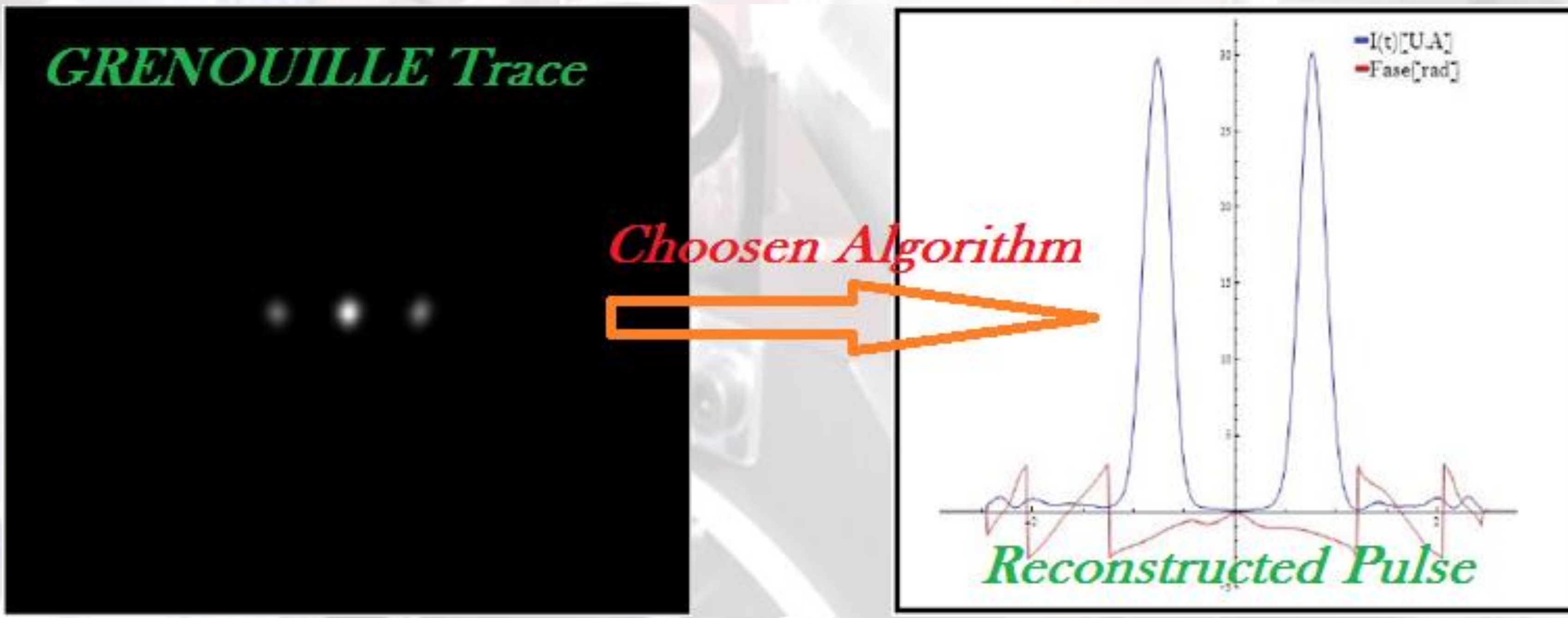
Previous algorithm

In order to characterize a pulse one must use a pulse retrieval algorithm, in which the GRENOUILLE TRACE serves as an input data.



M.Galletti, *Sviluppo di un software di riscostruzione e caratterizzazione di impulsi laser ultracorti di alta potenza, Master Thesis, 15 Dec. 2014, Pisa*

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Previous algorithm

- **BASIC FROG** based on an iterative loop, where after calculating I_{GREN} from an initial guess of E(t), it substitutes the magnitude I_{GREN} with the magnitude I_{EXP} and makes the inverse-FT to conclude the loop;

__K. W. DeLong and R. Trebino,__ Improved ultrashort pulse-retrieval algorithm for frequency-resolved optical gating, Vol.11, No.9, Sept.1994, JOSA A

- **GENERAL PROJECTION** based on a 1-D minimization algorithm;
- **COMPOSITE ALGORITHM** based on the mix of the previous two algorithm with other minimization algorithms.

__K. W. DeLong, D. N. Fittinghoff, R. Trebino, B. Kohler and K. Wilson,__ Pulse retrieval in frequency-resolved optical gating based on the method of generalized projections, OPT. LETT./ Vol.19, No.24/ Dec. 15, 1994

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Ultra-Short Pulse Reconstruction Software

The algorithm is based on the *1-D "CONIUGATE GRADIENT" MINIMIZATION METHOD*. It consists of 2 main parts:

1. *EXPERIMENTAL IMAGE CAPTURE,* image that will be compared with (involves determining the χ^2 "distance") a calculated one

$$I^{SHG}_{GRENOUILLE} = \left|\int_{-\infty}^{\infty} E(t)E(t-\tau)e^{-iwt}dt\right|^2,$$

the latter produced by a reasonable initial pulse guess;

2. *AN ITERATIVE LOOP* (includes a minimization algorithm) that proposes to vary the arbitrary initial pulse for decreasing of the χ^2, succeeding so to obtain a reconstructed pulse as similar as possible to the real one.

Ultra-Short Pulse Reconstruction Software

The experimental image is not ready to be processed, so before processing in the first part of the algorithm, the images have been:

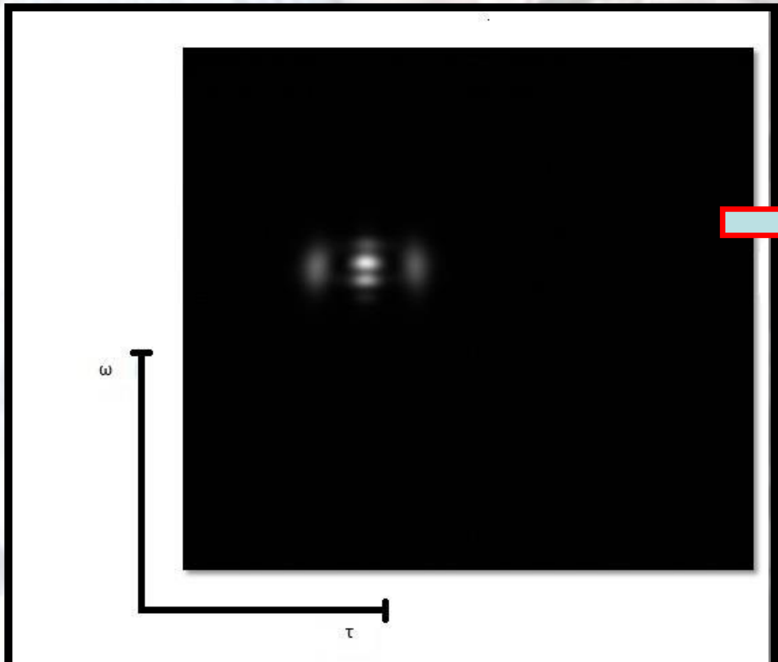
1.1 *SUBTRACTED* from the background;

1.2 *RE-SCALED* to have the needed dimension to be reconstructed;

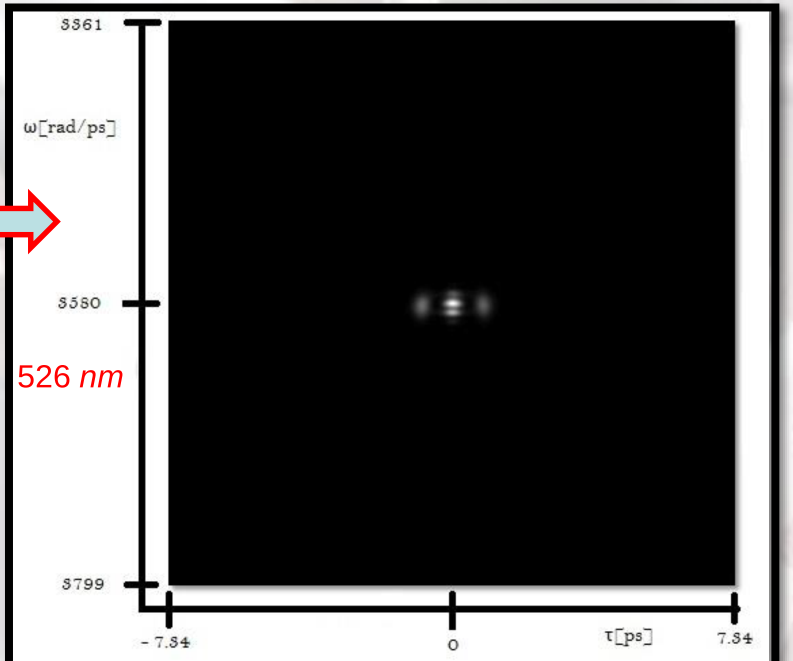
1.3 *CENTERED* in the maximum of I(t).

Ultra-Short Pulse Reconstruction Software

GRENOUILLE Trace of a ***DOUBLE PULSE*** made using a Michelson interferometer with a ***100 FS*** *Ti:Sa laser*, ***80 MHZ, 1053 NM.***



EXPERIMENTAL *GRENOUILLE TRACE*

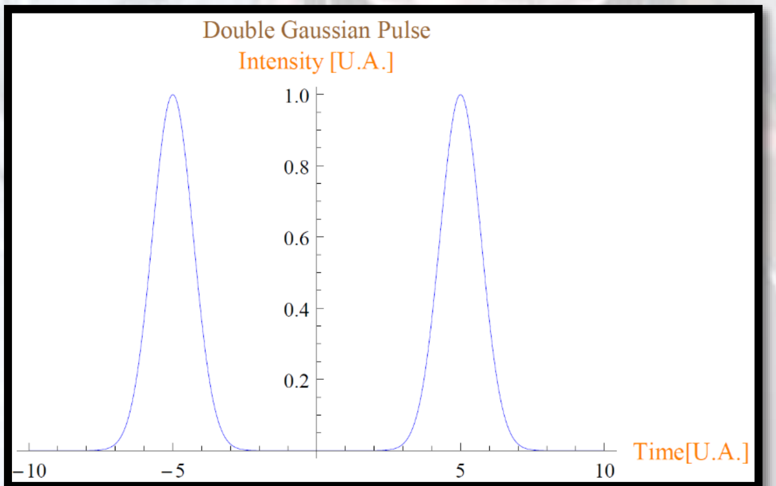


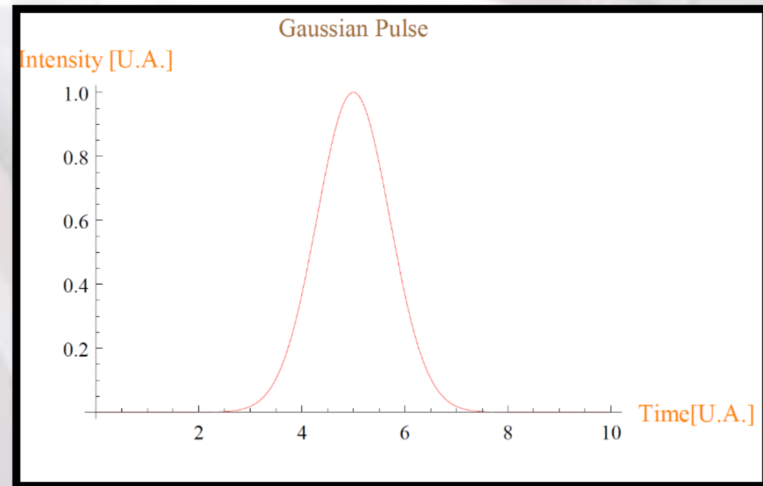
MODIFIED EXPERIMENTAL TRACE

Ultra-Short Pulse Reconstruction Software

The first part ends with:

1.4 ***CHOICE OF THE FIELD*** $E(t)$, in this case:





1.5 ***SAMPLING*** of the field, E_j;

Ultra-Short Pulse Reconstruction Software

The second part starts with the iterative loop that consists in:

2.1 ***CALCULATION*** of the GRENOUILLE signal, of the "distance" χ^2,of the χ^2 gradient with respect to E_j and of χ^2 minimum in the gradient direction.

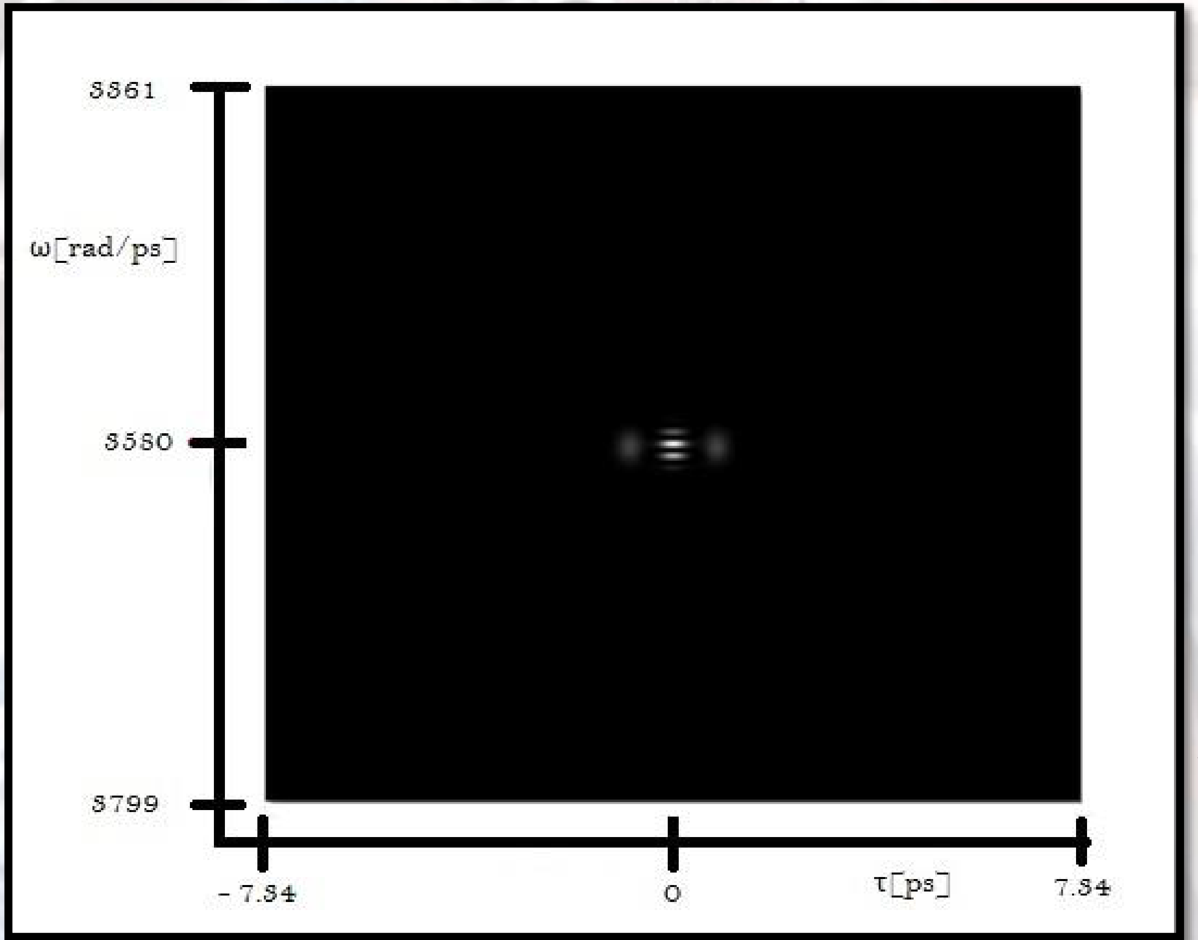
The "distance" χ^2 is made up by 2 parts: one is ***THE "REAL DISTANCE"*** between the sperimental and the analytical image, and the other was added to maintain the ***TEMPORAL BARYCENTER*** in the middle of the analytical one so as to permit a better reconstruction of the GRENOUILLE trace.

2.2 ***UPDATING*** of the new E_j with the minimum position.

The steps are repeated until reaching conditions for which the reconstructed pulse does not vary significantly.

M.Galletti, M.Galimberti, D.Giulietti,
Ultra-Short Pulse Reconstruction Software
in High Power Laser System, NIMB May 2015

Ultra-Short Pulse Reconstruction Software



- The choice of the ***INITIAL FIELD WAS A DOUBLE PULSE*** with the parameters different from the real one.

M.Galletti, *Sviluppo di un software di riscostruzione e caratterizzazione di impulsi laser ultracorti di alta potenza, Master Thesis, 15 Dec. 2014, Pisa*

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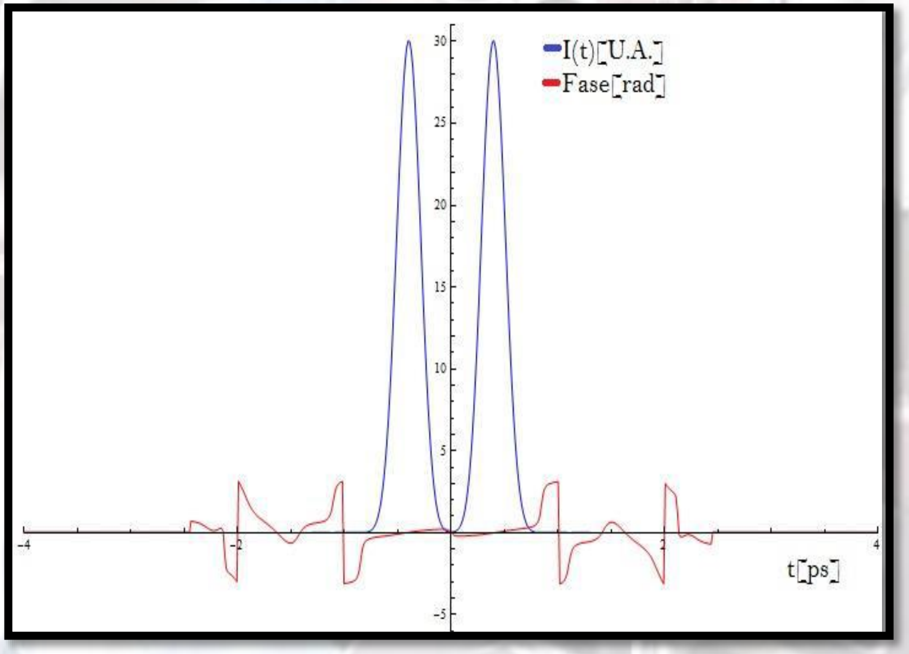
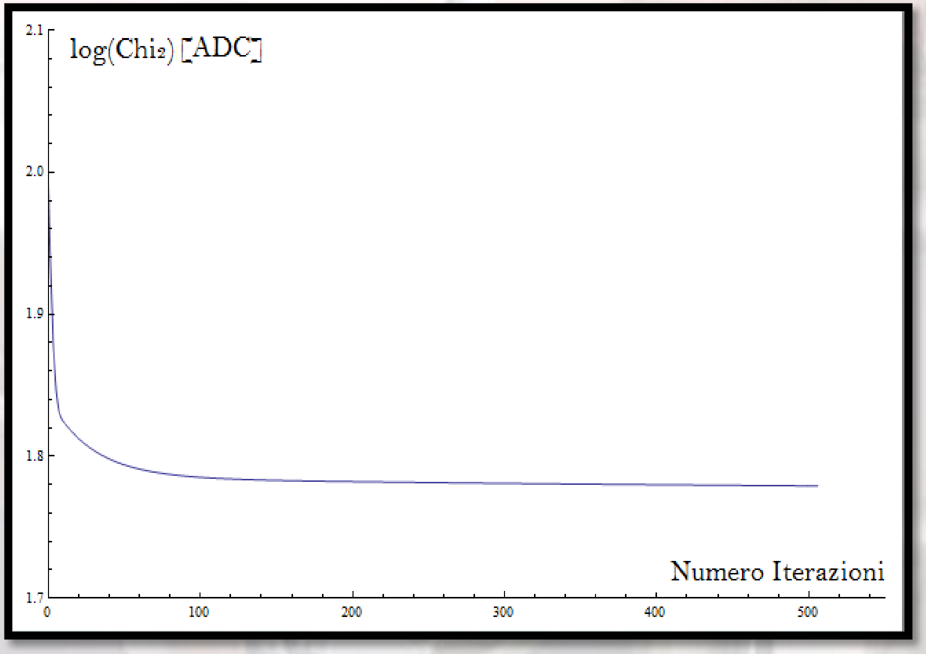
Ultra-Short Pulse Reconstruction Software

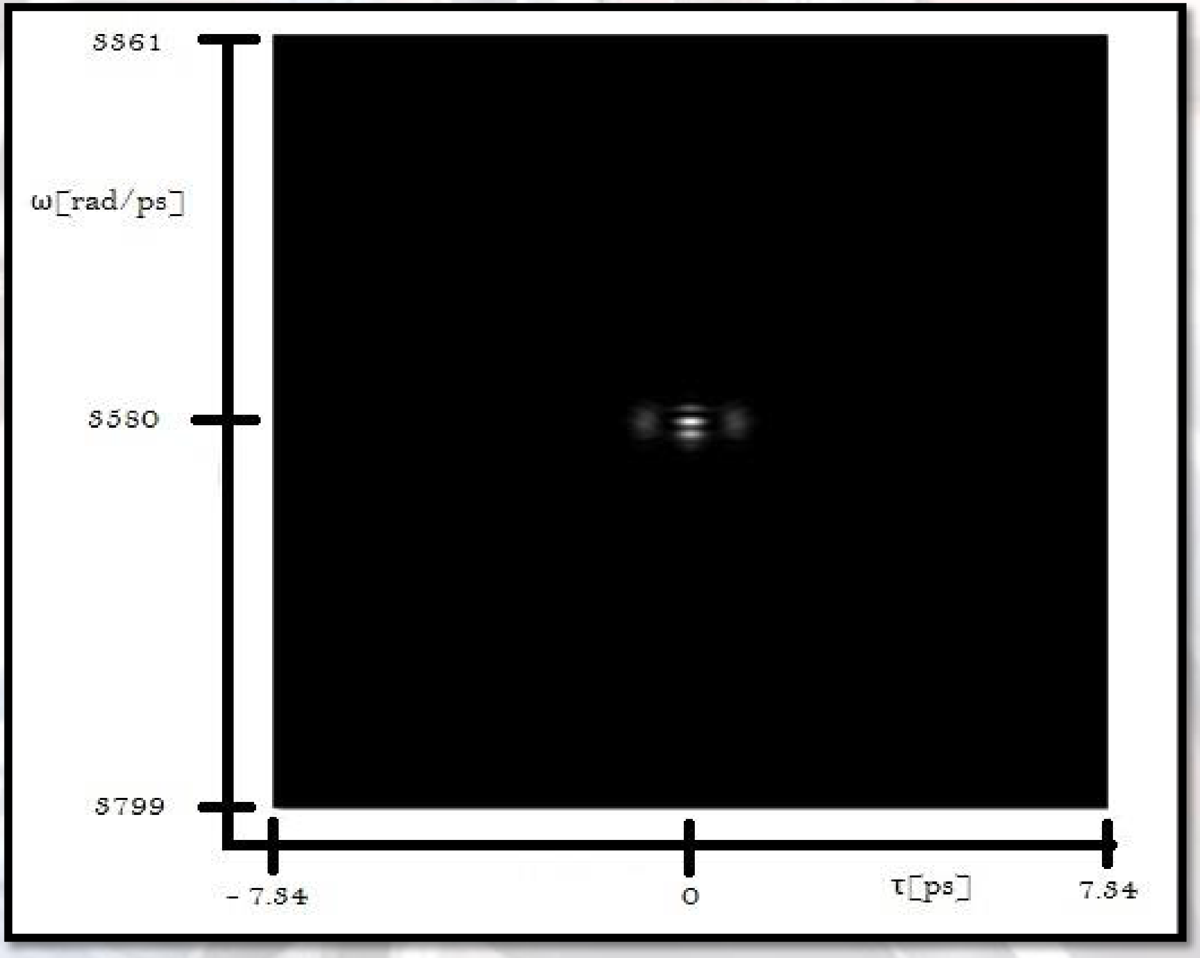




→ The phase is reported even where the intensity is zero and it doesn't have a real physical sense and it is not treated with the unwrapping technique;

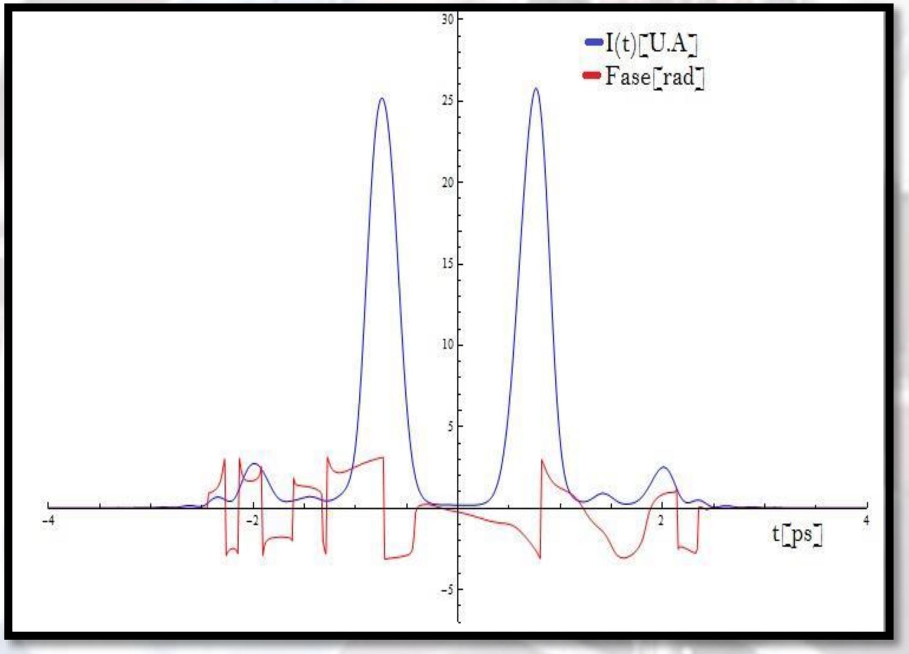
→ The *CONVERGENCE IS REACHED IN A REALLY FAST WAY* (60 iterations).

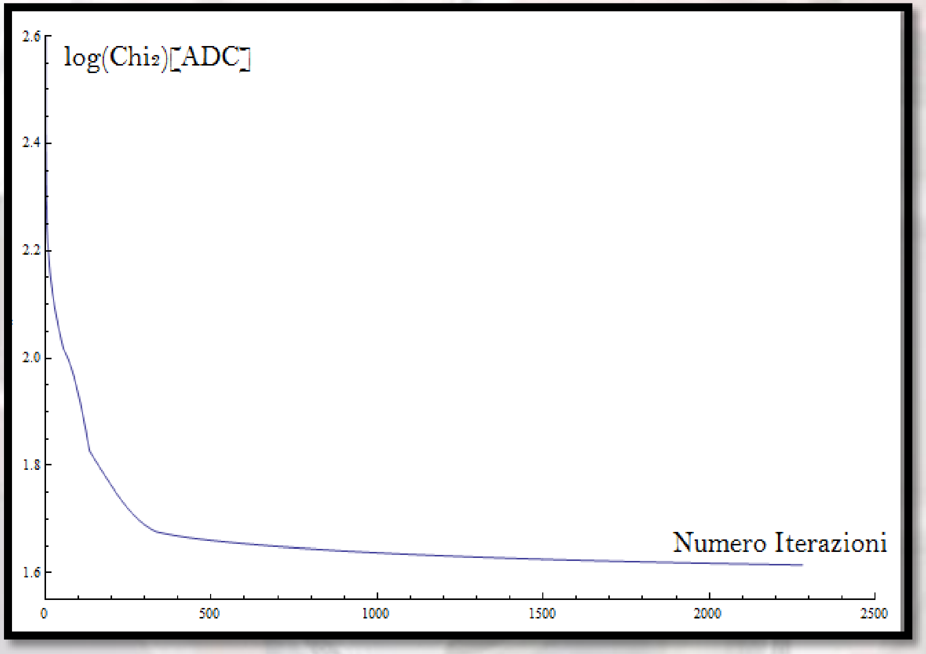
Ultra-Short Pulse Reconstruction Software



- The choice of the ***INITIAL FIELD WAS A GAUSSIAN PULSE*** with FWHM larger than the temporal lenght of the real double pulse.
- The ***GAUSSIAN PULSE IS THE MOST GENERAL ONE***. It can be applied to most of the pulses deriving its parameters from the experimental traces.

Ultra-Short Pulse Reconstruction Software



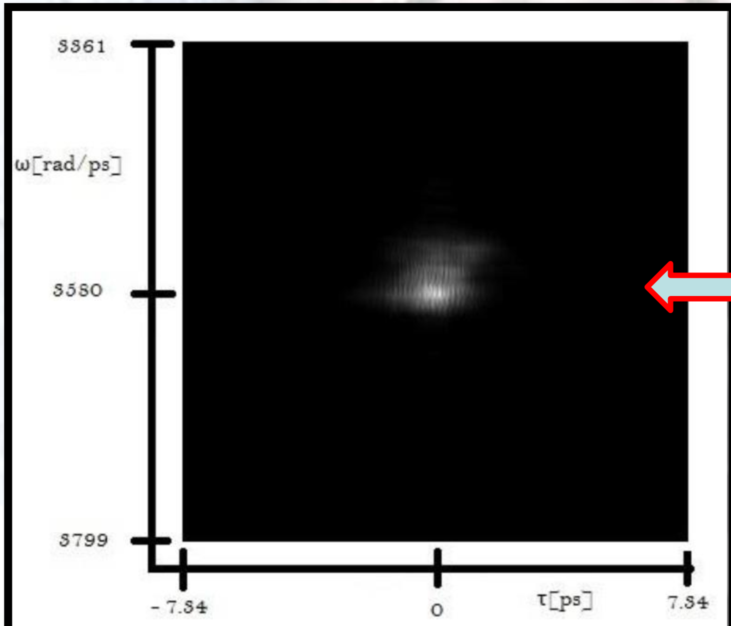


→ The phase is reported even where the intensity is zero and it doesn't have a real physical sense and it is not treated with the unwrapping technique;

→ The *CONVERGENCE IS REACHED IN A FAST WAY* (300 iterations), moreover we reach a lower "distance" value than before.

Vulcan Measurements

In this experimental research was analyzed for the first time, in Target Area Petawatt of Vulcan (*GW*), the laser pulse (*MJ, 2 HZ, 1053 NM*) with a *DIFFERENT TECHNIQUE* from the AC.



Images	FWHMAC pulse (ps)	FWHMGR pulse (ps)
GR_25		0.717
GR_26		1.0038
AC_14	0.7662	
AC_13	1.0071	

The results show an excellent agreement between the two type of measurements.

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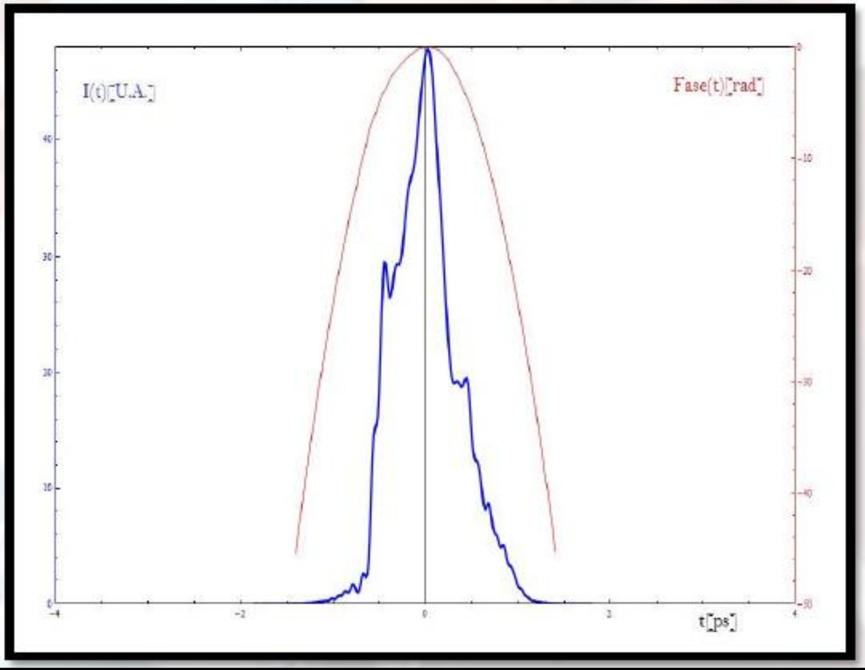
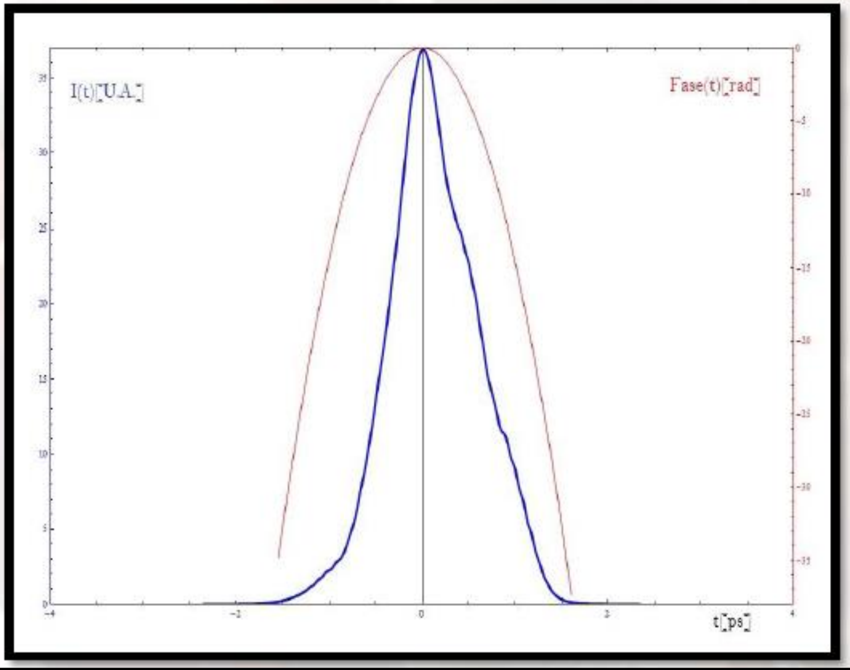
Vulcan Measurements

The ***RETRIEVED TEMPORAL SHAPE*** are that expected.

GR_25



GR_26



M.Galletti, M.Galimberti, D.Giulietti,
Ultra-Short Pulse Reconstruction Software
in High Power Laser System, NIMB May 2015

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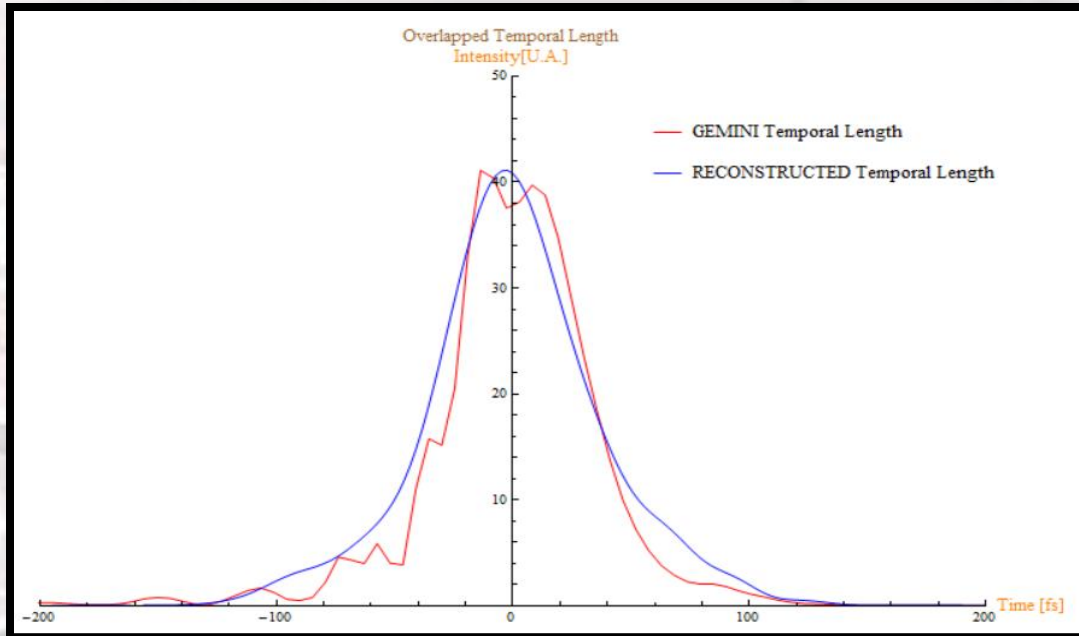
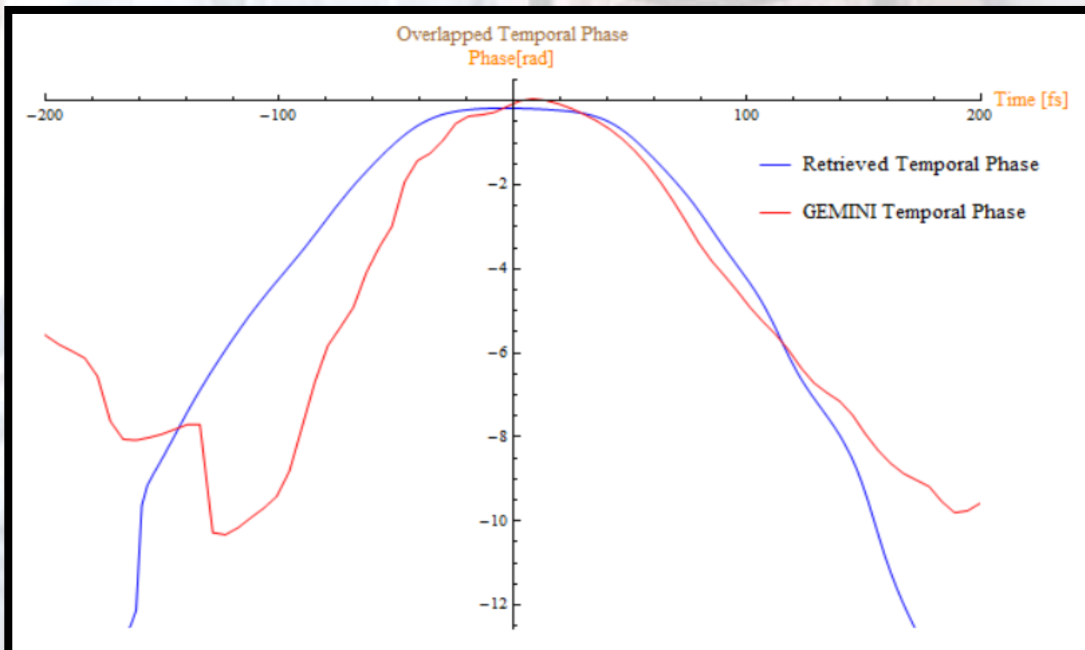
Gemini Full Power Measurements

This is a GRENUILLE trace of a GEMINI pulse.

Each beam will deliver ***15 JOULES*** to target in a pulse of ***61 FEMTOSECONDS*** (i.e. a peak power of about ***PW***), with a shot rate of ***ONE SHOT PER 20 SECONDS***.

Gemini Full Power Measurements





The GEMINI temporal length is 61 fs while the ***RECONSTRUCTED TEMPORAL LENGTH IS 64.29 FS***.

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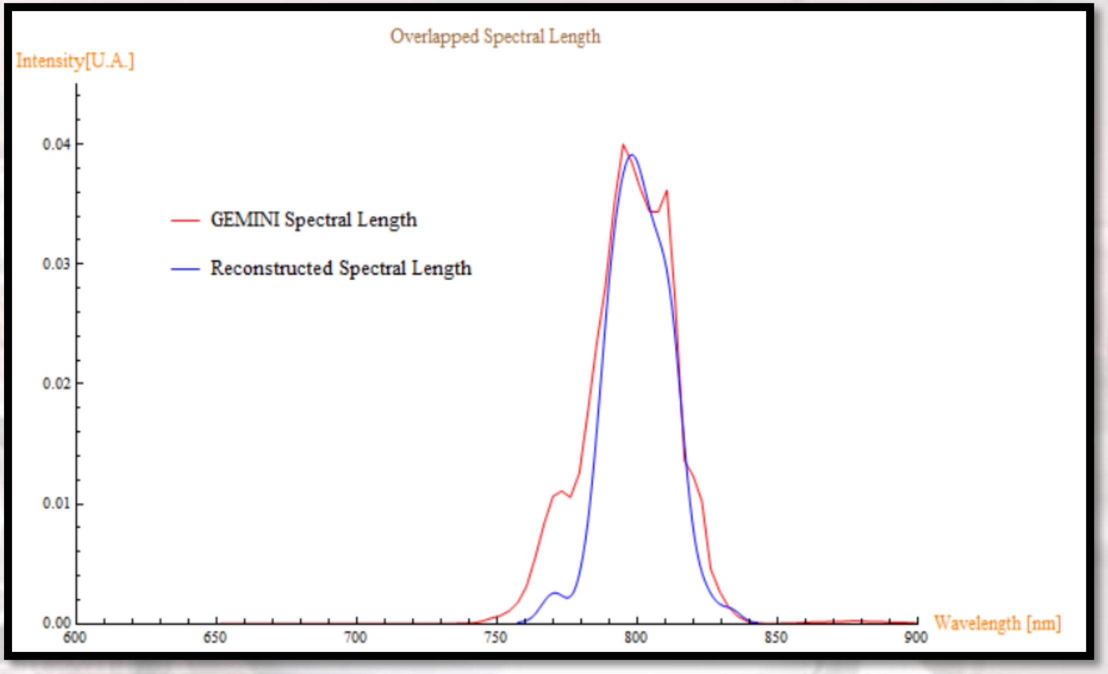
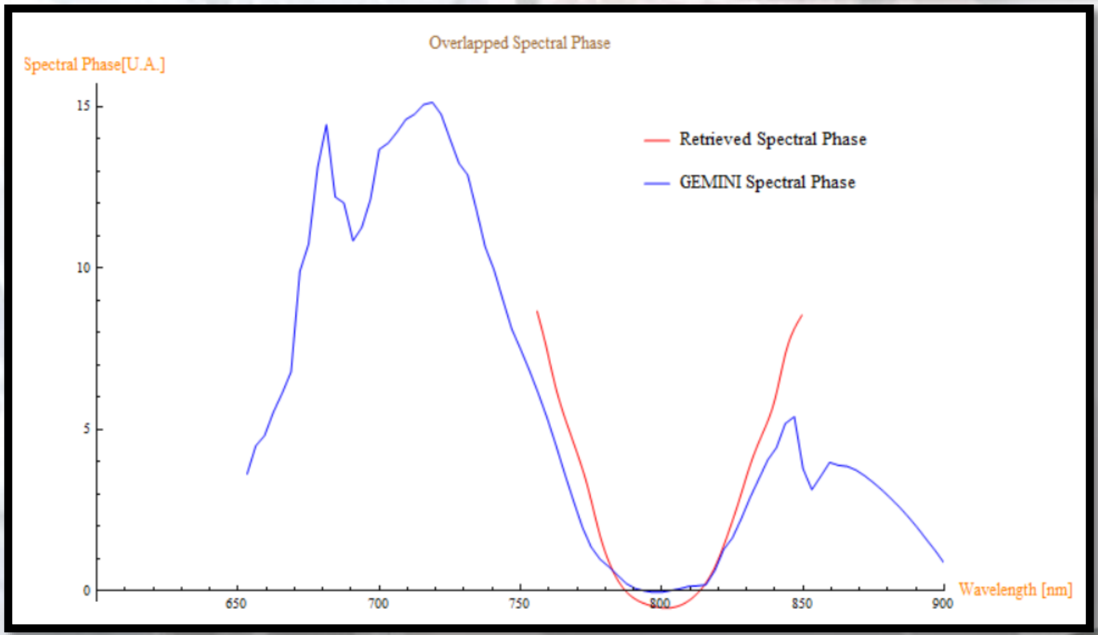
Gemini Full Power Measurements





The GEMINI spectral length is 29,5 nm while the ***RECONSTRUCTED SPECTRAL LENGTH IS 29,7 NM***.

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Conclusions 1/2

- The algorithm will be improved with functions analyzing information derived by other diagnostic tool (like ***SPIDER***) so as to obtain more precise pulse characterization.

- The improved algorithm can be made faster and it could be used to make ***ON-LINE MEASUREMENTS***.

Conclusions 2/2

- Our purpose is to make temporal and spectral characterization of *FLAME PULSES*.

FLAME LASER is based upon Ti:Sa, CPA system that will deliver *30 FS, 800 NM (BW 60 NM), 200 TW,* laser pulses with a *10 HZ* repetition rate.

The system has a *CONTRAST RATIO >10^8.*

Thank you for your attention!!

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