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Dezvoltarea laserilor de mare putere in femtosecunde in INFLPR. Stadiul actual si perspective

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CUPRINS:

1. Facilitatea laser cu pulsuri de femtosecunde (2006-2010)

2. Perspectivele de dezvoltare in perioada 2011-2015

Laseri de mare putere cu pulsuri de femtosecunde

Progrese pe plan mondial in anii '80:

- Oscilatoare laser cu Ti:safir in regim *"self-mode-locking"* cu banda larga spectrala si pulsuri ultrascurte de ordinul sute-zeci femtosecunde

-**"Chirped pulse amplification"**

D. Strickland and G. Mourou, "Compression of amplified chirped optical pulses", Opt. Commun. 56, 219-221 (1985)

25 de ani pentru laserii de mare putere cu pulsuri ultrascurte

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2006 – CPA 2101 (~ 4 GW), CLARK MXR, USA

Proiect NANOLAS – 2005-2008

2009 - TEWALAS (> 15 TW), Amplitude Technologies, France

Proiecte CAPACITATI – TEWALAS (2007-2009), MULTITERA (2008-2010)

CLARK MXR Laser – CPA 2101 (2006)

Er:glass fiber oscillator, frequency doubled

- Laser wavelength: 1550 nm → 775nm
- Pulse duration ~200fsec
- Repetition rate: 35MHz
- Pulse energy ~43 pJ
- Average power ~1.5mW

Ti:sapphire regenerative amplifier

- Laser wavelength 775nm
- Pulse duration ~ 200 fsec
- Repetition rate 2kHz
- Maximum pulse energy ~ 700 μJ
- Average power ~ 1.4W

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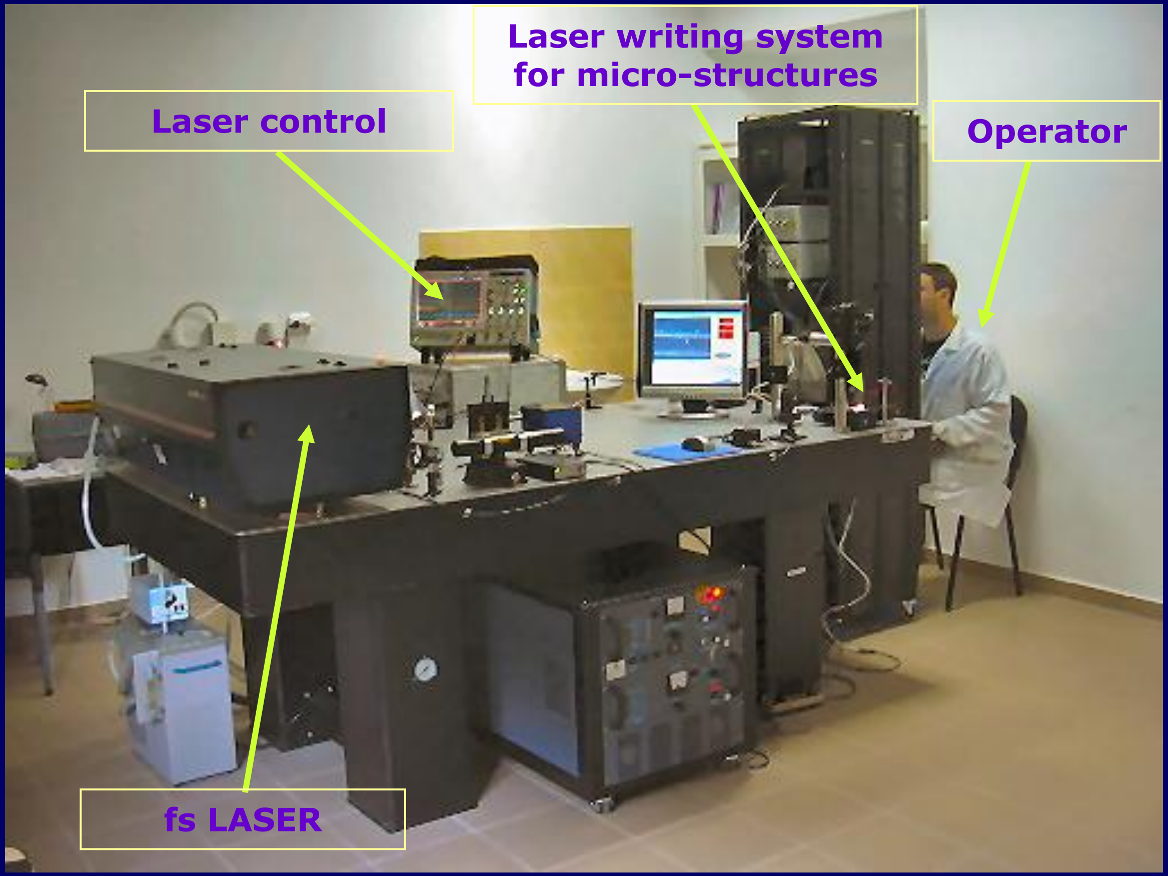
Femtosecond Laser and the Experimental Set-up for Micro-nanotechnologies (2007)



Laser wavelength, 775 nm; E_{pulse}= 0.7 mJ; t_p < 200 fs; f_{rep}= 2 kHz

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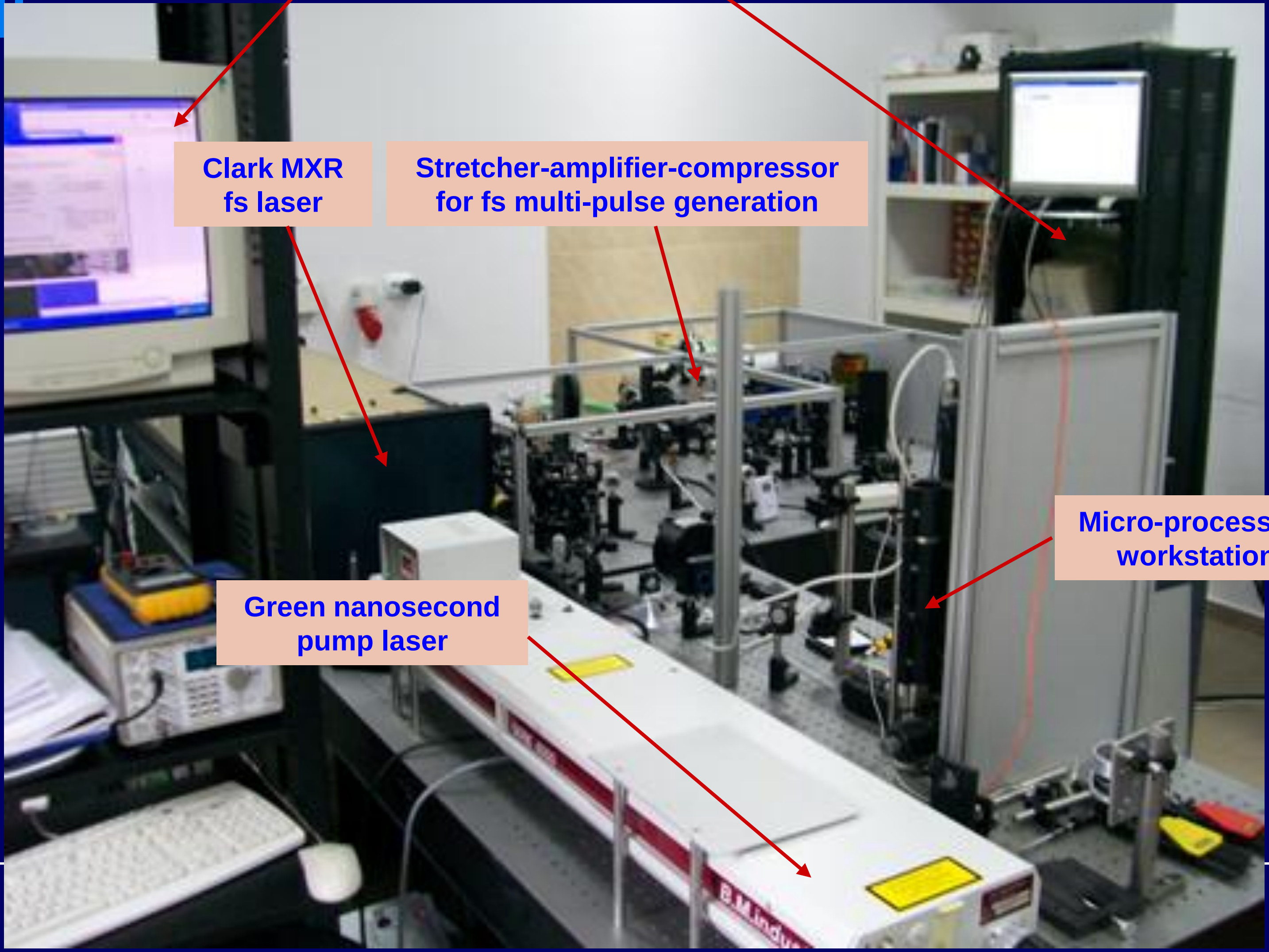
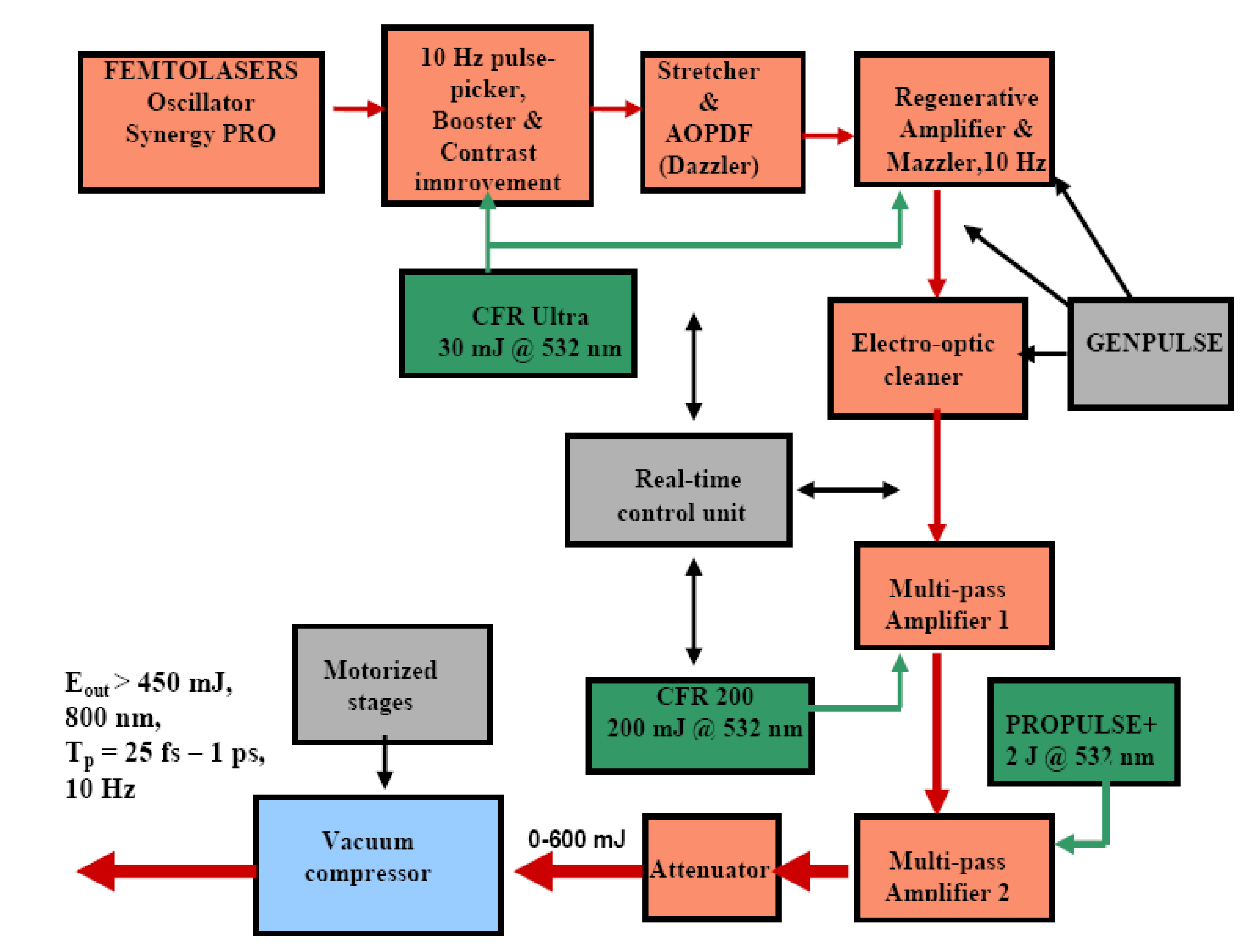
Experimental Room (2010)

Computer control unit



TEWALAS – Schematic Drawing of the 15-TW laser System (2009)



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Important Features of High Power Femtosecond Lasers

- **Pulse duration** (spectral bandwidth, phase corrections)

- **Intensity contrast** (ASE, picosecond-nanosecond pre-pulses)

- **Available focused intensity - Strehl ratio** (high beam quality pump lasers, wavefront corrections with deformable mirrors)

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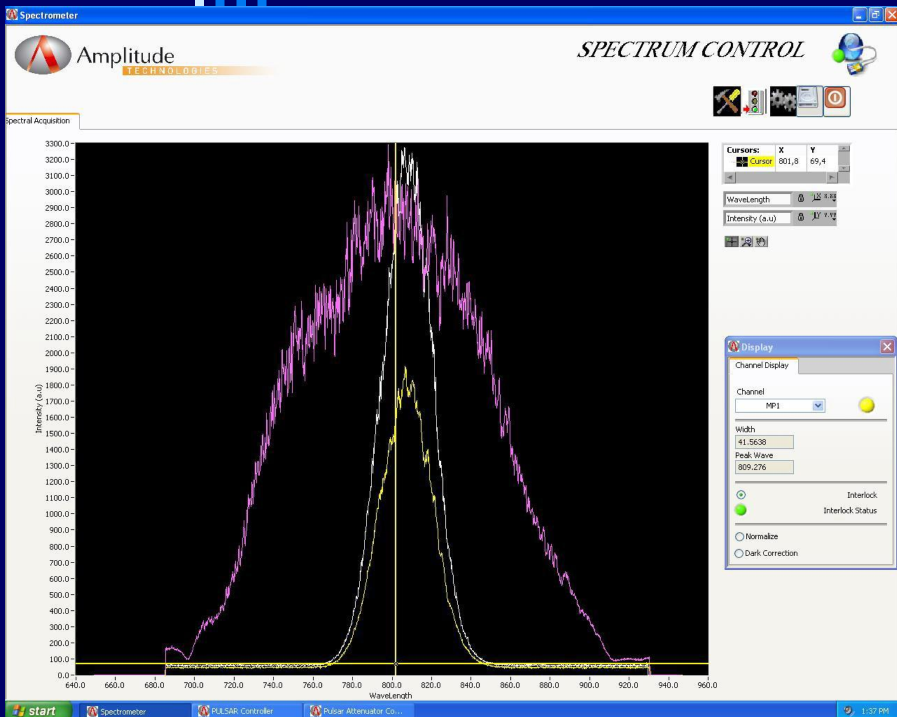
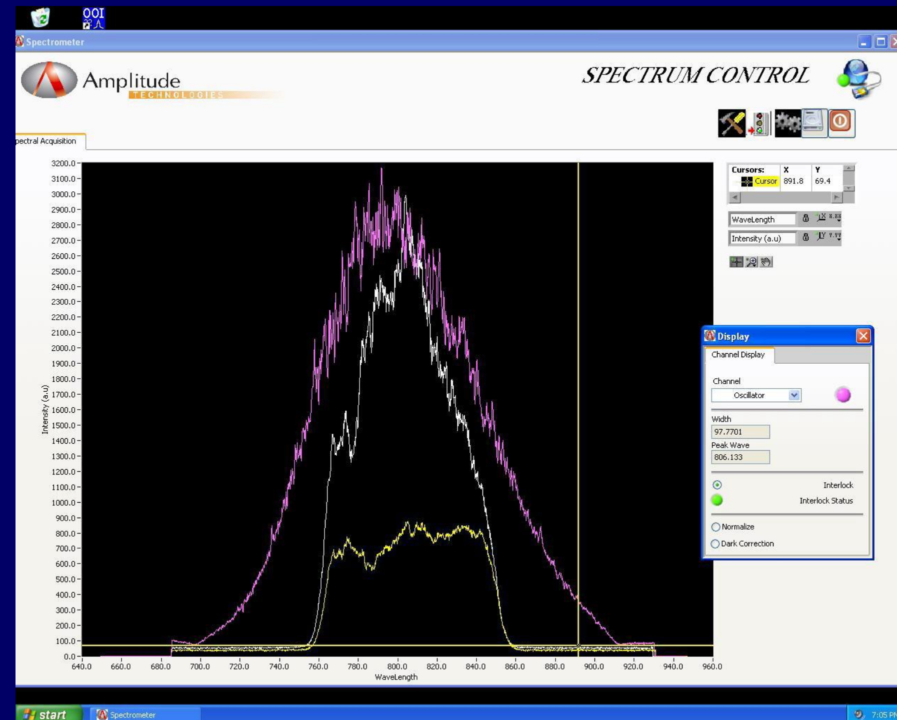
Pulse spectrum narrowing during Ti:S amplification – TEWALAS_INFLPR



(a)



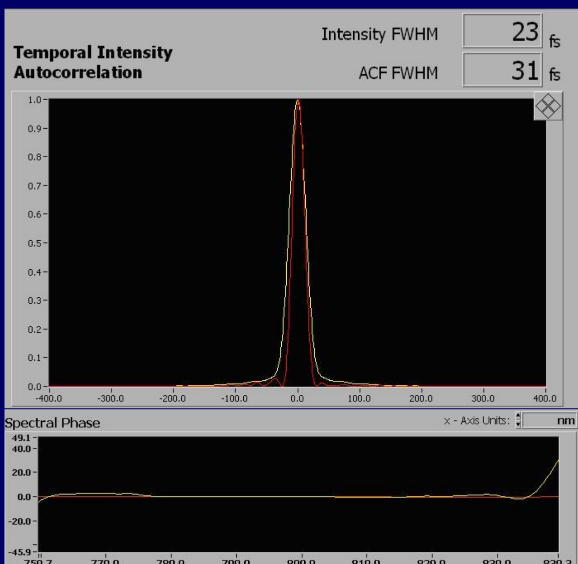
(b)

TEWALAS laser spectra: (a) without active Mazzler; (b) optimized by Mazzler. Mauve line – FEMTOLASERS oscillator (100 nm bandwidth); yellow line – after the first multi-pass amplifier, bandwidths - (a) 40 nm, (b) 75 nm; white line - after the second multi-pass amplifier- bandwidths (a) 35 nm, (b) 65 nm**.**

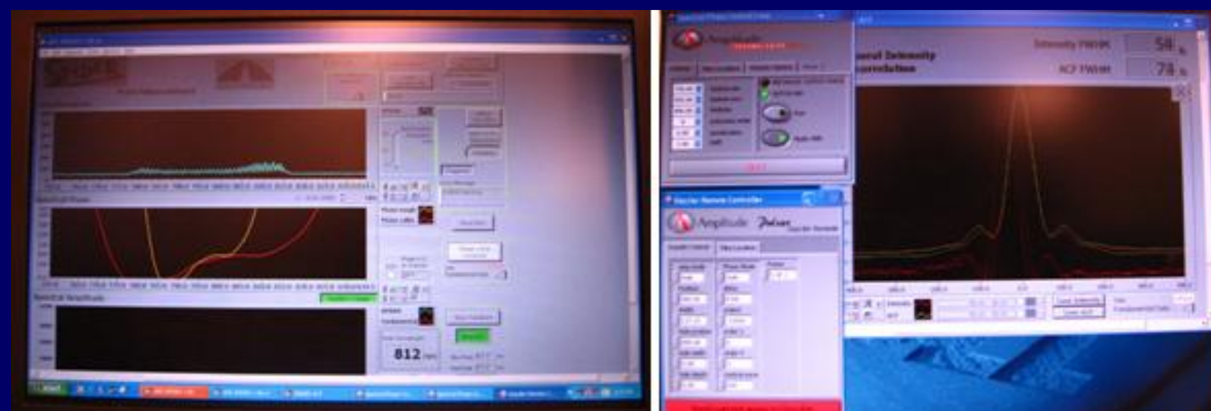
Correction of Spectral Phase Dispersion Using Acousto-optical Programmable Dispersion Filter (AOPDF) - Dazzler

Temporal distortion of the amplified re-compressed pulse is produced by:

- **dispersion and phase distortions introduced by the laser amplifier system**
- **spectral gain narrowing in Ti:sapphire amplifiers**



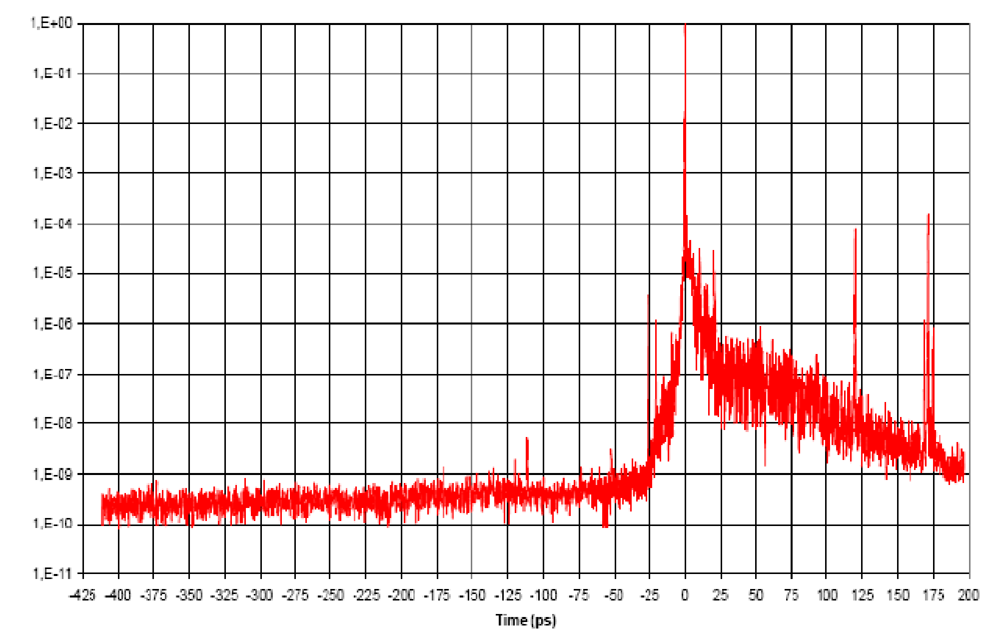
(a)



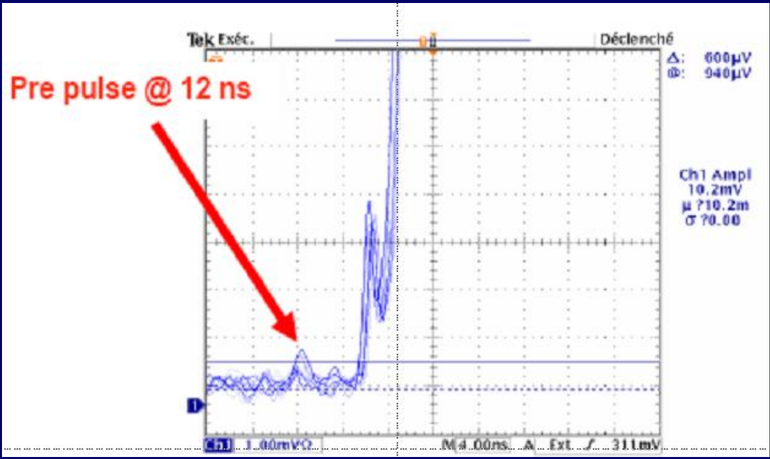
(b)

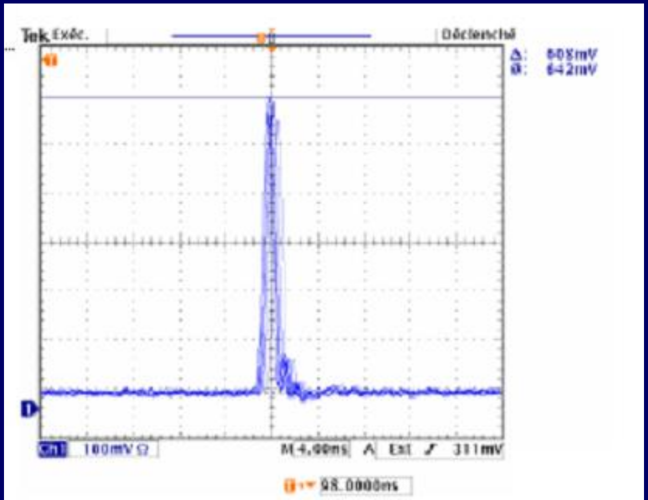
TEWALAS: Pulse duration measurements using SPIDER (a) with Dazzler phase correction; (b) without phase correction. All cases: with spectrum correction by Mazzler

Amplified spontaneous emission (ASE) and nanosecond intensity contrast



ASE contrast measured with a 3-rd order auto-correlator (SEQUOIA)





Nanosecond contrast

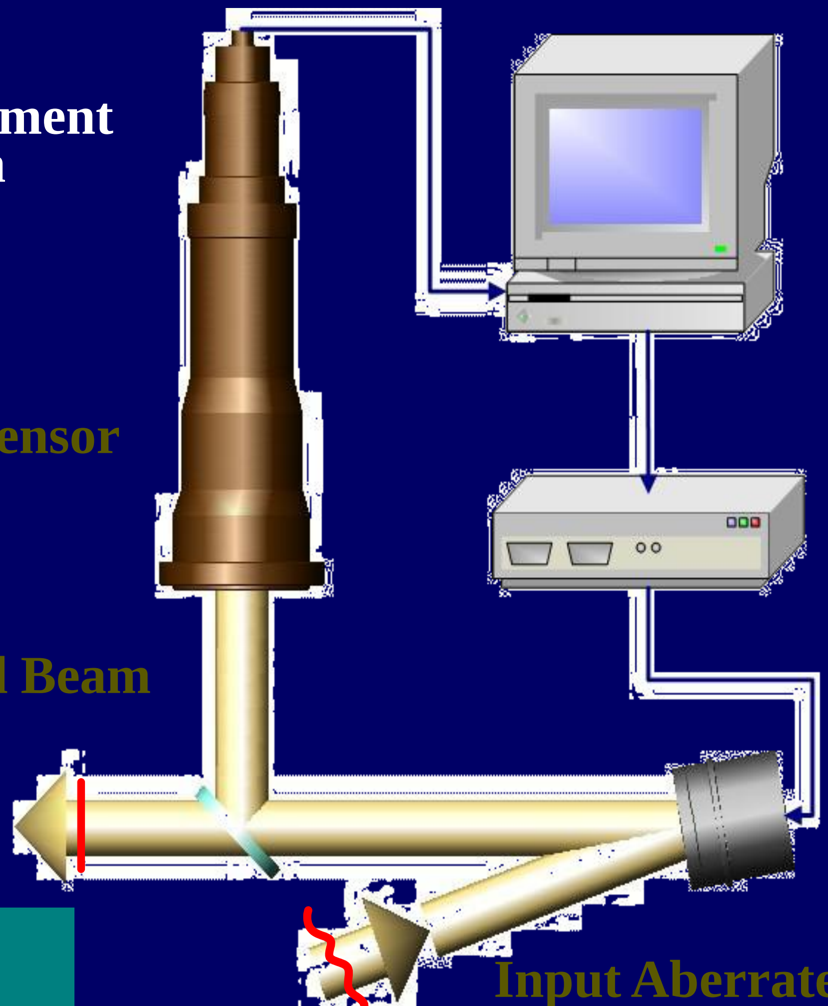
Measured intensity contrast:

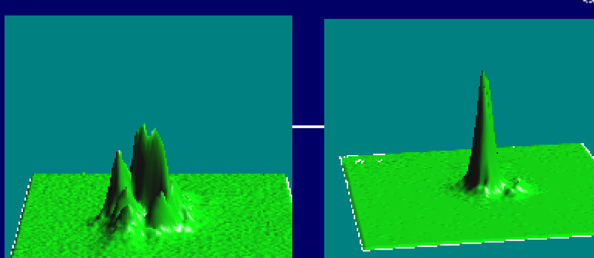
ASE < 10^{-9}

Nanosecond @ 600mJ: 8×10^{-8}

Principal scheme for wave-front correction
(Strehl ratio increase to reach high intensity focused radiation)

Focusability improvement
Wavefront correction
Beam shaping





Focal spot before and after wave-front correction
(V. Samarkin, LEI, 16-21 Oct 2009, Brasov)

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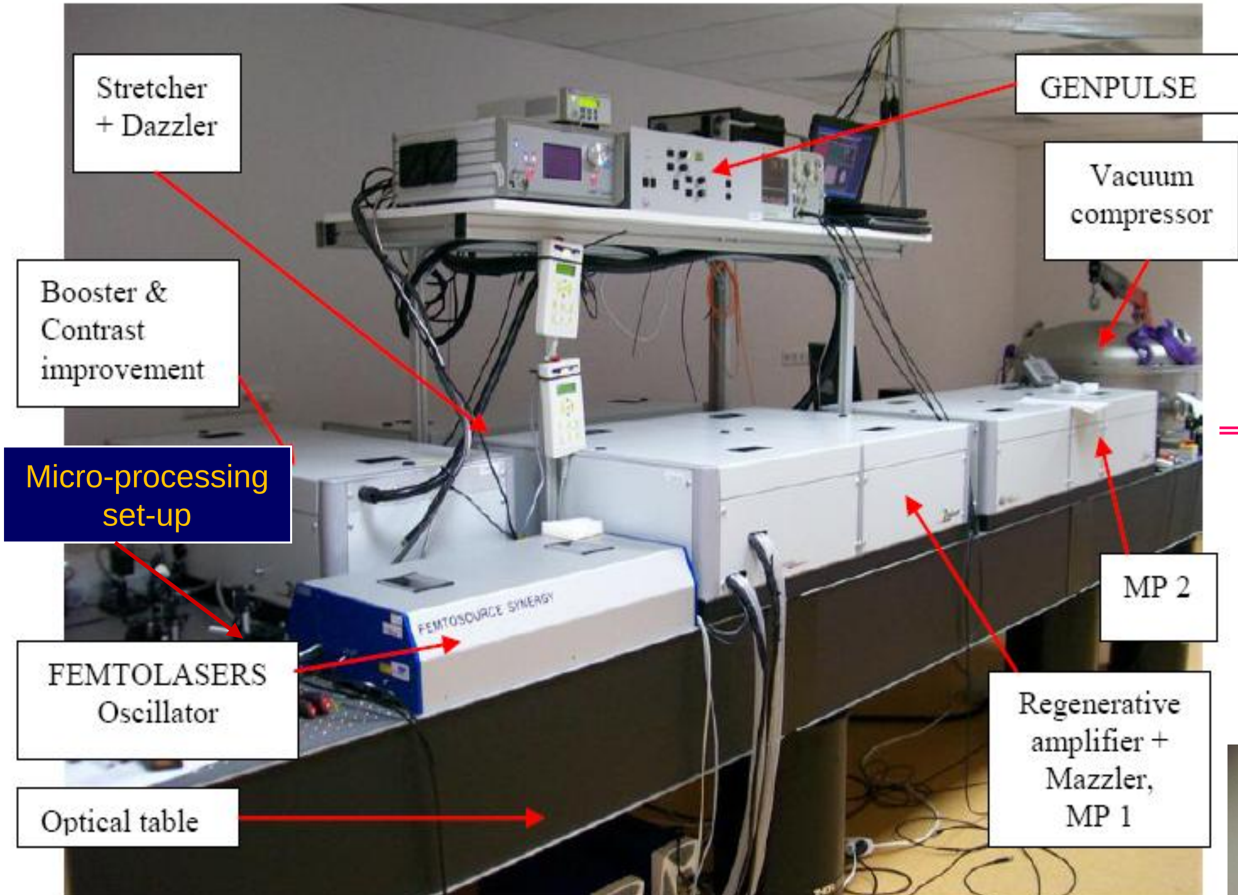
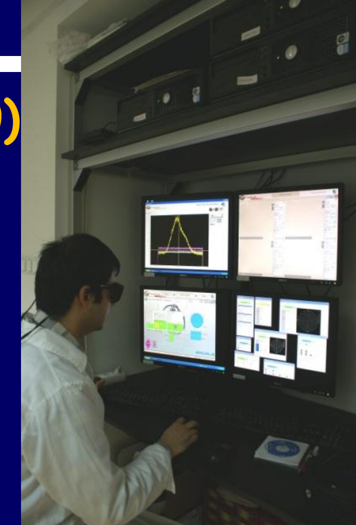
TEWALAS (> 15 TW) Laser System Layout (2009-2010)





Interaction chamber

Amplitude TECHNOLOGIES

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TEWALAS Specifications

Laser specifications	Measured value
Central wavelength	808 nm
Spectral bandwidth	> 65 nm
Pulse energy before compressor	≤ 600 mJ
Pulse energy after compressor	≤ 450 mJ
Compressed pulse duration	25 2 fs
Repetition rate	10 Hz
Pulse energy stabilization (RMS)	1.85%
Nanosecond pre-pulses contrast	8×10^{-8}
ASE contrast @1 ps	2×10^{-5}
ASE contrast @ 3 ps	3×10^{-6}
ASE contrast @ 5 ps	2×10^{-7}
ASE contrast @ 15 ps	2×10^{-8}
ASE contrast @ > 30 ps	7×10^{-10}

Femtosecond Laser Studies and Experiments

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Micro/nano-technologies (low energy, high repetition rate):

-Thin films micro-processing by femtosecond laser ablation

- Nano-processing in intensified laser field

- Direct laser writing of micro/nanostructures by two-photon photopolymerization

- Two-Photon Excited Spectroscopy

R&D based on femtosecond lasers (high energy):

- Multiple pulses generation in stretcher-compressor femtosecond laser systems

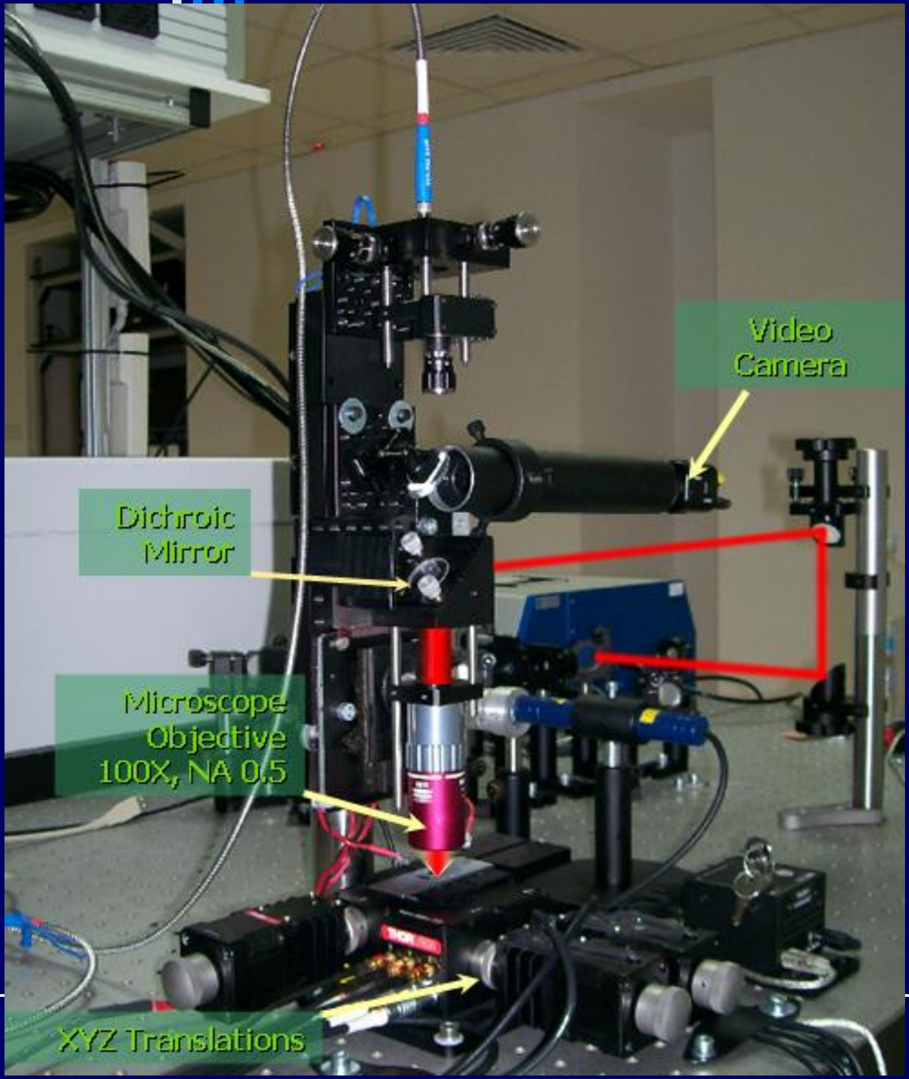
- Simulations and experiments of coherent beam combination

- Non-linear propagation of focused ultrashort pulses in air

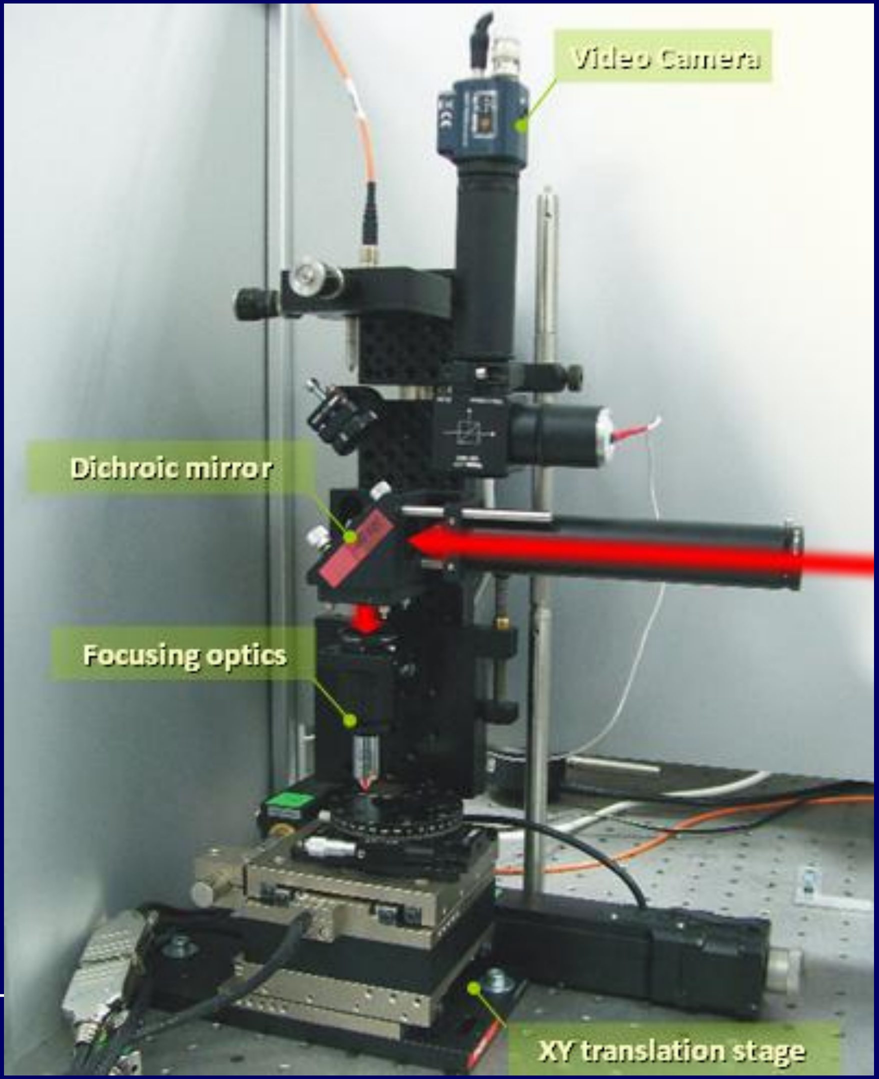
- Theoretical studies of high intensity laser field – matter interaction

Direct Laser Writing (DLW) Workstations

Microscope for 3D lithography and laser spectroscopy



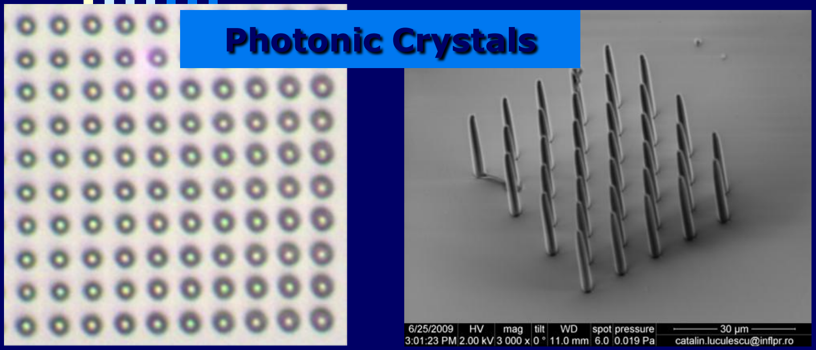
Experimental set-up using TEWALAS oscillator

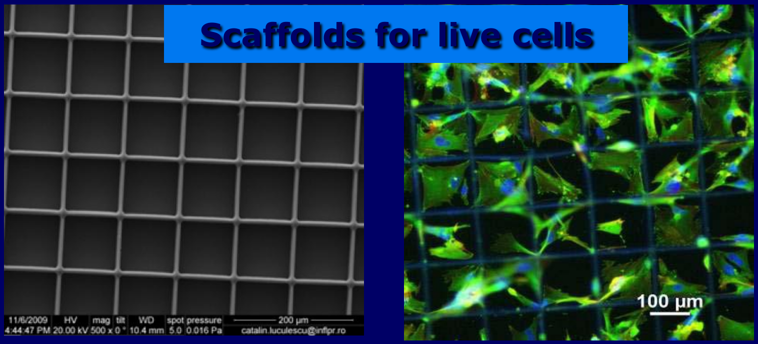


Workstation for Clark-MXR laser

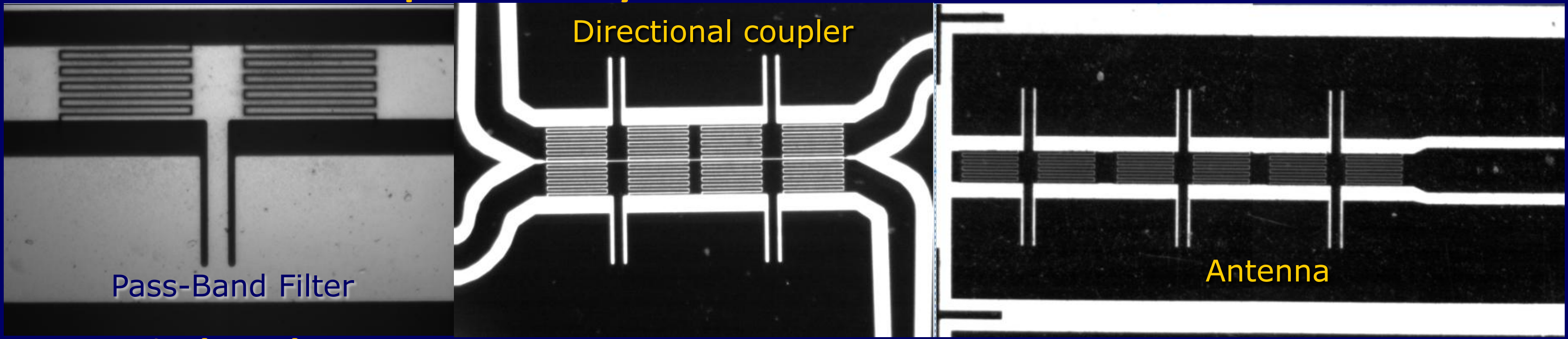
Direct Laser Writing (DLW) - Results

- Microstructures produced by TPP in photopolymers

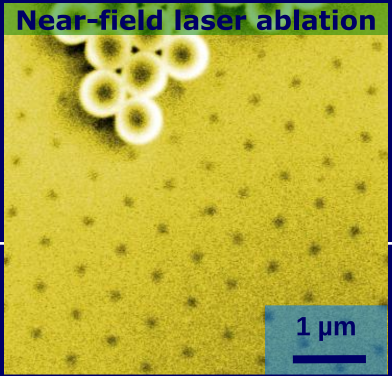


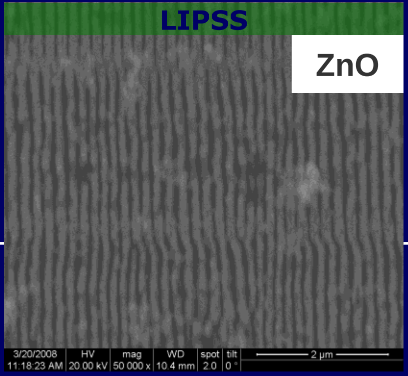


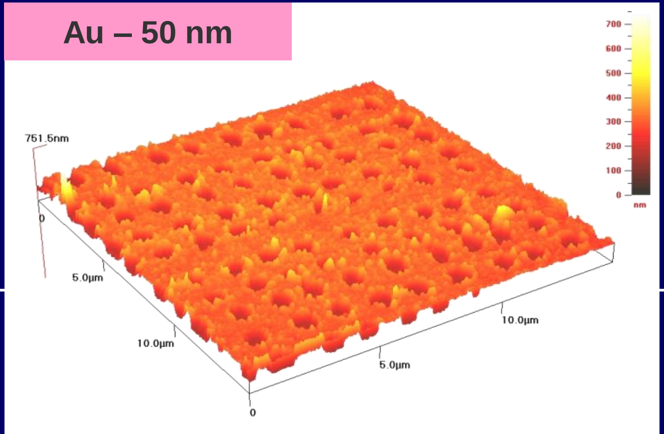
- Microwave devices produced by laser ablation



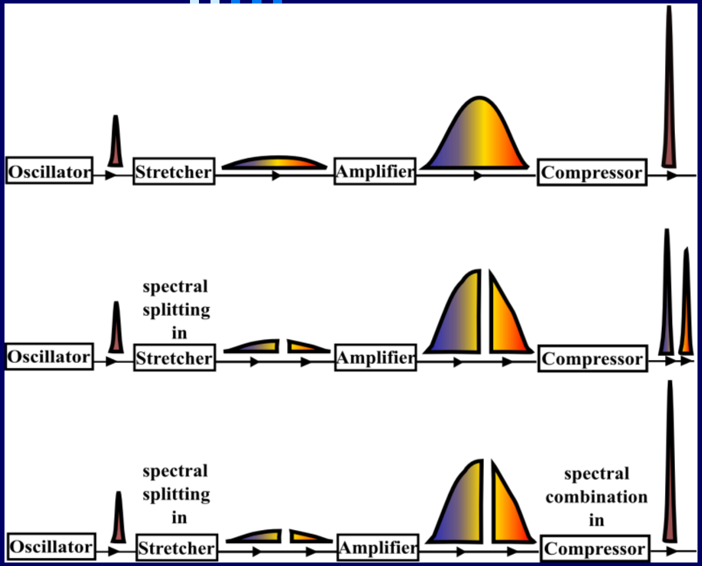
- Laser induced nanostructures

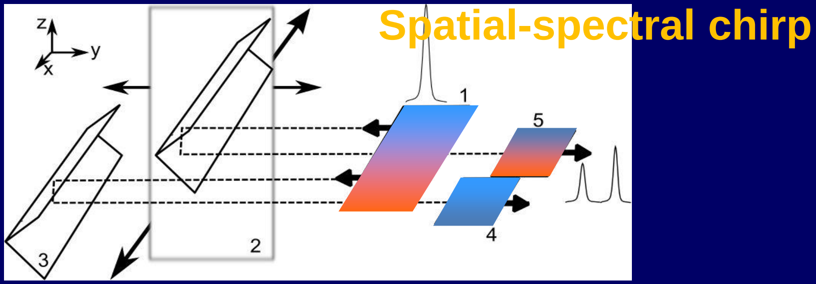


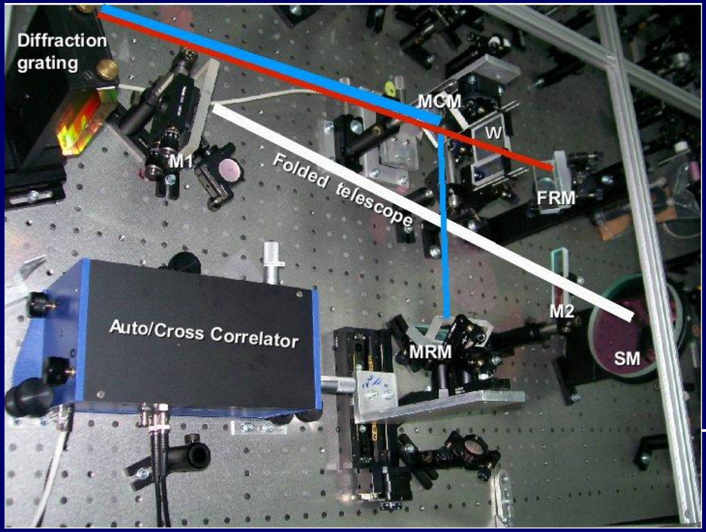


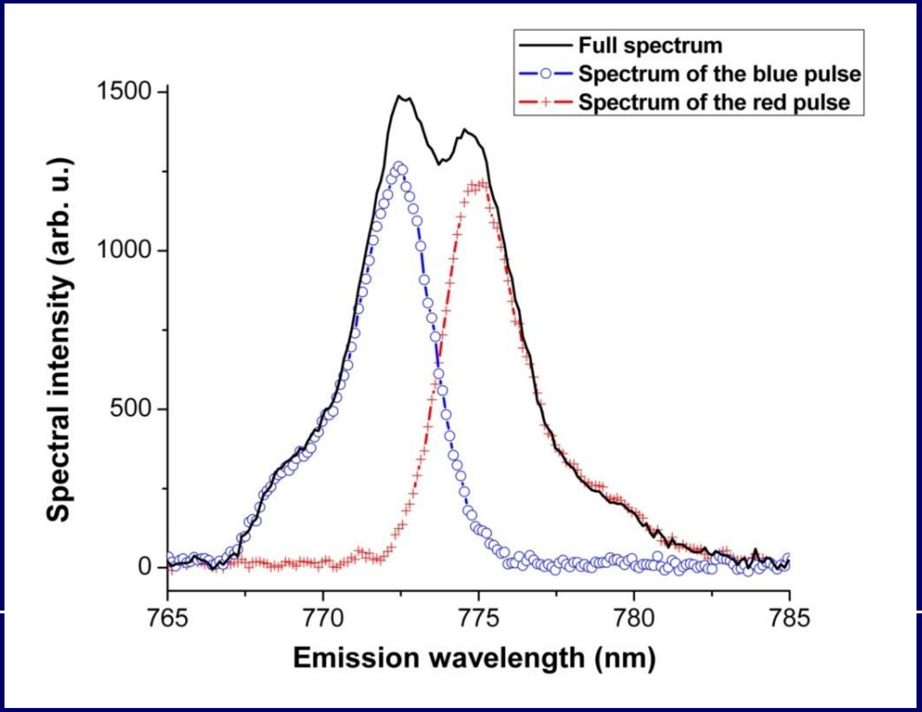


In Stretcher Generation of Spectrally Separated Optical Pulses









Physics of Extreme Light at NILPRP - Prospects

Next (possible) studies based on existing femtosecond lasers:

● Coherent combination of ultra-short pulses using interferometric methods

● X-ray generation using ultra-short laser pulses

Collinear pump–probe experiments

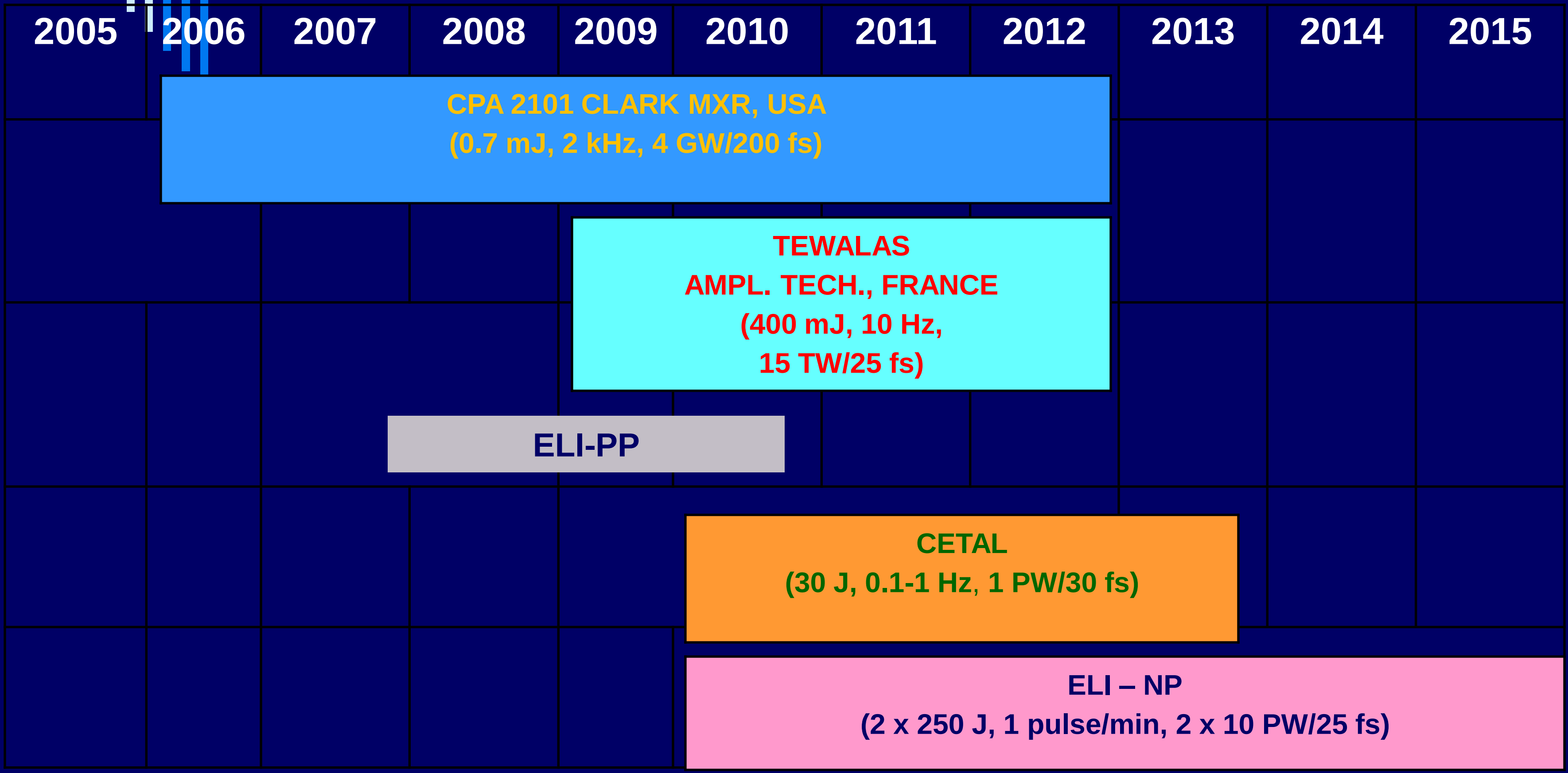
● Plasma mirror studies

● Study of absorption and density gradients in laser-produced plasmas

● Diagnosis and characterization of laser beams and optical components for nanosecond & femtosecond high energy lasers

● Large bandwidth OPCPA (OPCPA at critical wavelength degeneracy)

Prospects of High Power fs Lasers at INFLPR



High power femtosecond laser projects:

- 1-PW (CETAL project, 2010-2013)
- 10-PW (Extreme Light Infrastructure, Romanian Pillar for Nuclear Physics – ELI-RO-NP, 2010-2015)

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Possible solutions for a 10-PW laser

A) OPCPA based laser system (910-nm central wavelength):
Front-End → very broad-band signal radiation at 910-nm central wavelength generated by chirp-compensated collinear OPA.
High power OPCPA in large aperture DKDP crystals

B1) Hybrid laser system at ~ 800 nm central wavelength:

- Front-End based on OPCPA in nonlinear crystals (BBO, LBO)
- High energy amplification in Ti:sapphire crystals

or

B2) Ti:sapphire amplifiers at ~ 800 nm central wavelength :

- Front-End based on Ti:sapphire amplification
- High energy amplification in Ti:sapphire crystals

Basic solution for ELI-RO-NP laser (B1 or B2)

C) Hybrid laser system with Front-End based on OPCPA in BBO crystals and high energy amplification in mixed silicate/phosphate Nd-doped glasses near 1 μm wavelength

Alternative solution for ELI-RO-NP laser (C)

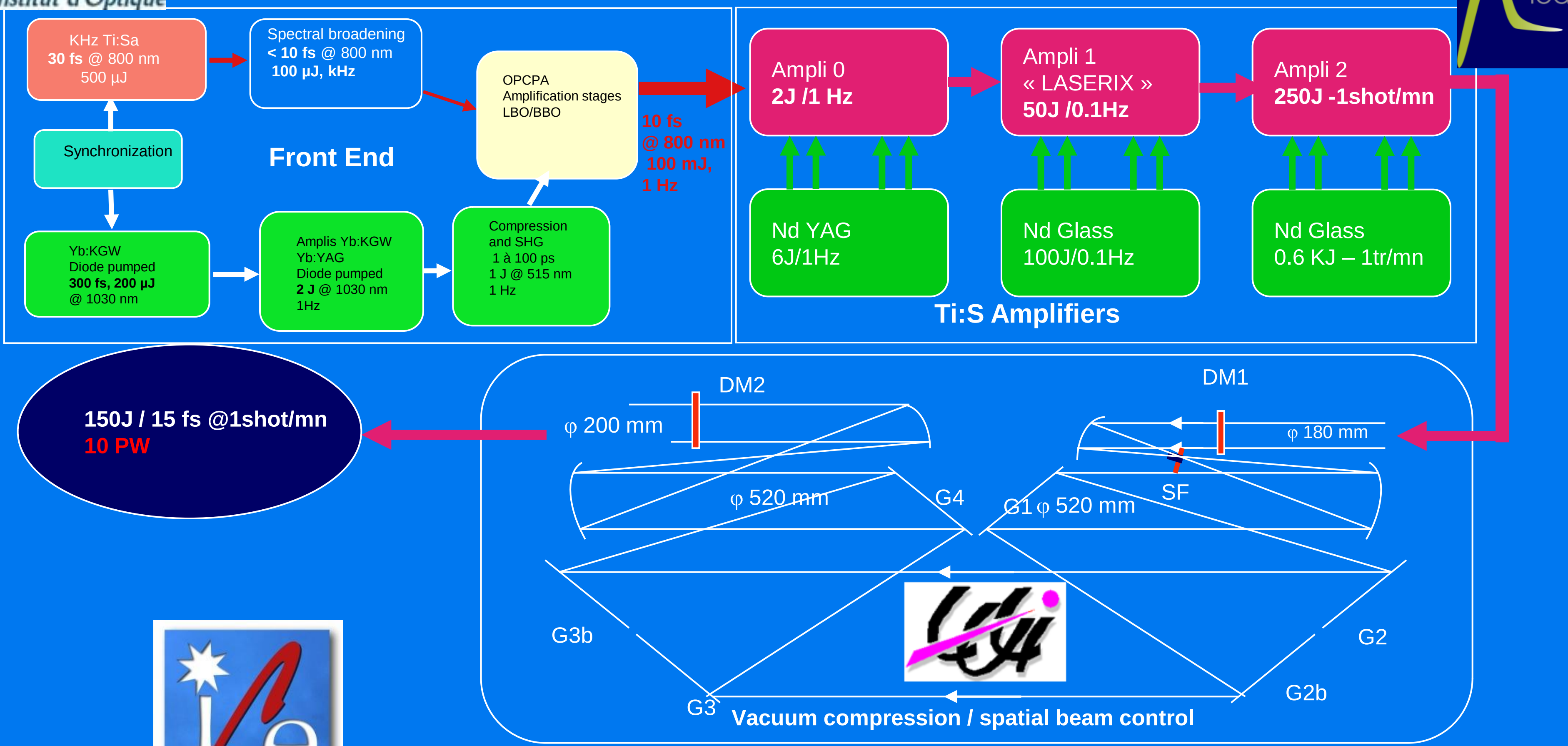
ILE – APOLLON 10P : A collaborative project

LEI Conference , Brasov (RO) October 21rst, 2009

Institut d'Optique

ILE APOLLON Single beamline 10PW laser

loa



Basic ELI –RO-NP Laser Architecture

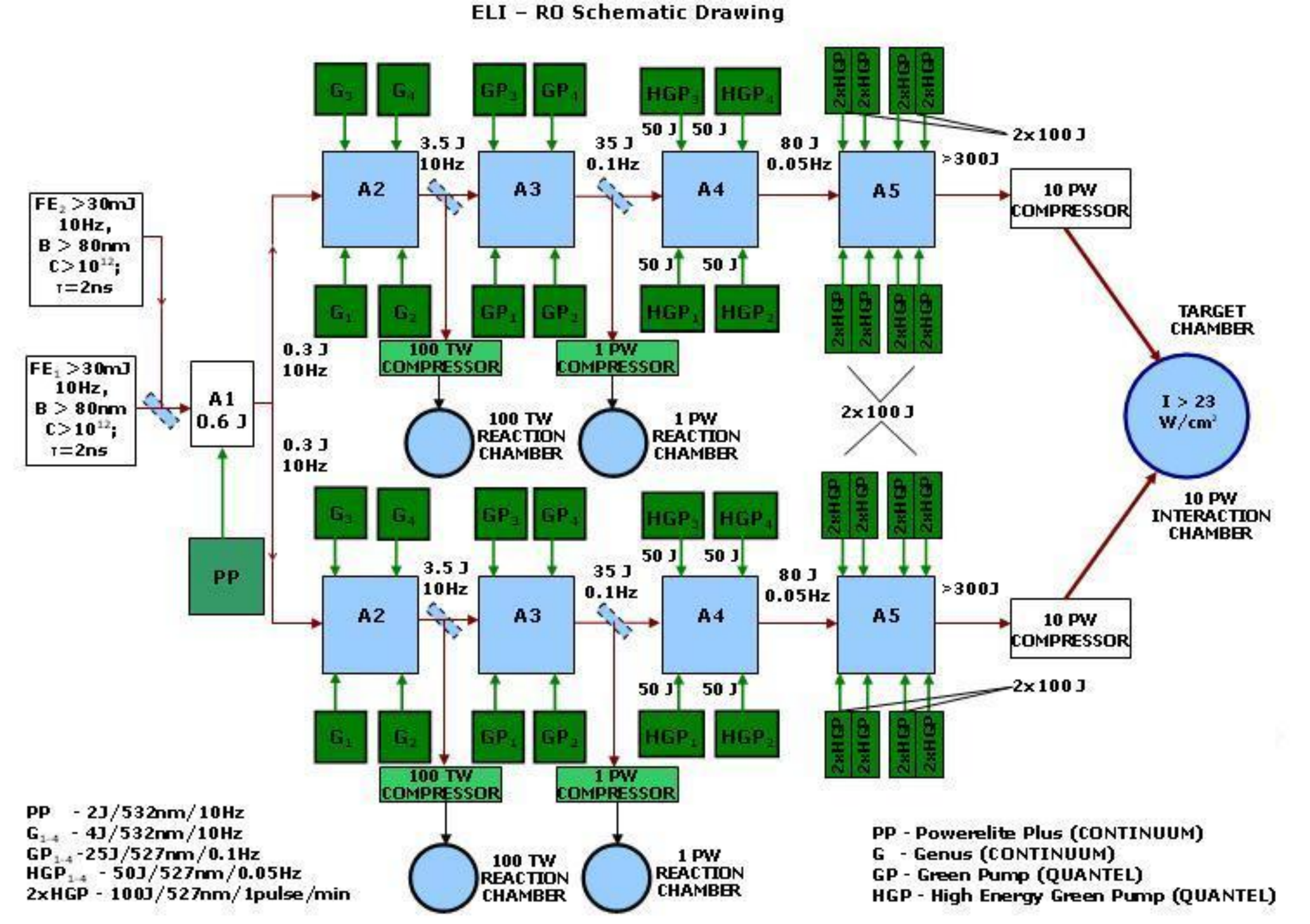
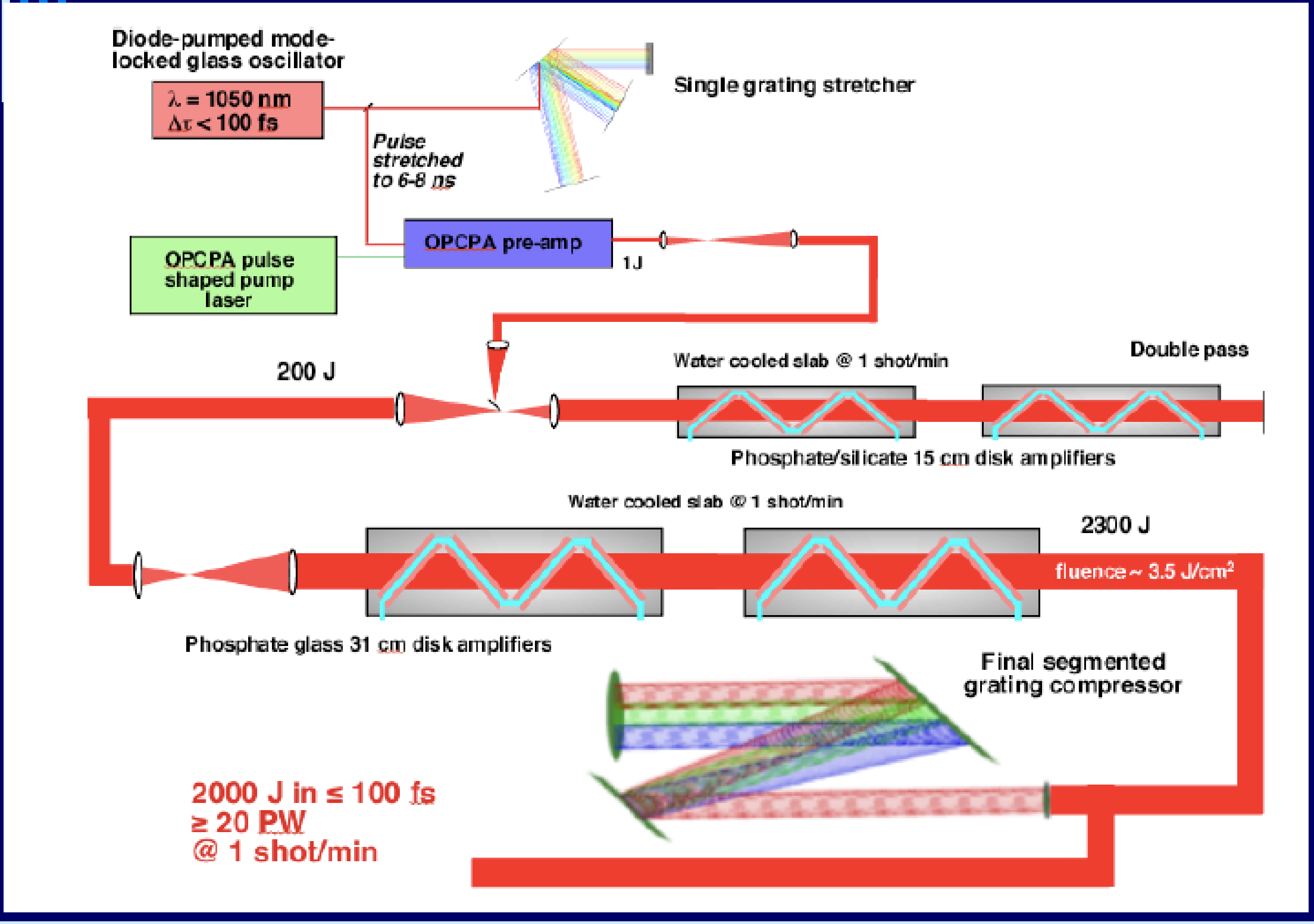


Figure 4. ELI-RO-NP Laser scheme.

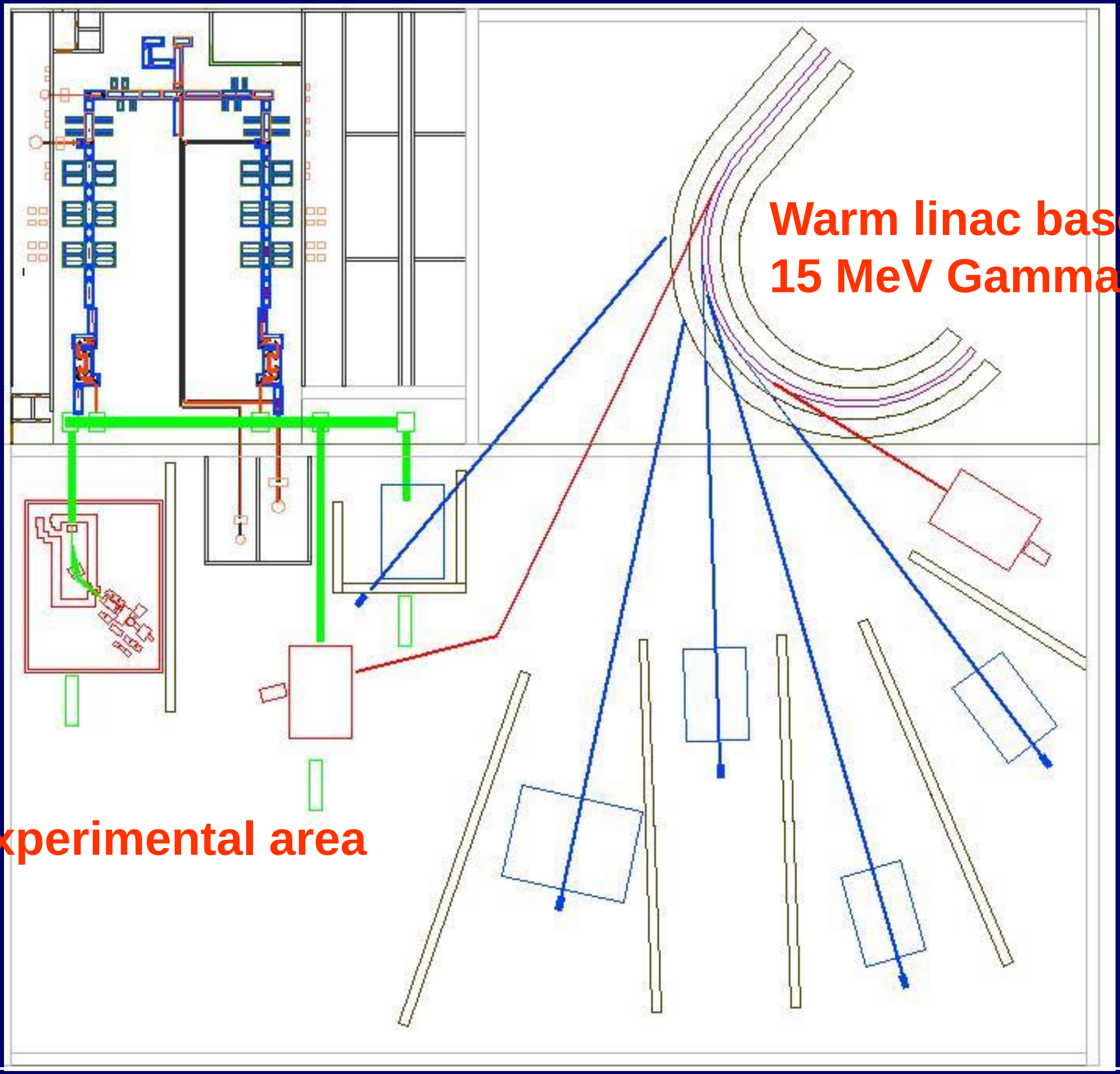
FE1, FE2 – Font-End based on OPCPA or Ti:sapphire amplification. A1-A5 – Ti:sapphire amplifiers.

Alternative ELI –RO-NP Laser Architecture

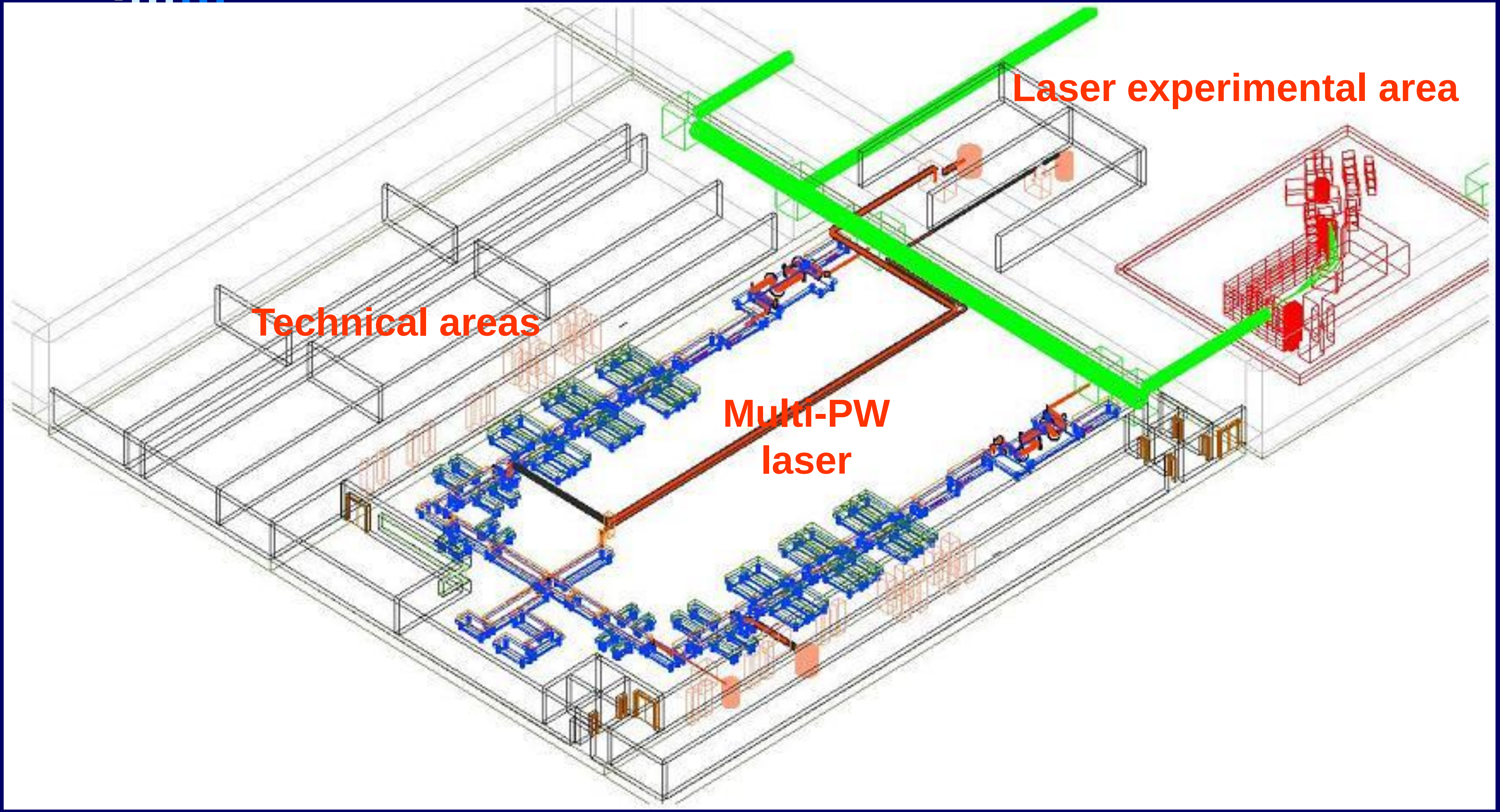


Conceptual design of a 20-PW laser system based on high energy amplification in mixed silicate/phosphate Nd-doped glasses (National Energetics – USA)

Overview of ELI-RO-NP



Overview of ELI-RO-NP Multi-PW Laser




ELI-NP

ELI-NP building

Thank You for your attention!