Romania and High Power Lasers
Towards Extreme Light Infrastructure in Romania

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Contents

- GiWALAS laser facility
- TEWALAS laser facility
- CETAL project
- Extreme Light Infrastructure project
Er:glass fiber oscillator, frequency doubled
- Laser wavelength: 1550 nm → 775 nm
- Pulse duration ~200 fsec
- Repetition rate: 35 MHz
- Pulse energy ~43 pJ
- Average power ~1.5 mW

Ti:sapphire regenerative amplifier
- Laser wavelength 775 nm
- Pulse duration ~200 fsec
- Repetition rate 2 kHz
- Maximum pulse energy ~700 µJ
- Average power ~1.4 W
Laser wavelength, 775 nm; $E_{\text{pulse}} = 0.7 \text{ mJ}$; $t_p < 200 \text{ fs}$; $f_{\text{rep}} = 2 \text{ kHz}$
GIWALAS Experimental Room (2010)

- Clark MXR fs laser
- Stretcher-amplifier-compressor for fs multi-pulse generation
- Green nanosecond pump laser
- Computer control unit
- Micro-processing workstation
# TEWALAS Specifications

<table>
<thead>
<tr>
<th>Laser specifications</th>
<th>Measured value</th>
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<tbody>
<tr>
<td>Central wavelength</td>
<td>808 nm</td>
</tr>
<tr>
<td>Spectral bandwidth</td>
<td>&gt; 65 nm</td>
</tr>
<tr>
<td>Pulse energy before compressor</td>
<td>( \leq 600 \text{ mJ} )</td>
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<tr>
<td>Pulse energy after compressor</td>
<td>( \leq 450 \text{ mJ} )</td>
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<tr>
<td>Compressed pulse duration</td>
<td>25 ± 2 fs</td>
</tr>
<tr>
<td>Repetition rate</td>
<td>10 Hz</td>
</tr>
<tr>
<td>Pulse energy stabilization (RMS)</td>
<td>1.85%</td>
</tr>
<tr>
<td>Nanosecond pre-pulses contrast</td>
<td>( 8 \times 10^{-8} )</td>
</tr>
<tr>
<td>ASE contrast @1 ps</td>
<td>( 2 \times 10^{-5} )</td>
</tr>
<tr>
<td>ASE contrast @3 ps</td>
<td>( 3 \times 10^{-6} )</td>
</tr>
<tr>
<td>ASE contrast @5 ps</td>
<td>( 2 \times 10^{-7} )</td>
</tr>
<tr>
<td>ASE contrast @15 ps</td>
<td>( 2 \times 10^{-8} )</td>
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<tr>
<td>ASE contrast @&gt;30 ps</td>
<td>( 7 \times 10^{-10} )</td>
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Critical Features of High Power Femtosecond Pulsed 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)
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
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

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

- Measured intensity contrast:
  - ASE $< 10^{-9}$
  - Nanosecond $@ 600\text{mJ}$: $8 \times 10^{-8}$

ASE contrast measured with a 3-rd order auto-correlator (SEQUOIA)
Femtosecond Laser Studies and Experiments

**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
<table>
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<tr>
<th>Next (possible) studies based on existing femtosecond lasers:</th>
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<tr>
<td>● Coherent combination of ultra-short pulses using interferometric methods</td>
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<tr>
<td>● X-ray generation using ultra-short laser pulses</td>
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<td>● Collinear pump–probe experiments</td>
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<td>● THz radiation generation</td>
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<tr>
<td>● Plasma mirror studies</td>
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<tr>
<td>● Study of absorption and density gradients in laser-produced plasmas</td>
</tr>
<tr>
<td>● Diagnosis and characterization of laser beams and optical components for nanosecond &amp; femtosecond high energy lasers</td>
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<tr>
<td>● Large bandwidth OPCPA (OPCPA at critical wavelength degeneracy)</td>
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Prospects of High Power fs Lasers at INFLPR

<table>
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<tr>
<th>Year</th>
<th>Project Details</th>
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<tr>
<td>2005</td>
<td>CPA 2101 CLARK MXR, USA (0.7 mJ, 2 kHz, 4 GW/200 fs)</td>
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<tr>
<td>2009</td>
<td>TEWALAS AMPL. TECH., FRANCE (400 mJ, 10 Hz, 15 TW/25 fs)</td>
</tr>
<tr>
<td>2010</td>
<td>CETAL (30 J, 0.1-1 Hz, 1 PW/30 fs)</td>
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<tr>
<td>2012</td>
<td>ELI – NP (2 x 250 J, 1 pulse/min, 2 x 10 PW/25 fs)</td>
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High power femtosecond laser projects:
- 1-PW (CETAL project, 2010-2013)
ELI-NP building
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

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

Basic solution for ELI-RO-NP laser

Alternative solution for ELI-RO-NP laser
Laser Architecture

ELI - RO Schematic Drawing


FE1 > 30 mJ, 10 Hz, B > 80 nm, C > 10^{-12}, τ = 2 ns

FE2 > 30 mJ, 10 Hz, B > 80 nm, C > 10^{-12}, τ = 2 ns

G1, G2 – 3.5 J, 10 Hz
G1, G2 – 35 J, 0.1 Hz
G1, G2 – 80 J, 0.05 Hz
G1, G2 – > 300 J

10 PW COMPRESSOR

10 PW COMPRESSOR

10 PW INTERACTION CHAMBER

TARGET CHAMBER

2x100 J

1 > 23 W/cm²

PP – 23/532 nm/10 Hz
G1, G2 – 43/532 nm/10 Hz
GP1, GP2 – 253/527 nm/0.1 Hz
HGP1, HGP2 – 503/527 nm/0.05 Hz
2xHGP – 100 J/527 nm/1 pulse/min

100 TW COMPRESSOR

1 PW COMPRESSOR

100 TW REACTION CHAMBER

1 PW REACTION CHAMBER

1 PW REACTION CHAMBER
Overview of ELI-NP
Multi-PW Laser

Laser experimenta area

Technical areas

Multi-PW laser
Overview of ELI-NP laser arm
Overview

- GIWALAS facility - productive
- TEWALAS facility - fully commissioned + productive
- CETAL PW laser system on the track
- Extreme Light Infrastructure feasibility study reviewed
Thank You for attention!