EPJ Web of Conferences **59**, 07003 (2013)
DOI: 10.1051/epjconf/20135907003

The *TRIDENT* laser at LANL: New "dial-a-contrast" and high-contrast experimental capabilities

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Abstract. The *Trident* laser facility at Los Alamos National Laboratory (LANL) has served for more than 20 years as an important tool in inertial confinement fusion (ICF) and Material Dynamics research. An energy and power upgrade of the short-pulse beam line to 100J / 200 TW was made in 2007 and contrast improvements have been made continually since. The combination of this powerful new short-pulse beamline with the two flexible long pulse beamlines, and a total of three different target areas, makes *Trident* a highly flexible and versatile research tool for high energy density laboratory plasma (HEDLP) research. The newest "Dial-a-Contrast" (DaC) features are described, along with nominal performance of the laser at the presently available highest contrast.

1. *TRIDENT* SYSTEM OVERVIEW

The *Trident* laser facility [1] is a flexible, adaptive facility for conducting high energy density physics experiments [2]. The facility consists of three Nd:Glass laser beamlines: two main beamlines, A and B, with a final amplifier aperture of 14 cm, and a third beamline, C, with a final aperture of 10 cm. Multiple oscillators are available to drive these beamlines, with pulse lengths ranging from 0.5 ps to 10 μs at 1054 nm. The maximum output energy is determined by beam size and pulse length. The two 14 cm beamlines are capable of producing up to 1 kJ per beam at 10 μs, 500 J at 5–10 ns, and approximately 100 J at 0.1 ns. The single 10 cm C beamline is capable of producing up to 80–120 J depending on pulse length, and is configured with a vacuum grating compressor, enabling the use of chirped-pulse amplification (CPA) [3] to produce pulses as short as 500–600 fs, yielding up to 200 TW of power.

Nonlinear crystals are available to produce harmonics of the fundamental laser frequency in all beamlines. Experiments performed with pulses in the nanosecond range often use the second harmonic of the laser frequency (i.e. 527 nm), which can produce up to 250 J of light at 527 nm in each beam, in pulses of a few nanoseconds in lines A and B. The 10 cm C beamline can be modified to produce a diagnostic beam of high optical quality, which has been used to produce 1st, 2nd, 3rd, and 4th harmonics of the fundamental, depending on experiments. In addition, a 20 J, 600 nm, near diffraction limited diagnostic beam has been produced using Raman scattering of the 2nd harmonic of the laser fundamental in a gas cell [4].

Arbitrary pulse shapes can be produced in all pulse length regimes. For microsecond pulses, an acousto-optic modulator in a single longitudinal mode ring resonator is driven by a Radio Frequency

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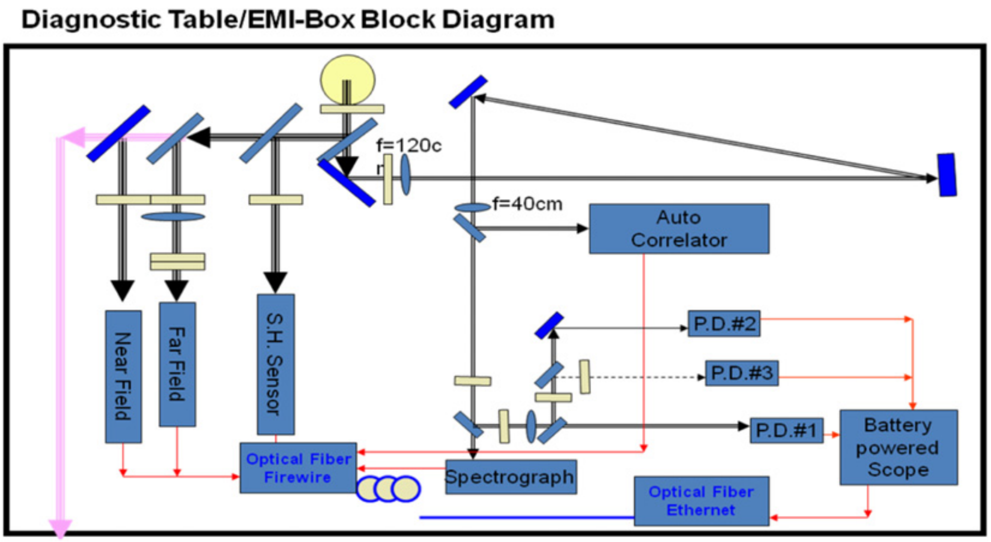

Figure 1. Schematic layout of the diagnostic suite used only for the short-pulse laser beam on each laser shot. Beam enters via the hole (yellow circle) in the table, situated above the compressor chamber, and is split (gray lines) to the various diagnostics (blue boxes).

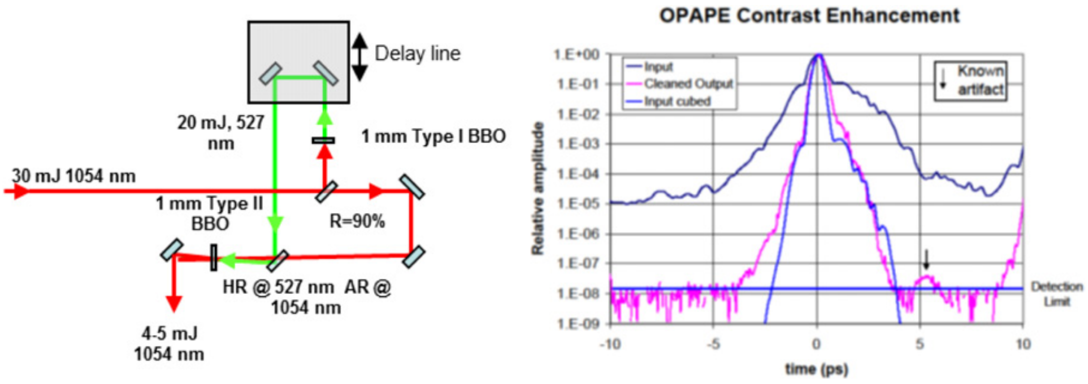

Figure 2. Optical Parametric Amplification based Pre-pulse Elimination technique (left) and results (right) [6].

(RF) source modulated by an arbitrary waveform generator, producing arbitrary pulse shapes from 100 ns to 10 μs. Arbitrary pulse shapes 0.1–10 ns long are produced by modulating the output of a single frequency fiber oscillator, with a high bandwidth electro-optic modulator driven by a high bandwidth arbitrary waveform generator. An electronic feedback system assures pulse shape accuracy. Pulse shaping in the range of 0.5–5 ps is accomplished using an acousto-optic programmable dispersive filter (AOPDF) to modulate a sub-picosecond pulse from a laser-diode-pumped glass laser. Different pulse lengths and pulse shapes can be propagated down the individual beamlines, simultaneously allowing for a wide range of pump-probe experiments.

A full array of laser diagnostics is also available in the north target area for sub-picosecond experiments. Pulse length, pre-pulse contrast, focal spot quality, pulse spectrum, and near field beam quality are measured on each shot. A layout of this diagnostic package is shown in Figure 1.

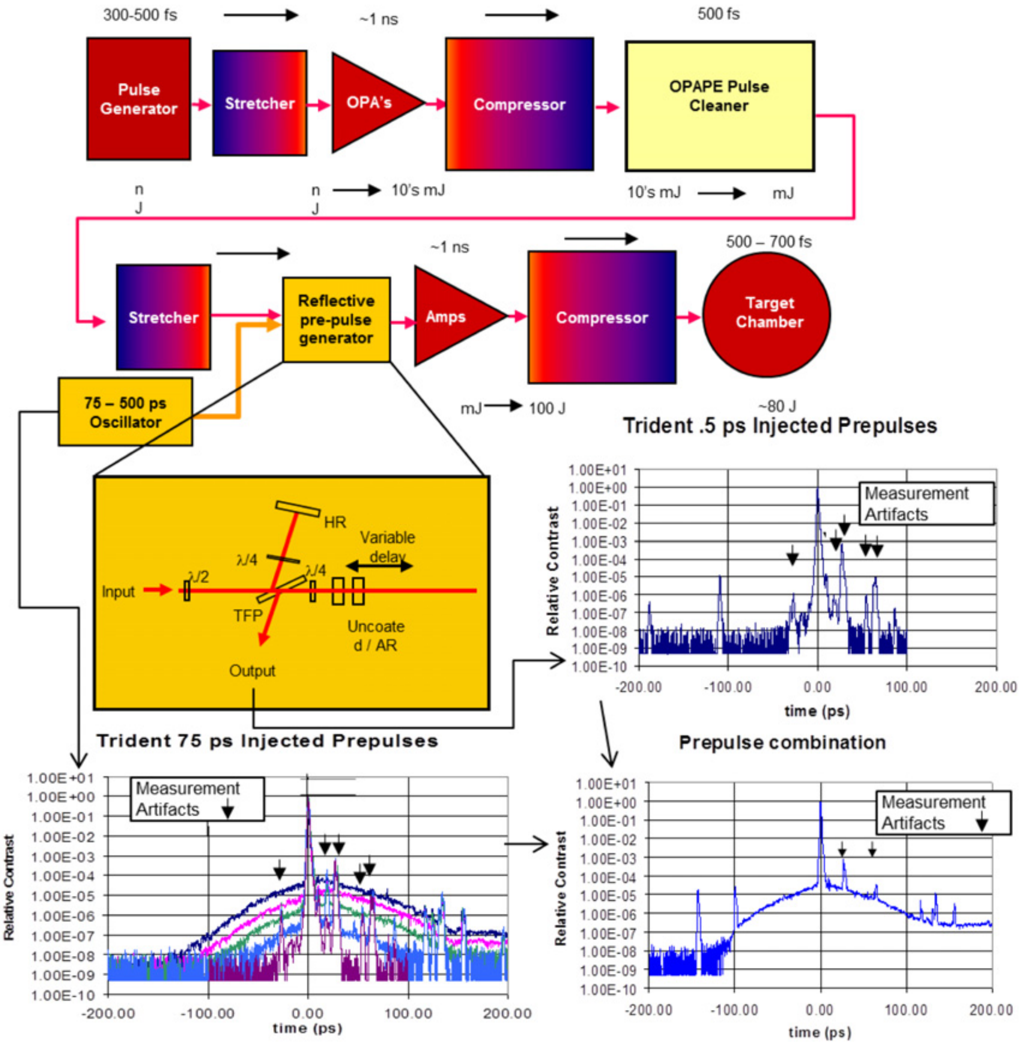

Figure 3. (Upper left) schematic of the *C* DaC beamline at *Trident* showing the short-pulse OPA (SPOPA) or OPAPE cleaner (pale yellow), and the 2 DaC components (orange): the "long" Oscillator, and the reflective pre-pulse generator. Long black arrows point from the 2 DaC components to the plots of their output, and arrows follow to a plot of the combined output. Short black arrows point to measurement artifacts in the cross-correlator. Bottom left plot: different colored lines correspond to different injection energies of the 75–500 ps oscillator. Measurements are from the front-end, before propagation and amplification.

2. THE ROAD TO HIGH-CONTRAST SHORT-PULSES

Though the short-pulse front end has been upgraded to an ultraclean $>10^{-9}$ in ASE contrast [5, 6], this was not always the case. The laser has gone through a number of changes and experiments; the experiments that have made use of those changes are referenced. To start with, in late 2007, the system had an intrinsic 10^{-7} contrast pulse from the regenerative amplifier (Regen) and no deformable mirror, giving a laser spot of about 12 μm [7]. Then, early 2008, a deformable mirror was added, improving the spot size to 7 μm [8]. Shortly after, late 2008, the system was contrast cleaned, using a new technique termed Optical Parametric Amplification based Pre-pulses Elimination (OPAPE) or short-pulse OPA

(SPOPA) [6] (see Fig. 2) after the Regen, allowing the first round of high-contrast experiments [9]. Shortly thereafter, early 2009, an OPCPA front-end was added, replacing the Regen, as input into the OPAPE, and an f/8 parabola was added [10]. Most recently, in 2010, the stretcher was improved, leading to an even steeper main pulse by swapping a metal mirror for a dielectric. These steps and the effect on the contrast were detailed in Ref. [5].

Fig. 2(left) shows the OPAPE short-pulse cleaning system, which 1) takes the 30 mJ input and splits it into two chains (90:10), doubling the more energetic chain to 527 nm; 2) then uses this green beam to imprint its clean profile on the fundamental beam, in a degenerate OPCPA scheme. The result of this cleaning is a front-end with better than 10^{-9} in contrast (the limit of our measurement ability using a 3rd order cross-correlator), as shown in Fig. 2 (right).

3. THE RESULT: "DIAL-A-CONTRAST" (DAC) CAPABILITY

With this very clean pulse, we are now able to add essentially arbitrary short-pulse prepulse via a reflective pre-pulse generator [11], and an arbitrary pedestal via a 2nd longer oscillator, which are the two components of the DaC system. In Fig. 3, one can see the results of both these components in terms of the laser contrast, and the resultant combination (bottom-right). This combination gives *Trident* the ability to replicate any high-intensity glass laser system in the world, in order to compare results across laser platforms.

This is also extremely important as some processes, e.g. x-rays production, ion acceleration and electron acceleration may be optimized by adding small amounts of pre-pulse energy into the system. At most laser facilities, this pre-pulse is a fixed characteristic of the particular laser beam. At *Trident*, however, after removing insipient pre-pulse energy, controlled amounts of pre-pulse can be added to optimize the effects of matched conditions at other laser facilities.

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