MTW-OPAL: A Technology Development Platform for Ultra-Intense All-OPCPA Systems

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Ultra-intense laser systems are being developed by several institutions to use the full potential of deuterated potassium dihydrogen phosphate (DKDP) for high-energy optical parametric chirped-pulse amplification (OPCPA).[1–4] Noncollinear optical parametric amplifiers (NOPA's) using DKDP can support broadband gain for supporting pulses as short as 10 fs. Large-aperture DKDP crystals (>400 mm) make it possible to use Nd:glass lasers as kilojoule pump sources.[5] Although OPCPA is now routinely used as a broadband front-end technology for many hybrid systems, scaling OPCPA to energies >100 J is still an active area of laser research and development. This summary reports on the MTW-OPAL Laser System, a mid-scale optical parametric amplifier line pumped by the Multi-Terawatt laser, as a platform for the laser technology development with a long-term goal of building EP-OPAL, a femtosecond-kilojoule system within the Omega Laser Facility.[6]

The MTW-OPAL Laser System is shown schematically in Figs. 1 and 2, and described in more detail in Ref. 7. The ultra-broadband front end produces stretched pulses using white-light continuum generation and a series of three NOPA's using beta

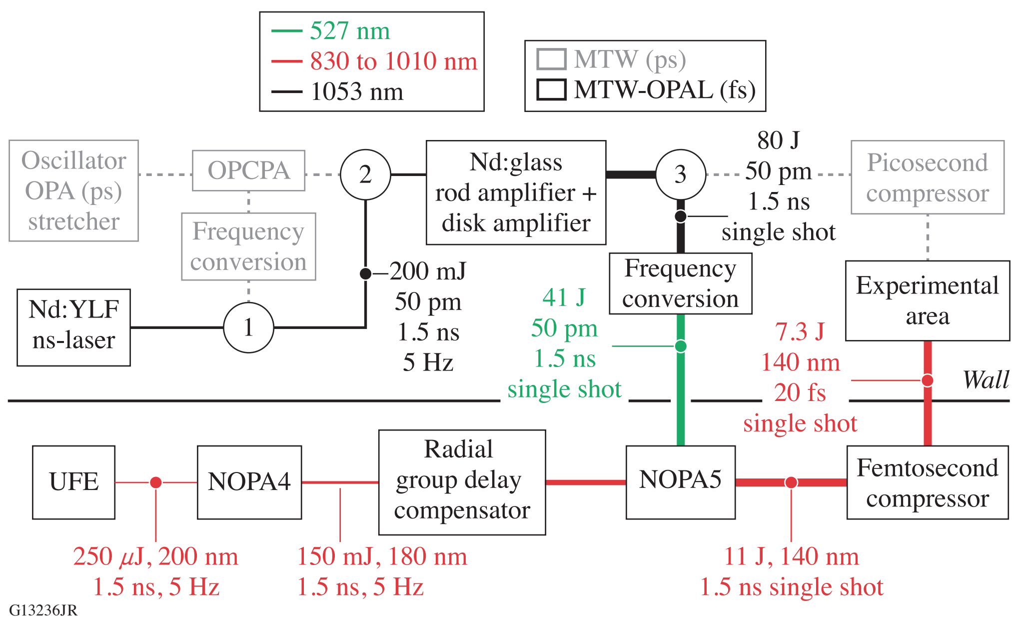

Figure 1
Schematic of the MTW-OPAL Laser System. UFE: ultra-broadband front end.

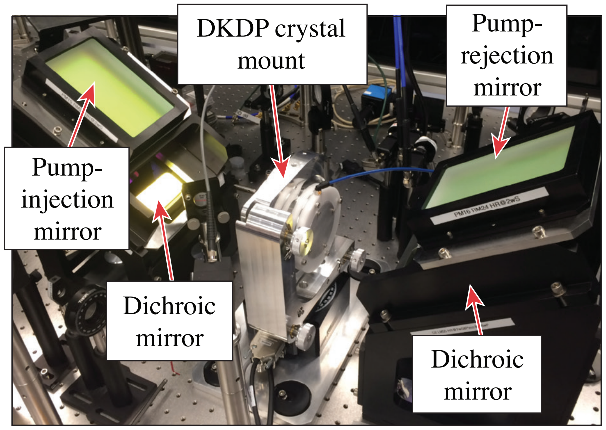

Figure 2
NOPA5 amplifier showing surrounding optics.

barium borate (BBO) crystals that are pumped with picosecond pulses for maximum temporal contrast. The pulse is stretched to 1.5 ns and matched to the pump pulse for the two NOPA4 stages (also BBO crystals) and the pump for the final NOPA5 stage (DKDP); the NOPA5 pump pulse is produced by the MTW laser configured in a narrowband mode. Radial group-delay compensation is used to minimize temporal broadening from refractive telescopes that image each amplifier stage to the next. A femtosecond compressor with a suite of laser diagnostics is used to compress the pulse to <20 fs before transport in vacuum to the experimental area.

Demonstrating large-aperture OPCPA is a primary goal of the MTW-OPAL project. NOPA5 uses $63 \times 63 \times 52\text{-mm}^3$ 70% deuterated DKDP crystals to amplify 45-mm-sq beams with gains of ~100, producing 11-J broadband pulses with up to 40% pump-to-signal transfer efficiency.[8] Another primary goal is demonstrating a scalable four-grating compressor, transport optics, and diagnostics suitable for EP-OPAL. An all-reflective achromatic telescope has been developed for relay imaging NOPA5 to the final grating. Hybrid coatings (metal and multilayer dielectric) suitable for 200-nm bandwidth are being evaluated for use in the vacuum compressor chamber for both *s*- and *p*-polarized beams.

Figure 3 shows a summary of the primary results from the “First-Light” Campaign in March 2020 along with the subsequent campaigns to ramp the energy through the compressor to achieve 0.35 PW. These campaigns show that the laser design is fundamentally sound, and optimization continues as we prepare for “First Focus” campaigns later this year.

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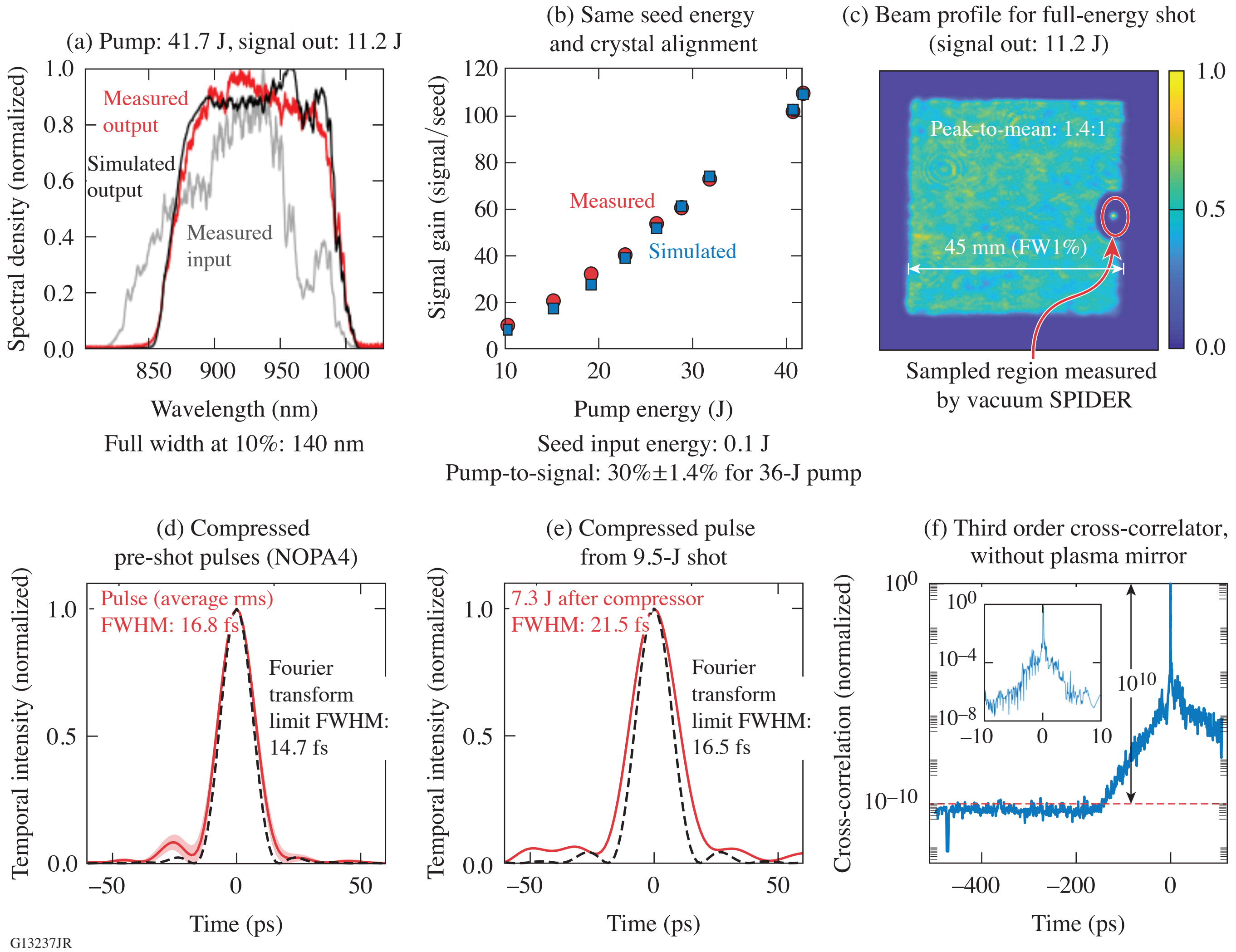

Figure 3
(a) NOPA5 spectral measurements for a full-energy shot (input, output, and simulated). (b) Signal gain measured after NOPA5, with a maximum signal energy of 11.2 J. (c) Full-energy NOPA5 output beam. (d) SPIDER measurement statistics (50 shots) and Fourier transform limit for compression without pumping NOPA5. (e) Vacuum SPIDER measurement of spatially sampled beam with the full-energy output from NOPA5. (f) Temporal contrast measurements of compressed NOPA5 seed pulses.