OMEGA Power-Balance Improvements: High-convergence laser-driven capsule implosions require a high degree of drive energy uniformity across the surface of the capsule. A significant contributor to imperfections in the uniformity of the drive energy arises from beam-to-beam power imbalance. Power balance is quantified as the percent rms beam-to-beam power variation averaged over any 100-ps interval.[1] It is useful to divide power balance into a beam-timing (i.e., beam-to-beam path length) specification and an "energy in a feature" specification (Fig. 1).

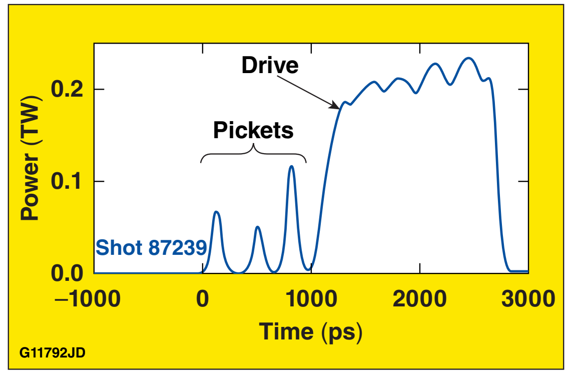

Figure 1. Typical cryogenic-implosion pulse shape. The pulse is typically divided into one or more "features," 1 to 3 "pickets" preceding the main "drive."

Beamline path length deviation from source to target chamber center is routinely measured and adjusted to be better than 1.5-mm (5-ps) rms (Ref. 2) across all 60 beams. The pulse-shape features that have their energies evaluated are the pickets and the drive (see Fig. 1). Energy in each "feature" is computed by temporally integrating the relevant portion of the end-of-chain (beam) power diagnostics. Particular emphasis is placed on the first picket since it can seed target–shell instabilities.

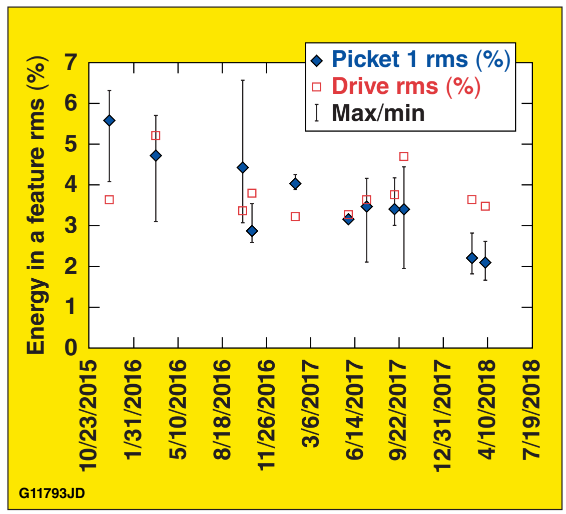

Figure 2. Power-balance improvement as a function of calendar time evaluated for cryogenic target implosion campaigns.

Power balance requires equal gains across all beams per amplification stage, equal losses across all beams per stage, equal beam size across all beams, equal frequency conversion, and equal beam timing. Monthly shot campaigns are used to equalize small-signal gains per stage across all beams to typically better than 1% rms. Quarterly dedicated power-balance campaigns have identified unequal passive losses caused by haze on disk amplifiers, scattering in liquid crystal optics, and damage (obscurations) in spatial-filter input lenses. These unequal losses are addressed during maintenance periods. Equal beam sizes are ensured by tight specification (<0.25%) of the focal lengths of intrastage beam expanders. The equality of frequency-conversion performance across all beams was addressed by matching total crystal thicknesses, increasing the frequency of tripler-crystal tuning-optimization runs, and removing a second tripler crystal that was previously used to enhance broadband conversion performance. In addition, prior to each power-balance sensitive campaign, additional "polishing" of the system power balance is performed by shifting gain in individual beamlines from more- and less-heavily gain saturated amplifiers. This permits adjustment of the pickets' energy while maintaining overall pulse energy.

Figure 2 shows the improvement in power balance and the resulting decrease of system energy imbalance as measured using the "energy in a feature" quantification on a pulse representative of an ICF pulse used on cryogenic target implosion campaigns. It can be seen that the picket balance has improved by a factor of ~3 while maintaining the overall beam-to-beam energy (drive) balance. The near-term goal has been to improve the first-picket balance which seeds nonuniformities in the target shell. Current efforts concentrate on further reducing both the picket and drive imbalance.

Omega Facility Operations Summary: The Omega Laser Facility conducted 144 target shots in March with an average experimental effectiveness (EE) of 97.6% (the OMEGA laser accounted for 83 shots with EE of 97.6% while OMEGA EP produced 61 shots with EE of 97.5%. The ICF program had 29 target shots for experiments led by LLE and the HED program had 48 shots for experiments led by LANL, LLNL, and LLE. The NLUF program accounted for 14 shots for an experiment led by MIT while the LBS program had 41 target shots for experiments led by LLNL and LLE. An experiment carried out by a collaborative team led by Rutherford Appleton Laboratory (UK) had 12 target shots.

1. S. P. Regan *et al*., Fusion Sci. Technol. **73**, 89 (2018); 2. W. R. Donaldson *et al*., Rev. Sci. Instrum. **87**, 053511 (2016).