# Power Balance on the OMEGA 60-Beam Laser

S. Sampat, T. Z. Kosc, K. A. Bauer, M. H. Romanofsky, A. L. Rigatti, J. Kwiatkowski, R. D. Dean, W. R. Donaldson, L. J. Waxer, R. Moshier, and J. H. Kelly

Laboratory for Laser Energetics, University of Rochester

Lasers that have multiple output beams can generate those beams by one of several methods: aperture division, amplitude division, and temporal division (multiplexing). The generated beams are often further amplified, frequency converted, and/or conditioned depending on the ultimate application. Inequalities in amplification, frequency conversion, or conditioning can lead to differences in the outputs of each of the beams, for which it can be difficult to compensate. This issue is termed "beam imbalance." For a multibeam laser, however, the quantification of the balance of the output beams is often the parameter used to assess laser performance. Balancing is performed by measuring the output properties such as energy, power, and/or intensity.

Energy balance requires that each beam's output have the same total energy without regard to either the spatial distribution or the temporal shape. Power balance requires that, in addition to energy balance, the instantaneous spatially integrated temporal shapes of the output beams match over some averaging time. A typical pulse shape used for cryogenic target implosion experiments on OMEGA is shown in Fig. 1(a). Typical beam-to-beam variations of the output pulse shape are shown in Fig. 1(b).

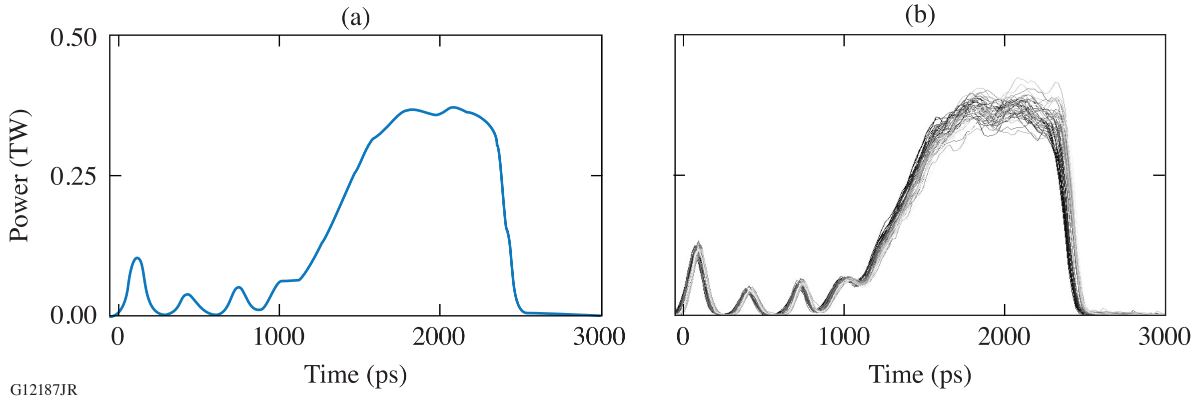

Figure 1
(a) Typical pulse shape used for cryogenic target implosion experiments on OMEGA containing three pickets followed by a drive. (b) The depicted pulse shape has an energy imbalance of 3.5% across 60 beams; the picket and drive have a power imbalance of 2.5% and 3.5% rms, respectively.

The power-balance requirement on OMEGA, as defined by an rms energy computation across 60 beams, is predicated on inertial confinement fusion target-physics simulations that indicate that a less than 1% rms power imbalance is required over any 100-ps interval of the pulse.[1] The near-term goal is to improve the first picket power balance to 1% rms imbalance while simultaneously reducing the drive imbalance. Power balance is sensitive to several factors that are less significant when assessing system energy balance. Given OMEGA's architecture that uses a single "seed" beam to generate 60 beams via splitting and subsequent amplification, choosing the appropriate amplifiers to compensate for any incidental losses on the system is paramount.

Since OMEGA's beamlines consist of amplifiers with varying degrees of saturation, a particular beam's square pulse distortion (SPD) can be significantly impacted by improper management of a saturating amplifier's gain.

A graphic with a simulation of this phenomenon is shown in Fig. 2. In Figs. 2(a) and 2(b), the black curve represents an IR pulse at the input of a different saturating amplifier. The blue and green curves are the pulse at the output of that amplifier. In both cases, a positive voltage offset has been applied to the amplifier's nominal voltage, thereby increasing its linear gain. Figure 2(a) shows the effect of increasing linear gain on the pulse shape in an amplifier where $F_{\text{out}}/F_{\text{sat}}$ is low and, therefore, the pulse shape is not significantly affected. On OMEGA, disk amplifier stages E and F operate under this regime. Figure 2(b) shows the effect of increasing linear gain in a heavily saturated amplifier. Here, the effect of a voltage change is expected to have a stronger impact on pulse shape. On OMEGA, the stage-D amplifiers operate under this heavily saturated regime.

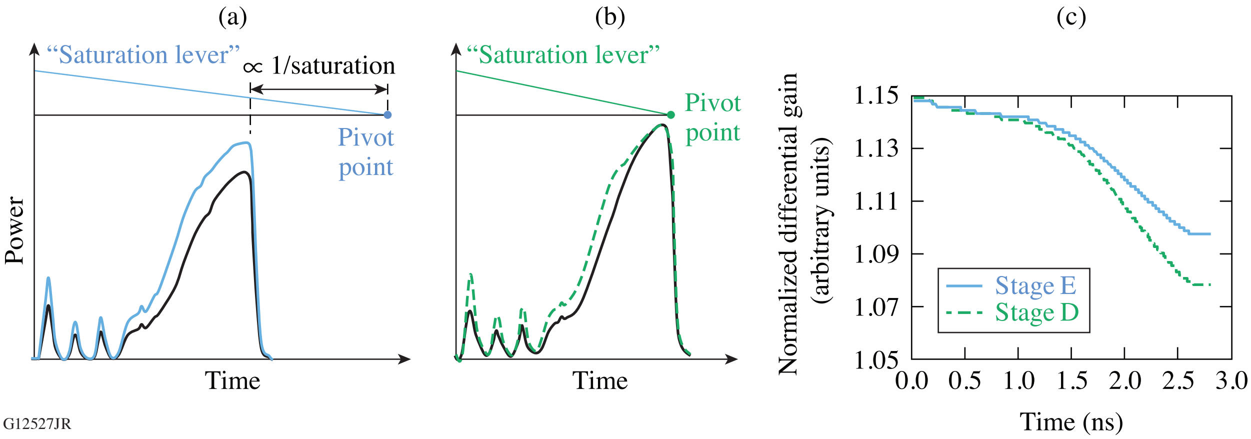

Figure 2
[(a),(b)] The black curve shows the same pulse simulated at the output of the stage-E disk and stage-D rod amplifiers, respectively. The blue and green curves show the change in the pulse shape resulting from a positive offset applied to the amplifier's operating voltage. (a) A uniform decrease in pulse power. (b) The effect of saturation results in a pronounced change in pulse power at the beginning of the pulse and almost no change at the back end of the pulse that experiences saturated gain. (c) A direct measure of the change in pulse shape showing the ratio of the nominal pulse to the gain-reduced pulse.

The "saturation lever" is a visual depiction of the aforementioned effect of operating in different saturation regimes and how gain manipulation of different saturating amplifiers can result in a more-pronounced effect on SPD and, thereby, power balance on the system. The location of the saturation lever pivot point with respect to the back of the pulse is dependent exclusively on the ratio of the output fluence to the saturation fluence of any given amplifier. In Fig. 2, vertical displacement of the end opposing the pivot point of the saturation lever represents a positive change in the amplifier's flash-lamp capacitor bank voltage.

Recent target-physics simulations have suggested that temporal simultaneity in the arrival of the ramp on the drive portion of the pulse shape [$t \sim 1400$ ps in Fig. 1(b)] governs implosion dynamics to a large degree. This region of the pulse can be manipulated by systematically adjusting the gain of the stage-D rod amplifiers, which affects the SPD more than the stage-E and -F amplifiers. This effort is currently being simulated in Miró and is planned for experimental testing in the near future.

This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0003856, the University of Rochester, and the New York State Energy Research and Development Authority.

1. V. N. Goncharov *et al*., Plasma Phys. Control. Fusion **59**, 014008 (2017).