Comparison of On-Shot, In-Tank, and Equivalent-Target-Plane Measurements of the OMEGA Laser System Focal Spot

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Target-physics simulations indicate that on-target uniformity of the OMEGA Laser System[1] of the order of 1% rms is required for each 100-ps interval of a cryogenic target implosion pulse shape.[2] Current laser diagnostic systems on OMEGA, located upstream of the target chamber, characterize the on-shot energy and temporal profile of all 60 beams at the output of the laser. In addition, there is the capability to characterize both the UV near field and the equivalent-target-plane (ETP) focal spot of a single beam. These two diagnostics use a 4% pickoff beam, located upstream of the final optics assembly, near the output of the frequency-conversion crystals. Combining the data from all of these diagnostics suggests that the beam-to-beam uniformity is sufficient to nearly meet this requirement.[3] Conversely, the results from implosion experiments suggest that the on-target uniformity is worse than the diagnostics measure. To resolve this discrepancy, we have recently developed the full-beam-in-tank (FBIT) diagnostic, which is capable of measuring the on-shot, on-target focal spot of multiple beams inside the OMEGA target chamber.[4] FBIT has the ability to directly characterize the on-shot near field and far field of multiple beams in the target chamber. FBIT uses a small sample of the full-energy beam inside the target chamber to analyze the beam separately from the light that hits the target. The main portion of the beam crosses target chamber center (TCC) and is terminated at a calorimeter in the opposing port so the on-target fluence (J/cm^2) of the beam can be calculated. Since FBIT directly measures the focal spot in the target chamber, we can analyze the fluence of each beam, which can be used in combination with data from OMEGA temporal diagnostics to investigate intensity (power per unit area) balance.

To meet the uniformity requirements for target implosion experiments, a smoothed far-field focal spot, with a size comparable to that of the target, is necessary. A distributed phase plate (DPP),[5] a distributed polarization rotator (DPR),[6] and smoothing by spectral dispersion (SSD)[7,8] all contribute to meeting the uniformity specifications. Using FBIT, we can study the individual effects on the focal spot of each of these in turn.

Figure 1 shows the evolution of the OMEGA focal spot as the single-beam uniformity improves. First we show the raw OMEGA far-field spot [Fig. 1(a)]; then a DPP is inserted at the input to the focus lens [Fig. 1(b)], which redistributes the spatial phase of the beam, effectively reducing the coherence across the beam. Next, SSD modulation is applied in one dimension [Fig. 1(c)], followed by both dimensions [Fig. 1(d)]. Finally, the DPR is added to the system [Fig. 1(e)] to increase the smoothing on target.

These images show the on-shot effect of each optic on the focal spot in the target chamber, measurements that were previously unavailable prior to FBIT. Images of multiple beamlines that include 2-D SSD and a DPR show similar results (Fig. 1 data were taken in Beamline 56). We can fit the azimuthal average of the beam profiles of each beamline to estimate the width of the profile, an example of which is shown in Fig. 2. The fit shows $1/e$ R_0 values of approximately 360 μm, which is very close to the designed spot size of the DPP's.

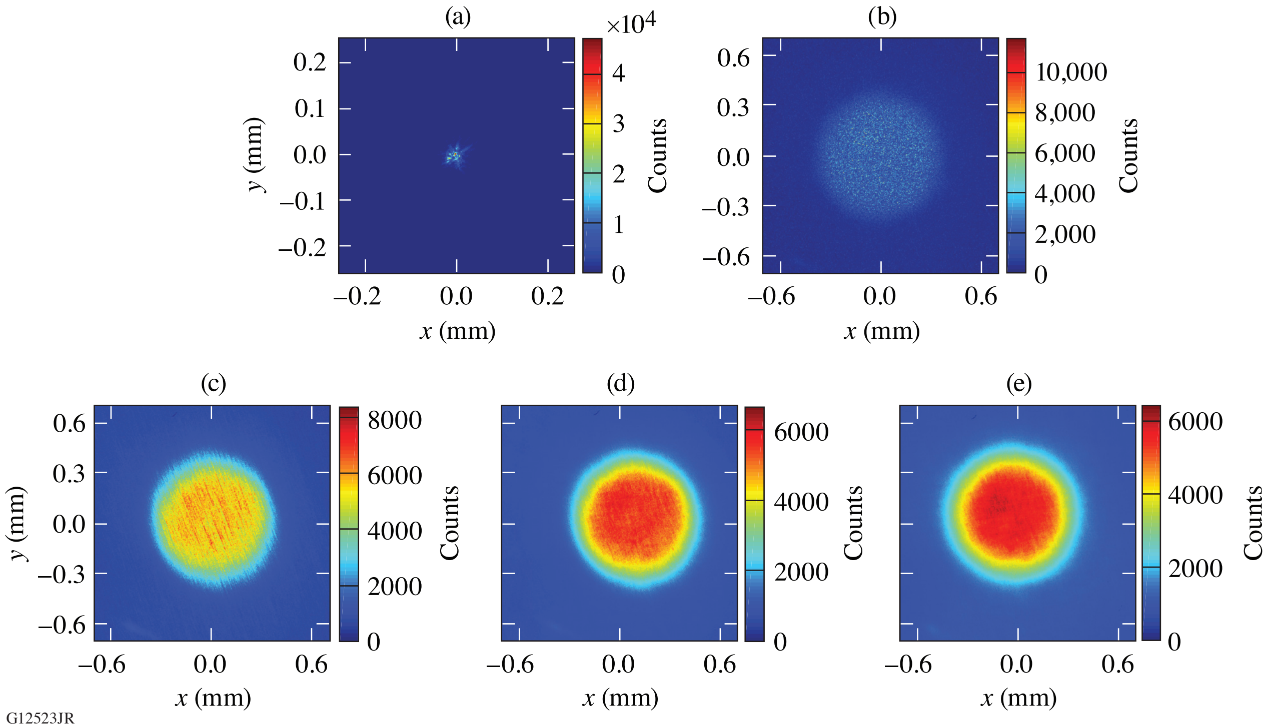

Figure 1
Evolution of the SSD focal spot, as seen from FBIT: (a) raw OMEGA far-field focal spot; (b) OMEGA far-field focal spot with a DPP; (c) focal spot with a DPP and 1-D SSD modulation; (d) focal spot with a DPP and 2-D SSD modulation; (e) focal spot with a DPP, 2-D SSD, and a DPR. Note that (a) is plotted on a different spatial scale to better show the far-field spot.

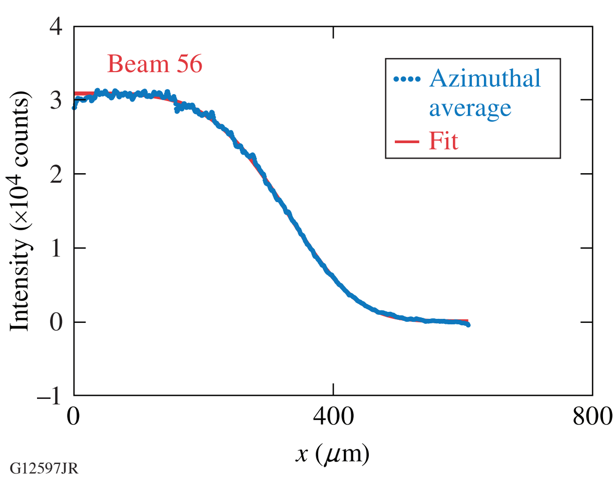

Figure 2
A super-Gaussian fit is used on the azimuthal average of the DPP far-field focal spot with 2-D SSD and a DPR.

We demonstrate the wide array of data that the new FBIT diagnostic is able to obtain. We can compare the focal spot from multiple beamlines easily within a shot cycle, analyze the SSD kernel, and characterize the effect of polarization smoothing on the focal spot. Using this data, we can more effectively understand the limitations of other diagnostics in the OMEGA Laser System and improve existing simulations of the laser performance on target. The preliminary data shown in Ref. 9 suggest that the upstream diagnostics compare closely with results found by using the FBIT diagnostic.

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.

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