Laser Diagnostic for High-Energy, Laser Fusion Drivers

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Abstract

A complete set of diagnostics for use on a frequency-tripled high-energy glass laser system is described. We employed high resolution imaging, temporal pulse-shape, beam bandwidth, phase-front, and precision energy instrumentation.

The Beamlet laser system is the scientific prototype of one beamline of the proposed 192 beam National Ignition Facility. With a 35 X 35 cm beam-size, Beamlet was designed to evaluate new architectures, components, and materials which will make a National Ignition Facility economically feasible. A full diagnostics suite was designed to measure Beamlet spatial gain uniformity, temporal pulse shaping, SBS suppressing phase modulation, beam phase-front, and overall energy performance.

Beamlet generates high energy 1.053 μm light, which is doubled and finally tripled to 351 nm. Critical to understanding the efficiency and losses in the tripling process are energy diagnostics for the fundamental, doubled, and tripled laser light. We developed NIST traceable energy diagnostics for all three wavelengths utilizing absorbing glass calorimeters, and recorded the results using nanovoltmeters controlled by a LabView control system. The three wavelengths were separated by an uncoated dispersing prism system directed onto three calorimeters in the Output Sensor, while the incident 1.053 μm beam and the composite output beam energies were measured in the Input Sensor and beam dump respectively. All transport reflectors were either high reflectors or else bare surfaces using calculated Fresnel...
reflection/transmission values. The three calorimetry systems utilized different makes of calorimeters and employed independent algorithms, yet routinely demonstrated better than ±4% energy balance.

Imaging diagnostics were used extensively. A 3% sample of the incident 1.053 μm beam was directed to a diagnostic station for near and far field imaging, a Hartmann sensor wavefront diagnostic, radial shear interferometer wavefront diagnostic, and a time integrated Fizeau bandwidth image. The frequency tripled beam was similarly diagnosed in the output beam diagnostic station, where near- and far-field images of the doubled and tripled beams were recorded using both standard and high resolution CCD cameras. For both the incident beam and output imaging, the optical transport path was fully characterized to the far-field and phase front diagnostics to verify that the optical aberrations by the transport system were kept to a small fraction of the passive and active wavefront aberrations of the Beamlet system.

Measuring Beamlet temporal performance was done using a combination of slow and fast photodiodes, and a streak camera. These diagnostics revealed features such as gain saturation and phase-to-amplitude modulation in the output beam. The slow photodiodes, consisting of integrating spheres and biased silicon photodiodes recorded by 100 MHz transient digitizers, were used to measure the intensity build-up in the amplifier cavity. The fast vacuum photodiode signals were recorded by 4.5 GHz transient digitizers, and were extremely effective at capturing the gain saturation and ripples on the beam caused by the beam phase modulation converting to amplitude modulation. The streak camera was used to capture the beam temporal profile at the highest bandwidth. Comparison between the fast photodiode system and the streak camera showed strong agreement, with the streak camera revealing greater detail (as expected) in the temporal profile.
Figure captions

Figure 1. Simplified top view of the Beamlet output diagnostics. Imaging temporal energy diagnostics are done both before and after the frequency converters.