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PREPRINT

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PRECISION OPERATION OF THE NOVA LASER FOR FUSION EXPERIMENTS*

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Nova is a neodymium glass laser consisting of 10 amplifier chains that are driven from a single master oscillator. The 1.05 μm wavelength input pulse shape is designed so that gain saturation in the amplifiers, combined with frequency conversion in KDP crystals yields the desired 0.35 μm output pulse shape. In order to improve the reproducibility of experiments it was necessary to make substantial improvements in both output power balance and in pointing of the 10 beams to inertial confinement fusion targets. The required improvement in precision was estimated to be a factor of 3 in both power balance and pointing [1].

Improved power balance required several upgrades to Nova. Among these were (1) sensor upgrades to improve laser diagnostic measurement accuracy, (2) development of a new technique to improve pulse synchronization on target, (3) installation of regulated high voltage power supplies to improve gain stability, and (4) development of new techniques to allow compensation for differences in harmonic conversion efficiency and in gain saturation rates of the 10 Nova beamlines.

Among the sensor upgrades, we developed and installed incident beam diagnostics (IBDs) which accurately measure the 0.35 μm power and energy for target experiments [2]. The IBDs use a full-aperture sample of each beam produced by a 1% back reflection from a partial antireflection coating on each final focusing lens. The sensitivities of the IBDs are determined with calibration shots fired into calorimeters on the opposite target chamber wall. By swapping calorimeters we determined that the relative IBD calibration accuracy was better than 3% rms.

In order to improve pulse synchronization we developed a method which uses x-ray streak cameras to monitor arrival times of 100 ps pulses on a gold foil at target chamber center [3]. Initial measurements indicated timing differences of 30 ps rms. Proper adjustment

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of optical delays reduced these differences to less than 10 ps rms, sufficient to permit power balance within desired specifications for all pulseshapes currently in use on Nova

Given precision beam synchronization and gain stability, the primary causes of power imbalance on target are beam-to-beam differences in net gain, and frequency conversion efficiency. Independent control of the input energy to each beamline has always been used to produce equal energy on target. Differences in net frequency conversion efficiency, however, can be as high as 20% (largely due to differences in transmission of the debris shields), and differences of this magnitude in 1 μm output energy produce large differences in pulseshape distortion due to gain saturation. Differences in pulseshape distortion can be reduced, however, if the lateral beam area is varied in proportion to the required 1 μm output power and energy so that the 1 μm output irradiance and fluence become the same for all beams. We have found that differences in frequency conversion efficiency among the beams can be described by multiplicative factors that are independent of 1 μm drive irradiance. Consequently, while frequency conversion alters the pulseshape, it makes exactly the same alteration for each beam so that power balance is maintained. We find that simultaneous adjustment of input energies and beam areas produces adequate power balance on target for most pulseshapes currently in use on Nova [3].

At very high output energies we find that beam-to-beam differences in gain saturation rates become noticeable. These arise from differences in the distribution of gain and loss in the amplifier chains. We have found that adjustment of the gain in the most heavily saturated amplifiers allows us to compensate for these differences, and produce equal gain saturation rates up to the highest output energies available on Nova. Using a combination of these techniques we are able to reduce power imbalance to less than 10% rms in the foot and 5% rms at the peak of shaped pulses with peak to foot contrast ratios up to 10:1, and output energies up to 40 kJ at 0.35 μm .

Pointing accuracy on Nova is limited by subaperture beam sampling, and pump induced beam steering, among other things. We established a number of new procedures that reduced short term variability, and found that the residual pointing offsets are relatively stable over long periods of time. We developed techniques to measure these offsets precisely, and then apply corrections to the aim points after beam alignment. Residual pointing errors were reduced to 30 μm rms using these techniques, meeting our goal for precision operations [4].

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